DATA REPORT article

https://doi.org/10.59711/jims.11.110005

Analyses of Biometric Growth Parameters, Feeding Composition and Fisheries Aspects of *Auxis thazard* (Frigate Tuna) of the East, West and South Coasts of Sri Lanka

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Abstract: This study examines the biometric parameters of *Auxis thazard*, a commercially significant neritic tuna species in Sri Lanka, after primary and secondary data analyses. In secondary data analysis, data following the year 2017 were obtained from the Department of Fisheries and Aquatic Resources for a comparative study of Western, Southern and Eastern coasts. The Length-Weight Relationships (LWR) for *Auxis thazard* in West, South and East coasts were $W = 0.0012TL^{3.6586}$, $W = 0.0026TL^{3.4846}$ and $W = 0.0147TL^{2.951}$. The pooled regression coefficient ('b') values indicated positive allometric growth in West and South, and isometric growth in East. The condition factor showed relatively healthy conditions in fish for West and South and poor condition for East. The gillnets reported 98% of catches in West and ringnets reported. 68% and 67% of catches in South and East respectively.The primary data

Citation: Rathnayaka, H.; P Perera, H.A.C.C.; Perera, L. Analyses of Biometric Growth Parameters, Feeding Composition and Fisheries Aspects of *Auxis thazard* (Frigate Tuna) of the East, West and South Coasts of Sri Lanka. *J. Isl. Mar. Stud.* **2024**, *2*, 110005. https://doi.org/10.59711/jims.11.110005
Received: 23 December 2023 Revised: 20 May 2024
Accepted: 25 June 2024 Published online: 29 September 2024
Editorial Assistant: Chandel Chen

analysis was conducted in the West coast from November 2021 to February 2022. The LWR was $W = 0.0114TL^{3.0366}$ indicating isometric growth and fish were relatively healthy. Shrimps were the most preferred prey item at each stomach fullness level. The percentages below 29.5 (length at first maturity reports by FishBase) included 18.8, 39.2 and 34.0 for West, South and East suggesting continuous fish landing monitoring.

Keywords: *Auxis thazard* (frigate tuna); catches; condition factor; growth; length–weight relationship climate change

1. Introduction

The Yellowfin tuna (*Thunnus albacares*), Bigeye tuna (*Thunnus obsesus*), Skipjack tuna (*Katsuwonus pelamis*) are the most available tuna resources in Sri Lankan waters. Apart from them, the neritic tuna species include kawakawa (*Euthynnus affinis*), frigate tuna (*Auxis thazard*), and bullet tuna *(Auxis rochei)* [1]. Neritic tuna makes up a significant portion of Sri Lanka's coastal large pelagic catch and accounts for about 13% of the nation's overall tuna production [2]. Out of all the neritic tuna species, *Auxis thazard* has emerged as the predominant species, currently accounting for more than 40% of the nation's total neritic tuna production [3]. Thus, *Auxis thazard*, also known locally as "Alagoduwa" in the Sri Lankan market, is regarded as one of the most significant neritic tuna species in Sri Lanka.

Being one of the neritic species, *Auxis thazard* is a highly migratory species found in both coastal and oceanic waters [4]. This fish is mostly available in all tropical and subtropical waters [5]. In addition, it is highly gregarious and often schools with other scombrids [4]. Because of its abundance, *Auxis thazard* is valued as a vital component of the food web, especially when used as a source of food for other commercially valuable species. Larger fish, including other tunas, feed on *Auxis thazard*. *Auxis thazard* is used in dried or salted, smoked, and canned products in addition to being sold fresh and frozen [6]. This fish is harvested from across the Indian Ocean mainly using gillnets (~41%), coastal longline and trolling, handline and trolling (~33%) and to a lesser extent coastal purse seine nets. This species is also a by-catch of industrial purse seine vessels and the target of some ring net fisheries [7].

Auxis thazard makes up a significant portion of the nation's total tuna harvest, but not much research has been done on the biological aspects of *Auxis thazard*. Data on catches, length, weight, biology, and fisheries across geographical regions are lacking. As a result, the Indian Ocean Tuna Commission (IOTC) promotes the search for more trustworthy information about this species. Given the migratory nature of *Auxis thazard* and the significant economic contribution of the fishery to Sri Lanka, it is imperative to obtain reliable data on this fish population to effectively implement management plans. Therefore, this research was conducted to study the growth condition indices, feeding ecology and fisheries aspects of *Auxis*

thazard in selected coastal waters around Sri Lanka mainly focusing on secondary and primary data analyses. The main objective was to examine the LWR, condition factor, feeding habits and fisheries aspects of *Auxis thazard* in the western, eastern and southern coasts of Sri Lanka. The other objectives were to study the length-weight relationships (LWR) of the *Auxis thazard* stocks in three selected coastal waters in Sri Lanka, to analyze the gut contents of *Auxis thazard* living in Sri Lankan waters and to identify the main gear types used to catch *Auxis thazard* in Sri Lanka. Under this study, it is hypothesized that, there is a difference between 'b' values from Length-Weight relationship of *Auxis thazard* in the western, eastern and southern coasts of Sri Lanka, the condition factor 'K' of *Auxis thazard* differs among the western, eastern and southern coasts of Sri Lanka and the gears used to catch *Auxis thazard* differ among the western, eastern and southern coasts of Sri Lanka.

The relationship between length and weight is crucial for estimating growth with increasing length and it is used to determine the type of somatic growth [8]. The Fulton's condition factor (K) is used to understand the growth condition of the fish [9]. The feeding habits of *Auxis thazard* can be studied using stomach content analysis, Gastro-Somatic Index (Ga.SI), and Relative Gut Length (RGL) analysis. Based on reports, *Auxis thazard* collected in Indian waters ranges in length from 20 to 50 cm [10]. *Auxis thazard*'s standard length in Sri Lankan waters ranges from 19.4 to 40.7 cm [11], with a total length variation of 21.50 to 44.20 cm [9]. According to existing research, *Auxis thazard* is a type of carnivorous feeder that consumes a wide variety of prey items available in the environment. Their voracious nature allows them to consume nearly anything that is abundant in their surroundings [11].

2. Methodology

2.1. Secondary Data Analysis

2.1.1. Secondary Data Collection

The data regarding *Auxis thazard* from January 2017 to December 2017 from three sampling sites of Negombo (the West coast), Galle (The South coast) and Trincomalee (The East coast) were obtained from the Department of Fisheries and Aquatic Resources (DFAR). A total of 796 fish of *Auxis thazard* (324 from Negombo, 319 from Galle and 153 from Trincomalee) were taken into analysis from the data obtained through the DFAR. The weight and length of the fish were recorded to the nearest 0.1 g, standard length (SL) and total length (TL) to the nearest 0.1 cm respectively.

The data regarding the coastal catches and fishing gears of *Auxis thazard* from January 2017 to December 2017 from the West coast, the South coast and the East coast were obtained from the fisheries department of Sri Lanka. Coastal catches were divided into coastal Gillnet (GI), Beach seine (BS), coastal Handline (HL), coastal Longline (LLCO), coastal Troll line (TLL) and coastal Ringnet (PSRN) catches separately.

2.1.2. Morphological and Biological Analysis of *Auxis thazard*

Biological analysis was carried out for the data that were collected from DFAR for the above-mentioned sampling locations. The relationship between TL and the weight of the sampled fish was evaluated using the following equation:

$$W = aL^b \quad (1)$$

Where, W is the body weight of fish in g, L is the TL of fish in cm, 'a' is the regression intercept and 'b' is the regression coefficient or slope of a plot of log W vs log L [4,8,12]. The K value was estimated from the following relationship:

$$K = 100W/L^3 \quad (2)$$

Where, W is the body weight of fish in g and L is the TL in cm [13,14].

2.1.3. Analysis of the Catch from Different Gears Used in *Auxis thazard* Fishery

Total landings of *Auxis thazard* by different fishing gears such as BS, GI, HL, LLCO, TLL and PSRN were calculated for the West, South and East coasts and total landings and percentage of landings were graphically represented.

2.1.4. Statistical Analysis for Secondary Data

The statistical analysis was carried out using both Minitab 17 statistical software and Microsoft Excel. For the secondary data analysis, length frequency distributions were carried out for *Auxis thazard* from the West, South and East coasts. The LWR of *Auxis thazard* were graphically represented for all three coasts: the West, South and East and 'b' values were obtained from the Log weight vs Log total length plots. Regression analyses were carried out for all three locations and one sample t-tests were carried out for each coast; the West, South and East to find out whether the 'b' values follow isometric or allometric growths.

