Walailak J Sci & Tech 2009; 6(2): 189-202.

Population Dynamics and Stock Assessment of Blue Swimming Crab (*Portunus pelagicus* Linnaeus, 1758) in the Coastal Area of Trang Province, Thailand

Amonsak SAWUSDEE[1] and Apirak SONGRAK[2]

[1]*Division of Technology for Marine and Coastal Resources Management, School of Engineering and Resources Management, Walailak University, Nakhon Si Thammarat 80161, Thailand*
[2]*Department of Fishery Technology, Faculty of Science and Fisheries Technology, Rajamangala University of Technology Srivijaya, Trang Campus, Trang 92150, Thailand*

(E-mail: samonsak@wu.ac.th)

ABSTRACT

The population dynamics and stock assessment of blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) in the coastal area of Trang province, Southern Thailand was done through stratified sampling of 7,499 crabs that were caught by crab gill nets and crab traps. The sampling was done from September 2006 to August 2007. The carapace width and weight relationship was measured, including parameters such as asymptotic outer carapace width (OCW_{α}), curvature (K), asymptotic inner carapace width (ICW_{α}), total mortality coefficient (Z), natural mortality coefficient (M), fishing mortality coefficient (F), exploitation rate (E), and total stock at first catch (L_c). The maximum sustainable yield (MSY), maximum economic yield (MEY) and total biomass (B) were estimated. Results showed that the asymptotic outer carapace width was 17.30. The asymptotic inner carapace width was 16.70 cm and its curvature was 1.5 per year. The total mortality coefficient was 8.96 per year, natural mortality coefficient was 1.61 per year and fishing mortality coefficient was 7.35 per year. The exploitation rate was 0.82. The total stock of blue swimming crab at first catch at 2.5 - 3.0 cm was 7,895,170 individuals. Results of stock assessment also showed that the maximum sustainable yield was 364.33 tons, maximum economic yield was 25.29 million Baht (1 Baht = US$ 33) and total biomass was 139.83 MT. A 40 % decrease in the level of fishing effort is recommended to ensure sustainability of the blue swimming crab stock.

Keywords: Blue swimming crab, population dynamics, Trang province, marine fisheries

INTRODUCTION

The Blue Swimming Crab, BSC (*P. pelagicus*) is an important economic aquatic fauna of Thailand. It is also important in recreational fisheries. The BSC fishery is a major livelihood for small-scale fishers in many parts of West and East Southern, Thailand. In 2005, the BSC yield of Thailand was third in the world [1] and in 2004, the total yield was 42.2 MT with a value of 2,563.3 million Baht (= 35 million US$) [2]. However, 2005 exports fell off rapidly, due to low crab production, and the size of BSC caught were smaller than in previous years [2]. This was thought to be the result of increased fishing due to an increased number of fishing gears and an improvement in efficiency.

BSC fishery in Trang is an important source of income for small-scale fishers. In Sikao Bay, Trang, the yield of BSC was 120 MT with a value of 6.4 million Baht. However, the maximum sustainable yield (MSY) of BSC decreased by 50 percent [3] resulting in a decline in production. Therefore, there is a need for appropriate management measures of the BSC fishery in the coastal area of Trang to ensure the sustainability of this fishery.

MATERIALS AND METHODS

The study was conducted in the coastal area of Trang Province, Thailand from September 2006 to August 2007. All fishing villages were selected from 4 districts, Sikao, Kantang, Hatsumran and Palian (**Figure 1**). Stratified sampling was done using crab gill nets and crab traps. The samples were then individually measured and weighed for the following parameters: carapace width; (outer: OCW and inner: ICW) (cm) and body weight (g). Prices were recorded by size classes (Baht/kg) at the ports close to the villages. An analytical model was applied using the FiSAT program, FAO-ICLARM Stock Assessment Tools [4], as recorded by Gayanilo and co-workers [5].

