Desimal: Jurnal Matematika Vol 8 No 1 (2025) 59-70

Contents lists available at DJM

DESIMAL: JURNAL MATEMATIKA

p-ISSN: 2613-9073 (print), e-ISSN: 2613-9081 (online), DOI 10.24042/djm

http://ejournal.radenintan.ac.id/index.php/desimal/index

Fuzzy time series markov chain and discrete-time markov chain analysis of export gonggong in Batam

Andini Setyo Anggraeni[1,*], Sabarinsyah[1], Nahrul Hayati[1], Dia Cahya Wati[2] , Serly Tri Ananda[1]

[1] Institut Teknologi Batam, Indonesia

[2] Universitas Insan Cita Indonesia, Indonesia

ARTICLE INFO

Article History

Received : 04-01-2025

Revised : 08-02-2025

Accepted : 11-03-2025

Published : 30-04-2025

Keywords:

Discrete Time Markov Chain; Export Gonggong; Fuzzy Time Series Markov Chain.

*Correspondence: E-mail: andini@iteba.ac.id

Doi: 10.24042/djm.v8i1.26494

ABSTRACT

Gonggong snails are an important fisheries commodity that has high economic value. However, freight on board export Gonggong has a bigger probability to decrease (below the half-term weighted average). So, more in-depth research is needed about Gonggong exports. In this research we will model and forecast Gonggong exports in Batam City using the Fuzzy Time Series Markov Chain (FTMC) and Discrete-Time Markov Chain (DTMC) methods. In FTMC the data will be divided into six states based on the fuzzification results, while in DTMC the data will be divided into four states, namely very low, low, high, and very high. Gonggong export data in kilograms for Batam City for 2020-2024 is sorted based on H.S. Code. The results of research using FTMC and DTMC provide similar results, namely that in the next six months, in December 2024, Gonggong's export size will experience an equilibrium condition where in the following months the export size will not experience significant changes. The highest possibility that will occur in this condition is that Gonggong's exports will be low with a probability of 39.99%, and the probability that exports will be very low is 24.75%. This is confirmed by the results of analysis using the fuzzy time series Markov chain. The results of the analysis predict that Gonggong's export in the following month, namely July 2024, will be 6,169.97 kg, which is in the low export size category. Predictions for the next month can also be made by continuing the calculation using FTMC.

http://ejournal.radenintan.ac.id/index.php/desimal/index

INTRODUCTION

As an archipelagic country, Indonesia has the potential for marine and fisheries resources that can improve the Indonesian economy (Firdaniza & Gusriani, 2018). Batam, as a free trade zone, plays an important role in the export of fishery products. One of the fishery export products in Batam City is gonggong snails. The gonggong snail is a gastropod-class animal that lives in littoral to sublittoral areas. Globally, the distribution of gonggong snails is found in the

Indopacific region, especially in Southeast Asia, one of which is Indonesia (Supratman & Syamsudin, 2018). The sea snail gonggong is an icon of Tanjungpinang, Riau Islands Province. It is a favorite seafood item in Riau Islands Province and has high economic value (Viruly, Andarwulan, Suhartono, & Nurilmala, 2019a). Gonggong snails are an important fisheries commodity that has high economic value and are made into various processed food products, and their shells are used as various decorations. Apart from that, gonggong snail meat extract contains antibacterials that can kill pathogenic bacteria (Yoswaty & Zulkifli, 2016). However, freight on board Gonggong snail exports in the long term will exceed the half-term weighted average of exports after 17 months (from November 2023 to April 2025) with a probability of 44.9438%, while the probability that Gonggong's FOB exports will be below the half-term weighted average is 55.0562%. It means that in the long-term condition, export Gonggong has a bigger probability to decrease (under the half-term weighted average).