2.2. Primary Data Analysis

2.2.1. Sample Collection for Primary Data Analysis

A total of 63 *Auxis thazard* fish were collected from the coastal area of Negombo in Western province. Sampling was carried out from November 2021 to February 2022 twice a week.

2.2.2. Morphological and Biological Analysis of *Auxis thazard*

Fish samples were collected from the fishermen. Biological analysis was carried out for *Auxis thazard* fish samples that were collected from coastal waters from the West coast.

The relationship between the total length and weight of sampled fish and the K value was estimated using the same equations mentioned in the secondary data analysis.

2.2.3. Food and Feeding Analysis of *Auxis thazard*

Auxis thazard fish samples were dissected and the length of the guts was measured to the nearest 0.1 cm. The guts were weighed to the nearest 0.1 g. RGL was estimated from the following equation:

$$\text{RGL} = \text{Total length of Gut} / \text{Total length of Fish} \quad (3)$$

Where the Total length of gut and Total length of fish are in cm. Ga.SI was estimated from the following equation:

$$\text{GaSI} = \text{Wt of Gut} / \text{Wt of Fish} \times 100 \quad (4)$$

Where, Weight (Wt) of Gut and Weight (Wt) of Fish are in g. The fish was cut opened, and stomach fullness was observed visually. Following the visual observation, it was categorized into 5 classes: full, three-fourths (3/4) full, half (1/2) full, one-fourth (1/4) full, and empty. The prey items were separated to identify the different types of food items (crustaceans, fish, cephalopods, etc.) that could be found within the stomach cavities. The gonads were observed to determine the sex of each fish.

2.2.4. Statistical Analysis for Primary Data

The statistical analysis was carried out using both Minitab 17 statistical software and Microsoft Excel. For the primary data analysis, length frequency distribution was carried out for *Auxis thazard* from the West coast. The length-weight relationship of *Auxis thazard* was graphically represented for the West coast and 'b' value was obtained from the Log weight vs Log total length plot. One sample t-test was carried out for the 'b' value to find out what type of growth; isometric or allometric is followed by *Auxis thazard* from the West coast.

3. Results

3.1. Secondary Data Analysis

3.1.1. Length Frequency Distribution of *Auxis thazard* from the West, South and East Coasts

Based on Figures 1, 2 and 3, the size classes 36.8 cm - 37.8 cm for the West coast and 26.5 cm - 27.5 cm for both the South and East coasts recorded the highest length percentage frequencies. The lowest frequencies were recorded in the size classes of 29.8 cm - 30.8 cm for the West coast, 21.5 cm - 22.5 cm and 45.5 cm - 46.5 cm for South coast and 42.5 cm - 43.5 cm for East coast.

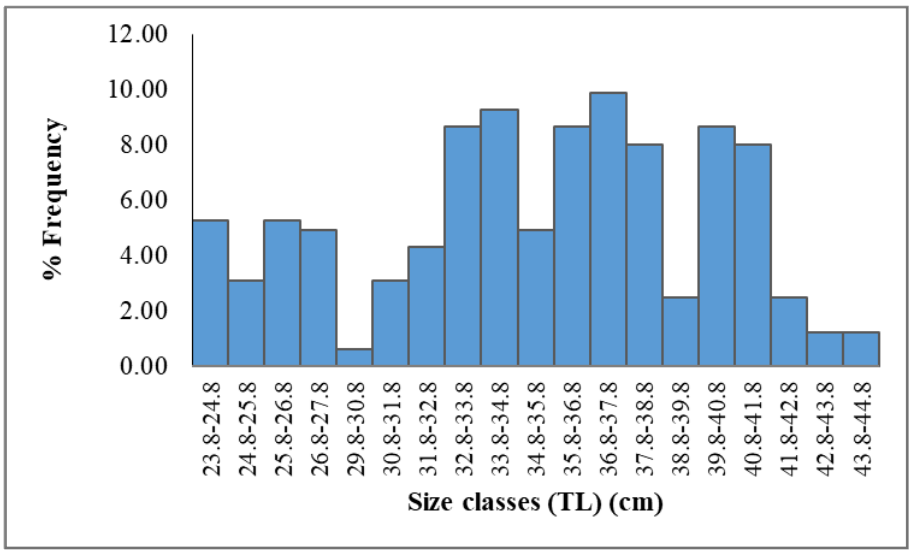

Figure 1. Length frequency distribution of *Auxis thazard* sample from the West coast

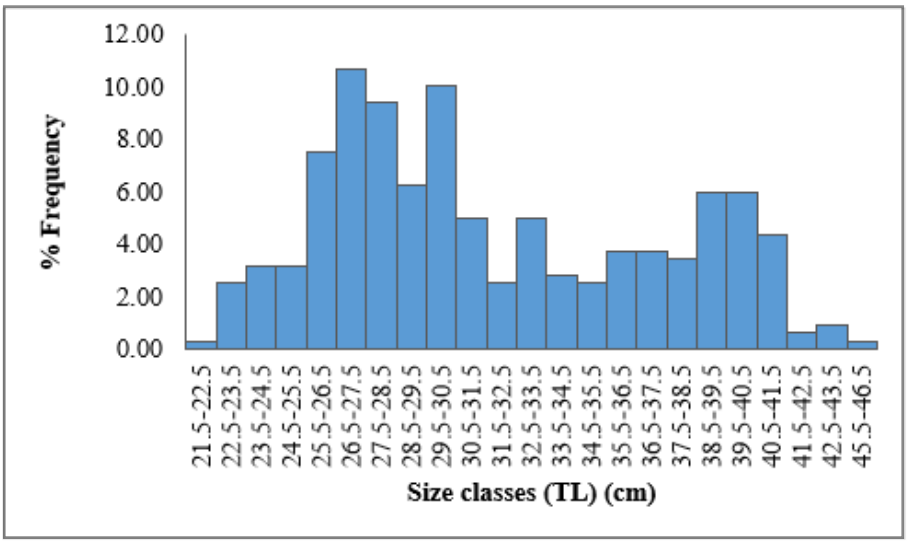

Figure 2. Length frequency distribution of *Auxis thazard* sample from the South coast

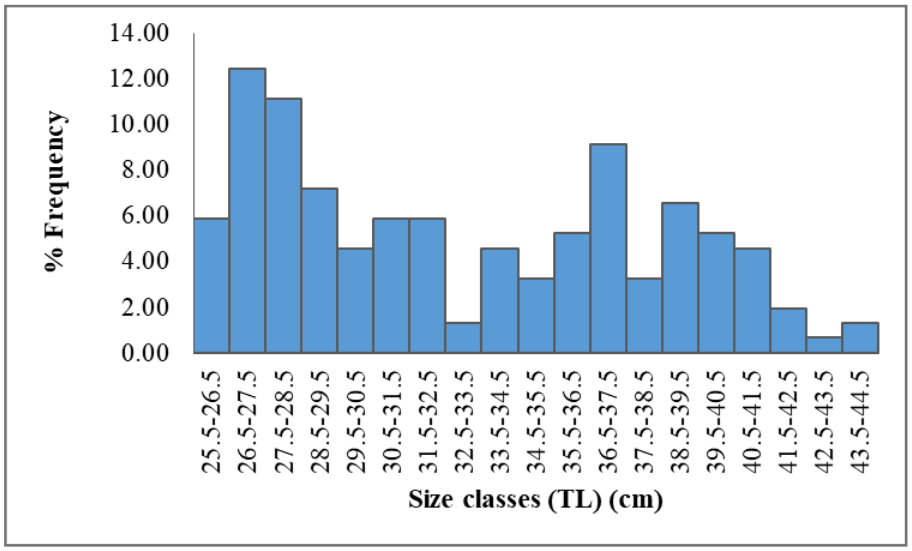

Figure 3. Length frequency distribution of *Auxis thazard* sample from the East coast

3.1.2. LWR and The K value for *Auxis thazard* from the West, South and East Coasts

The non-linear plot of Length–weight relationship equation, and the linear regression relationship derived into the equation are shown in Figures 4, 5, 6, 7, 8, and 9.

