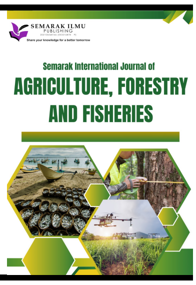
SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Semarak International Journal of Agriculture, Forestry and Fisheries

Journal homepage: https://semarakilmu.com.my/journals/index.php/sijaff/index
ISSN: 3030-5667




# Growth Patterns, Status of Well-Being and Trend Analysis of Three Commercially Important Clupeid Species from Selangor Landing Port

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**ARTICLE INFO**

***Article history:***
Received 29 March 2024
Received in revised form 24 April 2024
Accepted 19 May 2024
Available online 24 May 2024

***Keywords:***
Length-weight relationship; condition factor; growth pattern; landing trend; autoregressive integrated moving average

**ABSTRACT**

Length-weight relationships (LWRs) and condition factors are vital to quickly understanding the fitness and well-being of fish. There is currently no available evidence on LWRs, condition factors and landing trend for these three species and an absence of this information will result in improper management and monitoring of fish species. In this study, the growth patterns, status of well-being and trend analysis of commercially important clupeid species from the west coast of Peninsular Malaysia were studied. *Sardinella lemuru*, *Amblygaster sirm* and *Nematalosa japonica* were selected due to high commercial value and conservation status. *S. lemuru* was specifically categorized as near threatened by the IUCN with decreasing global populations. Total length (cm) and body weight (g) of *S. lemuru, A. sirm* and *N. japonica* were accounted for in this study, which was obtained from the wet market in the west coast of Peninsular Malaysia. The relationships among length, weight and condition factors (Fulton's, $K_F$; relative condition factor, $K_n$; Allometric) were assessed. The allometric equation; $W = aL^b$ was used to evaluate the length-weight relationships while $K_F = 100W/L^b$ and $K_n = W/aL^b$ were used to estimate fish condition factor. Prediction based on Autoregressive Integrated Moving Average (ARIMA) (1,1,1) and ARIMA (0,1,0) models were utilized to forecast the fish landing pattern until 2030. The results showed that the coefficient of determination $R^2$ values varied between 0.263 (*Sardinella lemuru*), 0.5187 (*Amblygaster sirm*) and 0.8443 (*Nematalosa japonica*) and b values ranged from 0.0959 to 2.1005. From this, all three fish species have shown a negative allometric growth pattern b<3, reflecting a relatively slow growth rate and size of fish. No positive allometry was detected for any of the sampled fish species. A low value of relative condition factor (Kn < 1) suggests that all the fish species in this study have poor physical characteristics due to inadequate food resources and unsuitable habitats for expansion of the fish population. ARIMA model showed that *N. japonica* would increase gradually in the coming years, while *S. lemuru* would remain constant. This study contributed to the knowledge base for *S. lemuru*, *A. sirm* and *N. japonica* in the west coast of Peninsular Malaysia, and is crucial in terms of understanding the ecology of the habitat for supporting conservation strategies, restoration and management of these species in future.

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## 1. Introduction

The fisheries resources are vital to the economy and food security of the nation. The contribution of the entire fishing industry to Malaysia's GDP is 11.17 billion Malaysia Ringgit. The importance of fish is not limited to the economy, GDP and human consumption but it serves an important role in providing the main nutrition for human health [1]. As specified in the handbook of the Convention on Biological Diversity (CBD) for small-scale fishing communities, the health of the aquatic ecosystems and its associated biodiversity, are the fundamental basis for the livelihoods of marine and fishing communities and contribute to the overall well-being [2]. Hence, research on the biology, ecology and production trend of fish is crucial to enhancing fishery management and conservation.

Tropical marine clupeid species including *Sardinella lemuru*, *Amblygaster sirm* and *Nematalosa japonica* form important marine fisheries resources in the Indo-west Pacific region and serve as economically important marine species that provide a significant contributions to the total fisheries production in Southeast Asian region [3]. However, information about their biology and ecology is scattered across diverse localized research. These three species were listed as near threatened, least concern and data deficient in the Global Red List of IUCN with the maximum length for *S. lemuru* is 23 cm for male standard length, *A. sirm* recorded the maximum length as 27 cm for male standard length while *N. japonica* recorded a maximum of 19 cm of standard length for both sexes [4]. Furthermore, there is currently no available evidence on Length-weight relationships (LWRs) and condition factors for these three species. The LWR is not only a morphological characteristic of a species; it also reveals details about the general health, habitat, and physical state of a fish, while condition factors are the first aid facility, which contributes to a quick assessment of the fish's physical health status, nutritional conditions, or spent energetic sources with cyclical activities [5,6]. An absence of this information will result in improper management and monitoring of fish species.

