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Statistical Process Control Applications for Monitoring of Volume Changes of Saltwater Fishery in Satun Province

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Abstract This study was intended to investigate changes in the amount of saltwater fishery in Satun Province. From Cumulative sum control chart (2004-2016), it found that saltwater fish species is the most abundant in Satun, whereas cephalopod-crustacean, and other species were caught in the similar quantity. In addition, CUSUM indicates the abnormality occurred rapidly with less than one side of the cumulative sum S_i^- which has decreased since 2013. This sent a clear warning that the process started out of control in 2014. Therefore, CUSUM control chart can verify that the saltwater fishery in Satun province has decreased rapidly since 2013 .

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1. Introduction

Satun province is one of the provinces that the area adjoin to the Andaman coast. Districts connected the coast are Muang, Tha Phae, La-ngu and Thung Wa. This is 12.37% of the total area in Satun province. Satun province is considered one of the finest gems of the South with nationally renowned beautiful islands. There are many interesting attractions, so it is very popular with tourists. Satun is a province in the south of Thailand and it is also home to a number of Thailand's major fishing ports. In addition, it is one of Thailand's most important maritime resources. Fishery in Thailand divides into two important marine fishing areas; Gulf of Thailand and Andaman Sea. The Gulf of Thailand has a length of 1,870 kilometers, starting from the north from the Thai-Cambodia border from Trat province to the border with Thailand and Malaysia. The Andaman coast has a length of 1,200 kilometers from north to south. Approximately

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126,000 square kilometers is the part of the Indian Ocean and the north connected to the Irrawaddy River in Burma. The east is the Burmese, Malaysian and Thai peninsula. The west is the Nicobar Islands and Andaman Sea and the south is to the island of Sumatra Island, Indonesia. Thailand has 6 provinces bordering the Andaman coast that include Ranong, Satun, Trang, Krabi, Phang- Nga and Phuket provinces.

Fishery in Satun are divided into three categories: freshwater fishery, saltwater fishery and the coastal aquaculture fishery. This study was emphasized on saltwater fishery. Fishery is the main occupation of the people in Satun and considered to generate income for people and the country with great value each year. It also affects the country's economy because the major export products from fisheries are in the form of fresh seafood and processed food. In addition, the demand for fishery products of both domestic and foreign consumers has increased. Therefore, the value and quantity of seafood tends to be higher in the same direction. In contrast, the number of marine life is rapidly declining, which is due to changes in marine ecosystems caused by Overfishing, Bycatch, and Transshipment at Sea and etc. These changes degrade marine ecosystems and leave many marine life at risk or endangered or rapidly degrading as these organisms have to adapt to the environment change.

Literature Review for saltwater species are divided into Statistical Process Control: SPC) such as Saithanu et al.[1], studied the change of Longtail Tuna in Thailand by using CUSUM control chart. It found that Longtail Tuna has decreased rapidly since 2008-2011. Mesnil, B., and Petitgas, P. [2] used CUSUM control chart to detect the quantity change of North Sea cod in the project of FISBOAT by using Survey data from International Bottom Trawl since the first quarter; 1985-2005, to calculate and that is in control of the process. The result found that since 1999, the amount of cod in the North Sea has decreased. Saithanu, K., and Mekparyup, J. [3] used CUSUM control chart which is one of the tools for Statistical Process Control (SPC) to check the change of cod in Thailand. It found that the quantity of cod in Thailand has decreased since 2008-2011. Saithanu, K., and Mekparyup, J. [4] used CUSUM control chart to apply with Marine ecosystems for examining changes in the amount of saltwater-shrimp species in Thailand from 1999-2012. It found that since 2007-2012, the amount of saltwater crustaceans has decreased significantly. Saithanu, K., and Mekparyup, J. [5] used CUSUM control chart to monitor changes of Marine Fish Landing Amount in Chonburi from 2001-2010. It found that from 2006-2010, Marine Fish Landing has been significantly reduced. [6], [7] It is said that the control chart is one of the tools of the SPC, that monitors the production process and the efficiency of the manufacturing process. For research, it is a model for predicting or predicting the amount of saltwater fishery, for example, Miyahara et al. [8], studied Multiple Regression Analysis and Simple Regression Analysis. Ghani I.M.M., Ahmad S. [9] studied Multiple Linear Regression: MLR of the quantity of sea species-sea fish by using the data from Fisheries Annually Statistics of Department of Fisheries, Malaysia that Minitab 15 and SPSS 17.0 were used to analyze data. Ghani I.M.M., Ahmad S. [10] studied Stepwise Multiple Regression to select the appropriate variable for forecasting fish quantity from the annual statistics of the Department of Fisheries in Malaysia, analyzed data by using Minitab 15 and SPSS 17.0. Data from Shabri A., Samsudin R. [11], studied the comparison of Wavelet ARIMA and ARIMA (Autoregressive Integrated Moving Average) for the quantity of fish prediction. It found that Wavelet ARIMA provides better performance than ARIMA. Bako H.Y., et al, [12] studied and predict by using Seasonal Autogressive Integrated Moving Average (SARIMA) data used from Fish