Curvilinear relationship of Weight (g) vs. Total length (cm) for the equation $W = a L^b$

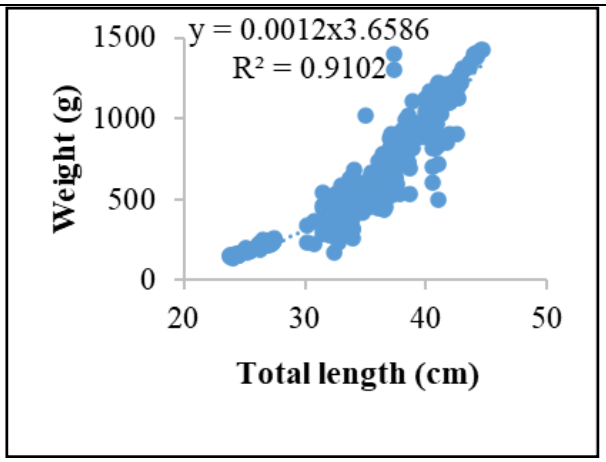

Figure 4. The Weight (g) vs. Total length (cm) for the West coast

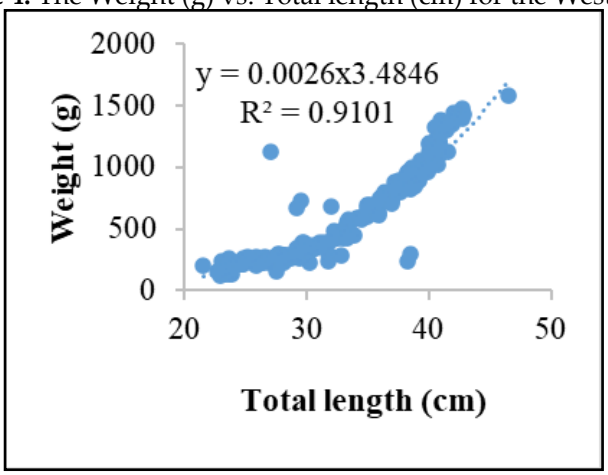

Figure 5. The Weight (g) vs. Total length (cm) for the South coast

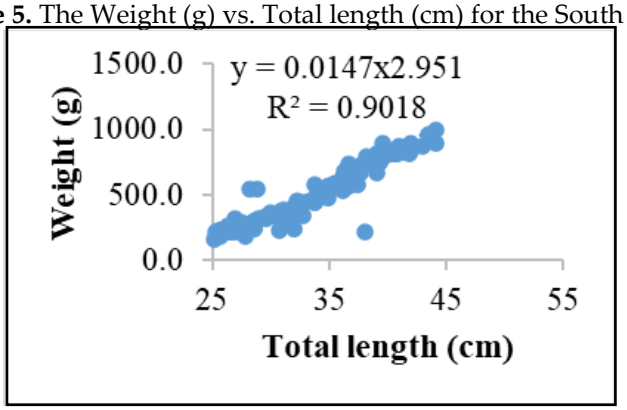

Figure 6. The Weight (g) vs. Total length (cm) for the East coast

Linear relationship of Log Weight (g) vs. Log Total length (cm) for the equation log W = log a + b log L

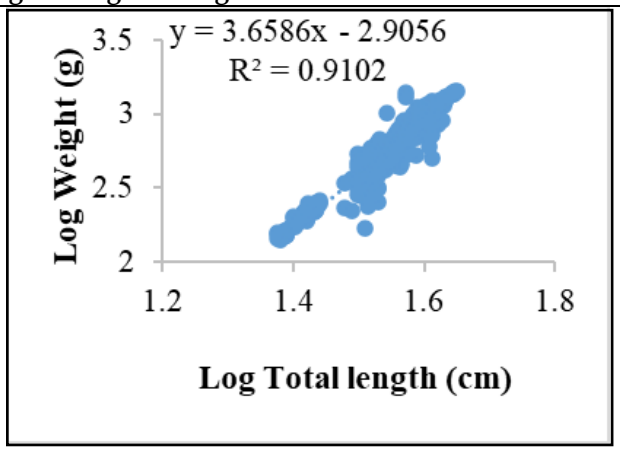

Figure 7. The Log Weight (g) vs. Log Total length (cm) for the West coast

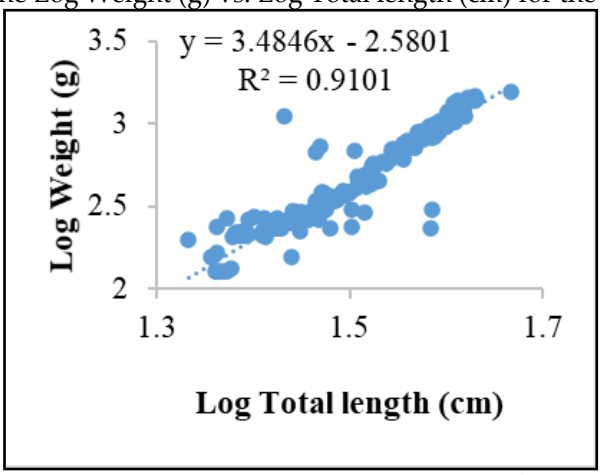

Figure 8. The Log Weight (g) vs. Log Total length (cm) for the South coast

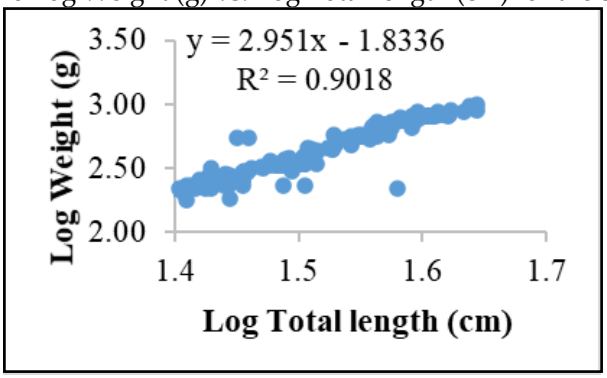

Figure 9. The Log Weight (g) vs. Log Total length (cm) for the East coast

The regression intercept (a) values and the regression coefficient (b) values obtained from the plots of log W vs. log TL are shown in Table 1. The type of somatic growth given by the 'b' values followed by t-tests are mentioned in the same table.

Table 1. LWR parameters of *Auxis thazard*

Location	N	LWR	Parameters of LWR		r^2	Growth type
			a	b		
West coast	324	$W= 0.0012TL^{3.6586}$	0.0012	3.6586	0.9102	Positive Allometric
South coast	319	$W = 0.0026TL^{3.4846}$	0.0026	3.4846	0.9101	Positive Allometric
East coast	153	$W = 0.0147TL^{2.951}$	0.0147	2.951	0.9018	Isometric

3.1.3. Linear Relationship of Log Weight (g) vs. Log Total Length (cm) for Male and Female *Auxis thazard*

The LWR was taken for the subsets of male and female in each sample (Figure. 10 and Figure. 11). The 'b' values were observed to see any difference in the growth pattern based on the sex of the fish. The LWR parameters of male and female *Auxis thazard* fish are shown in Table 2 and Table 3.

Table 2. LWR parameters of male *Auxis thazard*

Location	N	LWR	Parameters of LWR		r^2	Growth type
			a	b		
West coast	55	$W= 0.0007TL^{3.8293}$	0.0007	3.8293	0.9364	Positive Allometric
South coast	88	$W = 0.0014TL^{3.6671}$	0.0014	3.6671	0.9657	Positive Allometric
East coast	48	$W = 0.0124TL^{3.0006}$	0.0124	3.0006	0.9254	Isometric

Table 3. LWR parameters of female *Auxis thazard*

Location	N	LWR	Parameters of LWR		r^2	Growth type
			a	b		
West coast	121	$W= 0.0006TL^{3.8466}$	0.0006	3.8466	0.9125	Positive Allometric
South coast	158	$W = 0.0023TL^{3.5194}$	0.0023	3.5194	0.9047	Positive Allometric
East coast	82	$W = 0.0167TL^{2.9179}$	0.0167	2.9179	0.9152	Isometric