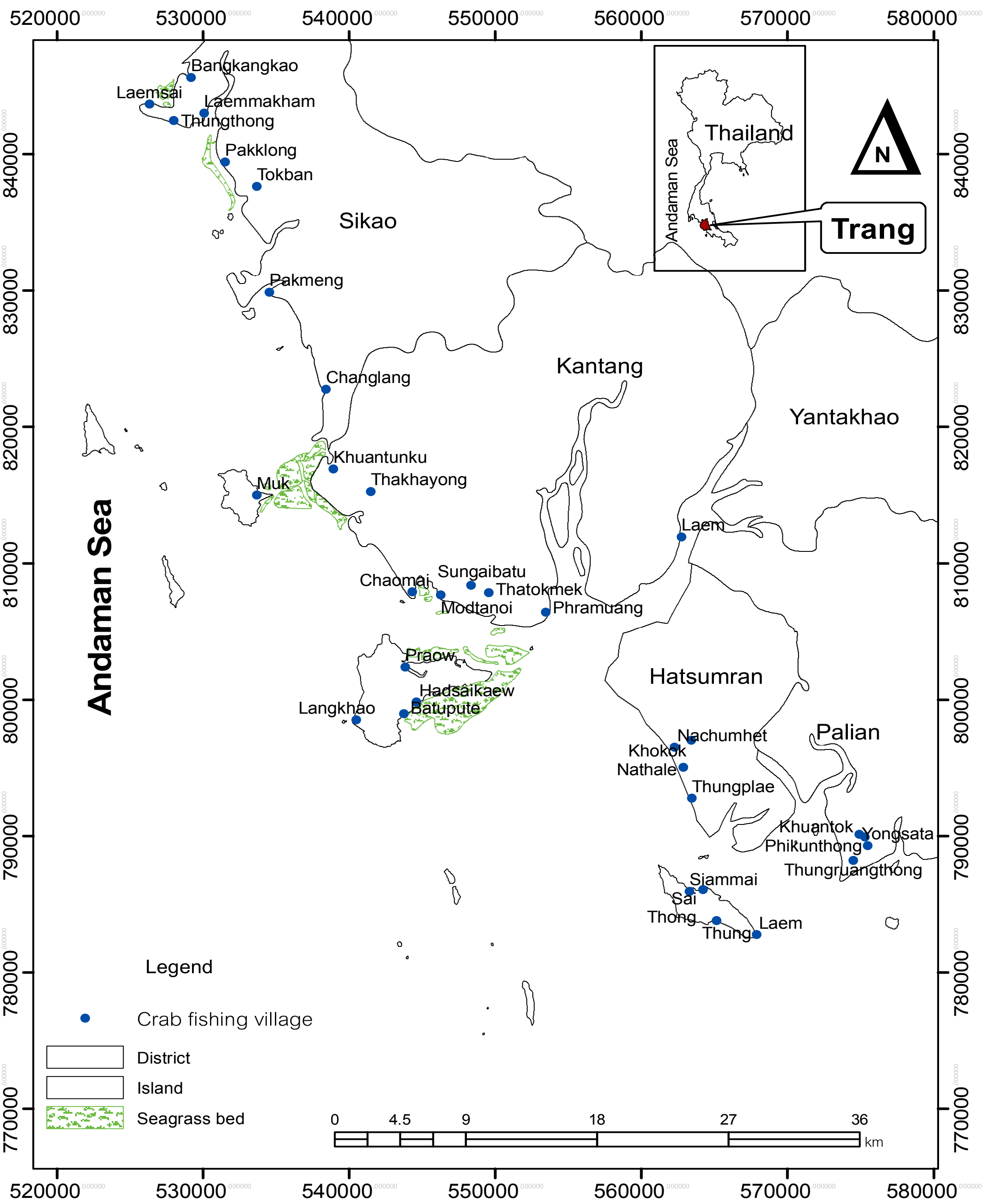

Figure 1 Map of fishing villages in the coastal area of Trang province, Thailand.

Carapace Width-Weight Relationship

To establish the carapace width-weight relationship, the commonly used relationship $W = aCW^b$ was applied [6] where W is the weight (g), CW the carapace width (cm), a intercept (condition factor) and b the slope (growth coefficient). The parameters a and b were estimated using power regression and the coefficient of determination (R^2) to show the carapace width-weight relationship.

Estimation of Growth and Mortality Parameter

The asymptotic length (L_α) and growth coefficient (K) of the von Bertalanffy growth equation (VBGF) [7] were estimated by means of ELEFAN-1 [8] incorporated into the FiSAT program. The L_α value was estimated using a modified Powell-Wetherall plot [9], which was then used as seed value in ELEFAN-1 analysis to assess a reliable estimate of the growth parameter K [10] by using an estimate of the growth performance index (Ø) [11]. The inverse von Bertalanffy growth equation and growth curve were used to determine the carapace width of the BSC at various ages, by using the hypothetical age at which the length equals zero (t_0) [12] as calculated from the culture of BSC by the Department of Fishery in Samut Songkhram Province, Thailand [13] where t_0 was estimated to be –0.041 per year for this study.

The mortality parameters were estimated using the FiSAT program for which the total mortality rate (Z) was estimated using the length converted catch curve [14]. The natural mortality rate (M) was estimated using a modified method described by Rikhter and Efanov [6]. The fishing mortality rate (F) was estimated using the relationship of the mortality parameter ($Z = F + M$). The exploitation level (E) was estimated using the Beverton and Holt’s equation ($E = F/Z$) [15].

Estimation of Yield Per Recruit Models

The analysis of yield per recruit was conducted as described by Thompson and Bell [16]. The number of recruits of BSC was calculated by the Jones’ Length-Based Cohort Analysis model [4]. The number of recruits, the growth and mortality parameters were used for calculating production (P), biomass (B) and value (V) [3]. The analysis of exploitation was computed based on present low and high levels with results showing maximum sustainable yield (MSY), maximum economic yield (MEY) and optimum fishing effort in time series data on the production of BSC in the Trang coastal area.

RESULTS AND DISCUSSION

A total of 7,499 crabs were caught in all fishing villages from 4 districts (4,385 males and 3,114 females). The distribution of the OCW ranged from 5.5 - 17.0 cm and the ICW ranged from 4.0 - 15.5 cm. The carapace width-weight relationship of BSC had high R^2 value and the exponent was not significantly different from 3 ($p > 0.05$). Therefore, it is assumed that growth of this species is "isometric"
(**Table 1** and **Figures 2** and **3**).

