Aquatic Resource Sciences

Journal homepage: www.journal.inrrd.com/ars

Original article

First report on population parameters of Bengal tongue sole (*Cynoglossus cynoglossus*): Suggestion for optimum catchable length in the Bay of Bengal, Bangladesh

Taiba Akter Laboni[1], Mst. Shahinur Khatun[1], Obaidur Rahman[1,2], Most. Shakila Sarmin[1,2], Yeasmin Akter Ratry[3], Md. Mahfuz Uddin[4], Tarek Rahman Likhon[5], and Kazi Ahsan Habib[6]*

[1]*Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh*
[2]*Institute of Natural Resources Research and Development, Rajshahi 6206, Bangladesh*
[3]*Department of Mathematics, University of Rajshahi, Rajshahi 6205, Bangladesh*
[4]*Department of Statistics, University of Rajshahi, Rajshahi 6205, Bangladesh*
[5]*Institute of Health Economics, University of Dhaka, Dhaka 1000, Bangladesh*
[6]*Department of Fisheries Biology and Genetics, Faculty of Fisheries, Aquaculture and Marine Science, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh*

ARTICLE INFO

Article history
Received 27 November 2023
Revised 28 December 2023
Accepted 09 January 2024
Available online 13 January 2024

Keywords
Population structure
Cynoglossus cynoglossus
Growth pattern
Life History
Bay of Bengal

ABSTRACT

The current research provides first comprehensive explanation of population dynamics of *Cynoglossus cynoglossus* from the Bay of Bengal in Bangladesh, encompassing population structure (LFD), growth patterns (LWR and LLR), growth parameters, condition factors (including allometric K_A, Fulton K_F, relative K_R, and relative weight W_R), form factor ($a_{3.0}$), size at sexual maturity (L_m), natural mortality *(M)*, and optimum catchable length (L_{opt}). Over the course of January to December 2022, a total 100 samples were randomly collected through various distinctive fishing techniques. Total length (TL), standard length (SL), and total body weight (BW) were measured with a precision of 0.01 cm and 0.01 g. The TL spanning from 10 to 38.5 cm. The estimated allometric coefficient *(b)* indicated negative allometric growth (b = 2.46). The $a_{3.0}$ value of 0.0052 suggests that this fish possesses an elongated body shape. In evaluating the health status of *C. cynoglossus* in the Bay of Bengal, K_F appeared as the best condition factor among others. Furthermore, W_R exhibited a significant deviation from 100 (p< 0.0001), signifying an unstable environment for *C. cynoglossus*. The growth parameters were determined as follows: L_∞ = 40.20 cm, K = 1.09 year^{-1}, and 'φ' = 3.25. The maximum age (t_{max}) was calculated as 2.76 years. The size at first sexual maturity (L_m) was measured at 21.52 cm TL with t_m = 0.77 year. Moreover, the natural mortality (M) was estimated to be 1.67 year^{-1}. Additionally, the suggested optimum catchable length (L_{opt}) for this species was 26.61 cm. These valuable insights into the population parameters, growth patterns, mortality and L_{opt} of *C. cynoglossus* can serve as a foundation for informing future management strategies.

Introduction

Fish and their products stand as one of the most substantial sources of protein for the global population (Roy et al. 2020). Fish is particularly rich in essential fatty acids, notably omega-3, which play a pivotal role in the cognitive development of children. In the context of Bangladesh, around 60% of the total animal protein consumed originates from fish, underscoring its vital dietary significance (Mawa et al. 2021). Moreover, the fisheries sector contributes a noteworthy 3.50% to the nation's gross domestic product (GDP), as highlighted by the Department of Fisheries (DoF, 2020). In contemporary times, the marine fisheries sector has ascended to a position of paramount importance within Bangladesh's economy.

The Bengal tongue sole, scientifically classified as *Cynoglossus cynoglossus* and belonging to the Cynoglossidae family within the Pleuronectiformes order, is predominantly found in tropical and subtropical Indo-West Pacific waters. In the local context of Bangladesh, it

*Corresponding author
Email address: ahsan.sau@gmail.com (Kazi Ahsan Habib)

is referred to as "kukur jeeb." According to Munroe (2001), the distribution of this species spans the Indo-West Pacific region, encompassing the Malay Archipelago, Philippines, and extending westward to Myanmar, Bangladesh, India (specifically West Bengal), and even Pakistan. This species is typically found in shallow, muddy, and sandy bottoms within inshore areas and estuaries, as documented by Talwar and Jhingran (1991). Its habitat includes the Bay of Bengal, estuaries, rivers, and it has been observed in the Sundarbans (Huda et al. 2003). The Bengal tongue sole is notably common in the Gangetic delta (Talwar and Jhingran 1991) and primarily feeds on benthic invertebrates (Rainboth 1996). The "Bengal tongue sole" is a species that is frequently harvested in the Ganges delta, and there is significant demand for it as a source of fish for consumption in Bangladesh. Its consumption of invertebrates also plays a role in controlling the abundance of these organisms. This species is primarily available in the market in fresh and frozen forms, but it is also processed into dried and salted products, as outlined by Munroe (2001). In Bangladesh, the Bengal tongue sole finds common use as a food fish, readily available in both its fresh and dried iterations. Remarkably, its global conservation status is classified as "least concern" by IUCN (2022).