Male *Auxis thazard*

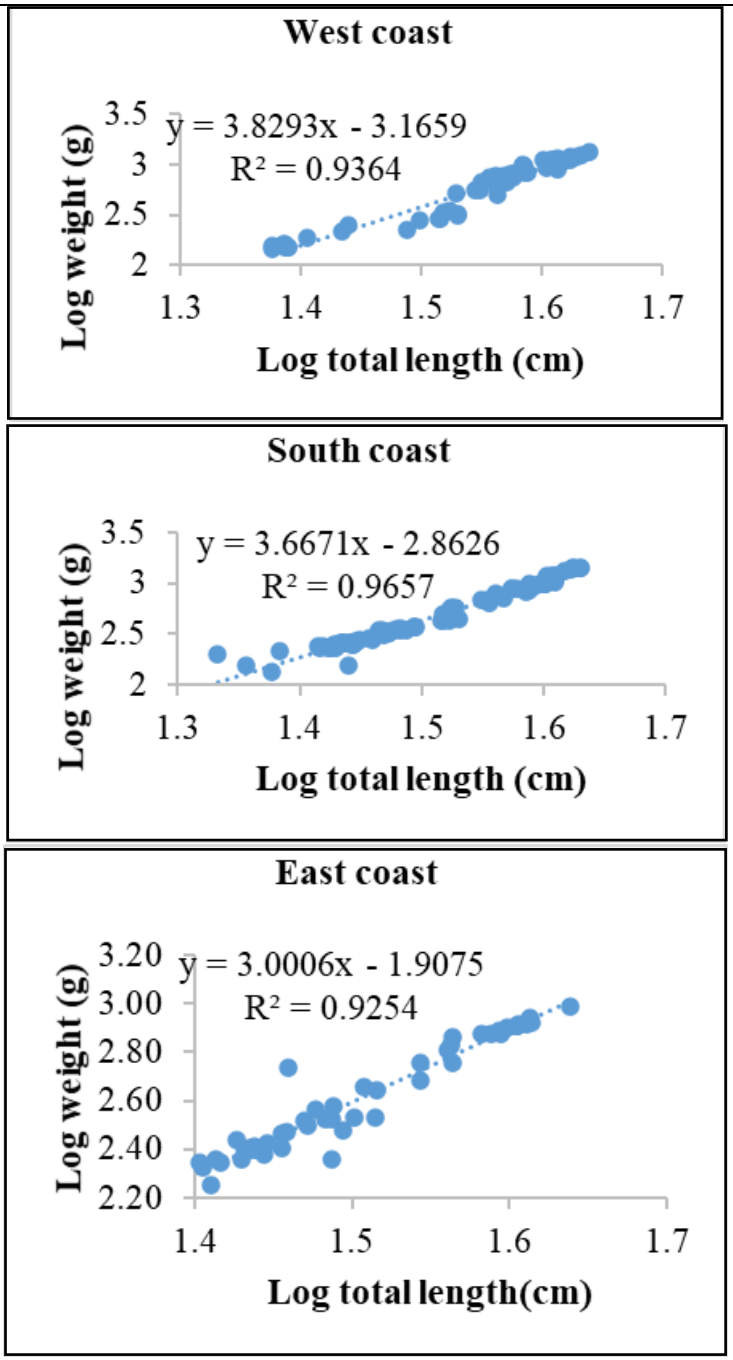

Figure 10. The plots of Log weight (g) vs. Log total length (cm) for males in the West, South and East coasts

Female *Auxis thazard*

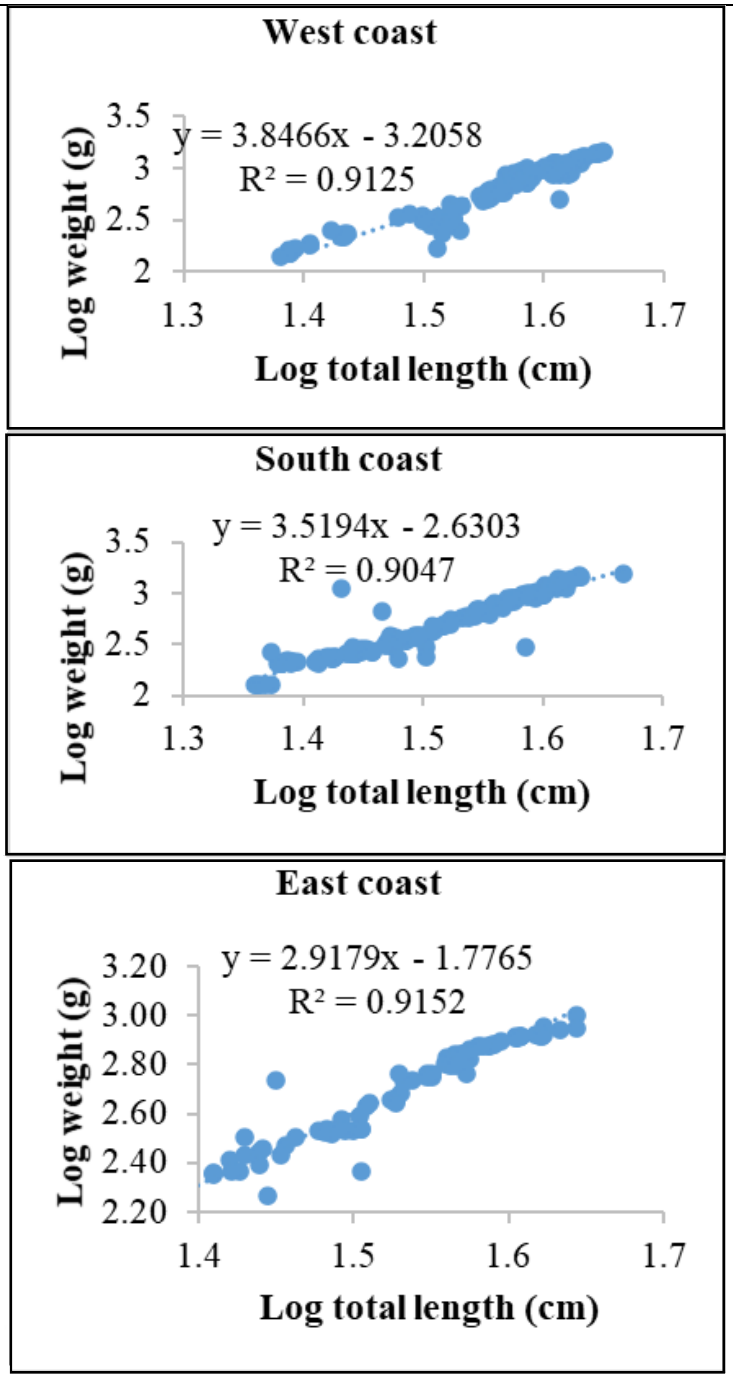

Figure 11. The plots of Log weight (g) vs. Log total length (cm) for females in the West, South and East coasts

The ranges of TL (cm) and weight (g), as well as the mean values for TL (cm), weight (g) and calculated K values for all three coastal locations are shown in Table 4. The same parameter values were obtained for male and female *Auxis thazard* fish separately (Table 5 and Table 6).

Table 4. Parameter values of Length (cm), Weight (g) and K values of *Auxis thazard* collected from three locations

Location	TL (cm)		Weight (g)		K
	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Mean ± SD
West coast	23.8 – 44.2	34.90 ± 5.26	124.9 – 1405.05	535.06 ± 285.48	1.21 ± 0.42
South coast	21.5 – 46.5	31.65 ± 5.44	157.00 – 1475.00	436.11 ± 296.05	1.43 ± 0.98
East coast	25.5 – 44.1	32.87 ± 5.21	152.60 – 890.40	311.3 ± 171.93	0.94 ± 0.51

Table 5. Parameter values of Length (cm), Weight (g) and K values of male *Auxis thazard* collected from three locations

Location	TL (cm)		Weight (g)		K
	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Mean ± SD
West coast	23.8 – 43.6	35.39 ± 5.79	145.00 – 1320.00	674.97 ± 365.95	1.33 ± 0.28
South coast	21.5 – 42.7	32.42 ± 5.77	132.98 – 1435.71	560.40 ± 384.61	1.40 ± 0.24
East coast	25.3 – 43.5	32.48 ± 5.43	178.70 – 965.80	464.5 ± 240.01	1.25 ± 0.20

Table 6. Parameter values of Length (cm), Weight (g) and K values of female *Auxis thazard* collected from three locations

Location	TL (cm)		Weight (g)		K
	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Mean ± SD
West coast	24.0 – 44.7	36.42 ± 5.46	140.14 – 1424.00	718.94 ± 366.06	1.33 ± 0.28
South coast	22.9 – 46.5	32.77 ± 5.72	126.66 – 1575.00	587.34 ± 370.53	1.46 ± 0.43
East coast	25.1 – 44.1	34.48 ± 5.06	155.40 – 995.7	546.1 ± 219.08	1.26 ± 0.18

3.1.4. Coastal Catches (Metric Tonnes) of *Auxis thazard* by Different Fishing Gears in the West, South and East

The percentages of catches from different fishing gears (BS, GI, HL, LLCO, TLL and PSRN) are represented in pie charts to show the most commonly used fishing gear for catching *Auxis thazard* (Figure. 12). The most frequently used fishing gear in the West coast was Gillnet. Ringnets were the most widely used fishing gear in both the South and East coastal waters. The total catches/landings and percentages of catches from every fishing gear in all three coastal waters are shown in Figure. 13 and Figure. 14 respectively.