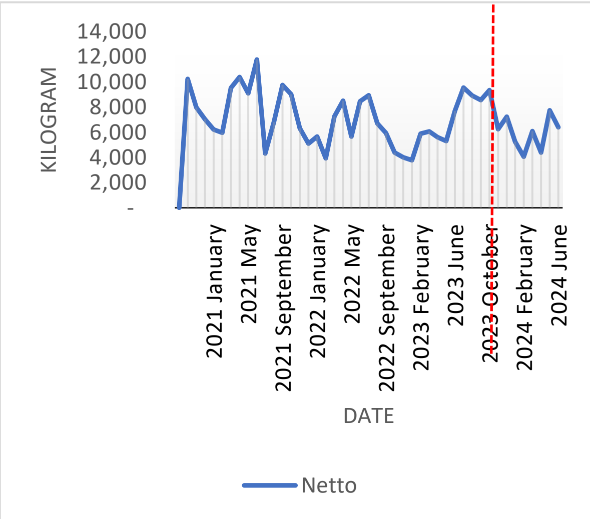

Figure 1. Export Gonggong 2020-2024

Figure 1 shows Gonggong export data based on net weight (in kg). The red line is Gonggong export data used in previous research by Anggraeni, Jabnabillah, Reza, & Wati (2024). The results of this research show that in the long term (17 months after November 2023), the probability that Gonggong's exports will fall below the 6-month weighted average is greater, namely 55.814%, compared to the probability that Gonggong's exports will exceed the 6-month weighted average, namely 44.186% (Anggraeni et al., 2024). The results of this research are supported by the latest data obtained, namely Gonggong export data from December 2023 to June 2024. Gonggong exports based on net exports generally experienced a decline compared to exports in November 2023. If you look at the uniqueness of Gonggong, which is rarely found in other places apart from Batam and the Riau Islands, then Gonggong should be an export commodity product that gets more attention from the government. With the projected decline in Gonggong exports in the city of Batam, the government should intervene to anticipate this. Efforts that can be made are to conduct a more in-depth study of Gonggong snails, their potential, and projections from various points of view, especially Gonggong export projections. Based on the results of these studies, the government can make appropriate policies.

There is previous research that discusses the analysis and forecasting of fisheries exports, including research by Anggraeni et al. (2024) on the analysis of exports of five main fishery product commodities in Batam City using the Markov chain. Sri Bintang, Huang, & Asmara (2019) on forecasting seaweed exports using fuzzy time series with and without Markov chains. Research by Hartanto, Suharno, & Burhanuddin (2021) on the export of Indonesian skipjack tuna to the United States market and Sirisha & Rao (2020) research on shrimp exports in India using Markov chains. Meanwhile, previous research on Gonggong snails includes research by (Yoswaty & Zulkifli, 2016) on the antibacterial analysis of

Gonggong snail ethanol extract. (Viruly, Andarwulan, Suhartono, & Nurilmala, 2019b) research on protein profiles of Gonggong Snail, research by Bora, Jama, Syahril, Setyabudhi, & Susanti (2019) regarding feasibility analysis of the Gonggong industry in Batam City, and research by (Anggraeni et al., 2024) regarding Gonggong export projections using a Markov chain with two states, namely above the 6-month weighted average and below the 6-month weighted average. The research results indicate that the probability of Gonggong exports being below the 6-month weighted average is higher. However, this research only uses two statuses, and it has not been projected how much of a decline in exports will occur in the next period. So more in-depth research is needed about Gonggong exports.

In this research, Gonggong export forecasting will be based on Gonggong export net (kilogram) data from October 2020 to June 2024. The method used is a discrete-time Markov chain with four states, namely very low, low, high, and very high. These four statuses were selected based on the categorization of Gonggong's net export weight in kilograms. Analysis using Markov chains aims to find out what the probability of transition between states is when Gonggong exports experience an equilibrium condition and the probability at an equilibrium condition. The analysis will be continued using the Fuzzy Time Series Markov Chain to see in more detail the projected net weight (kilograms) of Gonggong exports in the following month and modeling the transition of Gonggong exports using fuzzyfication result categories. It is hoped that the output of this research will contribute to the development of fishery product exports, especially Gonggong exports in Batam City.

METHOD

This research is quantitative, with the research location being Batam City. The population of this research is the net exports of fishery products from Batam City, while the sample for this research is the net exports of Batam Gonggong snails from October 2020 to June 2024. The data collection technique used in this research is document collection. The document used is the Batam City Export document. The data is secondary data from the Ministry of Maritime Affairs and Fisheries. The data taken is monthly net export data for fishery product commodities, especially Gonggong Snails, in kilograms from October 2020 to June 2024. Data is sorted based on the Harmonized Commodity Description and Coding System (H.S. Code).

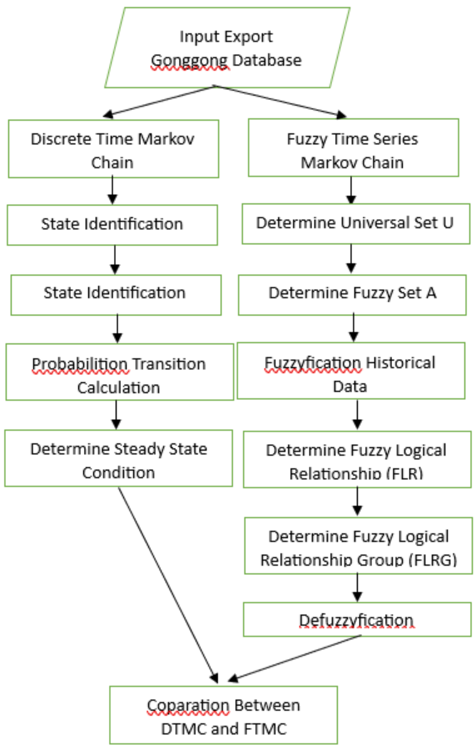

Figure 2. Research Flowchart

The variable input used in this research is the net export of Gonggong in Batam City. The method used in this research is a Markov chain with four states (export size is very high, high, low, and very low) and a fuzzy time series Markov chain with the help of Excel.