Length-frequency distribution (LFD) serves as a vital biometric statistic widely employed in diverse applications, including the calculation of growth rates, the determination of growth performance indices, and the assessment of fish mortality (Ilah et al. 2023). Moreover, LFD plays a pivotal role in estimating river health by evaluating residual biomass and identifying breeding seasons (Ranjan et al. 2005). Additionally, LFD facilitates the comparative analysis of the physical characteristics of various species and the population of a single species across different aquatic ecosystems (Sabbir et al. 2020).

Length-Weight Relationships (LWRs) assume significance as they enable the derivation of weights from lengths, which proves advantageous when direct weight measurements at the site might be time-consuming. The parameters derived from LWRs hold substantial importance in fish biology, offering insights into the stock or stock status of organisms (Koutrakis and Tsikliras 2003; Acosta et al. 2004; Ecoutin et al. 2005; Khatun et al. 2023). LWR and LLR is as another crucial method for delineating population growth patterns.

In order to ensure the sustainable management and conservation of wild fish stocks, it is imperative to conduct comprehensive assessments of various life-history aspects. These aspects encompass growth patterns, reproductive characteristics, recruitment dynamics, and mortality rates (Foster and Vincent 2004). Moreover, biological indices comprising abundance, distribution, mortality rates, age distribution, population structure, condition factors, and physiological status hold pivotal roles in providing invaluable insights into the overall health and dynamics of fish populations. Through the meticulous study of these parameters, scientists can effectively assess the status of fish populations, track changes across temporal scales, and thereby formulate well-informed decisions pertaining to conservation and management strategies. Profound comprehension of fish population parameters stands as a pivotal component in ecosystem management, ensuring sustainable fisheries practices, and conserving biodiversity.

The author acknowledges the limited scope of existing studies centered on *C. cynoglossus*, with notable instances encompassing research on aspects like on feeding, metabolism and growth of this species from Arabian Sea, southwest coast of India (Edwards et al. 1971); as well as investigations into the condition factors of *C. cynoglossus* (Tanjin et al. 2021). However, it's worth noting that no prior studies on the population dynamics of *C. cynoglossus* have been undertaken in our specific ecosystem in Bangladesh. Therefore, the primary objective of this research is to provide comprehensive insights into population parameters, population structure, growth patterns, best condition factors, prey-predator status, form factor, life span, size at first sexual maturity (L_m), natural mortality and the optimum catchable length (L_{opt}) of *C. cynoglossus* in the Bay of Bengal, Bangladesh, over the course of a one-year investigative period.

Materials and methods

Sampling and sampling site

A total of 100 distinct specimens of *C. cynoglossus* were obtained from local fishers operating in the Bay of Bengal, southern region, Bangladesh (located at 21.324923°N and 91.081852°E), as depicted in Fig. 1. These fish were captured in the month of January to December 2020, employing conventional fishing techniques and gear, including gill nets and trawls, featuring wire spacing ranging from 1-2 cm. Once collected, the specimens were immediately preserved in a solution of 10% buffered formalin and thereafter

stored on ice, ensuring their optimal condition for any potential subsequent investigations. To facilitate future studies, these steps were taken to maintain the specimens in a suitable state. Subsequently, the fundamental length of each individual *C. cynoglossus* was measured the subsequent day within a laboratory setting, utilizing digital slide calipers to achieve measurements accurate to the nearest 0.01 cm. Additionally, the complete body weight of each creature was meticulously determined, with a precision of 0.01 g, through the use of an electric balance.

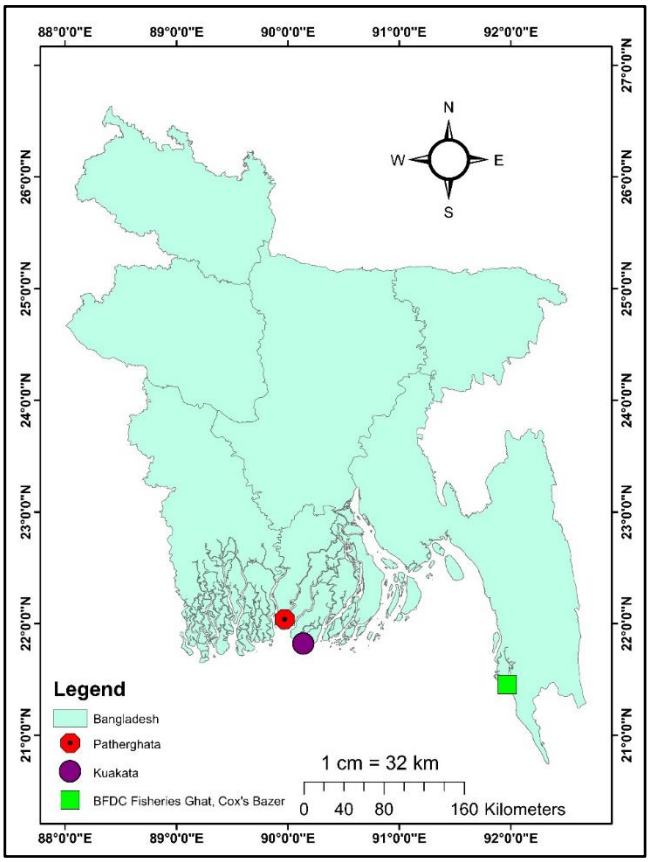

Fig. 1. Map of the study site in the Bay of Bengal, Bangladesh

Population Structure

The length frequency distribution (LFD) for the *C. cynoglossus* species was structured based on a total length (TL) class interval of 3.0 cm.

Growth pattern

The growth pattern of the species was evaluated through the utilization of Length-Weight Relationships (LWRs) employing the approach outlined by Le Cren (1951). This method involves the equation $W = a^* L^b$, where parameters '*a*' and '*b*' can be determined by employing the equation: *ln* (BW) = *ln* (*a*) + *b ln* (TL).