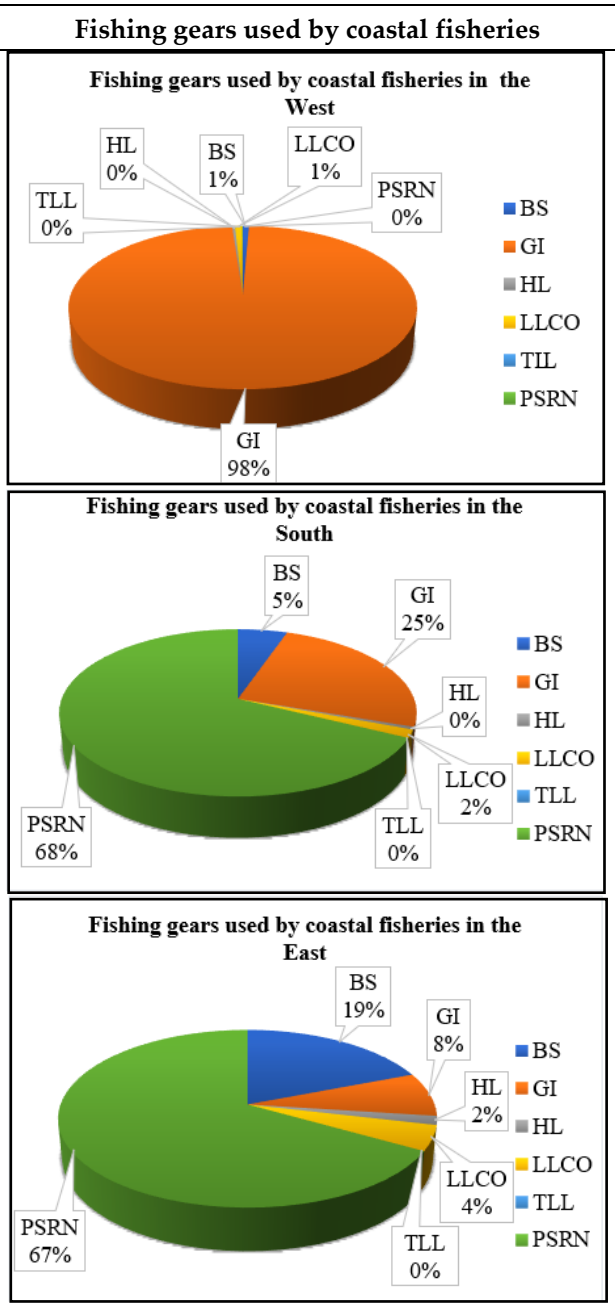

Figure 12. Percentage landings of *Auxis thazard* in coastal fisheries by different fishing gears in the West, South and East, 2017 (BS- Beach Seine, GI- Coastal Gillnet, HL- Coastal Handline, LLCO- Coastal Longline, TLL- Coastal Troll line and PSRN- Coastal Ringnet)

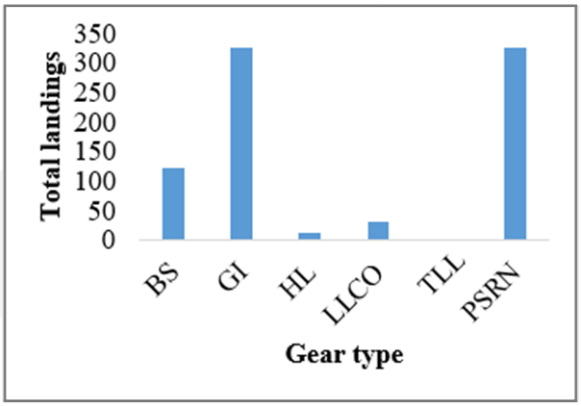

Figure 13. Total landings of *Auxis thazard* in coastal fisheries by different fishing gears in the West, South and East coasts, 2017

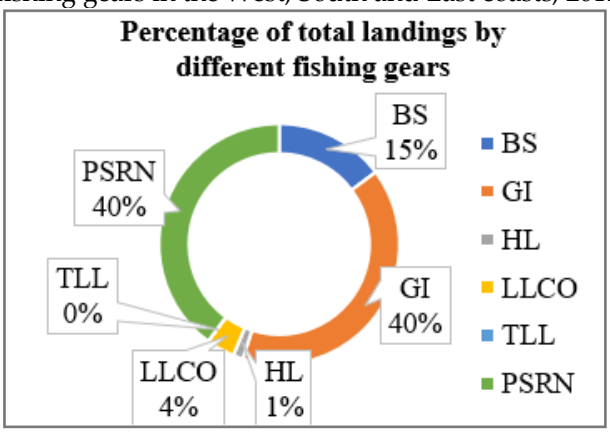

Figure 14. Percentage of total landings of *Auxis thazard* in coastal fisheries by different fishing gears in the West, South and East coasts, 2017

3.2. Primary data analysis

According to the length frequency distribution of *Auxis thazard* samples from the West (Figure. 15), the highest frequency was recorded in the size class of 34.7 cm – 35.7 cm and the lowest frequency in the size class of 26.7 cm – 27.7 cm.

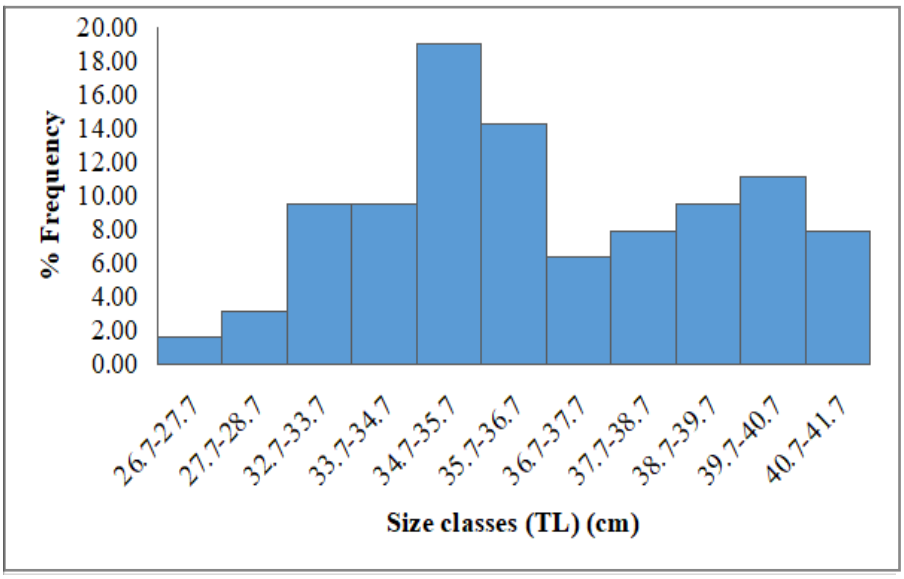

Figure 15. Length frequency distribution of *Auxis thazard* from the West coast

3.2.1. Length – Weight relationship of *Auxis thazard* from the West coast

The linear regression relationship derived into the equation is shown in Figure 16 and the Length – Weight relationship taken for the subsets of male and female is in Figure 17 and Figure 18. The LWR parameters of *Auxis thazard* from the West and the LWR parameters of male and female *Auxis thazard* are shown in Table 7 and Table 8 respectively.