Catch of Two Fish Species since 2007-2011. The results of the study will make it easier to make decisions in terms of fishery.

For the aforementioned reasons, it makes the researcher interested in investigating the change in quantity of saltwater species in Satun since 2004-2016 (Year = 1, 2, .., 13) by collecting data from the research and the analysis of fisheries statistics, Information Center, Department of Fisheries. Data were analyzed using a tool included in the SPC called the CUSUM control chart for monitoring, planning and controlling the amount of saltwater fish catching. Therefore, overfishing of saltwater species can lead to extinction of some species.

2. Theory

2.1 Saltwater species This study focuses on saltwater fishery that divided into 4 types: saltwater species of fish, saltwater cephalopod, and other types of saltwater species as follow;

2.1.1 Saltwater Total Fish- 3 types;

2.1.1.1 Demersal Fish are fish that live in the sea: ornate threadfin bream, croaker, bream, lizard fish, cutlass fish, red snapper, shark, purple- spotted bigeye, striped sea catfish sea catfish, stingray, largescale tongue sole, grouper and etc.

2.1.1.2 Pelagic Fish are fish that like to live in the sea from the surface of the water down to the middle level that are mackerel, Indian mackerel, spotted mackerel, king mackerel, mackerel scad, hardtail scad, anchovy, barebreast jack, roundbelly sardine, bigeye scad and etc.

2.1.1.3 Trash Fish is a kind of small fish including fry and fish species. It's the fish that the market doesn't want. It is mostly used as an ingredient in animal feed production.

2.1.2 Cephalopod is in the phylum Mollusca that distinctive features in which the body is symmetrical, such as the head that stands out, Mollusca's feet have been converted into arms or tentacles (Muscular Hydrostat) for example clams, squid and cuttlefish.

2.1.3 Crustacean; crab, shrimp and prawn

2.1.4 Other species; jellyfish and starfish

2.2 CUSUM Control Chart

The CUSUM Control Chart originated in 1954, [13] said CUSUM was able to monitor changes in the process when the process mean has little changed. And it is suitable when the sample size of the subgroup is 1 (n=1) . Therefore, to investigate changes in the amount of fishery for saltwater fish in Satun province, CUSUM is used to investigate the changes, which are the following steps.

2.2.1 Estimate the parameters when assigning processes to be in control that are:

2.2.1.1. Mean of saltwater species fishery (μ_0) estimated by mean of saltwater species fishery ($\overline{X}$).

2.2.1.2. Standard deviation of saltwater fishery quantity (σ_0) estimated by standard deviation of saltwater fishery quantity (S).

2.2.2 Calculate the statistics From Mesnil, B., and Petitgas, P. [2] studies were able to calculate statistical values and then plot points into CUSUM as follows.