Growth parameter

The growth parameter, asymptotic length (L_∞), was computed by the maximum length utilizing a specific formula: $L_\infty = 0.044 + 0.9841 * log(L_{max})$ (Froese and Binohlan 2000) and the estimation of asymptotic weight was carried out using $W_\infty = aL_\infty^b$. Furthermore, the age at zero length (t_0) was derived through the equation $log(-t_0) = -0.3922 - 0.2752\, log(L_\infty) - 1.038\, log(K)$ (Pauly 1980). The growth performance index (φ) was accomplished using the formula $\varphi = log10(K) + 2log10(L_\infty)$ (Pauly 1984). Additionally, the growth coefficient (K) was calculated employing the formula $K = ln(1 + L_m/L_\infty)t_m$ (Beverton 1992).

Condition factor

The Fulton condition factor (K_F) was calculated using the equation established by Fulton in 1904: $K_F = 100 * (W/L^3)$. To determine K_A, the formula devised by Tesch in 1968, $K_A = W/L^b$, was applied. For K_R, the equation proposed by Le Cren in 1951, $K_R = W/(a * L^b)$, was utilized in our calculations.

Prey predator status

The prey-predator status of *C. cynoglossus* was assessed based on the relative weight (W_R), which was computed using the formula: $W_R = (W/W_S) * 100$. In this formula, *W* represents the weight of an individual, while W_S corresponds to the expected standard weight for each specimen, calculated as $W_S = a * L^b$. The values of '*a*' and '*b*' have been determined from the length-weight relationships (LWRs).

Form factor ($a_{3.0}$)

The form factor was computed utilizing the equation $a_{3.0} = 10^{\log a\text{-}s(b\text{-}3)}$, as described by Froese in 2006. In this equation, '*a*' and '*b*' represent the regression parameters of LWRs, while's' signifies the regression slope of *ln* (*a*) *vs. ln* (*b*).

Size at first sexual maturity (L_m)

The L_m of *C. cynoglossus* in the Bay of Bengal was determined utilizing the Binohlan and Froese (2009) equation: $log(L_m) = -0.1189 + 0.9157 \times log\, L_{max}$, which applies separately to both male and female specimens.

Life span (t_{max})

The life span (t_{max}) was computed through the model: $t_{max} = 3/K$ (Pauly 1984), where t_{max} denotes longevity or life span, reach throughout the population

(years), and *K* denotes growth coefficient, was used to calculate the life span (t_{max}) of *C. cynoglossus*.

Natural mortality (M)

The model established by Peterson and Wroblewski (1984) was used to determine the *M* value. The model's equations are as follows: $M = 1.63\ year^{-1} * (W)^{-0.25}$, where *M* is natural mortality at mass *W*. *W* is computed in this equation using the formula $W = a*L^b$, where *a* and *b* are LWR parameters.

Optimum catchable length (L_{opt})

The optimum catchable length was calculated using the formula $Lopt = 3L_{\infty}(3 + MK^{-1})^{-1}$ (Beverton 1992). Here, *K*, L_{∞}, *M* stand for the relevant growth coefficients, asymptotic lengths, and natural mortality.

Statistical analysis

The statistical analysis was performed using Graph Pad Prism 8.0 and Microsoft Excel (version 2013). To determine if there was any link between the condition variables and TL or BW, the Spearman rank correlation test was used. The mean relative weight (W_R) was distinguished from 100 using a Wilcoxon sign-ranked test (Anderson and Neumann 1996). The statistical study made use of the 5% ($p < 0.05$) level.

Results

Population structure

A total of 100 individuals of *C. cynoglossus* were collected from fishermen in the Bay of Bengal. The measurements of their length and weight, along with their corresponding 95% confidence limit (CL), are presented in Table 1. Among the specimens, the smallest individual measured 10 cm in total length, while the largest reached 38.5 cm. In terms of body weight, the range extended from 9.1 g to 210 g respectively, as observed through LFD.

Notably, the Length Frequency Distribution illustrated that the most prevalent total length sizes fell within the range of 23.99 to 26.99 cm, as exemplified in Fig. 2.

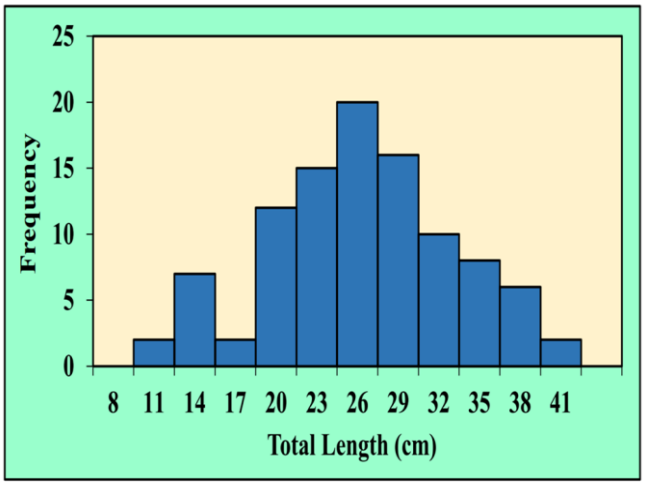

Fig. 2. Length frequency distributions of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

Growth pattern

The sample size, along with the regression parameters of the length-weight relationship (LWR) accompanied by their 95% confidence limit, coefficient of determination (r^2), and the growth pattern of *C. cynoglossus*, have been presented in Table 2 and Fig. 3. Specifically, the derived *b* value (TL *vs* BW) for this species signifies a negative allometric growth pattern. Furthermore, as depicted in Fig. 4, the *b* value in the length-length relationship (LLR) (TL *vs* SL) demonstrates a comparable developmental trend.