Table 1 Carapace width-weight relationships of BSC in the Trang coastal area, Thailand.

Crabs	Outer carapace width-weight		Inner carapace width-weight	
	Equation	**(R^2)**	**Equation**	**(R^2)**
Male	$W = 0.0404 \times OCW^{3.2192}$	0.8805	$W = 0.1553 \times ICW^{2.9531}$	0.8942
Female	$W = 0.0425 \times OCW^{3.1860}$	0.8714	$W = 0.1969 \times ICW^{2.8351}$	0.8872
Total	$W = 0.0416 \times OCW^{3.2024}$	0.8748	$W = 0.1738 \times ICW^{2.8978}$	0.8893

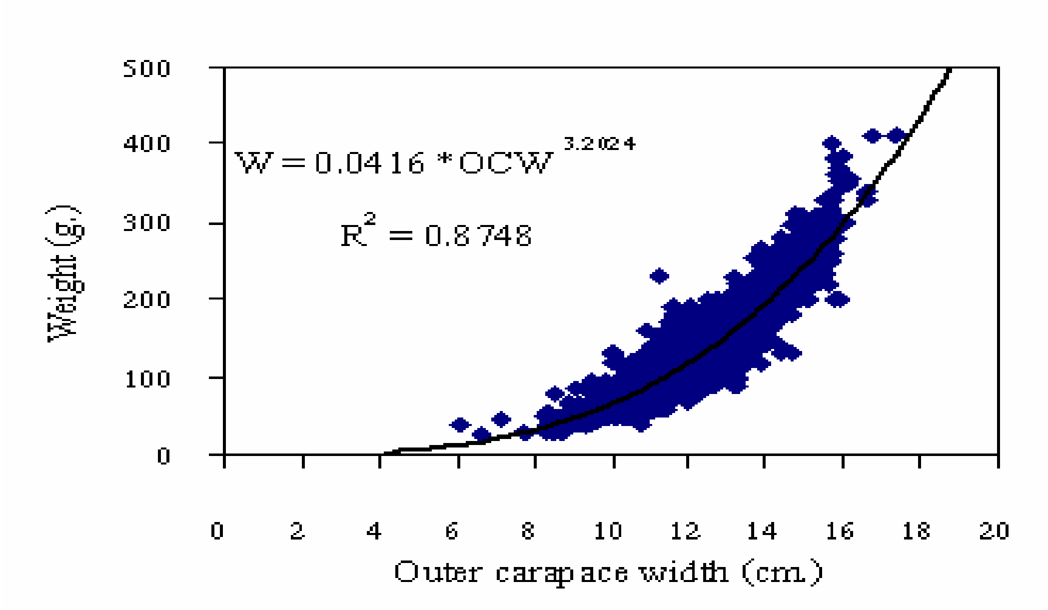

Figure 2 Outer carapace width-weight relationship of BSC in the Trang coastal area.

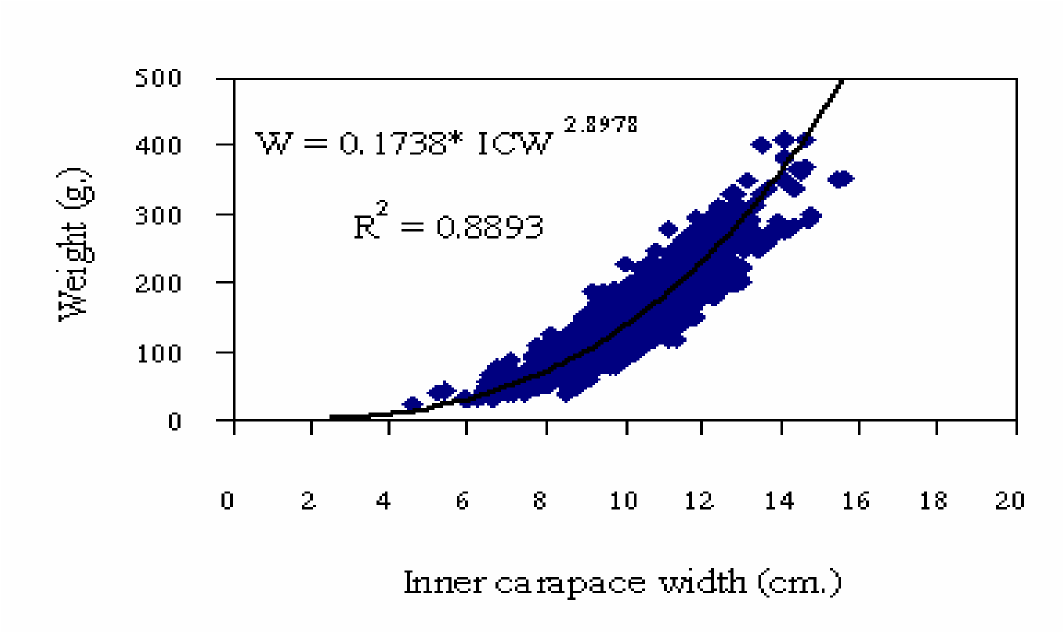

Figure 3 Inner carapace width-weight relationship of BSC in the Trang coastal area.

