Analyses of length-weight, length-length relationships, and condition factor of Frigate tuna, *Auxis thazard*, collected from coastal fishing boats: a study on Negombo fishery harbour, west coast of Sri Lanka

A. P. H. B. Rathnayaka and H. A. C. C. Perera*

Department of Zoology and Environmental Management, University of Kelaniya, Kelaniya, GQ 11600, Sri Lanka.

*Corresponding author: chinthap@kln.ac.lk

https://orcid.org/0000-0001-8681-9663

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Abstract *Auxis thazard* (Frigate tuna) is one of the commercially important neritic tuna species found in Sri Lankan waters. Even though frigate tuna contributes a higher percentage than the total tuna production income of the country, less information is available related to the biometric parameters due to the lack of studies based on this migratory species. Therefore, this study mainly focuses on length-weight relationship (LWR), length-length relationship (LLR) and the condition factor of *A. thazard* focusing mainly on the Western coast of Sri Lanka. The study was carried out from July 2021 to December 2021 collecting 214 *A. thazard* fish from the fishermen. Based on the results, the LWR was $W = 0.0038TL^{3.3889}$. The pooled 'b' value 3.3889 indicated positive allometric growth ($b > 3$, t-test, $p < 0.05$) confirming *A. thazard* in the West Coast are in a suitable, healthy environment. The K value 1.51 ± 0.17 indicated relatively healthy condition in fish. The LLRs were highly correlated ($r^2 > 0.951$; $P < 0.001$). The FishBase reports length at first maturity as 29.5 cm. The percentage below 29.5 cm included 17.29%. Therefore, continuous monitoring of fish landings is recommended for a sustainable fishery.

Keywords: *Auxis thazard*, Fulton's condition factor, Length-length relationship, Length–weight relationship

Introduction

Frigate tuna, *Auxis thazard* (Lacepède, 1800), Kawakawa, *Euthynnus affinis* (Cantor, 1849), and bullet tuna, *Auxis rochei* (Risso, 1810) are the neritic tuna species mainly found in Sri Lankan marine waters (Abdussamad et al., 2013). Neritic tunas contribute approximately 4% to the total tuna production of the country while the frigate tuna dominates by contributing over 28% to the total neritic tuna production of Sri Lanka (Dalpathadu & Haputhantri, 2020) becoming a very important tuna species locally referred to as 'Alagoduwa'.

Frigate tuna is a highly migratory species. It is found in both coastal and oceanic waters in all tropical and subtropical waters (Colette & Aadland, 1996). It is highly gregarious and often schools with other scombrids. Due to their abundance, frigate tunas are important elements of the food web, mainly as forage for other commercially important species. These tunas are preyed upon by larger fishes including other tunas. Frigate tunas are considered non-selective carnivorous feeders who feed on a range of prey items available in the environment and the appetite of this fish can be satisfied by anything that is abundantly found in the surrounding environment (Herath et al., 2019). Their main food items include small fish, squids, planktonic crustaceans (megalops) and stomatopod larvae.

Frigate tunas are marketed fresh and frozen as well as utilized dried or salted, smoked and canned (IOTC, 2013). The main gears used in the Indian Ocean for harvesting of frigate tunas include gillnets (~41%), coastal longline and trolling, handline and trolling (~33%) and to a lesser extent coastal purse seine net. Frigate tuna can be collected as a by-catch of industrial purse seine vessels and the target of some ring net fisheries (IOTC, 2020). In recent years, over 90% of catches of frigate tuna have been concentrated in four countries; Indonesia (65%), I.R. Iran (10%), Sri Lanka (8%) and India (8%) (Data as of October 2016, IOTC).

Even though frigate tuna is one of the commercially important neritic tuna species of Sri Lanka, the data on the biometric parameters of this species is scanty. There is a data deficiency of catches, length, weight, biology and fishery among the geographical regions. Therefore, the Indian Ocean Tuna Commission (IOTC) encourages to find out more reliable data regarding this species. Since frigate tunas are migratory in nature and as frigate tuna fishery mainly contributes to the Sri Lankan economy, it is better to have reliable data on this fish stock to meet management strategies. Therefore, this study mainly focuses on the length-weight relationship (LWR), length-length relationship (LLR) and the condition factor of *A. thazard* in the West coast of Sri Lanka.