Growth parameter

The growth parameters identified for *C. cynoglossus* encompass L_{∞} = 40.20 cm, W_{∞} = 249.29 g, *K* = 1.09 $year^{-1}$, and t_0 = 0.011 year. The value of t_m was calculated to be 0.77 year, and the growth performance index (φ) was determined to be 3.25.

Table 1. Explanatory statistics on the length (cm) and weight (g) measurements of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

Measurement	*n*	Minimum	Maximum	Mean ± SD	95% CL
TL (cm)	100	10.0	38.5	24.98±6.65	23.657-26.295
SL (cm)		9.0	37.6	24.01±6.58	22.699-25.313
BD (cm)		3.5	8.0	5.48±1.22	5.241-5.723
BW (g)		9.1	210.0	89.05±51.71	78.792-99.312

TL, total length, SL, standard length; BW, body weight; GW; *n*, sample size; Min, minimum; Max, maximum; SD, standard

Table 2. Descriptive statistics and estimated parameters of the total length (TL), standard length (SL), fork length (FL) and body weight (BW) relationship of *Polynemus paradiseus* in the Bay of Bengal, Bangladesh

Equation	Regression parameters		95% CL of *a*	95% CL of *b*	r^2
	a	*b*			
$BW=a*TL^b$	0.0282	2.46	0.0168 - 0.0471	2.3002 - 2.6230	0.903
$BW=a*SL^b$	0.4856	0.99	0.4019 - 0.5865	0.9827 - 0.9973	0.999

a, intercept; *b*, slope; CL, confidence limit for mean values; r^2, coefficient of determination;

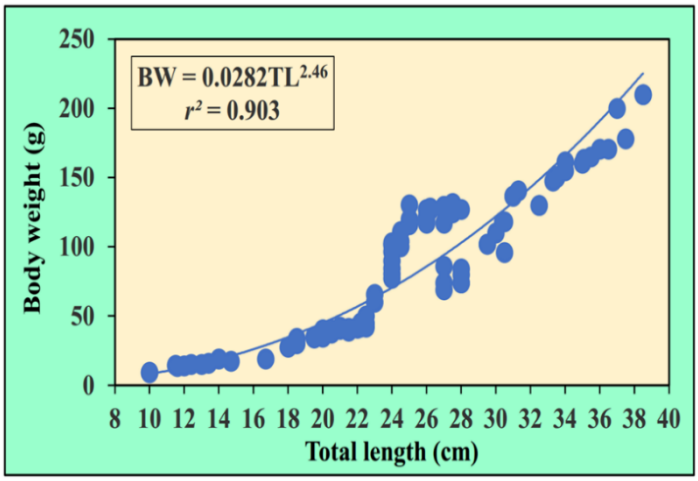

Fig. 3. Relationships between total length and body weight of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

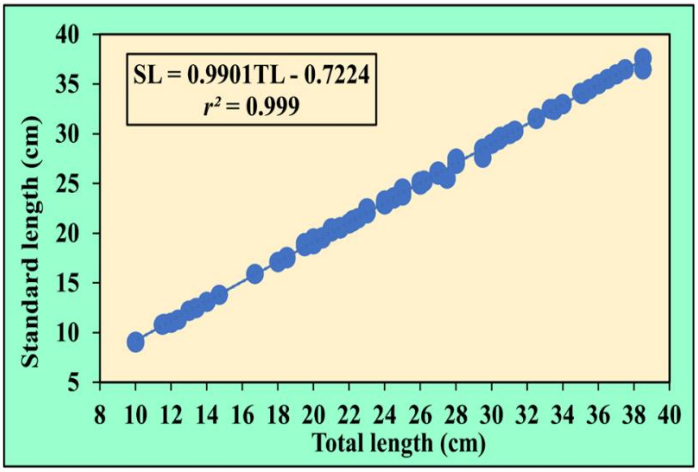

Fig. 4. Relationships between total length and Standard length of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

Condition factor

The values of four distinct condition factors, specifically K_A, K_F, K_R, and W_R, have been detailed in Table 3. The outcomes of the Spearman rank correlation test, depicted in Table 4, distinctly highlight a robust correlation between the conditions factor and both the total length and body weight of *C. cynoglossus*.

Prey predator status

The relative weight W_R (103.10 ± 25.97) exhibited significant deviation from 100 (p = 0.3083) for *C. cynoglossus* as illustrated in Fig. 5.

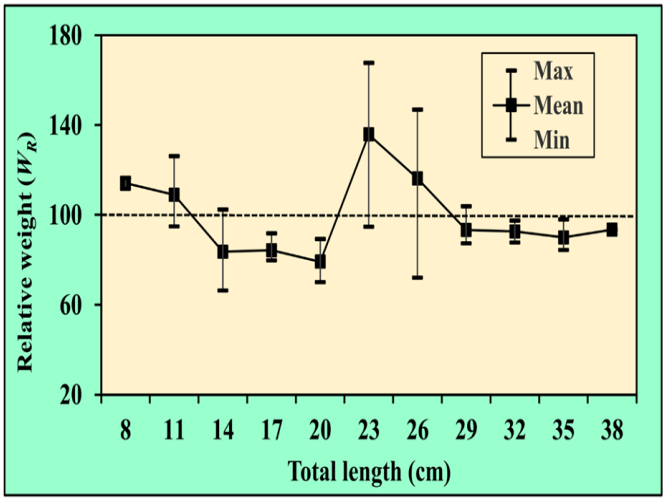

Fig. 5. Relative weight of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

Form factor

The form factor ($a_{3.0}$) was calculated to be 0.0052, signifying an elongated body shape.