2.2.2.1 One-sided Upper CUSUM (S_i^+) is the positive deviations which is calculated as follows:

$$S_i^+ = \max[0, S_{i-1}^+ + z_i - k] \tag{2.1}$$

2.2.2.2 One-sided lower CUSUM (S_i^-) is the negative deviations which is calculated as follows:

$$S_i^- = \min[0, S_{i-1}^+ + z_i + k] \tag{2.2}$$

That z_i is the standard value of the amount of saltwater species fishery at the time point i which is calculated as follows:

$$z_i = \frac{x_i - \mu_0}{\sigma_0} \tag{2.3}$$

k is a parameter value that represents a reference value of CUSUM control chart. In this research, $k = 1.3$ is used for default value of S_i^- and S_i^+ is set it to be equal to zero $S_i^+ = S_i^-$ =0

x_i is the quantity of saltwater fishery at the point of time i

2.2.3 Calculate CUSUM Control Limit as follow;

$$UCL = +h \tag{2.4}$$

$$CL = 0 \tag{2.5}$$

$$LCL = -h \tag{2.6}$$

That h is parameter value of Decision Interval of CUSUM Control chart and $h = 1$. 2.2.4 Take the statistic calculated from step 2.2.2 and plot it into the CUSUM control chart calculated from step 2.2.3.

3. Results

In the statistical control process applying CUSUM to investigate changes in the amount of saltwater fishery in Satun Province, the research results can be summarized as follows. 3.1 In the descriptive statistical evaluation of saltwater fishery from 2004-2016 (Year = 1, 2, 3,, 13) of Satun which are classified by type of saltwater animals can be summarized as follows;

3.1.1 Overview of the total saltwater fishery of Satun

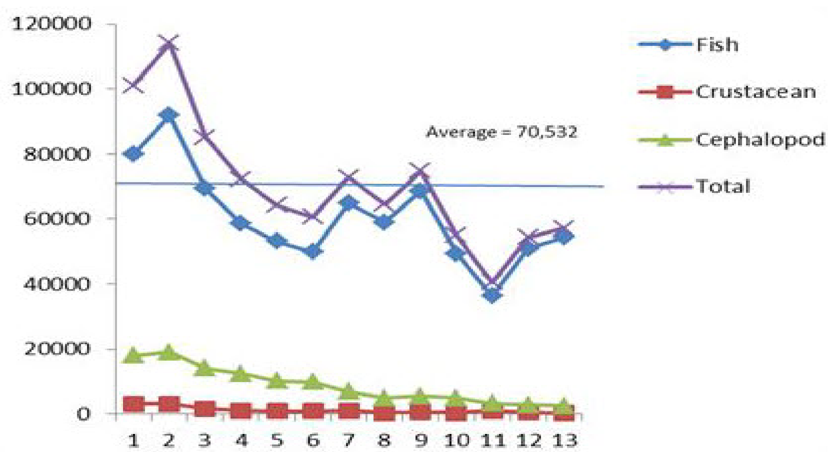

Figure 1. Total volume of saltwater fishery of Satun

From figure 1, it was found that the mean saltwater fishery were all in the period from 2004 to 2016, it was 8,817 tons. The amount of total saltwater fishery was significantly reduced from 2014 to 2016 (Year = 11-13). Subsequently, the amount of all saltwater fishery fluctuates. The fisheries of cephalopod and crustacean decreased steadily. And considering the type of saltwater species, all fish types were caught the most, followed by the cephalopod and the least crustacean.

3.1.2 Saltwater fishery volume (Total Fish)

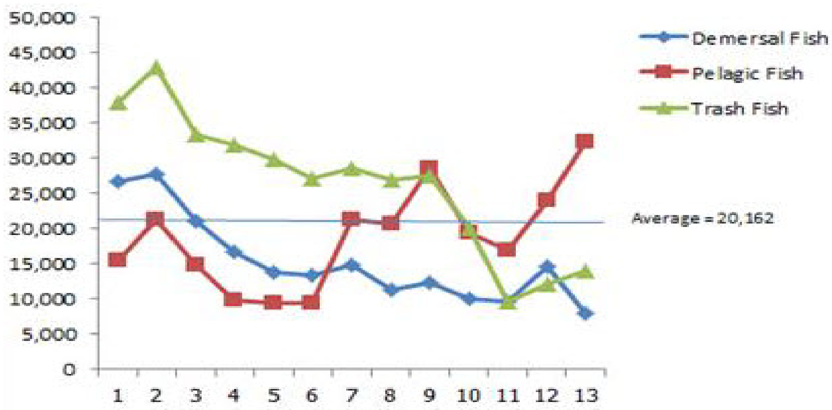

Figure 2. Total volume of saltwater species-fish caught of Satun

From Figure 2, it was found that the average fishery of all fish species from 2004 to 2016 was 20,162 tons. The volumes of that had dropped significantly from 2012 to 2014 (Year = 9-11), well below the mean. Afterward, the number of catch increased slightly. When considering all saltwater species, Trash Fish was the most caught, followed by Pelagic Fish and Demersal Fish the least caught.