To overcome the limitation, this study analyzed the biometric characteristics, as well as production trend of three important clupeid species, *S. lemuru*, *A. sirm* and *N. japonica*. The length-weight relationship is crucial for effective fish population management and exploitation, as well as for sustaining the taxonomic characteristics of the species. These details are necessary for stock assessments such as calculating growth rates, length and age distributions and other aspects of the population dynamics [7]. The estimation of length-weight relationships enables fisheries scientists to calculate fish conditions, compare the life histories and morphological characteristics of populations living in various regions, convert growth-in-length equations to growth-in-weight in stock assessment models and estimate biomass from length frequency distributions [1].

## 2. Methodology

### *2.1 Morphological Species Identification*

Morphological species identification of *Sardinella lemuru*, *Amblygaster sirm* and *Nematalosa japonica* were carried out according to [4] key to the species and fishbase database. The wet body weight (g) of fish was recorded using an electronic balance with an accuracy of 0.01 g. The total length (TL) of the fish was measured from the tip of the snout until the end of the caudal fin ray [8] and the standard length (SL) was measured from the tip of the snout to the posterior end of the vertebra using a 30 cm ruler and thread. Figure 1 showed the illustration of the traditional morphometric measurements to determine the TL and SL of the fish.

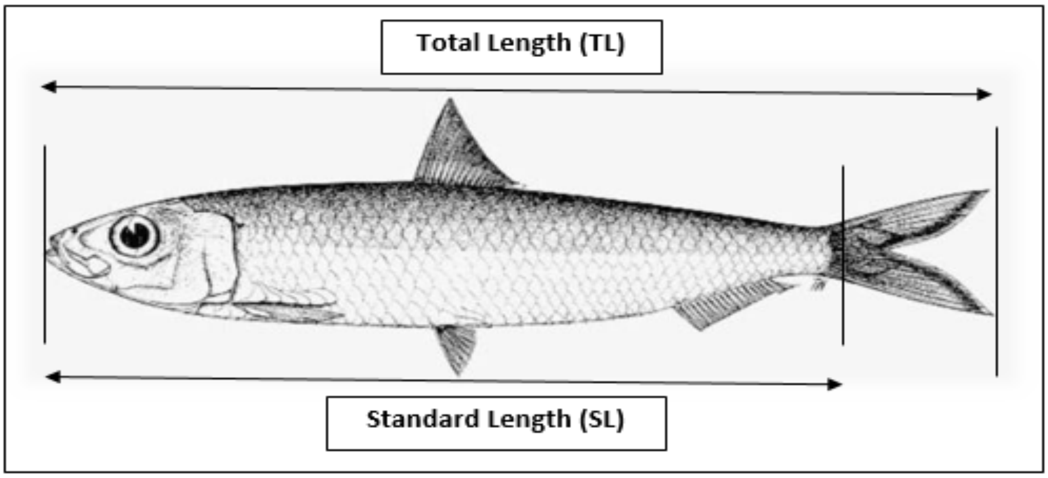


**Fig. 1.** The illustration shows the traditional morphometric measurements to determine the TL and SL of the clupeid fish. SL is measured from the tip of the snout until the last vertebrae and TL is measured from the tip of the snout until the caudal fin tip

*2.2 Length and Weight Analysis*

Simple linear and non-linear regression was used to analyze the correlation between the fish's length and weight. The length-weight relationship (LWRs) of fish was identified using the equations, Eq. (1) and (2):

$W = aL^b$ [9] (1)

Where,
W = Total body weight of fish (g)
L = Total length of fish (cm)
a = Y-intercept or the initial growth coefficient
b = Slope or the growth coefficient

The values of constant 'a' and 'b' were estimated after logarithmic transformation of Eq. (1) using the least square linear regression as described by [10]:

$\text{Log } W = \log a + b \log L$ (2)

Extreme outliers were removed from the regression analysis by performing log-log plot of length and weight. The degree of association between total length (mm) and weight (g) was calculated using the coefficient of determination ($R^2$). The 95 % confidence interval of the parameters a and b were estimated. One-way analysis of variance (ANOVA) was used to identify the difference in the mean log weight adjusted for variance (log length), and to evaluate the homogeneity of regression slopes at 5 % level of significance [11]. Student's t-test was performed for estimated b values to study the growth pattern of fish against null hypothesis of isometric growth ($H_0$ : b=3) at 5 % level of significance and 356 degrees of freedom using the statistic: $t_s = (b-3)/S$ , where, S is the standard error of the slope [12]. Linear regression was performed by plotting $\log_{10}$ of W against $\log_{10}$ of TL to find the slope and intercept.