Size at first sexual maturity (L_m)

The size at first sexual maturity (L_m) was established at 21.52 cm in total length (TL), accompanied by 95% confidence limits of 16.56-27.79 cm.

Life span (t_{max})

The longevity (t_{max}) of *C. cynoglossus* was computed at 2.76 year in the Bay of Bengal, Bangladesh.

Natural mortality (M)

Throughout the course of this investigation, the natural mortality rate (*M*) of *C. cynoglossus* within the study area was ascertained to be 1.67 per year. Notably, a notable trend emerged wherein specimens with a total length (TL) of less than 5.0 cm demonstrated a markedly elevated natural mortality (*M*), while larger individuals exhibited a comparatively lower *M* value (Fig. 6).

Table 3. Descriptive statistics on condition factor measurements and with their 95% CL of *Cynoglossus cynoglossus* in the Bay of Bengal (Bangladesh)

Condition factors	*n*	Minimum	Maximum	Mean ± SD	95% CL
Allometric condition factor (K_A)		0.33	0.95	0.531±0.162	0.499-0.564
Fulton's condition factor (K_F)	100	0.66	1.678	1.031±0.260	0.979-1.083
Relative condition factor (K_R)		0.02	0.05	0.029±0.007	0.028-0.031
Relative weight (W_R)		66.33	167.76	103.10 ± 25.97	97.95-108.25

Table 4. Relationships of condition factor with total length (TL) and body weight (BW) of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

Relationships	r_s values	95% CL of r_s	*p* values	Significance
TL *vs.* K_F	-0.5229	-0.6557 to -0.3588	<0.0001	****
TL *vs.* K_R	0.1028	-0.1013 to 0.2987	0.3086	ns
TL *vs.* K_A	0.1027	-0.1011 to 0.2988	0.3088	ns
TL *vs.* W_R	0.1028	-0.1012 to 0.2987	0.3084	ns
BW *vs.* K_F	-0.2638	-0.4423 to -0.0651	0.0080	**
BW *vs.* K_R	0.3637	0.1745 to 0.5271	0.0002	***
BW *vs.* K_A	0.3638	0.1746 to 0.5250	0.0003	***
BW *vs.* W_R	0.3635	0.1744 to 0.5261	0.0002	***

CL, confidence limit; r_s, Spearman rank-correlation values; *p*, shows the level of significance; ns, not significant; *** highly significant.

Natural mortality (M)

Throughout the course of this investigation, the natural mortality rate *(M)* of *C. cynoglossus* within the study area was ascertained to be 1.67 per year. Notably, a notable trend emerged wherein specimens with a total length (TL) of less than 5.0 cm demonstrated a markedly elevated natural mortality *(M)*, while larger individuals exhibited a comparatively lower *M* value (Fig. 6).

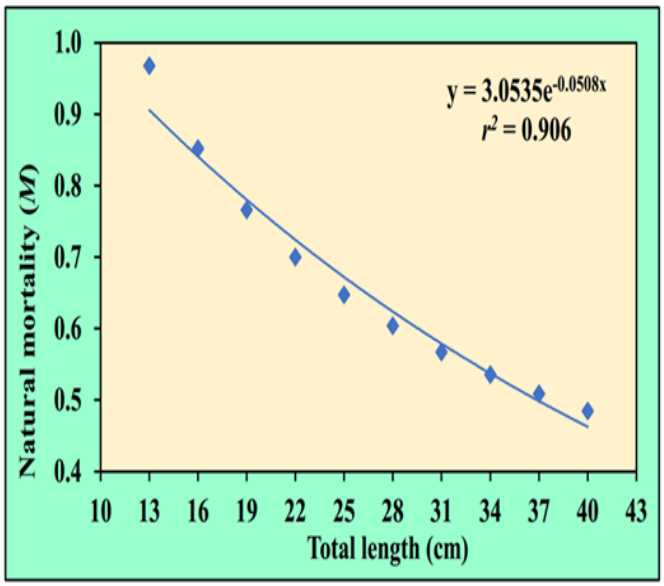

Fig. 6. Natural mortality of *Cynoglossus cynoglossus* in the Bay of Bengal, Bangladesh

Optimum catchable length (L_{opt})

The calculated optimal catchable size *(L_{opt})* for *C. cynoglossus* in the Bay of Bengal, Bangladesh, was determined to be 26.61 cm TL.

Discussion

There is a noticeable dearth of information pertaining to the population dynamics of *C. cynoglossus* in the existing literature, both within Bangladesh and internationally. Consequently, the present study represents the inaugural endeavor to elucidate the population dynamics of *C. cynoglossus* in the Bay of Bengal, Bangladesh. Our investigation encompasses a comprehensive analysis of various facets, including growth parameters, population structure, growth pattern, best condition factor, prey-predator status, form factor, life span, size at first sexual maturity (L_m), mortality (total, natural and fishing), optimum catchable length (L_{opt}). Throughout a rigorous twelve-month sampling period, a total of 100 specimens with varying body sizes were meticulously collected through locally employed equipment.