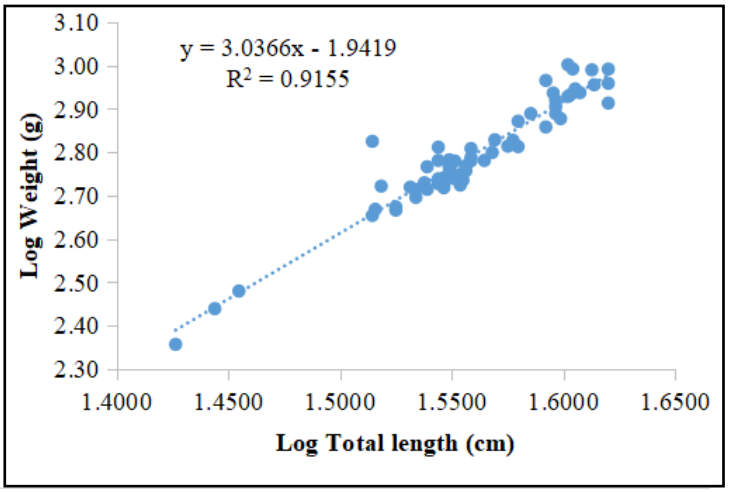

Figure 16. The plot of Log Weight (g) vs Log Total length (cm) for the West coast

Male *Auxis thazard*

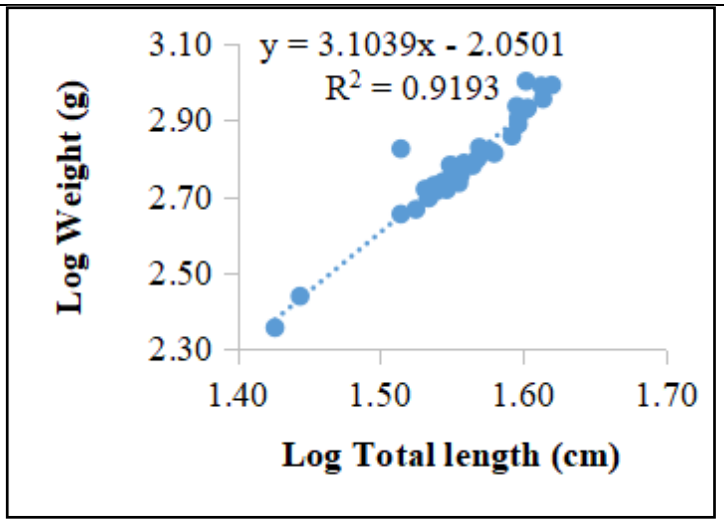

Figure. 17. The plot of Log Weight (g) vs Log Total length (cm) for the West coast males

Female *Auxis thazard*

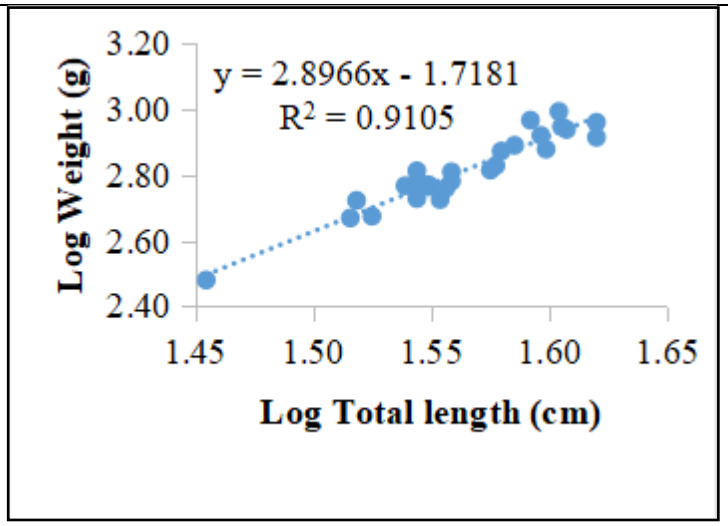

Figure. 18. The plot of Log Weight (g) vs Log Total length (cm) for the West coast females

Table 7. LWR of *Auxis thazard* (pooled values)

Location	N	LWR	Parameters of LWR		r^2	Growth type
			a	b		
West coast	63	$W= 0.0114TL^{3.0366}$	0.0114	3.0366	0.9155	Isometric

Table 8. LWR of male and female *Auxis thazard*

Location: West coast Male/Female	N	LWR	Parameters of LWR		r^2	Growth type
			a	b		
Male	37	$W= 0.0089TL^{3.1039}$	0.0089	3.1039	0.9193	Isometric
Female	26	$W= 0.0191TL^{2.8966}$	0.0191	2.8966	0.9105	Isometric

The ranges of TL (cm) and Weight (g), as well as the mean values for TL (cm), Weight (g) and calculated K values for the West coast are shown in Table 9. The same parameters were observed for males and females separately and results are shown in Table 10.

Table 9. Parameter values of Length (cm), Weight (g) and K values of *Auxis thazard*

Location	TL (cm)		Weight (g)		K
	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Mean ± SD
West coast	26.7 – 41.7	36.46 ± 3.20	227.50 – 1004.00	648.86 ± 173.15	1.31 ± 0.12

Table 10. Parameter values of Length (cm), Weight (g) and K values of male and female *Auxis thazard*

Location: West coast Male/ Female	TL (cm)		Weight (g)		K
	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Mean ± SD
Male	26.7 – 41.7	36.22 ± 3.28	227.50 – 1004.00	632.85 ± 178.39	1.30 ± 0.13
Female	28.5 – 41.7	36.81 ± 3.12	302.0 – 918.5	671.60 ± 166.16	1.32 ± 0.11

3.2.3. Feeding of *Auxis thazard*

3.2.3.1. Stomach fullness of *Auxis thazard*

The number of fish in each category of stomach fullness was recorded. The stomach fullness and percentage of stomach fullness are shown in Figure 19 and Figure 20. Figures 21, 22, 23 and 24 show prey item separation to find out the most preferred prey item of *Auxis thazard* inhabiting the West coast of Sri Lanka. Based on the analysis, shrimps are their preferred food item at each stomach fullness level.

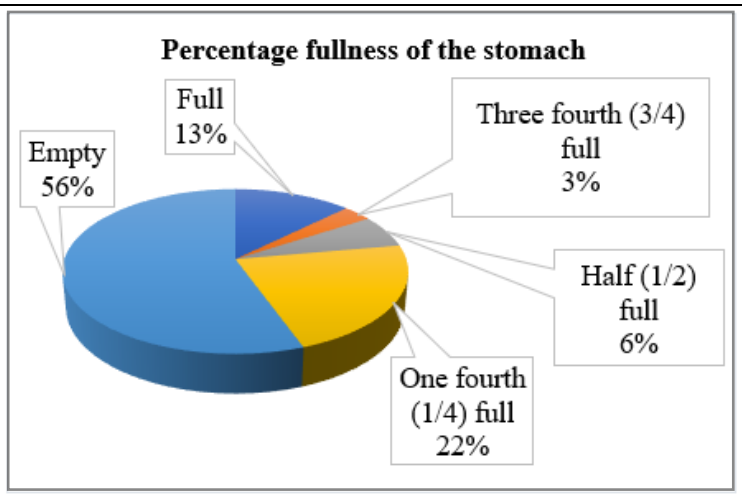

Figure 19. The percentage fullness of *Auxis thazard* from the West coast

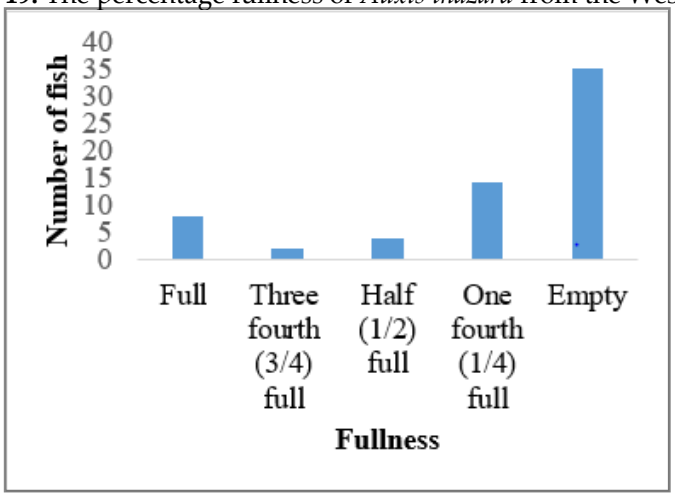

Figure 20. The plot of stomach fullness of *Auxis thazard* inhabiting in the West coast

Figure 21. Cut opened fish with full stomach

Figure 22. Separated guts of *Auxis thazard*

Figure 23. Stomach cavity full of shrimps

Figure 24. Separated shrimps from stomach

3.2.3.2. RGL and Ga.SI

RGL values plotted against the size classes of SL (cm) to determine the feeding habit of *Auxis thazard* are shown in Figure 25. The results confirmed that *Auxis thazard* is a carnivorous fish. Ga.SI values plotted against SL (cm) to determine the feeding intensity of fish are shown in Figure 26. The range of Standard length varied from 26.7 cm to 41.7 cm. The ranges of RGL and Ga.SI were 0.28 – 0.52 and 2.50 – 17.67 respectively. Mean values for RGL and Ga.SI were recorded as 0.40 ± 0.0421 and 5.96 ± 2.2959 for all *Auxis thazard* fish considered.

