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Detecting Change of Longtail Tuna Quantity in Thailand with CUSUM Control Chart

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Abstract

This study presented to apply utilizing control chart as the statistical process control (SPC) tool for detecting the state of marine ecosystem. The cumulative sum (CUSUM) control chart was practically tuned to monitor the change in longtail tuna quantity in Thailand. The result of study illustrates the CUSUM control chart is quickly potential to detect changing in the amount of longtail tuna. That is, the one-sided lower CUSUM abruptly indicates an apparent signal that stock abundance of long tail tuna was sharply decreasing since 2008 to 2011.

Keywords: Longtail tuna, CUSUM control chart

Mathematics Subject Classification: 62-07, 62G35

INTRODUCTION

Thailand is located on the southern Indochina peninsular which is the wide continental shelf of the two long coasts of 2, 615 km. One is 1, 660 km coast along the Gulf of Thailand and the other is 955 km coast along the Andaman Sea [1]. Because of such landscape, Thai seashore is the profusion of marine resources so marine fisheries come to be an important role for the national economy of Thailand, particularly in term of fishery industry foundation such as fish processing, frozen food factory or fish meal factory, etc. Longtail tuna (Thunnus tonggol) is one of three main species of Neritic tunas which are one of the considerable pelagic resources in Thailand. They profusely distribute in coastal areas having more than 20 meters of sea depth. The demand of longtail tuna consumption has gradually increased at present since the longtail tunas are not only suitable material for making canned tunas but also it is popular to consume them as the Japanese food like sushi. Furthermore, Thailand has become the world top exporter according to the annual export value of canned tuna cost more than 10 billion baht [2]. For these mentioned reasons, the longtail tunas in Thai territorial waters (both of the Gulf of Thailand and the Andaman Sea) have been found overexploited or employed over the level of maximum sustainable yield [3], [4].

Control chart is one of statistical process control (SPC) tools which is routinely and extensively utilized in manufacturing contexts for monitoring production processes and signaling abnormalities in performance [5], [6], [7]. Control chart is normally displayed statistic of the observed data against the order of the sample (or time) together with the control limits which are the three reference lines: Upper Control Limit (UCL.), Center Line (CL.) and Lower Control Limit (LCL). The decision problem for manufacturing contexts is concerned in monitoring the status of fish stocks or marine ecosystems for advising managers and warranting corrective action when a worrisome change is happening in marine resources based on strong sign. Therefore, it is reasonable to believe that the SPC tools are pertinent for natural resources management [8].

This study purposed to use the general rules of control charts also provide practical guidelines for their application to longail tuna quantity indicators through the cumulative sum (CUCUM) control chart. The CUSUM control chart is a running total of deviations from a reference value [9]. [10], [11] are the researchers who initially pursued awareness raising among marine scientists by using the decision interval CUSUM (DI-CUSUM) also known as tabular CUSUM. Moreover, [12] showed the outstanding example of using CUSUM control chart with the real data for detection of change of the North Sea cod stock. For detecting change of longtail tunas quantity in this study, two parameters of the CUSUM control charts were set the allowance $k = 1.3$ and the decision limit $h = \pm 1$ according to recommendation of [13] for the real data.

MATERIALS AND METHODS

The Fisheries Statistics, Department of Fisheries provide the stock abundance of longtail tuna in the amount of 1, 000 tons during 1994-2011 [14]. Since data of fish resources were just recorded in a few decades, the in-control mean and standard deviation of longtail tuna amount were not known from a pilot study or for a reference period.

Suppose a suit of longtail tuna amount x_i collected at time i; $i = 1994, 1995, \ldots, 2011$ and estimate the in-control mean and standard deviation of longtail tuna amount from a reference period (1994-2006). The procedures to detect the change of longtail tuna stock abundance were as follows.

1. Standardizing the amount of longtail tuna through the transformation as of Equation 1.

$$z_i = \frac{x_i - \bar{x}}{s} \qquad (1)$$

where z_i be the standardized amount of longtail tuna $\bar{x}$ and s be the estimated value of the mean and the standard deviation of longtail tuna amount, respectively.

2. Calculating the test statistic to be plotted in the CUSUM control chart which consists of two separated deviations. First, the one-sided upper CUSUM statistic is the positive deviations defined as of Equation 2.

$$S_i^+ = \max[0, S_{i-1}^+ + z_i - k] \quad (2)$$

The other one is the negative deviations called the one-sided lower CUSUM statistic defined as of Equation 3.

$$S_i^- = \max[0, S_{i-1}^- + z_i + k] \quad (3)$$

3. Plotting these two statistics, the one-sided upper CUSUM and the one-sided lower CUSUM, against i into the CUSUM control chart containing the control limit equal to the decision limit h called the decision interval. Whenever S_i^+ exceeds the decision interval h (UCL.) or S_i^- lies below the decision interval $-h$ (LCL.), the process is indicated the out-of-control state.

RESULTS

The in-control mean and standard deviation of longtail tuna amount were estimated from the reference period. The two statistic values, S_i^+ and S_i^-, then were obtained by substituting z_i in Equation 2 and Equation 3, respectively. Once both of S_i^+ and S_i^- were plotted, the CUSUM control chart of longtail tuna quantity in Thailand was pictured in Figure 1.

The resulting CUSUM control chart clearly showed the one-sided upper CUSUM, S_i^+, remained within the control limits while the one-sided lower CUSUM, S_i^-, gave a signal that the longtail tuna quantity was sharply decreasing since 2008 to 2011.

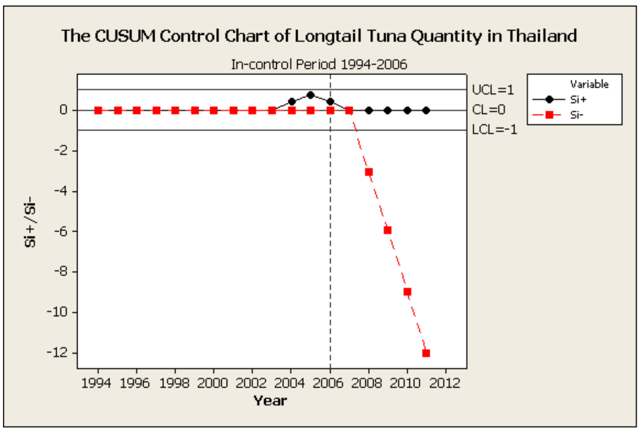

Figure 1: The CUSUM Control Chart of Longtail Tuna Quantity in Thailand

DISCUSSION

The CUSUM approach was capably utilized in fisheries application. Since the CUSUM method does not presume the characteristic of change (may be linear or trend or etc.), the positive and negative deviations are equally treated. Thus, the CUSUM control chart is best fitted for detecting small persistent change. For this reason, the resulting CUSUM control chart of this study suddenly indicated the quantity of longtail tunas lessen since 2008 to 2011. The findings of this study may assist to caution the one who authorize to manage, control and turn the longtail tuna resources in Thai territorial waters back into the equilibrium of marine ecosystem.

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