In total, a diverse set of 100 specimens, exhibiting varying body sizes, were meticulously sampled for the purpose of this research. However, it's important to note that individuals of *C. cynoglossus* with a total length (TL) of 10 cm were not encountered during the sampling period due to several potential factors. These

factors could encompass biases stemming from the selection of fishing gear (Khatun et al. 2019), limitations in capturing smaller individuals within the fishing vicinity (Hossain et al. 2015), a scarcity of diminutive individuals (Azad et al. 2018), or the selective discarding of smaller fish (Rahman et al. 2018). Throughout this study, the range of observed total lengths (TL) for *C. cynoglossus* varied from a minimum of 10 cm to a maximum of 38.5 cm. Notably, these measurements exhibit comparably greater values than the TL values documented as 20 cm in the Western Central Pacific region (Munroe 2001), 12 cm (Rahman 1989 and 2005), 10 cm (Talwar and Jhingran 1991), and 20 cm (Huda et al. 2003). It is plausible that the geographical location and the availability of food resources might contribute to this observed variation (Hossain and Ohtomi 2010). For effective fisheries management and strategic planning, the acquisition of comprehensive data, encompassing parameters like asymptotic length and the fish growth coefficient, becomes paramount (Hossain et al. 2012; Khatun et al. 2019).

In general, the *b* values within Length-Weight Relationships (LWRs) are ideally situated between 2.5 and 3.5, as advised by Froese (2006). The growth pattern, as indicated by our analysis, encompasses both positive allometric growth ($b > 3$) and negative allometric growth ($b < 3$), in accordance with the framework established by Tesch (1971). In the case of *C. cynoglossus*, the allometric coefficient *b* value was determined to be 2.46. This finding implies negative allometric growth. However, it is crucial to acknowledge that our ability to directly compare these results with existing research is constrained by the limited availability of information on *b* values for this particular species.

Determining growth parameters holds paramount significance in projecting future yields and assessing stock biomass within a given aquatic ecosystem (Dadzie et al. 2017). Our analysis revealed asymptotic length of L_∞ = 40.20 cm for *C. cynoglossus*. This finding starkly contrasts with a prior study that reported an L_∞ of 21.1 cm within the Western Central Pacific region (Munroe 2001). Additionally, utilizing the King (2007) equation, the parameter t_0 was computed as 0.011 years for this particular species. Our study also encompassed the determination of asymptotic body weight values. Remarkably, *C. cynoglossus* attains an asymptotic body weight of 249.29 g with a growth coefficient of 0.83 per year. The growth performance index ($Ø'$), which serves as a measure of the relative well-being of aquatic organisms within their ecosystem, carries significant importance in evaluating their overall condition (Gabche and Hockey 1995; Rahman et al 2024). In this investigation, the computed growth performance index was 3.25 for *C. cynoglossus* based on the asymptotic length. It's important to emphasize that due to the absence of prior studies on this specific subject, we were unable to make direct comparisons with our current findings.

This research centered on the assessment of physiological condition and current status of *C. cynoglossus* in the Bay of Bengal, with a specific focus on three condition factors (allometric, Fulton, and relative condition factors) as well as the prey-predator status (relative weight). These parameters were chosen as indicators to assess the overall well-being of the species and to evaluate the environmental suitability of the study area. By examining these factors, we aimed to ascertain the health of the species and understand the ecological context of the surrounding ecosystems. Among the array of condition variables analyzed, the results of the Spearman rank correlation test unveiled a significant correlation only between K_F and both TL and BW. This outcome suggests that K_F stands out as the best condition factor of *C. cynoglossus* health within the Bay of Bengal. Furthermore, the results of the Wilcoxon signed-rank test demonstrated a significant deviation of the average relative weight (W_R) from 100 ($p < 0.0001$). This finding suggests that the presence of predators in the Bay of Bengal creates an ecological imbalance, impacting the accessibility of food resources for *C. cynoglossus* (Anderson & Neumann 1996; Rahman et al. 2020). Aligning with the insights from Rypel and Richter (2008), this assessment of the species' overall physical condition through W_R provides crucial insights into population well-being and environmental dynamics. Regrettably, due to the absence of comparable literature on the W_R of *C. cynoglossus*, we are unable to draw direct parallels between our findings and existing research.

Through the analysis of the $a_{3.0}$ parameter, researchers gain the ability to assess and juxtapose variations in body shape across different populations or species. This analysis provides crucial insights into potential

disparities in morphology and adaptation (Froese 2006). In our study, the $a_{3.0}$ parameter was determined to be 0.0052, indicating that *C. cynoglossus* in the Bay of Bengal, Bangladesh, possesses an elongated body form. Remarkably, we were unable to locate any references within the existing literature regarding the form factor ($a_{3.0}$) of this species. Hence, our study serves as an inaugural investigation into this aspect, effectively laying the groundwork for future research endeavors. The outcomes of this study not only contribute to our understanding of the form factor of *C. cynoglossus* but also establish a foundational knowledge base for subsequent research in this field.

Size at first sexual maturity (L_m) serves as a critical management metric employed to ascertain whether a gathered stock comprises an adequate quantity of juvenile specimens that have reached maturity and are prepared for reproduction (Beverton and Holt 1959; Rahman et al. 2023; Hossain et al. 2024). The study carried out in the Bay of Bengal unveiled the size at first sexual maturity (L_m) for *C. cynoglossus*, which was calculated as 21.52 cm. In contrast, previous literature, as documented by Munroe (2001), reported a notably lower L_m of 11.8 cm for this species. It's evident that our present study reveals a higher L_m compared to the previously recorded value Furthermore, the longevity of *C. cynoglossus* within the Bay of Bengal was estimated to be approximately 2.46 years. Regrettably, no prior research into the longevity of this species has been conducted, rendering direct comparisons unattainable. In our study, we determined the natural mortality rate to be 1.67 $year^{-1}$. This computation offers significant insights into the population dynamics of *C. cynoglossus* within the Bay of Bengal. Notably, our research represents the pioneering attempt to quantify the natural mortality *(M)* of this fish species across various aquatic environments worldwide.