1. Markov Chain

The discrete-time stochastic process X_n is a Markov Chain if it satisfies equation

$$P\left(X_n = j \,\middle|\, \begin{matrix} X_0 = x_0, X_1 = x_1, \\ \dots, X_{n-1} = i) \end{matrix}\right) = P(X_n = j \mid X_{n-1} = i) = p_{ij} \quad (1)$$

For all $n \geq 1$ and all $x_0, x_1, \dots, i, j \in S$. Then, the probability transition for $i, j = 0,1,2,3$ is denoted in the matrix shown in Equation (2).

$$P_{ij} = \begin{bmatrix} P_{00} & P_{01} & P_{02} & P_{03} \\ P_{10} & P_{11} & P_{12} & P_{13} \\ P_{20} & P_{21} & P_{22} & P_{23} \\ P_{30} & P_{31} & P_{32} & P_{33} \end{bmatrix} \quad (2)$$

where $\sum_{j=0}^{3} P_{ij} = 1$, $i = 0, 1,2,3$. P_{ii} is the probability of remaining in a state i. P_{ij} is the transition probability from state i to state $j, i \neq j$ (Serfozo, 2009).

The maximum-likelihood estimation (MLE) was used to estimate the transition probabilities for each disease with their respective standard errors. P_{ij} follows a binomial model in Equation (3).

$$L(P_{ij}|N, x) = \binom{N_i}{x_{ij}} P_{ij}^{x_{ij}} (1 - P_{ij})^{N_i - x_{ij}} \quad (3)$$

Where N_{ij} is the number of observed transitions that start from state i to j and $\sum_j P_{ij} = 1$. From Equation (4) and the assumption of constant transition probabilities over the period, the transition probability matrix is estimated as a multinomial distribution given in Equation (4).

$$\hat{P}_{ij} = \frac{x_{ij}}{\sum_j x_{ij}} = \frac{x_{ij}}{N_i} \quad (4)$$

For $i, j = 0,1,2,3,4$, with standard errors from the sampling distribution of the Maximum-Likelihood estimation given in Equation (5).

$$\hat{s}.e(P_{ij}) = \sqrt{\frac{\hat{P}_{ij}\,(1 - \hat{P}_{ij})}{N_i}} \quad (5)$$

The P^n transition probability matrix predicts the transition probabilities at any time step. The method for estimating the nth-step transition probability matrices for each disease uses the Chapman-Kolmogorov Equation. The P^n transition probability is

$$P(X_{m+n} = j \,|X_m = i) = P_{ij}(n) = P_{ij}(m, m+n) = P^n \quad (6)$$

Matrix transition of 2 step is

$$P^2 = P \times P \quad (7)$$

Matrix transition of 3 step is

$$P^3 = P^2 \times P \quad (8)$$

Matrix transition of n-step is

$$P^n = P^{n-1} \times P \quad (9)$$

The vector π is said to be the stationary distribution of a chain if $\pi = (\pi_j, j \in S)$ fulfills Equations (10) and (11)

$$\pi_j \geq 0, \forall j \in S \text{ and } \textstyle\sum_j \pi_j = 1 \quad (10)$$

$$\pi = \pi P \text{ or } \pi(P - I) = 0 \quad (11)$$

2. Fuzzy Time Series Markov Chain

Fuzzy time series has a combined method with Markov Chain, which was first introduced by Tsaur (2012) with the name fuzzy time series Markov Chain. The difference between fuzzy time series and fuzzy time series-Markov chain lies in the defuzzification or initial forecasting process. The steps in carrying out fuzzy time series-Markov chain forecasting are as follows:

1) Obtain historical data and determine the definition for the universal set U.

From historical data, this step looks for the minimum (D_{min}) and maximum (D_{max}) values. The universal set is defined in Equation (12).

$U = [D_{min} - D_1, D_{max} + D_2]$ or (12)
$U = [D_{min}, D_{max}]$ (4)

where:

U : Universal Set
D_{min} : Minimum Data
D_{max} : Maximum Data
D_1, D_2 : Corresponding positive numbers

Determination of the values of D_1 and D_2 is done randomly or by choosing positive numbers freely. The purpose of the values D_1 and D_2 is to make it easier to divide intervals.

2) Calculate the number and length of intervals required.