### *2.3 Determination of Fish Health Status*

To determine the health status of fish, Fulton's condition factor ($K_F$) and the relative condition factor ($K_n$) of the fish samples were studied. In fisheries assessment, the LWRs and the relative condition factors are critical because they provide information on the fish's development, general well-being and fitness in a marine environment. The condition factors were calculated based on the formula in Eq. (3):

$K_F = 100W/L^b$ [13] (3)
$K_n = W/aL^b$ [9]

Where,
K = condition factor
L = Total length (cm)
W = Weight (g)
B = the growth coefficient

### *2.4 Forecasting of Fisheries Production*

The autoregressive integrated moving average (ARIMA) within SPSS software has been applied to forecast the yearly landing of the two species (*Sardinella lemuru* and *Nematalosa japonica*) that are classified as near threatened and least concern according to the IUCN Red List of Threatened Species. Data for A. *sirm* is not available. The data is forecast using the yearly landing dataset of the selected species in Selangor state provided by the Department of Fisheries Malaysia. Landing data were compiled for 20 years (2001 to 2021) and used to produce the forecast models.

## 3. Results and Discussion

### *3.1 Fish Species Identified*

A total of three fish species from Clupeidae family were identified in this study. All the fish species identified was determined based on the information obtained from fishbase database (https://www.fishbase.se/search.php). The information on the family, scientific name, common name, English name and the IUCN redlist status were recorded in Table 1.

**Table 1**
The list of fish species from Clupeidae family obtained and their IUCN red list of threatened fish species. Note: LC – least concern; NT – near threatened and DD – data deficient

| Species | Common name | Local name | IUCN status |
|---|---|---|---|
| *Amblygaster sirm* | Spotted sardinella | Tamban beluru tompok | LC |
| *Sardinella lemuru* | Bali sardinella | Tamban sisik bali | NT |
| *Nematalosa japonica* | Japanese gizzard shad | Selangat | DD |

### *3.2 Analysis of Fish Growth Pattern*

The significance of the LWR and relative condition factors in fisheries assessment can be attributed to the information they provide about fish development, general health and fitness in a marine environment [8]. All samples were assessed for the relationship between body length (total length and standard length) (cm) and weight (g). The minimum, maximum and average values were recorded in Table 2. *Amblygaster sirm* showed the total length and weight varying between 18.6 and 23.9 cm (average = 21.53 cm) and 46.9 and 107.3 g (average = 81.55 g), and the standard length between 15.4 and 21.7 cm (average = 18.89 cm). For *Sardinella lemuru*, the total length and weight vary between 19.8 cm and 23.5 cm (average = 22.07 cm) and 88 to 130.9 g (average = 105.77 g), and the standard length ranges from 17.7 to 20.7 cm (average = 19.33 cm), respectively. Whereas, *Nematalosa japonica* recorded the total length and weight between 13.5 and 20.3 cm (average = 15.02 cm) and 33.1 and 80.0 g (average = 46.33 g), and the standard length varied between 11.4 and 16.4 cm (average = 12.67 cm). Figure 2 to 4 showed the LWR of fish from the Selangor landing port.

**Table 2**
LWR of three species from West Coast of Peninsular Malaysia (Johor, Melaka and Selangor)

| Species | N | Length (mm) (Min-Max) | Weight (g) (Min-Max) | b | T | P | $R^2$ | GT |
|---|---|---|---|---|---|---|---|---|
| *Sardinella lemuru* | 10 | 198 -235 | 88 -130.9 | 0.096 | 51.19 | 0.00000000001 | 0.263 | A- |
| *Amblygaster sirm* | 30 | 186 -239 | 46.9 -107.3 | 1.789 | -3.72 | 0.00044516 | 0.519 | A- |
| *Nematalosa japonica* | 33 | 135 - 203 | 33.1 - 80 | 2.100 | -5.55 | 0.000002 | 0.844 | A- |

***Note:*** Length is reported in millimeter (mm) and weight is reported in 0.1 grams' accuracies for all the species. N: sample size; b: the regression slope with the confidence interval; T: t-test for the regression slope; P: p-value of t-test for the regression slope; $R^2$: the coefficient of determination; Growth type (GT): A-, negative allometric growth; Correlation is significant at the 0.01 level ($p < 0.05$)