The length-weight relationship is important to estimate growth with increasing length and it is use in determining the type of somatic growth (Froese, 2006). This relationship is used to examine the well-being of the individuals and to determine the possible differences among different stocks of the same species (King, 2007). Length and weight play a major role as input parameters when estimating the total biomass of a fish population (Moutopoulos & Stergiou, 2002). The 'b' value in the length-weight relationship determines the growth type of the fish; either allometric or isometric growth. When 'b' is close to 3, it indicates that fish grow isometrically and 'b' values significantly different from 3.0 indicate allometric growth (Tesch, 1971). In the positive allometric growth pattern, fish become heavier as they increase in length and size whereas in negative allometric growth, fish become slender as they increase in length and weight. The shape of the fish doesn't change with increasing weight and length in isometric growth (Froese, 2006).

Length–weight relationship (LWR) and Length-Length relationship (LLR) parameters are useful in the management and assessment of fishery resources. The length-length relationships play an important role in fisheries management for comparative growth studies (Moutopoulos & Stergiou, 2002; Hossain et al., 2006).

The Fulton's condition factor, K is used to analyze the growth condition of the fish (Moutopouos & Stergious, 2002). The condition factor (K) of fish compares the growth trends of species between regions, seasons, and sexes (Froese, 2006). K is helpful in determining the productivity, health, and physiological status of fish populations (Blackwell et al., 2000). The K value more than 1 indicates a healthy condition and less than 1 indicates poor condition of fish (Hall & Van Den Avylle, 1986). When there is a high K value, fish have a better condition (Froese, 2006).

Materials and methods

A total of 214 frigate tuna fish were collected from the coastal area of Negombo in Western province from July 2021 to December 2021. The Total Length (TL), Fork Length (FL), Standard Length (SL) and Head Length (HL) were recorded to the nearest 0.1 cm. Total weight was recorded to the nearest 0.1 g. The length–weight relationship (LWR) was estimated using the equation;

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

The Fulton's condition factor (K) was estimated by the equation;

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

W is the body weight of fish in g, L is the Total Length (TL) of fish in cm, 'a' is the regression intercept and 'b' is the regression coefficient. The parameters 'a', 'b' and coefficient of determination (R^2) were estimated by linear regression relationship of the logarithm transformed LWR expressed as,

$$\log W = \log a + b \log L \quad (3)$$

The relationships of SL vs TL, TL vs FL, FL vs SL and HL vs TL were established by linear regression of the log-transformed values.

Results and discussion

When the analyzed fish sample of 214 frigate tuna is considered, the total weight ranged from 118.9 g to 1353.6 g and the total length ranged from 21.5 cm to 44.2 cm. The standard length ranged from 19.4 cm to 40.7 cm, fork length ranged from 20.1 cm to 42.0 cm and head length ranged from 5.2 cm to 11.4 cm.

According to IOTC (2016), the length of *A. thazard* caught in the Indian Ocean is in the range of 20 cm – 50 cm. As well as IOTC (2019) has

stated that the total length of *A. thazard* in Sri Lankan waters varies from 21.50 cm – 44.20 cm. Therefore, based on the results of this research, it can be concluded that the total length of *A. thazard* from the west coast of Sri Lanka is in the exact length range as mentioned by IOTC (2019). Further, all the length ranges of frigate tuna observed from the west coast are included within the range of 20 - 50 cm, which is the length range of frigate tuna in the Indian Ocean. When the weight range is considered, the weight range of frigate tuna on the west coast is included within the range of 118.9 - 1430.9 g, which is the weight range reported in Sri Lanka by Herath et al., (2019).

The mean weight of frigate tuna recorded from the West coast was 666.7 g. The mean values of TL, SL, FL and HL were 34.3 cm, 31.3 cm, 32.5 cm and 8.86 cm respectively. According to Herath et al., (2019), the mean weight of frigate tuna on the West coast in 2019 was 621.02 g and the mean SL was 30.6 cm. When compared with those results it can be observed a sight difference in the measurements between the years of 2019 and 2021.

According to FishBase, the length at first maturity is 29.5 cm. FishBase reports in Karnataka, India the length at first maturity has been 30.5 cm from the year 2011 to 2012 and it has become 29.7 cm in the year 2016. Based on the data of the West coast of Sri Lanka in 2021, the percentages below 29.5 cm were recorded as 17.29%. Length at first maturity seems to be decreasing. Therefore, to have a sustainable fishery of frigate tuna, continuous monitoring of fish landings is recommended.