3.1.3 Cephalopod fishery volume

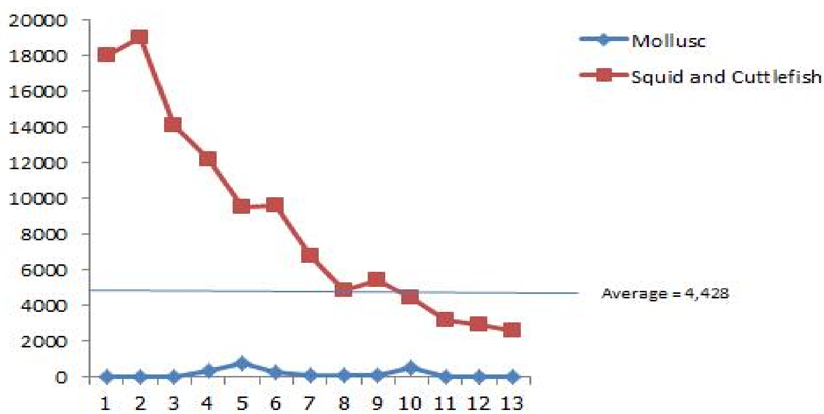

Figure 3. The Cephalopod fishery volume of Satun Province

Figure 3 shows that the mean cephalopod fishery in the period from 2004 to 2016 was 4,428 tons. The amount of saltwater fishery was significantly lower from 2012 to 2014 (Year = 9-11), well below the average. Subsequently, the amount of the catch decreased slightly. And when considering the type of cephalopods-quid and cuttlefish were caught the most and the Mollusca was caught in very small numbers.

3.1.4 Crustacean fishery volume

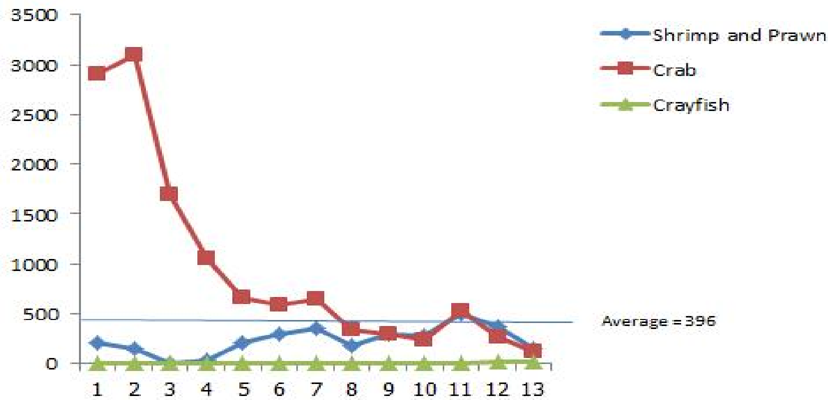

FIGURE 4. Crustacean fishery volume of Satun Province

Figure 4 shows that the average fishery volume for crustaceans between 2004 and 2016 was 396 tons. The volumes of the catch dropped significantly from 2011 to 2013 (Year = 8-10), well below the mean. Subsequently, the amount of catch fluctuated slightly. And when considering the crustacean fishery, the crabs were caught the most, followed by the shrimp and prawn, and crayfish were caught the least.

3.1.5 Other categories fishery, it found that in Satun, there was very little catch of this type of fish, almost none, from 2004 to 2016.

3.2 The results of the inspection of the amount of saltwater fishery in Satun Province using the CUSUM control chart

After using the CUSUM control chart in the process of changing the amount of saltwater fishery in Satun, the results were as follows:

3.2.1 The result of parameter estimation when the process is under control Because the amount of saltwater fishery in Satun from 2004 to 2007 was greater value than from 2008 to 2016, the amount of fish caught in Satun has decreased since 2008. The amount of saltwater fishery from 2008 to 2016 was less than the average for 13 years; therefore, during 2004 to 2007, it was set to be the period when the process was under control. When estimating the parameters, the mean of saltwater fishery in Satun was 87,388 tons and the standard deviation of the saltwater fishery in Satun was 20,446 tons.