The growth parameters of BSC in the Trang coastal area were estimated using Bhattacharya's method [4]. It is used for separating the length frequency to determine the mode length of crab cohorts. Consequently, model progression analysis is used for linking the mean length of the same cohort which shows monthly growth progression. The line that is drawn to indicate the growth of the same cohort is further used for estimating the growth parameters (K and CW_{α}) by ELEFAN-I using growth parameters of BSC at Sikao Bay [3] and t_0 was –0.041 per year [2]. The linked mean length of the same cohort showed the estimated growth of OCW_{∞} at 17.30 cm and K at 1.5 per year. The estimated growth of ICW_{∞} was 16.70 cm and K was 1.5 per year. In terms of sex, males had a growth of OCW_{∞} at 17.90 cm and K at 1.5 per year while females showed an OCW_{∞} of 17.10 cm and K of 1.6 per year. The estimated growth for males reveals an ICW_{∞} of 16.70 cm and K at 1.4 per year while for females ICW_{∞} is 16.50 cm and K at 1.5 per year. Thus, the estimated growth of BSC in the coastal area of Trang was essentially independent of sex.

Table 2 Estimated growth parameters of BSC in the Trang coastal area.

Crabs	Outer carapace		Inner carapace	
	OCW_∞ (cm)	**K (per year)**	**ICW_∞ (cm)**	**K (per year)**
Male	17.90	1.5	16.70	1.4
Female	17.10	1.6	16.50	1.5
Total	17.30	1.5	16.70	1.5

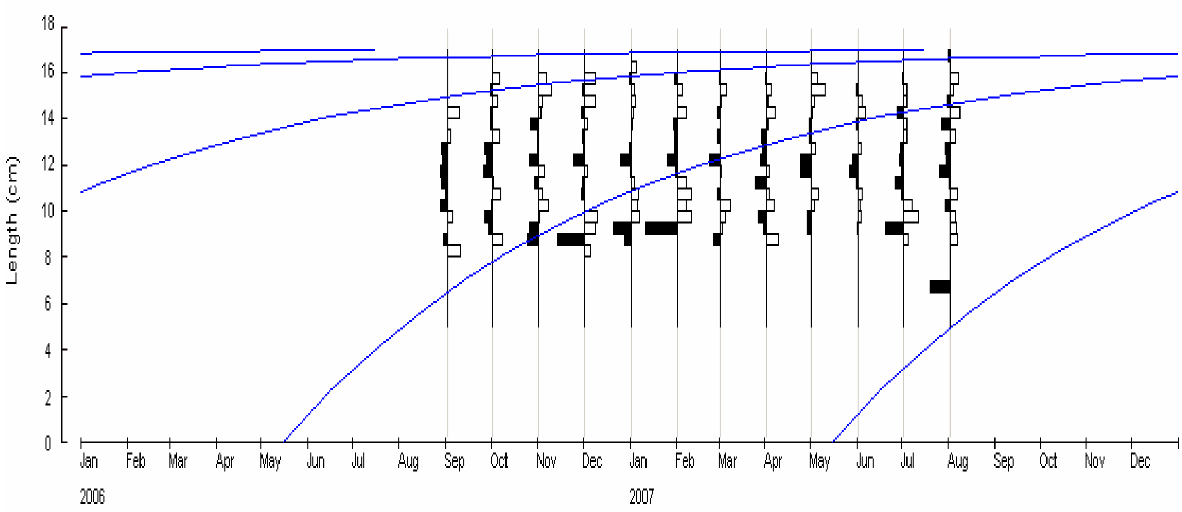

Figure 4 Restructured outer carapace width frequency distribution with growth curves of BSC in the Trang coastal area.