The length–weight relationship of frigate tuna derived into the equation $\log W = \log a + b \log L$ is shown in Figure 1.

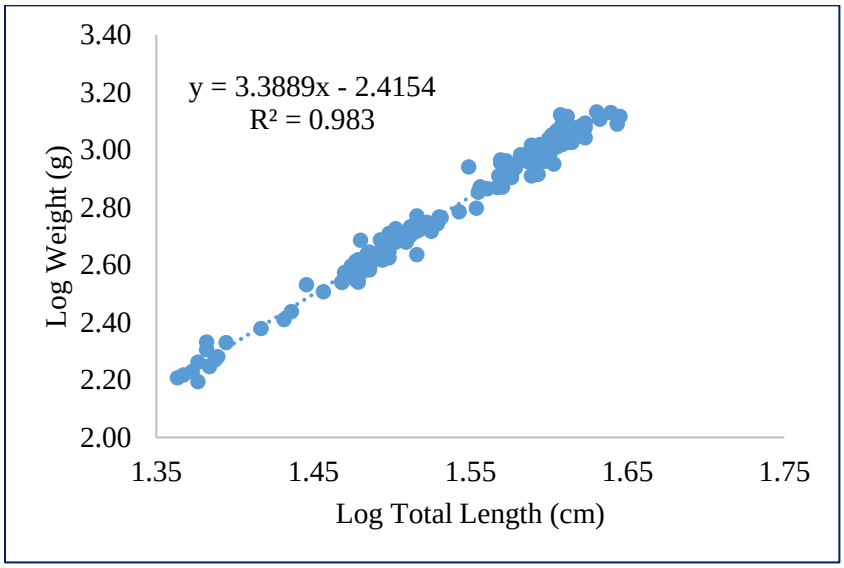

Figure 1: The plot of Log Weight (g) vs Log Total length (cm) for West coast

The LWR for West coast was $W = 0.0038TL^{3.3889}$. The pooled 'b' values 3.3889 indicated positive allometric growth (b > 3, t-test, p < 0.05) in which fish become heavier as they increase in length and size. Therefore *A. thazard* in West coast are in a suitable, healthy environment (Froese, 2006). The K value 1.51 ± 0.17, which is higher than 1 showed relatively healthy conditions in fish in the West coast (Froese, 2006). Even in the year 2019, as Herath et al., (2019) reported, the frigate tuna in Sri Lankan waters followed a positive allometric growth having a b value of 3.3385 and were in healthy conditions showing a K value of 1.93 for Sri Lankan waters and 1.959 for west coast.

When compared with other localities, the 'b' value for *A. thazard* in Southeast coast of India has been reported as 3.4679 (Yosuva et al., 2018) where this value coincides with similar exponent values from the study by Muthiah (1985) which

has given the 'b' values for males as 3.30 and for females as 3.02. On West coast of India, 'b' value has been reported as 3.17 (Ghosh et al., 2012). In all these coasts of India, 'b' values indicate a positive allometric growth for *A. thazard* in Indian waters. Apart from India, in Indonesian waters the 'b' value has been reported as 3.149 (Tampubolon et al., 2016) and even frigate tuna from Northeast Atlantic has shown a positive allometry giving a 'b' value of 3.240 (Petukhova, 2019).

The relationships of SL vs TL, TL vs FL, FL vs SL and HL vs TL are presented in Figure 2. The relationships between TL, FL, SL and HL with the estimated parameters of the length-length relationship and the coefficient of determination, r^2 are shown in Table 1. All LLRs were highly significant ($P < 0.001$), with most of the coefficient of determination values being > 0.951.