By using the Sturges formula. The universe U is divided into parts at uniform intervals using a formula $n = 1 + 3{,}332 \log N$ (2), where N is the count of historical data. The difference between two intervals n, or interval length, can be expressed as Equation (3.)

$$l = \frac{D_{max} - D_{min}}{n} \quad (13)$$

where:
l : Interval length
n : Numbers of interval
Then each interval can be calculated using,

$$u_1 = [D_{min} ; D_{min} + l]$$
$$u_2 = [D_{min} + l; D_{min} + 2l]$$
$$\vdots$$
$$u_n = [D_{min} + nl; D_{min} + (n + 1)l]$$

3) Determine Fuzzy set A, which is a fuzzy set consisting of real numbers from a previously defined domain. The universe set U is expressed as $U = \{u_1, u_2, u_3, \cdots, u_i\}$, with $i, j = 1, 2, 3, \ldots, n$, where n is the number of partitions in the data that will be taken for forecasting. The Fuzzy set A can be expressed as Equation (14)

$$A_j = \sum_{i=1}^{n} \frac{\mu_j(u_i)}{u_i} \quad (14)$$

where μ_j is the degree of membership of the fuzzy set A_j on set elements u_i, dengan i = 1,2,3, … , n and 0 < μ_j < 1.

4) Fuzzification of historical data is the step in which data is identified and transformed into fuzzy sets. This stage is important to identify the right fuzzy set for each data.

5) Determining fuzzy logical relations (FLR), relationships are identified based on the fuzzification values of historical data, as shown in the Equation (15).

$$A_i \rightarrow A_j \quad (15)$$

where:
A_i : current state
A_j : next state

6) Next, FLRG is determined by combining current states that have the same next state. Based on the previous example, the FLRG is obtained in Equation (16).

$$A_k \rightarrow A_{k1}, A_{k2}, A_{k3}, \ldots, A_{kn} \quad (16)$$

Where:
A_k : current state
A_m : a collection of next state relations based on the same current state

Defuzzification means the process of converting fuzzy output resulting from fuzzy logic rules into definite values using membership values that are appropriate when fuzzyfication is carried out. Defuzzification has 3 steps: early forecasting, adjustment of forecasting, and final forecasting.

RESULTS AND DISCUSSION

The data used in this research is monthly net exports of gonggong snails for Batam City in kilogram from October 2020 to June 2024. The data can be seen in Table 1. Based on the data in Table 1, the minimum export value is 3,768kg and the maximum export value is 11,780kg. Based on these two values, the net export weight of Gonggong is categorized into 4 statuses, namely very low net exports (less than 5,771 kg), low net exports (5,771kg ≤ exports < 7,774 kg), high net exports (7,774 kg ≤ exports < 9,777 kg), and very high net exports (more than or equal to 9,777kg).

Table 1. Net Export Gonggong

Date	Netto (Kg)
2020 October	10,230
2020 November	7,985
2020 December	7,035
2021 January	6,220
2021 February	5,970
2021 March	9,525
2021 April	10,400
...	...
2024 April	4,400
2024 May	7,750
2024 June	6,400

Suppose that the discrete states of the Markov chain model for export Gonggong are Very Low (state 0), Low (state 1), High (state 2), and Very High (state 3) states. Let $X_i, i = 0,1,2,3,$ represent the number of individuals at any state at any time t, which satisfies the first-order time-homogeneous Markov dependency from the equation. Clearly, X_i satisfies the Markov chain model with state space $S = \{0,1,2,3\}$. Figure 3 shows the multiple states model of TB transmission. Table 2 shows the number of transitions at any state at the end of the period.

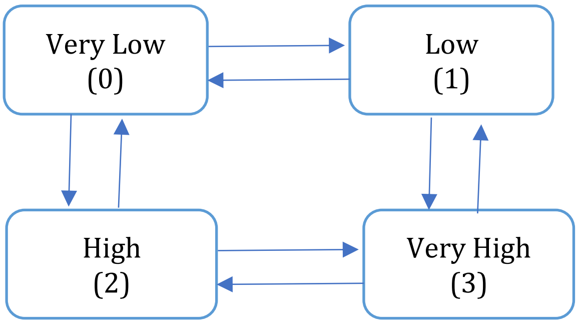

Figure 3. Multiple States Model for Export Gonggong

Table 2. Number of Transition at Any State at the End of the Period

State	Very Low	Low	High	Very High
Very Low	6	6	1	0
Low	5	6	4	0
High	1	4	5	2
Very High	1	1	1	0