The optimal catchable size *(L_{opt})* denotes the length at which the highest number of fish can be efficiently harvested (Froese 2018). The FAO's responsible fisheries strategy strongly advocates for setting the optimum catchable size above the mean size at first sexual maturity (L_m), a practice that preserves stock abundance by allowing a sufficient portion of the stock to reach reproductive maturity before being captured (Achmad et al. 2020). L_{opt} plays a pivotal role in guiding the selection of gear mesh sizes, preventing the capture of fish below this critical size, and promoting sustainable fishing practices by safeguarding the maximum brood stock (Mawa et al. 2021; Khatun et al. 2023). In our study, we assessed the optimum catchable length for *C. cynoglossus* in the Bay of Bengal. The suggested L_{opt} was found to be 26.61 cm, indicating the size at which the maximum yield could be achieved through targeted fishing efforts.

Nonetheless, it is evident that this study marks the first effort to explore the population dynamics of this particular fish species within the Bay of Bengal, Bangladesh. Consequently, these findings hold significant value as baseline information for forthcoming research endeavors. Furthermore, this data is of paramount importance in the context of formulating sustainable management strategies for *C. cynoglossus* in the Bay of Bengal and the adjacent aquatic ecosystems. Particularly, it aids in the selection of appropriate mesh sizes for fishing nets, a crucial aspect of ensuring the conservation and responsible management of this species.

Conclusion

This study delivers invaluable insights into the population dynamics and stock status of the Bengal tongue sole (*C. cynoglossus*) within the Bay of Bengal, Bangladesh. Based on our findings, the observed population structure suggests that optimal harvesting of these fish should be conducted when they exceed a length of 26.61 cm, thereby yielding the highest achievable sustainable output. In a nutshell, the present research provides critically essential data that holds significance for conservationists, aquatic managers, and government authorities. This data can be effectively utilized to establish sustainable conservation initiatives and strategic management approaches for the preservation of this species in the Bay of Bengal.

Conflict of interest

There are no conflicting interests that could potentially influence the outcome of their study.

Acknowledgement

We extend our sincere gratitude to the PIU-BARC-NATP-2 PBRG-156 for their financial support, which played a pivotal role in facilitating this research. Furthermore, we would like to express our deep appreciation to the fishers whose identities have been

protected, for their support and assistance during the process of sample collection have been integral to the success of this study.

References

Achmad DS, Jompa J & Nurdin MS (2020). Estimating the catchable size of orange-spotted grouper (*Epinephelus coioides*) in Kwandang Bay, Gorontalo Utara District, Indonesia. In IOP conference series: earth and environmental science, IOP Publishing, 473(1), 012133.

Acosta AFG, De La Cruz Agüero G & De La Cruz Agüero J (2004). Length–weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). Journal of Applied Ichthyology, 20(2), 154-155.

Anderson RO & Neumann RM (1996). Length, weight and associated structural indices. In: Fisheries Techniques, 2nd Ed. (Murphy BR & Willis DW Eds.). Bethesda MD: American Fisheries Society, 447–482 pp.

Azad MAK, Hossain MY, Khatun D, Parvin MF, Nawer F, Rahman O & Hossen MA (2018). Morphometric relationships of the tank goby *Glossogobius giuris* (Hamilton 1822) in the Gorai River using multi-linear dimensions. Jordan Journal of Biological Sciences, 11(1), 81–85.

Beverton RJH (1992). Patterns of reproductive strategy parameters in some marine teleost fishes. Journal of Fish Biology, 41, 137-160.

Beverton RJH and Holt SJ (1959). A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. In Ciba foundation symposium-the lifespan of animals (colloquia on ageing) 5: 142-180. Chichester, UK: John Wiley & Sons, Ltd.

Binohlan C & Froese R (2009). Empirical equations for estimating maximum length from length at first maturity. Journal of Applied Ichthyology, 25(5), 611-613.

Dadzie S, Abou-Seedo F & Moreau J (2007). Population dynamics of *Parastromateus niger* in Kuwaiti waters as assessed using length–frequency analysis. Journal of Applied Ichthyology, 23(5), 592-597.

DoF (2020) National fish week, compendium (In Bangla). Department of fisheries, ministry of fisheries and livestock, Bangladesh, 160.

Ecoutin JM, Albaret JJ & Trape S (2005). Length–weight relationships for fish populations of a relatively undisturbed tropical estuary: The Gambia. Fisheries Research, 72(2-3), 347-351.

Edwards RRC, Blaxter JHS, Gopalan UK, Mathew CV & Finlayson DM (1971). Feeding, metabolism, and growth of tropical flatfish. Journal of Experimental Marine Biology and Ecology, 6(3), 279-300.

Foster SA & Vincent AC (2004). Life history and ecology of seahorses: implications for conservation and management. Journal of fish biology, 65(1), 1-61.

Froese R & Binohlan C (2000). Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of fish biology, 56(4), 758-773.

Froese R (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of applied ichthyology, 22(4), 241-253.

Fulton TW (1904). The rate of growth of fishes. Twenty-second annual reports, part III. Fisheries Board of Scotland, Edinburgh, 141–241.