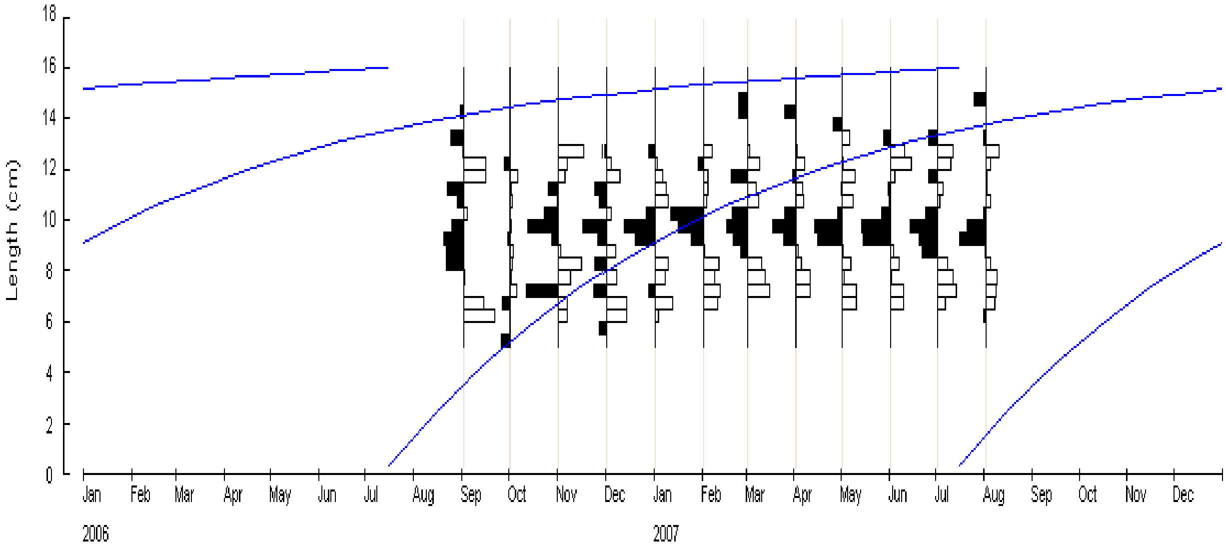

Figure 5 Restructured inner carapace width frequency distribution with growth curves of BSC in the Trang coastal area.

From computational studies, the growth equation of BSC in the Trang coastal area based on Bertalanffy's model [7] using growth parameters allowed the determination of the relationship between inner carapace width-age and weight-age. The results of the calculation are shown in **Table 3** and **Figures 6** and **7**.

Table 3 Equation growth curve of BSC in the Trang coastal area.

Crabs	Relationship between inner carapace width and age	Relationship between weight and age
Male	$L_t = 16.70\,(1 - e^{-1.40(t+0.041)})$	$W_t = 633.83\,(1 - e^{-1.40(t+0.041)})^{2.9531}$
Female	$L_t = 16.50\,(1 - e^{-1.50(t+0.041)})$	$W_t = 557.10\,(1 - e^{-1.50(t+0.041)})^{2.8351}$
Total	$L_t = 16.70\,(1 - e^{-1.50(t+0.041)})$	$W_t = 607.07\,(1 - e^{-1.50(t+0.041)})^{2.8978}$

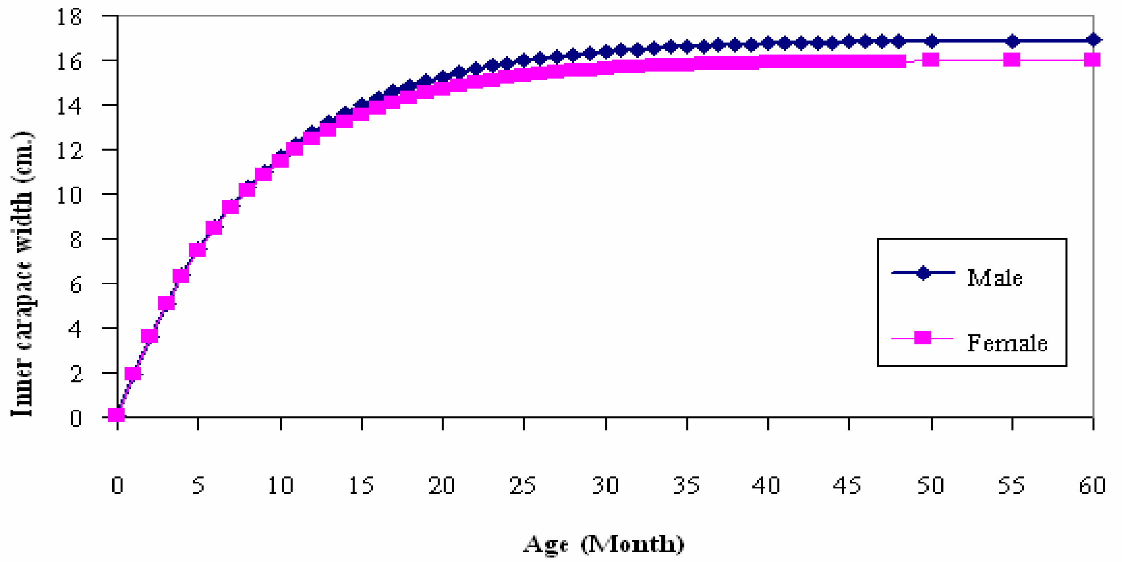

Figure 6 Relationship between inner carapace width and age of BSC in the Trang coastal area.