Based on the data in Table 2, it can be seen that when exports reach very low or low status, then in the following month exports will not immediately jump to very high. Likewise, when exports reach very high conditions, this condition will not be repeated in the following month. On the other hand, if this month's net exports are very low, there is a possibility that in the following month the amount of exports will be very low. To see more clearly the transition probability from each condition from this month to next month or the next few months, it is necessary to calculate the transition probability for each status. The transition probability and error of each transition can be calculated using Equations (4) and (5), while the calculation results can be seen in Table 3. The transition probability matrix for export Gonggong is presented as:

$$P = \begin{bmatrix} 0.461538 & 0.461538 & 0.076923 & 0.000000 \\ 0.333333 & 0.400000 & 0.266667 & 0.000000 \\ 0.083333 & 0.333333 & 0.416667 & 0.166667 \\ 0.333333 & 0.333333 & 0.333333 & 0.000000 \end{bmatrix}$$

$$P^2 = \begin{bmatrix} 0.373274 & 0.423274 & 0.190631 & 0.012821 \\ 0.309402 & 0.402735 & 0.243419 & 0.044444 \\ 0.239850 & 0.366239 & 0.324466 & 0.069444 \\ 0.292735 & 0.398291 & 0.253419 & 0.055556 \end{bmatrix}$$

$$P^3 = \begin{bmatrix} 0.319771 & 0.403388 & 0.239293 & 0.037548 \\ 0.311493 & 0.400009 & 0.247259 & 0.041239 \\ 0.300997 & 0.395511 & 0.257749 & 0.045743 \\ 0.309548 & 0.399252 & 0.249060 & 0.042140 \end{bmatrix}$$

$$P^4 = \begin{bmatrix} 0.311556 & 0.399984 & 0.247290 & 0.041170 \\ 0.311396 & 0.399918 & 0.247446 & 0.041240 \\ 0.311191 & 0.399832 & 0.247647 & 0.041330 \\ 0.311360 & 0.399903 & 0.247482 & 0.041256 \end{bmatrix}$$

$$P^5 = \begin{bmatrix} 0.311394 & 0.399917 & 0.247448 & 0.041241 \\ 0.311393 & 0.399917 & 0.247448 & 0.041241 \\ 0.311393 & 0.399917 & 0.247448 & 0.041241 \\ 0.311393 & 0.399917 & 0.247448 & 0.041241 \end{bmatrix}$$

$$P^6 = \begin{bmatrix} 0.311393 & 0.399917 & 0.247448 & 0.041241 \\ 0.311393 & 0.399917 & 0.247448 & 0.041241 \\ 0.311393 & 0.399917 & 0.247448 & 0.041241 \\ 0.311393 & 0.399917 & 0.247448 & 0.041241 \end{bmatrix}$$

Table 3. Probability Transition and Standard Error

Parameters	Estimate	SE
P_{00}	0.461538	0.07602
P_{01}	0.461538	0.07602
P_{02}	0.076923	0.04064
P_{03}	0.000000	0
P_{10}	0.333333	0.07189
P_{11}	0.400000	0.07471
P_{12}	0.266667	0.06744
P_{13}	0.000000	0
P_{20}	0.083333	0.04215
P_{21}	0.333333	0.07189
P_{22}	0.416667	0.07518
P_{23}	0.166667	0.05683
P_{30}	0.333333	0.07189
P_{31}	0.333333	0.07189
P_{32}	0.333333	0.07189
P_{33}	0.000000	0

P shows the probability of the net transition of Gonggong exports in the following month. Based on the data in Table 1, it is known that Gonggong's net exports in June are in the low category, so the highest probability for Gonggong's net exports in July 2024, namely 40%, is in the low category. Based on the P^2 results, it can also be seen that in the following two months, the highest probability of Gonggong exports, namely 40.2735%, is in the low category. This continued to happen for the following months. Therefore, it is necessary to carry out further calculations regarding the long-term condition of Gonggong exports by calculating steady-state conditions.

Next, steady-state conditions will be calculated to determine the equilibrium conditions for gonggong exports in the long term. Gonggong exports reach equilibrium conditions at $n = 6$, with $\pi_0 = 0.311393$, $\pi_1 = 0.399917$, $\pi_2 = 0.247448$, and $\pi_3 = 0.041241$. From our analysis, we find that in the steady state, the opportunity for net Gonggong exports to be very low is 31.1391%, the opportunity for net Gonggong exports to be low is 39.9917%, the opportunity for net Gonggong exports to be high is 24.7448%, and the opportunity for net Gonggong exports to be very high is 4.1241%. It means that in the long-term condition, the net export of Gonggong has a greater probability of becoming low or very low. On the other hand, in long-term conditions, the probability of Gonggong exports becoming very high is very low (only 4%). Considering the potential that Gonggong has, this is very unfortunate. In addition, Gonggong's net exports have been in the very high category three times in the last 4 years.