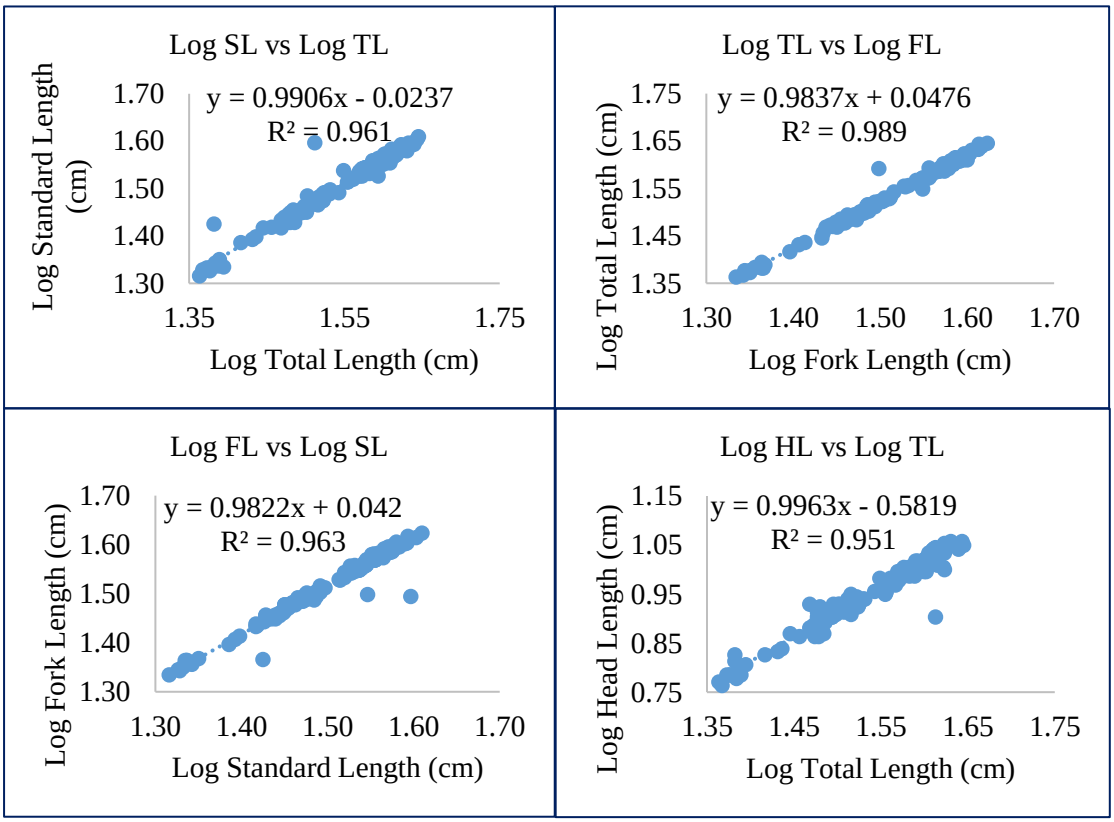

Figure 2: The plots of Length – length relationships of *A. thazard* in West coast

Table 1: Length – length relationships between total length (TL), standard length (SL), fork length (FL) and head length (HL) for of *A. thazard* in West coast

Equation	n	A	b	r^2
SL = a + b×TL	214	0.9469	0.9906	0.961
TL = a + b×FL		1.1158	0.9837	0.989
FL = a + b×SL		1.1015	0.9822	0.963
HL = a + b×TL		0.2619	0.9963	0.951

n, sample size; SL, standard length; TL, total length; FL, fork length; HL, Head length; a, intercept; b, slope; r^2, coefficient of determination.

The length-weight relationships are 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. (Froese, 2006; Jayaprabha et al., 2015). Therefore, the LWR of the same species, *A. thazard* can vary among the populations in Sri Lanka even though they inhabit the same coastal waters.

The Fulton's condition factor, K 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 (Barnham & Baxter, 1998). As well as the differences in predation rate on species, disease-prone environment, availability of food and factors such as pH, pollution level and temperature of water at the study site are also known to affect the K value of fishes (Wang et al., 2017) causing the condition value to deviate from the theoretical value of 1 (Le Cren, 1951). As Sri Lanka is a tropical country, the seasonal changes may not affect both LWR and K values, but other factors can directly or indirectly can affect them.

Conclusions

The LWR for the West coast is $W = 0.0038TL^{3.3889}$. *A. thazard* in West indicate positive allometric growth and are in a suitable, healthy environment. As well as they are comparatively healthy. Under LLR, relationships between the four length parameters of frigate tuna are all highly significant ($p < 0.001$). The Fishbase reports length at first maturity as 29.5 cm and the percentages below 29.5 cm include 17.29% of fish. Length at first maturity seems to be decreasing. Therefore, continuous monitoring of landing is recommended for a sustainable fishery of *A. thazard* in the West coast.

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Conflict of interest

The authors declare no conflicts of interest.

Author contributions

APHBR: Sample collection, Data Analyses; HACCP: supervision, review, critical feedback and editing.

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