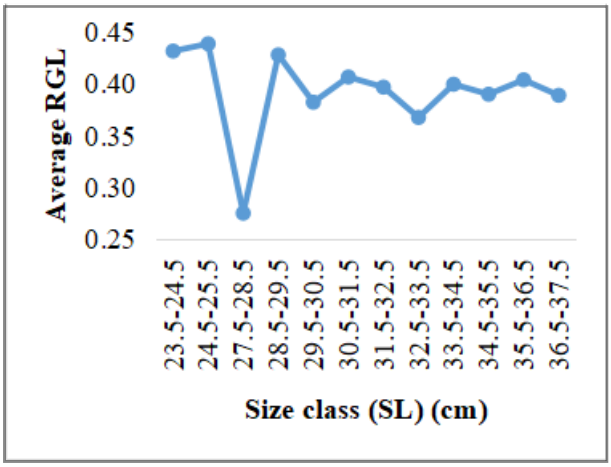

Figure. 25. Average RGL vs size class (SL) (cm) of *Auxis thazard*

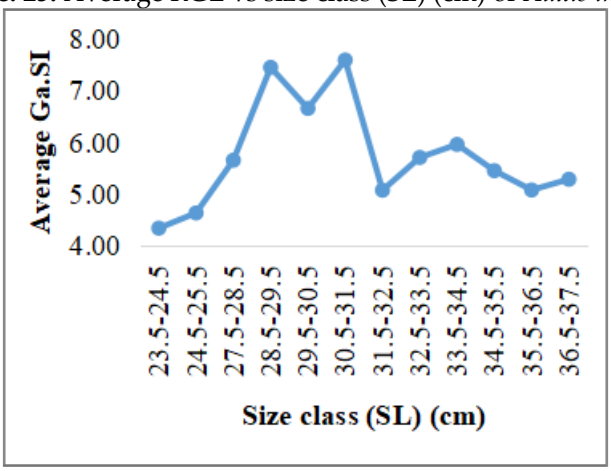

Figure. 26. Average Ga.SI vs size class (SL) (cm) of *Auxis thazard*

4. Discussion

This study focuses on a secondary data analysis and a primary data analysis. For secondary data analysis, *Auxis thazard* inhabiting the West (Negombo), South (Galle) and East (Trincomalee) coasts in the year 2017 were

considered. In primary data analysis, the West (Negombo) coast was only considered from November 2021 to February 2022. In both analyses, the length and weight of fish were taken into account to analyze the length-weight relationship of *Auxis thazard*.

4.1. Secondary Data Analysis

In secondary data analysis, a data set of 796 *Auxis thazard* fish was considered, including 324 fish from the West, 319 from the South and 153 from the East coast. Under the length frequency distributions based on the total length (cm) of fish, the highest percentage frequency recorded on the West coast was 36.8 cm – 37.8 cm in the size class. Both the South and East coasts showed their highest percentage frequencies in the size class of 26.5 cm – 27.5 cm. On the West coast the lowest percentage frequency was recorded 29.8 cm – 30.8 cm in the size class and the South coast showed its lowest frequency percentage in two size classes of 21.5 cm – 22.5 cm and 45.5 cm – 46.5 cm. On the East coast the lowest percentage frequency was 42.5 cm – 43.5 cm in the size class.

The *Auxis thazard* data sample from the West coast had the highest estimated mean total length, measuring 34.90 ± 5.26 cm. The South and East coasts recorded their mean total lengths as 31.65 ± 5.44 cm and 32.87 ± 5.21 cm. The total lengths varied from 23.8 cm - 44.2 cm, 21.5 cm – 46.5 cm and 25.5 cm – 44.1 cm for the West, South and East coasts respectively. The total length of *Auxis thazard* in Sri Lankan waters ranges from 21.50 cm to 44.20 cm [15]. Furthermore, the length range of *Auxis thazard* captured in the Indian Ocean is between 20 and 50 cm [10]. In this study, all three length ranges recorded on three coasts were included within the 20 -50 cm range.

When comparing with the FishBase [16,17], which gives the most common length of *Auxis thazard* as 60.5 cm, this study has shown that the lengths showing the highest frequencies have been much lower than that for all 3 coastal areas. Possible reasons for this decrease can be suggested as overfishing [18], all the growth stages without any size selection, climate changes, etc.

FishBase reports the length at first maturity of *Auxis thazard* as 29.5 cm. According to FishBase, the length at first maturity in Karnataka, India was 30.5 cm between 2011 to 2012, but this figure has decreased to 29.7 cm by 2016. Based on the data from the three coasts in 2017, the percentages below 29.5 cm included 18.8% for the West, 39.2% for the South and 34.0% for the East.

Therefore, continuous monitoring of fish landings is recommended for a sustainable fishery of *Auxis thazard*.

When the mean weights of *Auxis thazard* taken into account, the West coast had the highest average weight, measuring 535.06 ± 285.48 g. The South coast showed a mean weight of 436.11 ± 296.05 g and *Auxis thazard* from the East coast had a mean weight of 311.3 ± 171.93 g. The weight ranges varied from 124.90 – 1405.05 g, 157.00 – 1475.00 g and 152.60 – 890.40 g for the West, South and East respectively.

In this study, under secondary data analysis, LWR for the West, South and East coasts were $W= 0.0012TL^{3.6586}$, $W = 0.0026TL^{3.4846}$ and $W = 0.0147TL^{2.951}$ based on the Length relationship formula. This length-weight relationship of fish helps to estimate the fish's growth pattern and health condition. The 'b' value in the length-weight relationship determines the growth type of the fish; either allometric or isometric growth.

The 'b' values obtained for *Auxis thazard* in the West, South and East coasts were 3.6586, 3.4846 and 2.951 respectively, showing a positive allometric growth pattern ($b > 3$, t - test, $P < 0.05$) in the West and South coasts in which fish become heavier as they increase in length and size and isometric growth pattern ($b = 3$, t - test, $P > 0.05$) in the East coast where the shape of the fish does not change with increasing weight and length. Therefore, based on the 'b' values, *Auxis thazard* from the West and South coasts are in a suitable, healthy environment [8]. When the 'b' values of male and female fish from all three coasts are considered, males on the West coast show a 'b' value of 3.8293 and females a 'b' value of 3.8466. On the South coast, male *Auxis thazard* fish have a 'b' value of 3.6671 whereas females have a value of 3.5194. On both coasts, all the males and females reflect a positive allometric growth in a suitable, healthy environment. The males and females from the East coast show an isometric growth with 'b' values of 3.0006 and 2.9179 respectively.

When compared with other localities, the 'b' value for *Auxis thazard* in the Southeast coast of India has been reported as 3.4679 [19] where this value coincides with similar exponent values of the study [20], which has given the 'b' values for males as 3.30 and females as 3.02. In the West coast of India, 'b' value has been reported as 3.17 [21]. In all these coasts of India, 'b' values indicate a positive allometric growth for *Auxis thazard* in Indian waters. Apart from India, the 'b' value in Indonesian waters has been reported as 3.149 [22]

and even *Auxis thazard* from the Northeast Atlantic has shown a positive allometry, giving a 'b' value of 3.240 [23].

The K value is used to determine the growth condition of fish [9]. The mean K value for *Auxis thazard* on the West, South and East coasts were 1.21 ± 0.42, 1.43 ± 0.98 and 0.94 ± 0.51 respectively. The K value greater than 1 denotes a healthy condition, while less than 1 denotes poor conditions [24]. Fish are in better condition when the K value is higher [8]. Consequently, *Auxis thazard* in the West and South reflect that they are comparatively healthy and have a relatively better physical condition. The fact that the East Coast's K value for *Auxis thazard* is less than 1 suggests that *Auxis thazard* along that specific coast are generally in a poorer condition.

The LWR is not stable for different populations and tend to vary depending on the environmental conditions such as temperature, salinity, food (quality, quantity and size), habitat and gonad maturity, spawning period, sex and season, etc. [25]. That explains why, despite living in the same coastal waters of Sri Lanka, the LWR of the same species, *Auxis thazard*, differs among the West, South, and East populations. As well as the K value is influenced by the age and sex of the fish, season, maturity stage, fullness of gut, type of food consumed, amount of fat reserve and degree of muscular development [26]. Since Sri Lanka is a tropical nation, seasonal variations might not have an impact on LWR and K values, but other factors might have an impact either directly or indirectly.