The results of this research are in accordance with the results of previous research by Anggraeni et al. (2024) regarding predictions of freight on board (FoB) for Gonggong exports. If we look at the FoB data, it is known that Gonggong exports will experience a steady state condition in the next 17 steps (April 2025) with the probability that Gonggong export FoB will be below the half-term weighted average of 55.0562%. This indicates a decline in Gonggong's export FoB in the long term. In this study, the data used is net exports of Gonggong, where net exports are proportional to FoB exports. The analysis results show that Gonggong's net exports will experience steady-state conditions in the next 6 steps (December 2024), faster than previous research results, with the highest probability of exports being in the low category (39.9917%). Differences in steady-state time can be caused by differences in the status used and updated data in the latest research. However, it should be noted that these two studies give the same results, namely that in the long-term Gonggong exports will experience a decline.

The results of analysis using Markov chains have the advantage of being able to predict long-term export conditions.

However, to assist decision-making, both for the government and export players, further analysis needs to be carried out to predict Gonggong exports in the short term. Analysis can be carried out using a Fuzzy time series Markov chain. Analysis using this method will be able to provide detailed predictions, not just in probability, regarding Gonggong's net exports in the next period.

Based on Table 1, the minimum data obtained is $(D_{min}) = 3{,}768$ and the maximum data obtained is $(D_{max}) = 11{,}780$; then we get universal sets $U = [3{,}768; 11{,}780]$. The number of partitions of the universe set U is found using the Sturges formula to obtain $n = 1 + 3{,}322\ log\ N \approx 6$. So that the data obtained will be divided into 6 partitions with an interval of $l = 1{,}335$. The distribution of the universe set U and its middle value can be seen in Table 4.

Table 4. Division of the Universal Set U and the Middle Value

No.	u_n	Lower limit	Upper Limit	Middle Value
1	u_1	3,768.00	5,103.33	4,436
2	u_2	5,103.33	6,438.67	5,771
3	u_3	6,438.67	7,774.00	7,106
4	u_4	7,774.00	9,109.33	8,442
5	u_5	9,109.33	10,444.67	9,777
6	u_6	10,444.67	11,780.00	11,112

Based on the set U, data fuzzification can be carried out, where numerical data will be converted into linguistic data based on fuzzy sets (A_1 *to* A_6). The results of data fuzzification can be seen in Table 5. FRL can be searched by utilizing the fuzzification results in Table 5, which is the relationship between each data sequence and the next data in the form of a fuzzy set. The FLR results can be seen in Table 6. Next, FLRG can be done by grouping each status change. The current state is the data used as a condition for obtaining values for the next state. The FLRG results can be seen in Table 7. The FLRGs that have been grouped in Table 7 will then be used to determine the probability transition of each state. The transition process for forecasting Gonggong exports can be seen in Figure 4.

Table 5. Fuzifikasi Data

Date	Netto (Kg)	Fuzzifikasi
2020 October	10,230	A_5
2020 November	7,985	A_4
2020 December	7,035	A_3
2021 January	6,220	A_2
2021 February	5,970	A_2
2021 March	9,525	A_5
2021 April	10,400	A_5
...	...	...
2024 April	4,400	A_1
2024 May	7,750	A_3
2024 June	6,400	A_2

Table 6. Fuzzy Logical Relationship (FLR)

T	FLR
1-2	$A_5 \rightarrow A_4$
2-3	$A_4 \rightarrow A_3$
3-4	$A_3 \rightarrow A_2$
...	...
42-43	$A_1 \rightarrow A_3$
43-44	$A_3 \rightarrow A_2$

Table 7. Fuzzy Logical Relation Group (FLRG)

Current State	Next State	FLRG
A_1	$(2)A_1, (3)A_2, (3)A_3$	$A_1 \rightarrow 2A_1, 3A_2, 3A_3$
A_2	$(5)A_1, (4)A_2, (2)A_3, A_4, A_5$	$A_2 \rightarrow 5A_1, 4A_2, 2A_3, A_4, A$
A_3	$(4)A_2, A_3, A_4, (2)A_5$	$A_3 \rightarrow 4A_2, A_3, A_4, 2A_5$
A_4	$(2)A_2, (2)A_3,]\ (2)A_4, A_5, A_6$	$A_4 \rightarrow 2A_2, 2A_3, 2A_4, A_5, A$
A_5	$A_2, (4)A_4, A_5$	$A_5 \rightarrow A_2, 4A_4, A_5$
A_6	A_2	$A_6 \rightarrow A_2$