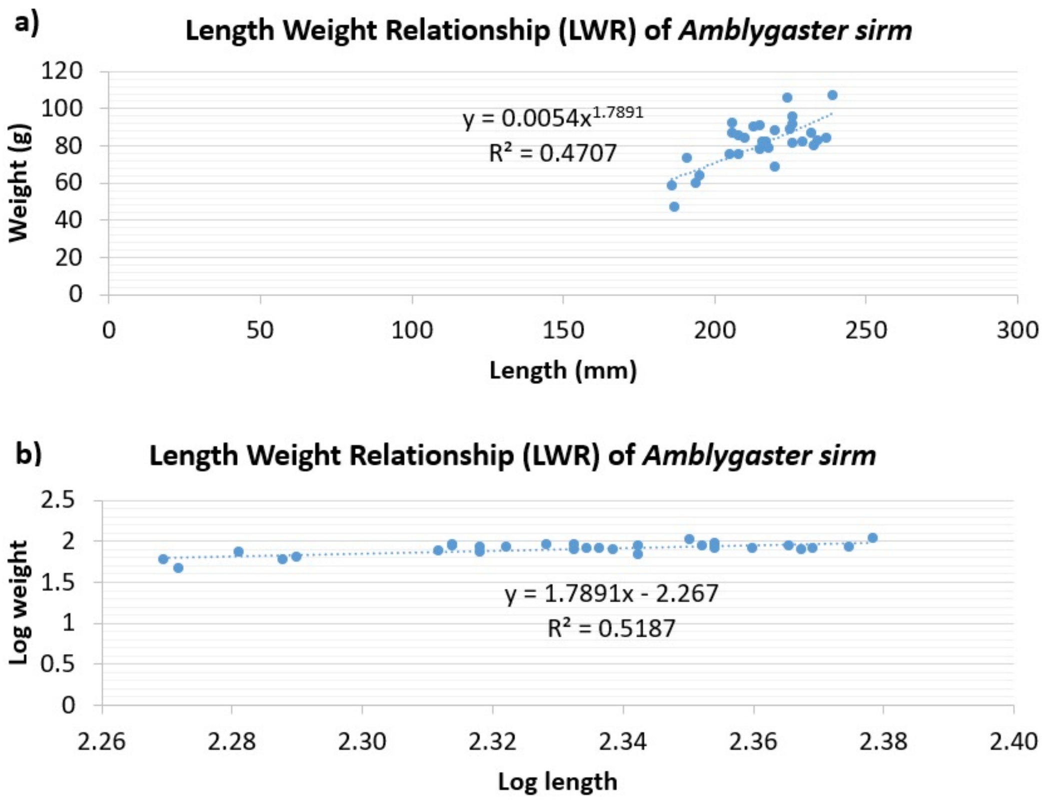


**Fig. 2.** LWR of *Amblygaster sirm* species collected from West Coast of Peninsular Malaysia (Johor, Melaka and Selangor). A) Non-Linear Equation (W = aL^b); B) Logarithms Linear Equation (log W = log a + b log L)