In the secondary data analysis, coastal catches of *Auxis thazard* by different fishing gears such as BS- Beach Seine, GI- Coastal Gillnet, HL- Coastal Handline, LLCO- Coastal Longline, TLL- Coastal Troll line and PSRN- Coastal Ringnet were taken into analysis to find out the most commonly used fishing gear to catch *Auxis thazard*. On the West Coast, gillnets were the most commonly used fishing gear, accounting for 98% of all catches, whilst on the East and South Coasts, ringnets were the predominant method. Ringnets accounted for 68% of catches on the South coast and 67% of catches on the East coast. Coastal Handline and Coastal Longline are the least used fishing equipment, while coastal Troll lines have never been used to catch *Auxis thazard*. Gillnets and ringnets have been employed equally when percentages of total catches from all three coasts are taken into consideration. Gillnets and ringnets are the two primary fishing gears used in Sri Lanka to target neritic tuna species out of a variety of other gears [27]. When monthly

usage of fishing gear is considered, a higher percentage of catches are reported by gillnets, mainly in the months of May, June and September on the West coast. Ringnets have been used in almost all months, becoming the most used gear on the South coast and even on the East coast and most of the monthly catches are accompanied by ringnets.

4.2. Primary Data Analysis

Under primary data analysis, the study was carried out specifically on the West (Negombo) coast from November 2021 to February 2022 considering a total of 63 *Auxis thazard* fish collected from the fishermen. The length frequency distribution of *Auxis thazard* inhabiting the West coast showed the highest percentage of frequency in the total length size class of 34.7 cm – 35.7 cm and the lowest percentage of frequency in the size class of 26.7 cm – 27.7 cm. The mean total length was estimated as 36.46 ± 3.20 cm and the total length varied in a range of 26.7 – 41.7 cm. The mean weight was recorded as 648.86 ± 173.15 g while having a weight range of 227.50 – 1004.00 g.

The length-weight relationship of the fish was represented by $W= 0.0114TL^{3.0366}$. The 'b' value being 3.0366 statistically concluded that the fish exhibit an isometric growth pattern (b = 3, t - test, $P > 0.05$). The male and female fish from the West Coast were analyzed separately based on their "b" values. The males showed a 'b' value of 3.1039 and the females showed a 'b' value of 2.8966, statistically reflecting an isometric growth. The mean K factor was recorded as 1.31 ± 0.12, indicating fish are comparatively healthy and have a relatively good physical condition.

Similar readings from a different recent study conducted on Sri Lanka's West coast between July 2021 and December 2021 also indicate that *Auxis thazard* are in a suitable and healthy environment [4]. The total length range is reported as 21.5 cm to 44.2 cm and the mean weight is 666.7g. The LWR is reported as $W= 0.0038TL^{3.3889}$, in which the 'b' value denoted a positive allometric growth. The K value of 1.51 ± 0.17 further suggests that the fish are generally healthy [4].

Furthermore, the primary data analysis focused on the feeding of *Auxis thazard* on the West coast. When the recorded stomach fullness of the fish is considered, most of the fish were with empty stomachs (56%). Only 13% of fish were with full stomachs. The cut-opened full stomach cavities showed that the shrimps (Crustaceans) were their most preferred food item. Parts of small fish species such as *Amblygaster sirm* and *Sardinella* sp. were also found

within the stomach. *Auxis thazard*'s stomach contents revealed a variety of prey items, including shrimp, small fish species, cephalopods, and stomatopod larvae [11]. This indicates that *Auxis thazard* is a nonselective feeder and that anything in its surroundings might satiate its voracious appetite. According to [11], the highest percentage of prey items reported in the gut of *Auxis thazard* was 47.8% of crustaceans, including shrimps, crabs and stomatopod larvae. The second most abundant prey item was small fish (31.2%), including species such as *Amblygaster sirm, Sardinella* and lizardfish. The third abundant prey item was cephalopods (10.2%), with cuttlefish and squid in the stomach content [11]. Moreover, visual observation of the stomach fullness of *Auxis thazard* revealed that 24% of fish stomachs were full, 19% were three-quarter full, 17% were half full, 24% were quarter full, 9% were one-eighth full and 6% were empty [11].

74% of the *Auxis thazard* from the West coast of India have dominated the empty stomach conditions similar to this study [25]. Their diet has included three categories as crustaceans, cephalopods and finfishes, where crustaceans included non-penaeid prawn (*Acetes* spp.) and crabs and finfish included sardines, anchovies, mackerels, scads and tuna juveniles. From 65 stomach contents analyzed from the Eastern Indian Ocean, the dominant group included unidentified fish (fish ruined) (41%) and 32% were with empty stomachs [28]. Some materials identified include sardines (14%), crustaceans (*Acetes* spp; 10%), anchovies (*Stolephorus* sp; 2%) and squids (Loliginidae; 1%).

The reason for most of the tunas with empty stomachs might be due to that the fishing times were in the very early morning when tunas had not yet fed [29]. Apart from that, some reasons that can be suggested are the presence of non-feeding life stages, individual fish health, environmental conditions, etc.

The RGL was estimated to determine the feeding habit of *Auxis thazard*. The RGL range was recorded as 0.28 – 0.52. RGL values smaller than 1 show a carnivorous diet. A diet based on vegetative materials or detritus is implied by RGL values of more than 3, while values between 1 and 3 indicate an omnivorous diet [30]. With the recorded mean RGL, it confirmed that *Auxis thazard* fish species is a carnivorous fish. According to the plot of Average RGL vs size classes in standard lengths, the highest peak was observed in the size class 24.5 cm – 25.5 cm and the lowest was observed at 27.5 cm – 28.5 cm. Feeding habits are associated with increased or decreased gut length that

could change depending on fish size and shape [31]. Additionally, as gonads cover the majority of the body during maturity, it is possible that gut length can decrease as gonads develop [32]. As a result, RGL can change based on how various development stages are fed.

Ga.SI shows the feeding intensities of fish. In this study, the range of Ga.SI was 2.50 – 17.67 and showed an average value of 5.96. Ga.SI can be used to determine feeding intensity at different size classes of *Auxis thazard*. According to the plot of average Ga.SI vs size classes in standard lengths, the highest feeding intensity was recorded in the size class of 30.5 cm – 31.5 cm and size class 23.5 cm – 24.5 cm, which accounted for the poor feeding. The food preferences tend to depend widely on the nature of food available in the living habitat, environmental conditions, size and sexual stages of fish as well as inter and intra-specific competitions [33].

5. Conclusion

In secondary data analysis, with respect to the year of 2017, the LWRs for the West, South and East coasts are $W= 0.0012TL^{3.6586}$, $W = 0.0026TL^{3.4846}$ and $W = 0.0147TL^{2.951}$. The West and South coasts indicate positive allometric growth and the East coast indicates isometric growth having pooled 'b' values of 3.6586, 3.4846 and 2.951 for the West, South and East. Based on the 'b' values, *Auxis thazard* from the West and South coasts are in a suitable, healthy environment. According to K values of 1.21 ± 0.42 and 1.43 ± 0.98, *Auxis thazard* in both the West and South coasts are comparatively healthy, having relatively good physical conditions and the East coast having a K value of 0.94 ± 0.51 indicates a poor physical condition of fish. This poor physical condition can be due to the influence of environmental factors and food supply which could greatly affect the health of the fish. Apart from that, factors like sex, age and maturity stages can also affect the condition of the fish. Gillnets and ringnets are the most commonly used fishing gears in the West, South and East coasts in 2017. In the primary data analysis from November 2021 – February 2022 on the West coast, the LWR is $W= 0.0114TL^{3.0366}$ in which the 'b' value 3.0366 shows an isometric growth. *Auxis thazard* are comparatively healthy with relatively good physical condition and have a K value of 1.31 ± 0.12. Most of the fish have empty stomachs at the time of capture and shrimp is their most preferred food item. RGL value confirms that *Auxis thazard* is a carnivore. Ga.SI shows the feeding intensities of fish in different size classes,

reporting the highest and lowest intensities in the size classes of 30.0 cm – 31.5 cm and 23.5 – 24.5 cm in standard length. The FishBase reports length at first maturity as 29.5 cm and the percentages below 29.5 include 18.8%, 39.2% and 34.0% for the West, South and East coasts respectively. As length at first maturity seems to decrease, continuous monitoring of landing and data collection is recommended for a sustainable fishery.

Supplementary Materials: Not applicable.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors highly acknowledge the support given by the Department of Fisheries of Sri Lanka and the facilities provided by the Department of Zoology and Environmental Management, University of Kelaniya. Special thanks to the fishermen in the Negombo fishery harbour who gave the required fisheries data and information.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

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