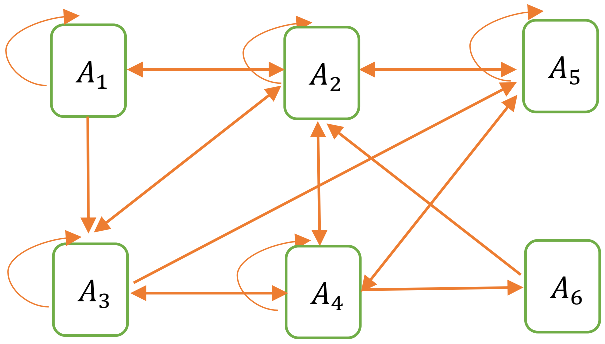

Figure 4. Transition Process Based on FLR

The transition probability matrix is formed by utilizing the FLRG results in Table 7. The transition probability matrix to be formed has the order of 6×6, where each element in the matrix is the probability of each event. The transition probability matrix is as follows:

$$\boldsymbol{P} = \begin{bmatrix} \mathbf{0.250} & \mathbf{0.375} & \mathbf{0.375} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0.385} & \mathbf{0.308} & \mathbf{0.154} & \mathbf{0.077} & \mathbf{0.077} & \mathbf{0} \\ \mathbf{0} & \mathbf{0.500} & \mathbf{0.125} & \mathbf{0.125} & \mathbf{0.250} & \mathbf{0} \\ \mathbf{0} & \mathbf{0.250} & \mathbf{0.250} & \mathbf{0.250} & \mathbf{0.125} & \mathbf{0.125} \\ \mathbf{0} & \mathbf{0.167} & \mathbf{0} & \mathbf{0.667} & \mathbf{0.167} & \mathbf{0} \\ \mathbf{1} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \end{bmatrix}$$

The probability values in the transition probability matrix that have been obtained can then be used as a basis for initial forecasting. Forecasting starts from the 2nd data, namely November 2020, by looking at the data from the previous date, namely the 1st data in October 2020, with the state transition $\boldsymbol{A_5 \rightarrow A_4}$. Then, the forecasting calculation is as follows:

$$\boldsymbol{F_2 = m_0(P_{20}) + m_1(P_{21}) + Y_1(P_{22}) + m_3(P_{23}) + m_4(P_{24}) = 8,294.61}$$

From the calculations, it is found that the initial forecast at $t = 2$ is 8,294.6110 kg. Next, the other data is done in the same way. The Fuzzy Time Series-Markov Chain method has a step of adjusting experience results, which is useful for minimizing the occurrence of deviations in forecasting results. The initial forecasting results, adjustment values, and final forecasting can be seen in Table 8. The comparison graph of Gonggong's net exports with the final forecasting results can be seen in Figure 4.

Table 8. Forecasting Result of Fuzzy Time Series Markov Chain

Date	Early Forecasting	Adjustment of Forecasting	Final Forecasting
2020 November	8,294.61	-667.67	7,626.94
2020 December	7,826.75	-667.67	7,159.08
2021 January	7,264.33	-667.67	6,596.67
2021 February	6,114.59	0.00	6,114.59
2021 March	6,037.67	2003.00	8,040.67
...	...	...	...
2024 March	1,012.50	667.67	6,509.17
2024 April	1,876.92	-667.67	5,410.00
2024 May	1,100.00	1335.33	7,264.33
2024 June	968.75	-667.67	6,686.04
2024 July	1,969.23	0.00	6,169.97

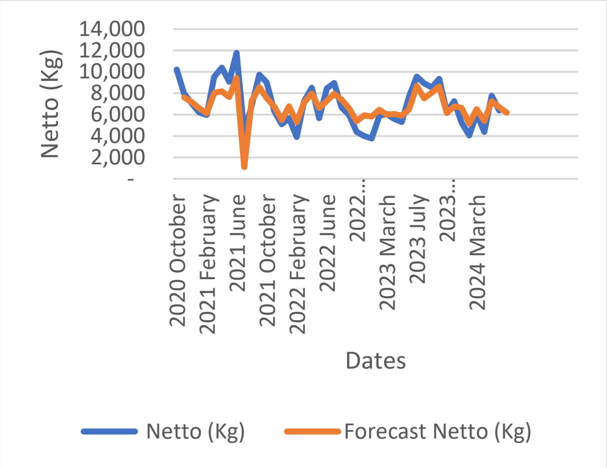

Figure 5. Comparison Graph of Actual Data with Forecasting Results

Accuracy level testing is a process to find out whether it is suitable for use or not. Accuracy testing is carried out using MAPE values. The FTMC MAPE value obtained was 15.04%. This accuracy result is in the good category.

In previous research results, in the long term (17 months after November 2023), the probability that Gonggong's exports will fall below the 6-month weighted average is greater than the probability that Gonggong's exports will exceed the 6-month weighted average (Anggraeni et al., 2024). Compared with that previous research, based on Table 8, the forecast for Gonggong's net exports in the next period is 6,169.97 kg. If you use Markov chain categorization, then Gonggong's exports for the next period are in the low category. The results of the analysis using the Fuzzy Time Series Markov Chain are in agreement.