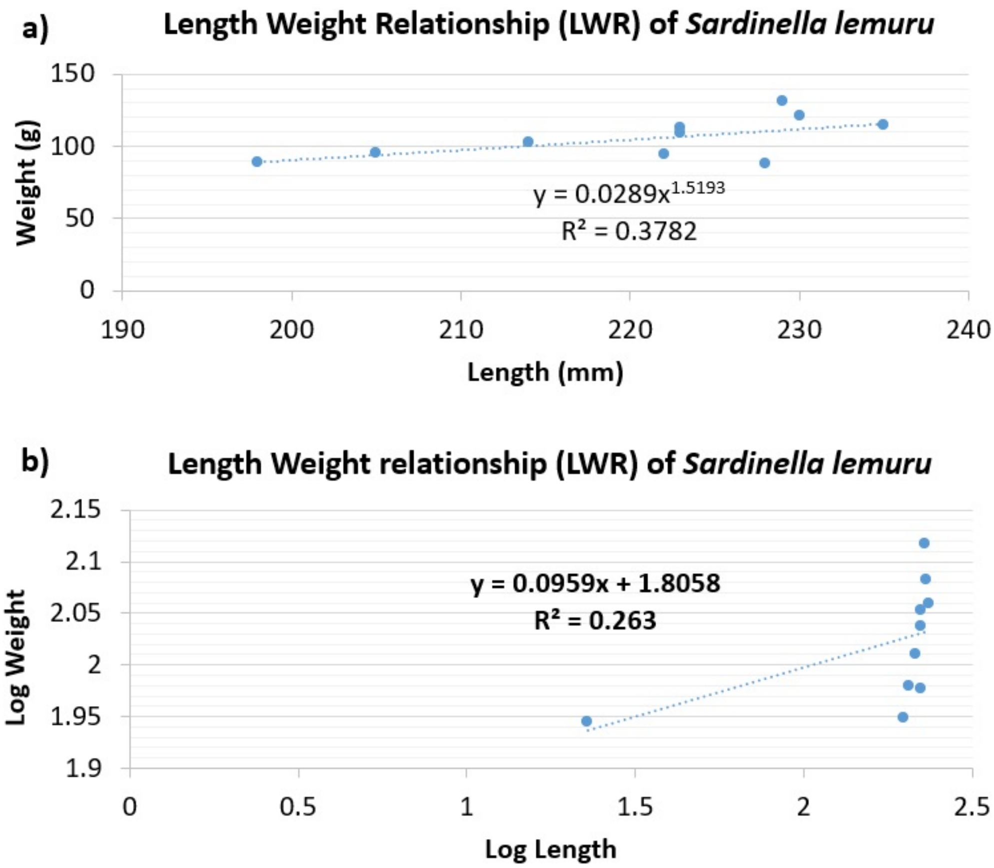


**Fig. 3.** LWR of *Sardinella lemuru* species collected from West Coast of Peninsular Malaysia (Johor, Melaka and Selangor). A) Non-Linear Equation (W = aL^b); B) Logarithms Linear Equation (log W = log a + b log L)

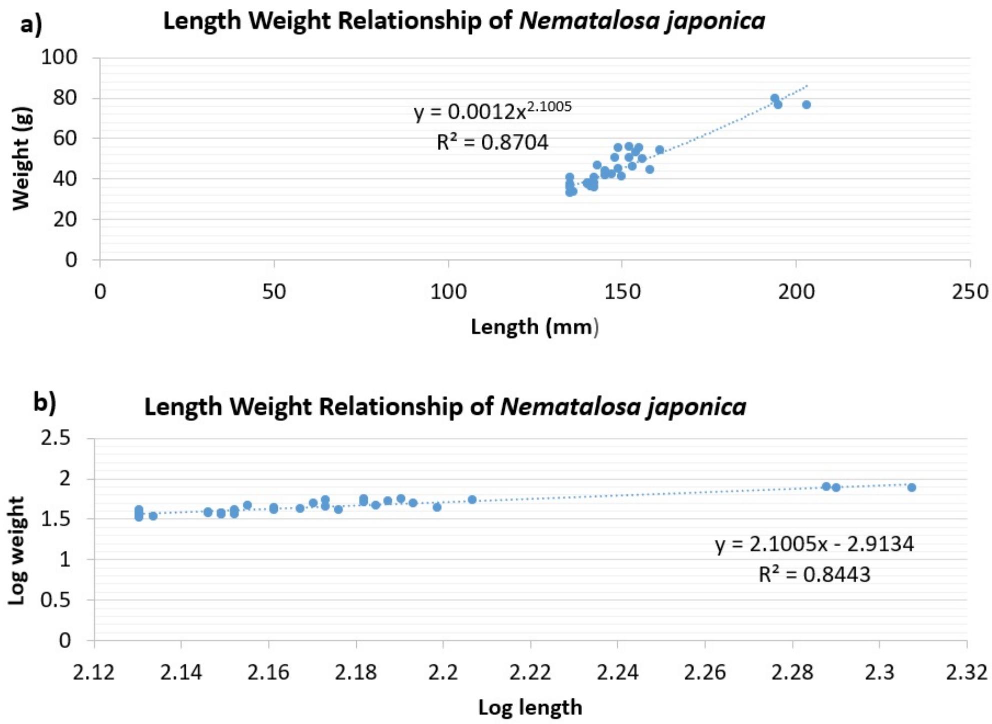


**Fig. 4.** LWR of *Nematalosa japonica* species collected from West Coast of Peninsular Malaysia (Johor, Melaka and Selangor). A) Non-Linear Equation (W = aL^b); B) Logarithms Linear Equation (log W = log a + b log L)

Based on the results, the coefficient of determination $R^2$ values varied between 0.5187 (*Amblygaster sirm*), 0.263 (*Sardinella lemuru*) and 0.8443 (*Nematalosa japonica*), a values ranged from 1.8058 to 2.9134, and b values ranged from 0.0959 to 2.1005. The growth pattern was deduced based on b value. From this, all three fish species have shown a negative allometric growth pattern b<3, and thus, it deduced for all analyzed fish samples suggested that these fish species have a relatively slow growth rate and tend to be thinner [8]. No positive allometry was detected for any of the sampled fish species.