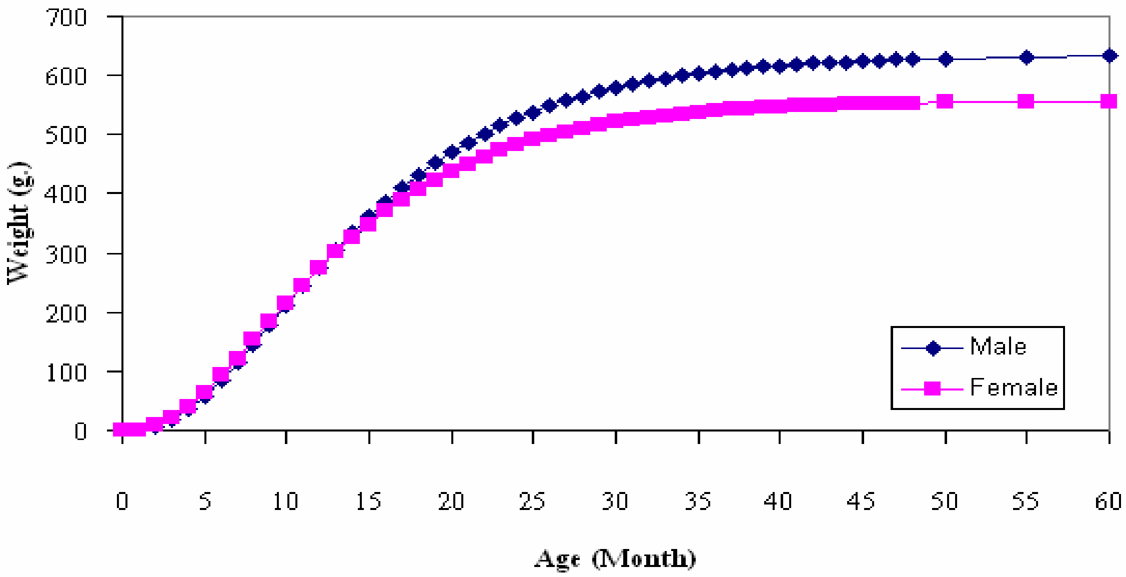

Figure 7 Relationship between weight and age of BSC in the Trang coastal area.

The natural mortality rate (M) of BSC in the Trang coastal area for both male and female using Rikhter and Efanov formula was calculated to be 1.61 per year. The total mortality rate (Z) was 8.96, 9.23 per year for male crabs and 8.85 for female crabs respectively. The fishing mortality rate (F) was 7.35, 7.62 per year for male crabs and 7.24 for female crabs respectively. The exploitation rate (E) was 0.82, 0.83 for male crabs and 0.82 for female crabs. Since the exploitation rate is more than 0.50, this shows that BSC are overexploited.

Table 4 Mortality and exploitation rate of BSC in the Trang coastal area.

Crabs	Total mortality rate Z (per year)	Natural mortality rate M (per year)	Fishing mortality rate F (per year)	Exploitation rate E = F/Z
Male	9.23	1.61	7.62	0.83
Female	8.85	1.61	7.24	0.82
Total	8.96	1.61	7.35	0.82

The exploitation rate of BSC for 1 year in the Trang coastal area was used to find the numbers of BSC in each length interval for growing in new stocks. This information was used to calculate the number of recruits of BSC by using Jones' Length-Based Cohort Analysis. The study was assigned the exploitation rate of the last length interval (16.50 - ∞) at 0.82 per year and discovered that the number of recruits of BSC (inner carapace width starting from 5.0 cm) in the fishing area was 7,895,170 crabs. The coefficient of total mortality and fishing mortality were 1.61 - 11.1 and 0.01 - 9.51 per year, respectively.

There is a high market demand for BSC with an inner carapace width from 10.0 cm. The average price was 90 Baht per kg. However, the coefficients of total mortality and fishing mortality of big-sized crab were higher than the small-sized crab. The maximum coefficient of fishing mortality of crabs with 12.0 cm inner carapace width was 9.51 per year.

From the correlation analysis between length and fishing mortality coefficient of BSC, it is possible to analyze and determine the number of crabs in future catches by increasing or decreasing the level of fishing effort (X-factor) to calculate the maximum sustainable yield (MSY), biomass (B) and value (V). The results such as yield, value of recruits, growth parameters and mortality coefficient including the value in each carapace width interval, were used to analyze the MSY and MEY by length-based Thompson and Bell Analysis. The results from the analysis were applied to the present situation because this method determined the X-factor as the value that indicated an increase in fishing if X is higher than 1, and decrease in fishing, if X is lower than 1. In the present situation, X-factor was assigned equal to 1, and then the numbers of recruitment of BSC (estimated at 7,895,170 crabs) as calculated by Jones' Length based cohort analysis were used for this analysis.

In the present fishing situation, the biomass, yield and value of BSC were 98,963,000 kg, 356,170,000 kg and 22.1 million Baht, respectively. In addition, the increment in fishing effort led to decreased yield, biomass and value of blue swimming crab, and vice versa (**Figure 8**). By adjusting the level of fishing effort, the study found that MSY of BSC would be 364,332,000 kg if 40 percent of fishing effort was decreased. The MEY of BSC would be a projected 25.29 million Baht if fishing effort was decreased by 60 percent.

Moreover, the study revealed that present MSY and MEY of BSC were lower than the MSY and MEY generated from the information collected from the fishers directly, because the length-based Thompson and Bell Analysis proceeds successively from the youngest to the oldest age classes and number of recruits. The BSC also affected the final yield. The recruitment of BSC was continual and since the Trang coastal area is situated in a tropical zone, the spawning season was almost throughout the entire year. Another important problem was the variation in price of BSC; meat of the small-sized boiled crab was sold at a higher price than fresh crab.

At present, the exploitation of BSC in the Trang coastal area is higher than the recruitment. Therefore, in order to sustain the utilization of BSC, a proper management program should be implemented urgently. The level of fishing effort should be decreased by 40 percent from the present level. The conservation of juvenile crabs through a Crab Bank program should be practiced. By keeping 9,000 broodstock per year, the number of crabs can be sustained for stock enhancement and recruitment activities.