Compared with previous research, this research has the same agreement that exporting Gonggong has a greater probability of decreasing. But this research complements the results of previous research in that this research determines not only the probability but also the forecast result of the next net export of Gonggong in kilograms, which is not stated in the previous research.

CONCLUSIONS AND SUGGESTIONS

Analysis of Gonggong exports in Batam City is in a condition that requires caution because it is vulnerable to a decline in the number of exports in the long term. If the export size is divided into very low, low, high, and very high categories, then it is estimated that in the next six months, namely in December 2024, Gonggong's export size will experience an equilibrium condition where in the following months the export size will not change. The highest possibility that will occur in this condition is that Gonggong's exports will be low with a probability of 39.99%, and the probability that exports will be very low is 24.75%. This is inversely proportional to the big chance that exports will stabilize in the high, very high, or very low categories. This is confirmed by the results of analysis using the fuzzy time series Markov chain. The results of the analysis predict that Gonggong's export size in the following month, namely July 2024, will be 6,169.97 kg, which is in the low export size category. Predictions for the next month can also be made by continuing the calculation using FTMC.

It is hoped that the conclusions from this research can be a reference for the government, especially the Batam City government, to take steps to intervene and prevent this large decline in Gonggong exports, considering the uniqueness and potential that Gonggong has to become a mainstay export product. In further research, a more in-depth analysis can be carried out regarding the factors causing the large decline in Gonggong exports as well as a more in-depth analysis regarding Gonggong's market share in the international realm. Education and deepening of problems for Gonggong exporters also need to be carried out to obtain more comprehensive study results.

REFERENCES

Anggraeni, A. S., Jabnabillah, F., Reza, W., & Wati, D. C. (2024). Forecasting freight on board for gonggong export in batam using markov chain. *Jurnal Pijar Mipa*, *19*(3), 469–472. https://doi.org/10.29303/jpm.v19i3.6534

Bora, M. A., Jama, J., Syahril, Setyabudhi, A. L., & Susanti, A. (2019). Feasibility analysis for local industry of gonggong crackers in batam. *International Journal of Scientific and Technology Research*, *8*(6).

Firdaniza, & Gusriani, N. (2018). Markov chain model for demersal fish catch analysis in Indonesia. *IOP Conference Series: Materials Science and Engineering*, *332*, 012022. https://doi.org/10.1088/1757-899X/332/1/012022

Hartanto, T. R., Suharno, S., & Burhanuddin, B. (2021). Daya saing ekspor ikan tuna-cakalang-tongkol indonesia di pasar amerika serikat. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *24*(2), 227–235. https://doi.org/10.17844/jphpi.v24i2.36075

Serfozo, R. (2009). *Probability and its application: Basic of applied stochastic processes*. Springer.

Sirisha, K. J. V. K., & Rao, D. V. S. (2020). Direction of trade and the structural stability of indian shrimp exports: Markov chain analysis. *International Journal of Current Microbiology and Applied Sciences*, *9*(7), 3069–3077. https://doi.org/10.20546/ijcmas.2020.907.362

Sri Bintang, A., Huang, W.-C., & Asmara, R. (2019). Forecasting of indonesia seaweed export: A comparison of fuzzy time series with and without markov chain. *Agricultural Social Economic Journal*, *19*(3), 155–164. https://doi.org/10.21776/ub.agrise.2019.019.3.4

Supratman, O., & Syamsudin, T. S. (2018). Karakteristik habitat siput gonggong (strombus turturella) di ekosistem padang lamun. *Jurnal Kelautan Tropis*, *21*(2). https://doi.org/10.14710/jkt.v21i2.2969

Tsaur, R. C. (2012). A fuzzy time series-markov chain model with an application to forecast the exchange rate between the taiwan and us dollar. *International Journal of Innovative Computing, Information and Control*, *8*(7 B), 4931–4942.

Viruly, L., Andarwulan, N., Suhartono, M. T., & Nurilmala, M. (2019a). Morphologycal and molecular partial histone-h3 characterization of bintan sea snail gonggong (strombus sp.) as a species validation. *HAYATI Journal of Biosciences*, *26*(2), 56. https://doi.org/10.4308/hjb.26.2.56

Viruly, L., Andarwulan, N., Suhartono, M. T., & Nurilmala, M. (2019b). Protein profiles and dna isolation of hemolymph gonggong snail (strombus sp.) from bintan. *IOP Conference Series: Earth and Environmental Science*, *278*(1), 012078. https://doi.org/10.1088/1755-1315/278/1/012078

Yoswaty, D., & Zulkifli. (2016). Analisis antibakteri ekstrak etanol siput gonggong (strombus canarium) terhadap bakteri patogen. *Jurnal Perikanan Universitas Gadjah Mada*, *18*(2).