### *3.3 Determination of Fish Condition Factor*

Table 3 showed the estimated Fulton's condition factor, $K_F$ and relative condition factor, $K_n$ for the three species (*Sardinella lemuru, Amblygaster sirm* and *Nematalosa japonica*). For Fulton's condition factor ($K_F$), *Nematalosa japonica* demonstrated high value (1.362) (k > 1) while, *Amblygaster sirm* and *Sardinella lemuru* showed low values (0.819 and 0.124) ($K_F$ < 1). Whereas, for relative condition factor ($K_n$), *Sardinella lemuru* showed low value (0.162) ($K_n$ < 1). Whereas, *Amblygaster sirm,* and *Nematalosa japonica* showed high values (61.957 and 126.560) ($K_n$ > 1).

**Table 3**
Descriptive statistics and estimated parameters of condition factors of three species sampled from West Coast Peninsular Malaysia

| Species | N | Fulton's condition factor, $K_F$ | | Relative condition factor, $K_n$ | |
|---|---|---|---|---|---|
| | | Range | Mean ± standard deviation (SD) | Range | Mean ± standard deviation (SD) |
| *Sardinella lemuru* | 10 | 0.742 - 1.145 | 0.124 ± 0.987 | 1.020 - 1.516 | 0.162 ± 1.229 |
| *Amblygaster sirm* | 30 | 0.630 - 1.057 | 0.819 ± 0.119 | 45.991 - 76.205 | 61.957 ± 7.318 |
| *Nematalosa come* | 33 | 0.916 - 1.672 | 1.362 ± 0.16 | 110.2 - 155.5 | 126.560 ± 11.915 |

For condition factor ($K_n$), all the three fish species, namely *Amblygaster sirm, Sardinella lemuru* and *Nematalosa japonica*, have obtained a low value (k<1). Overall, all fish species in this study recorded condition factor less than 1 (k<1). The relative condition factor ($K_n$) values of the three evaluated species in the current study fluctuated between 1.229 and 126.560 as shown in Table 3. These values suggested a state of wellbeing for the species tested. Many factors can influence these values including species' biology, food availability, environmental conditions, geographic region and climatic changes [1,14]. Values of Fulton and relative condition factor can indicate nutritional and physiological status of the fish [15-17]. Through this result, values above one (K>1 according to [14]) could indicate good conditions for growth. Nonetheless, many factors affected the growth condition of fish including reproductive cycles, availability of food, as well as habitat, activities and environmental factors [8,15]. In the present study, Nematalosa come obtained high values for Fulton condition factor, $K_F$ which is 1.362, indicating adequate conditions for development. Nonetheless, *Amblygaster sirm* ($K_F$ = 0.819) and *Sardinella lemuru* ($K_F$ = 0.987) obtained lower values of condition factor probably due to the different environment, method of capture and food availability [18].

### *3.4 Trend Analysis of Fish Landing*

The ARIMA model was developed to assess the impact of human exploitation and other anthropogenic factors on fish populations, specifically focusing on fish landing data for endangered species. There is a correlation between ecosystem type, species abundance and fish landing fluctuation, making this indicator useful for regulators. Fish landings also reflect changes in gear technologies and management methods [19]. Figure 7 shows the forecast model analyzed using the ARIMA. One-time differencing (d = 1) was performed to convert the non-stationary data into a stationary form. The values of p and q in the ARIMA models were identified based on the autocorrelogram and partial autocorrelogram plots (Figure 5 and 6). The data is summarized in Table 4.