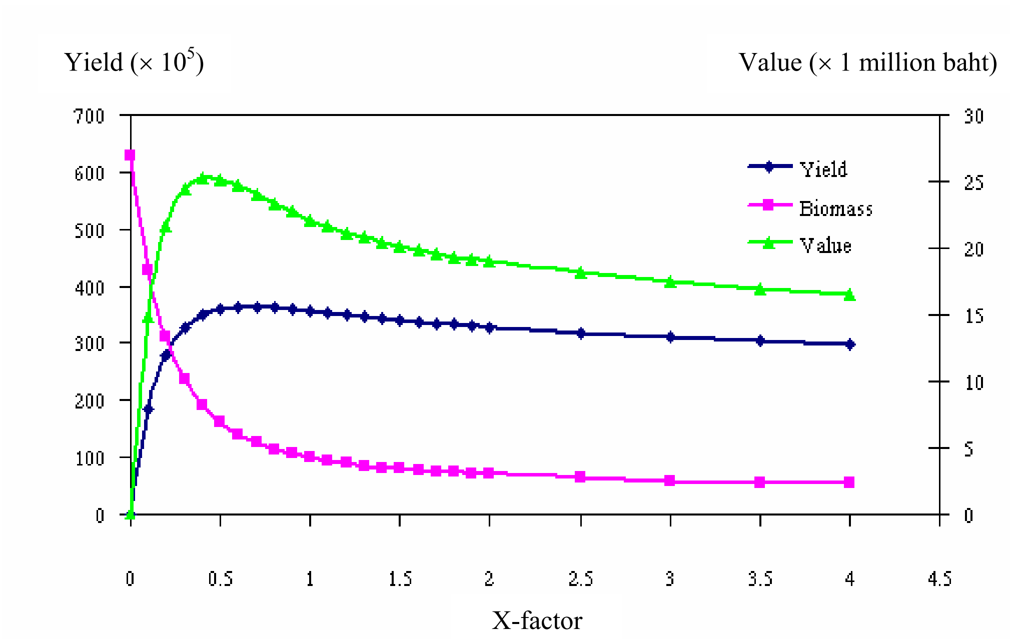

Figure 8 Results of Thompson and Bell Prediction Analysis showing the current status and the prediction of changes in fishing mortality of BSC in the Trang coastal area.

CONCLUSIONS

The management measures for BSC in the coastal area of Trang Province, Thailand as suggested by stock assessment are to decrease the number of fishing gears of small-scale fishers by approximately 40 percent. The decision-making on BSC management cannot use only biological information, the socioeconomic conditions of small-scale fishers in the Trang coastal area should also be considered to achieve sustainable management of the BSC resource and also ensure fairness to all stakeholders.

ACKNOWLEDGMENTS

This research was funded by the Thailand Research Fund and the Faculty of Science and Fisheries Technology, Rajamangala University of Technology Srivijaya. The authors would like to thank many small-scale fishers of the coastal area of Trang Province and staff members of our university who assisted in data collecting. We also owe a debt of gratitude to our colleague who assisted in editing this paper.

REFERENCES

[1] FAO. 2008. Total production 1950-2005, Available at: www.fao.org/fi/stat/windows/fishplus/fstat.zip, accessed December 2007.

[2] Department of Fisheries. Thailand Fishery Statistics 2004. Bangkok: Technical Paper No. 15/2007, 2007

[3] A Songrak and P Choopunth. Stock assessment of blue swimming crab (*Portunus pelagicus*, Linnaeus) in Sikao bay, Trang province, Southern Thailand. *In*: Proceedings of the Coastal Oceanography and Sustainable Marine Aquaculture, Confluence & Synergy, Kota Kinabalu, Sabah Malaysia, 2006, p. 260-7.

[4] P Sparre and SV Venema. Introduction to Tropical Fish Stock Assessment. Part 1-Manual FAO. Fisheries Technical Paper, 1989, p. 1-337.

[5] FCJ Gayanilo, P Sparre and D Pauly. FAO-ICLARM Stock Assessment Tools (FiSAT) User's Manual. FAO Computerized Information Series Fisheries, 1995, p. 1-126.

[6] WE Ricker. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can.* 1975; **191**, 1-382.

[7] L Von Bertalanffy. A quantitative theory of organic growth (Inquiries on growth laws (II)). *Human Biol.* 1938; **10**, 181-213.

[8] D Pauly and N David. ELEFAN-I BASIC program for the objective extraction of growth parameters from length-frequency data. *Meeresforschung* 1981; **28**, 205-11.

[9] JA Wetherall. A new method for estimating growth and mortality parameters from length frequency data. *ICLARM Fishbyte* 1986; **4**, 12-4.

[10] FC Jr Gayanilo and D Pauly. FAO-ICLARM Stock Assessment Tools (FiSAT) Reference Manual. FAO computerized information series (Fisheries). No. 8. FAO, Rome, 1997, p. 262.