3.2.2 The result of the statistical calculation to be plotted into the CUSUM control chart

When using the statistical values of the CUSUM control chart, recommended by Mesnil, B., and Petitgas, P. [2] that $k = 1.3$ After that the statistics of the CUSUM control chart are calculated as follows:

3.2.2.1. One-sided cumulative sum value is greater than at the point of time i.

The S_i^+ value can be calculated from the equation 2.1, which results are shown as in Table 1.

TABLE 1. One-sided cumulative sum value at the point of time i

Year (i)	Saltwater species volume of Satun (x_i)	Standard score of Saltwater species of Satun (z_i)	$z_i - k$	S_i^+
2547	101,092	0.6703	-0.6297	0
2548	114,168	1.3098	0.0098	0
2549	85,144	-0.1098	-1.4098	0
2550	72,202	-0.7427	-2.0427	0
2551	64,334	-1.1276	-2.4276	0
2552	60,622	-1.3091	-2.6091	0
2553	72,795	-0.7137	-2.0137	0
2554	64,595	-1.1148	-2.4148	0
2555	74,817	-0.6148	-1.9148	0
2556	54,932	-1.5874	-2.8874	0
2557	40,591	-2.2888	-3.5888	0
2558	54,415	-1.6127	-2.9127	0
2559	57,209	-1.4761	-2.7761	0

3.2.2.2. One-sided cumulative sum value is less than at the point of time . The S_i^- value can be calculated from Equation 2.2. The results are shown in Table 2.

TABLE 2. One-sided cumulative sum value at the point of time i

Year (i)	Saltwater species volume of Satun (x_i)	Standard score of Saltwater species of Satun (z_i)	$z_i + k$	S_i^-
2547	101,092	0.6703	1.9703	0
2548	114,168	1.3098	2.6098	0
2549	85,144	-0.1098	1.1902	0
2550	72,202	-0.7427	0.5573	0
2551	64,334	-1.1276	0.1724	0
2552	60,622	-1.3091	-0.0091	-0.0091
2553	72,795	-0.7137	0.5863	0
2554	64,595	-1.1148	0.1852	0
2555	74,817	-0.6148	0.6852	0
2556	54,932	-1.5874	-0.2874	-0.2874
2557	40,591	-2.2888	-0.9888	-1.2763
2558	54,415	-1.6127	-0.3127	-1.5890
2559	57,209	-1.4761	-0.1761	-1.7650

From Mesnil & Petitgas (2009) study, the control scope of the CUSUM control chart was calculated according to equations (2.4), (2.5) and (2.6) espectively.

In this research, set $h = 1$, then lead the point S_i^+ and S_i^- at the point of time i to plot into CUSUM Control chart as Figure 5.

Figure 5. CUSUM control chart of Saltwater Fishery in Satun Province

From figure 5, the parameter representing the $k = 1.3$ reference value of the CUSUM control chart is given. And assign it a parameter representing the decision range $h = 1$ of the CUSUM control chart. It found that one-sided cumulative sum was more at the time i or S_i^+ , all value were within the control scope. Whereas the one-sided cumulative sum is less at the point i or S_i^- is within the control range from 2004 to 2013. And after that since 2014, S_i^- has decreased by less than the lower control region. It shows that the amount of saltwater species in Satun had been outside the control process since the year 2014 to 2016.

4. Conclusions and Future Research

This research examines the changes in the amount of fish and cephalopod-crustaceans and other species of Satun province. The research results can be summarized that the number of fish species was caught in the highest and greater than the cephalopod - crustaceans and other species. When analyzing the changes in saltwater species volume in Satun by using the CUSUM control chart, it was found that the value of saltwater fish species fishery in Satun has decreased sharply since 2013, observed with the decrease in S_i^- value since 2013. This sent a clear warning that the process started to malfunction until 2014 onwards. The amount of saltwater fishery was also out of control, consistent with a significant decline in total fishery from 2014 to 2016. That is why there must be an urgent preventive analysis without over-catching of saltwater species that can lead to extinction of some species. Future research could use the CUSUM control chart to examine changes in marine animal counts in other provinces of Thailand with sea-facing areas.

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