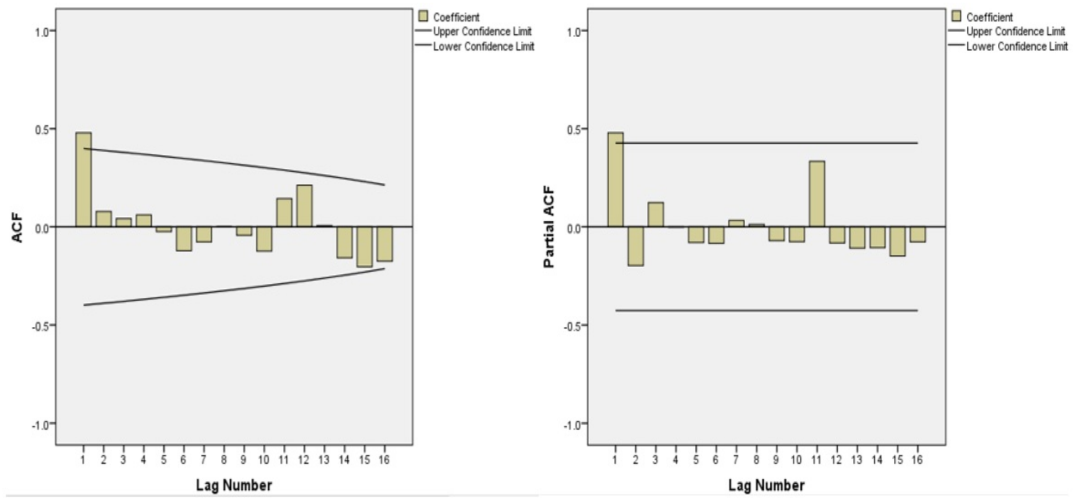


**Fig. 5.** ACF and PACF of first order differenced data for *Nematalosa japonica*

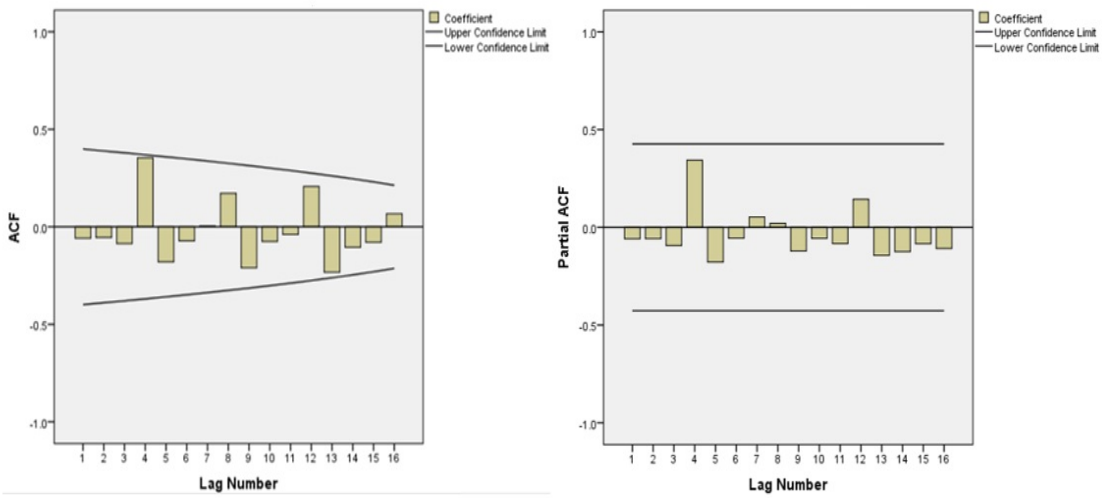


**Fig. 6.** ACF and PACF of first order differenced data for *Sardinella lemuru*

**Table 4**
The best ARIMA model chosen for the species catch prediction

| Species name | ARIMA (p, d, q) |
|---|---|
| *Nematalosa japonica* | ARIMA (1, 1, 1) |
| *Sardinella lemuru* | ARIMA (0, 1, 0) |