[11] D Pauly and JL Munro. Once more on the comparison of growth in fish and invertebrate. Int. Living Aquat. *Resour. Manage. Fishbyte* 1984; **2**, 21.

[12] SJ Newman. Growth, age estimation and preliminary estimates of longevity and mortality in the moses perch, *Lutjanus russelli* (Indian Ocean form), from continental shelf waters off northwestern Australia. *Asian Fish. Sci.* 2002; **15**, 283-94.

[13] J Jindalikit. Biology of the Blue Swimming Crab *Portunus pelagicus* (Linnaeus, 1766) in the Upper Gulf of Thailand. *In*: Seminar report 2001 Department of Fisheries, Ministry of Agriculture and Cooperatives, Bangkok. 2001, p. 242-52.

[14] D Pauly. Fish population dynamics in tropical waters: a manual for use with programmable calculators. *ICLARM Contrib*. 1984; **143**, 1-325.

[15] RJH Beverton and SJ Holt. On the dynamics of exploited fish populations. Fisheries Investigation Series, 1966, p. 2.

[16] WF Thompson and FH Bell. Biological statistics of the pacific halibut fishery effect of changes in intensity upon total yield per unit of gear. *Rep. Int. Fish. (Pacific Halibut) Comm.* 1934; **8**, 1-49.

บทคัดย่อ

อมรศักดิ์ สวัสดี[1] และ อภิรักษ์ สงรักษ์[2]

พลวัตประชากรและการประเมินสภาวะทรัพยากรปูม้า ในบริเวณชายฝั่งจังหวัดตรัง ประเทศไทย

พลวัตประชากรและการประเมินทรัพยากรปูม้า ในบริเวณชายฝั่งจังหวัดตรัง ภาคใต้ของประเทศไทย ศึกษาโดยการสุ่มแบบแบ่งชั้นด้วยเครื่องมืออวนจมและลอบปูม้า และทำการชั่งวัดปูม้า จำนวน 7,499 ตัว ซึ่งเก็บรวบรวมในช่วงเดือนกันยายน 2549 ถึงเดือนสิงหาคม 2550 การศึกษาครั้งนี้ครอบคลุมการศึกษาความกว้างสูงสุดของกระดองส่วนนอก (OCW_α) ความกว้างสูงสุดของกระดองส่วนใน (ICW_α) พารามิเตอร์การเติบโต (K) สัมประสิทธิ์การตายรวม (Z) สัมประสิทธิ์การตายโดยธรรมชาติ (M) สัมประสิทธิ์การตายโดยการประมง (F) อัตราการใช้ประโยชน์ (E) จำนวนตัวสัตว์น้ำในระยะแรกจับ (L_c) รวมทั้งประเมินค่าผลจับยั่งยืนสูงสุด (MSY) ผลจับที่ให้ผลตอบแทนทางเศรษฐกิจสูงสุด (MEY) และประมาณค่ามวลชีวภาพของปูม้าทั้งหมด ผลการศึกษาพบว่า ค่าความกว้างสูงสุดของกระดองส่วนนอกเท่ากับ 17.30 เซนติเมตร ความกว้างสูงสุดของกระดองส่วนใน เท่ากับ 16.70 เซนติเมตร ค่าพารามิเตอร์การเติบโต เท่ากับ 1.5 ต่อปี ค่าสัมประสิทธิ์การตายรวม เท่ากับ 8.96 ต่อปี โดยค่าสัมประสิทธิ์การตายโดยธรรมชาติ เท่ากับ 1.61 ต่อปี และสัมประสิทธิ์การตายจากการประมงเท่ากับ 7.35 ต่อปี อัตราการใช้ประโยชน์ทรัพยากรปูม้า เท่ากับ 0.82 จำนวนตัวสัตว์น้ำในระยะแรกจับ (2.5 - 3.0 เซนติเมตร) เท่ากับ 7,895,170 ตัว นอกจากนี้ผลการประเมินสภาวะทรัพยากรปูม้า แสดงให้เห็นว่า ค่าผลจับยั่งยืนสูงสุดของปูม้าในบริเวณชายฝั่งจังหวัดตรัง เท่ากับ 364.33 ตัน และผลจับที่ให้ผลตอบแทนทางเศรษฐกิจสูงสุดเท่ากับ 25.29 ล้านบาท ข้อเสนอแนะของผู้วิจัยเสนอว่า หากต้องการบำรุงรักษาทรัพยากรปูม้าสามารถใช้ปูม้าได้อย่างยั่งยืนถาวร ควรลดการจับปูม้าลงประมาณ 40 เปอร์เซ็นต์

[1]สาขาวิชาเทคโนโลยีการจัดการทรัพยากรทะเลและชายฝั่ง สำนักวิชาวิศวกรรมศาสตร์และทรัพยากร มหาวิทยาลัยวลัยลักษณ์ อำเภอท่าศาลา จังหวัดนครศรีธรรมราช 80161

[2]สาขาเทคโนโลยีการประมง คณะวิทยาศาสตร์และเทคโนโลยีการประมง มหาวิทยาลัยเทคโนโลยีราชมงคลศรีวิชัย วิทยาเขตตรัง จังหวัดตรัง 92150