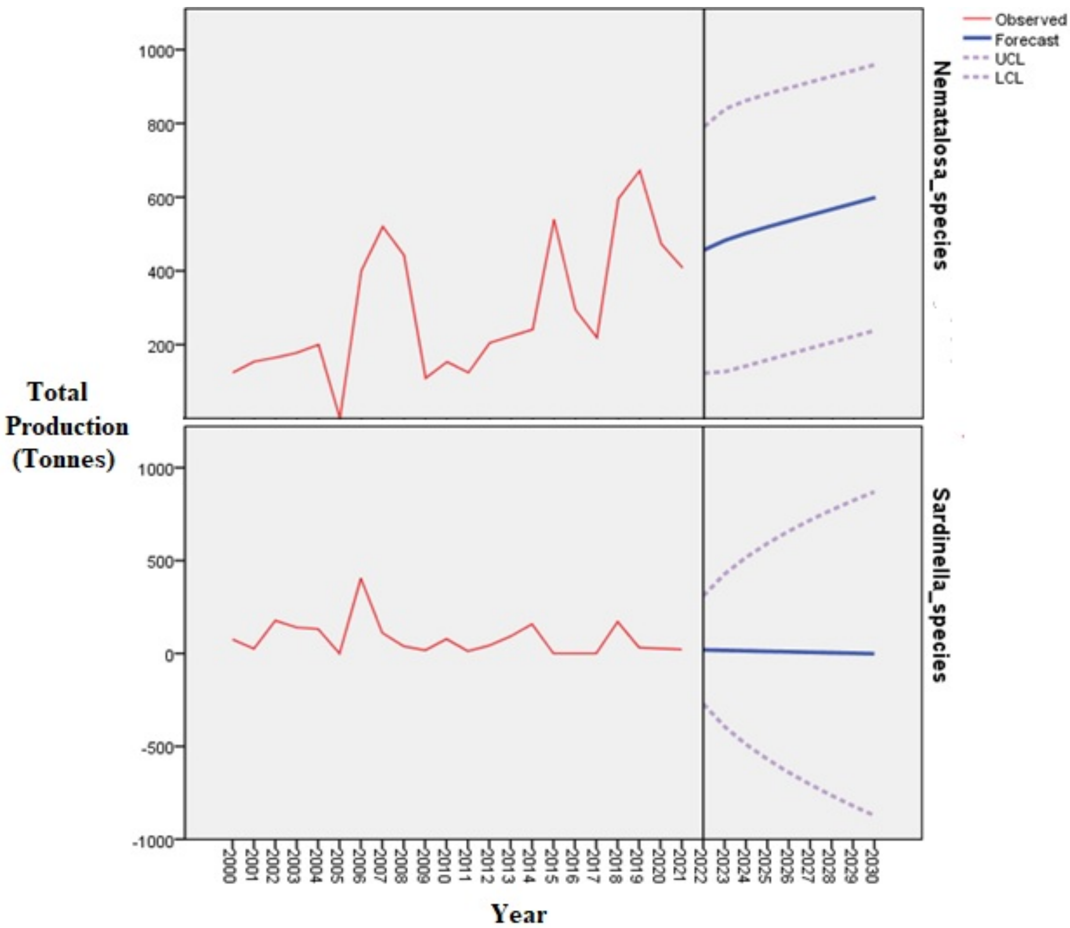


**Fig. 7.** Observed and forecasted landing of two clupeid species in Selangor using ARIMA model from year 2000 until 2030

Forecasts for the two species were made from 2022 until 2030 (Figure 7). Results showed that *Nematalosa japonica* would increase gradually in the coming years, while *Sardinella lemuru* would remain constant. This study selected the ARIMA (1,1,1) and ARIMA (0,1,0) models as the most accurate and the best at predicting Selangor fish landings for 8 years. It should be noted that the p=1 in ARIMA (1,1,1) for fish landings suggests that there was one autoregressive term, and the model was exponential smoothing. On the other hand, the p=0 and q=0 in ARIMA (0,1,0) suggest that the selected model was a random walk with a constant trend and had zero autoregressive and zero moving average terms. It was identified that the selected ARIMA model was the best model for forecasting the threatened species in this study. The eight-year duration was chosen to increase the accuracy of the model. It was also assumed that forecasting eight years in advance could be of great importance for planning and decision-making among related stakeholders, especially fisheries managers, fishermen and the fishing industry in general, as the prediction obtained by the models aids in providing a special interpretation and implies that the optimum fishing effort should be reduced below the current fishing effort. This strategy is important to avoid a further cycle of depression with declining economic returns for fishers and negative social and economic impacts [19,20].

## 4. Conclusions

In this study, the knowledge gained on fish biometry, length-weight analysis and condition factors has greatly contributed to the understanding of the population structure of the studied species on the west coast of Peninsular Malaysia. This study also provided useful information on the trend of landing these fish species. According to the study, the fish species caught in this water body showed negative allometric growth patterns and had low condition factors. This has great implications for the stock in the fishery, and it could be attributed to anthropogenic, biotic and abiotic factors such as overexploitation of these species, environmental influences, or the state of gonadal development. More details on biometry, length, weight and condition factors should be encouraged for a better overview of these parameters, for other species in this water, and for the knowledge of growth and population dynamics. Also, a detailed study of the species composition of this water body is essential to the sustainable utilization of its resources. In addition, in order to maintain a sustainable fishery, the taxonomic and molecular identification of fish in the family Clupeidae as well as an in-depth investigation of their evolutionary history are necessary. To assess the biology of the various fish species and other aquatic fauna present on the west coast of Peninsular Malaysia, research into their physico-chemical parameters is recommended.

**Acknowledgement**
This research was not funded by any grant. This research was supervised by technologist Dr. Siti Zulaiha Zolkaply and co-supervised by technologist Muhamad Afiq Faisal Yahaya. Sampling and research activities were conducted by technologist Dr. Siti Zulaiha Zolkaply, technologist Muhamad Afiq Faisal Yahaya and Mr. Thanakkumaran Supramaniam. This research paper was written and analyzed by technologist Dr. Siti Zulaiha Zolkaply. The revision and review were conducted by all the authors.

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