Gabche CE & Hockey HUP (1995). Growth and Mortality of the Giant African River Prawn *Macrobrachium-Vollenhovenii* (Herklots, Crustacea, Palaemonidae) in the Lobe River, Cameroon-a Preliminary Evaluation. Journal of Shellfish Research, 14(1), 185-190.

Hossain MA, Laboni TA, Khatun M, Rahman MA, Hossen MA, Rahman O, Ilah NE, Marey SA, Mostafa AA, Ohtomi J & Hossain MY (2024). Exploring the reproductive features of *Clupisoma garua* from Ganges River, Bangladesh: insights into eco-climatic factors for sustainable management and advancements in aquaculture practices. Environmental Science and Pollution Research, 1-15.

Hossain MY & Ohtomi J (2010). Growth of the southern rough shrimp *Trachysalambria curvirostris* (Penaeidae) in Kagoshima Bay, southern Japan. Journal of Crustacean Biology, 30(1), 75-82.

Hossain MY, Jewel MAS, Nahar L, Rahman MM, Naif A & Ohtomi J (2012). Gonadosomatic index-based size at first sexual maturity of the catfish *Eutropiichthys vacha* (Hamilton 1822) in the Ganges River (NW Bangladesh). Journal of Applied Ichthyology, 28(4), 601-605.

Hossain MY, Sayed SRM, Rahman MM, Ali MM, Hossen MA, Elgorban AM & Ohtomi J (2015). Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. Journal of Applied Ichthyology, 31(5), 967-969.

Huda MS, Haque ME, Babul AS & Shil NC (2003). Field guide to finfishes of Sundarban. Aquatic resources division, Sundarban, Boyra, Khulna, Bangladesh, 161.

Ilah N-E-F, Abedin MJ, Alice EJ, Laboni TA, Khatun MS, Sarmin MS, Rahman MA, Rahman O, Islam MA, Siddquy MAF & Hossain MY (2023). Growth and conditions appraisal of Atropus atropos (Carangidae) in the Bay of Bengal. Sarhad Journal of Agriculture, 39(4), 823-831.

IUCN (2022). The IUCN Red List of Threatened Species. Version 2022-2. Downloaded 10 Jan 2023.

Khatun D, Hossain MY, Rahman MA, Islam MA, Rahman O, Sharmin MS, Parvin MF, Haque ATU & Hossain MA (2019). Life-History Traits of the Climbing perch *Anabas testudineus* (Bloch 1792) in a Wetland Ecosystem. Jordan Journal of Biological Sciences, 12(2).

Khatun MS, Kabir MRK, Laboni TA, Islam MA, Hasan MR, Gabol K & Rahman MA (2023). Exploring the life history traits of *Polynemus paradiseus* (Linnaeus 1758) in the Bay of Bengal, Bangladesh. Fisheries Studies, 01, 20-31.

Khatun MS, Kabir MRK, Laboni TA, Islam MA, Hasan MR, Gabol K & Rahman MA (2023). Exploring the life history traits of *Polynemus paradiseus* (Linnaeus, 1758) in the Bay of Bengal, Bangladesh. Fisheries Studies (1), 20-31.

King M, Fisheries Biology Assessment and Management, seconded, Black well Science Publications, Oxford, 2007, 1–382.

Koutrakis ET & Tsikliras AC (2003). Length–weight relationships of fishes from three northern Aegean estuarine systems (Greece). Journal of Applied Ichthyology, 19(4), 258-260.

Le Cren ED (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). The Journal of Animal Ecology, 201-219.

Mawa Z, Hossain MY, Hasan MR, Tanjin S, Rahman MA, Sarmin MS & Habib KA (2021). First record on size at sexual maturity and optimum catchable length of 10 marine fishes from the Bay of Bengal (Bangladesh) through multi-model's approach: a key for sound fisheries management. Environmental Science and Pollution Research, 28, 38117-38127.

Munroe TA (2001). Cynoglossidae. Tongue soles. Species identification guide for fishery purposes. The living marine resources of the western central Pacific. Bony fishes part, 4, 3890-3901.

Pauly D & Munro JL (1984). Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2(1), 1-21.

Pauly D (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES journal of Marine Science, 39(2), 175-192.

Peterson I & Wroblewski JS (1984). Mortality rate of fishes in the pelagic ecosystem. Canadian Journal of Fisheries and Aquatic Sciences, 41(7), 1117-1120.

Rahman AKA (1989). Freshwater fishes of Bangladesh. Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, Dhaka-1000, 364.

Rahman AKA (2005). Freshwater Fishes of Bangladesh, 2nd edition, Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, Dhaka-1000, 48-49.

Rahman MA, Bashar MA, Mawa Z, Rahman O, Samad MA, Islam MA ... & Hossain MY (2020). Life history traits of the barred spiny eel *Macrognathus pancalus* (Hamilton, 1822) in a wetland ecosystem. Egyptian Journal of Aquatic Biology and Fisheries, 24(6), 425-438.

Rahman MM, Hossain MY, Tumpa AS, Hossain MI, Billah MM & Ohtomi J (2018). Size at sexual maturity and fecundity of the mola carplet *Amblypharyngodon mola* (Hamilton 1822) (Cyprinidae) in the Ganges River, Bangladesh. Zoology and Ecology, 28(4), 429-436.

Rahman MM, Kashmi MNS, Rahman MA, Sarwar MG, Sujana FM, Rahman O, Tariq-Al-Kasif, Hossain MS, Abedin MJ, Laboni TA, Khatun MS, Sirajammunira and Hossain MY (2023). First report on population dynamics and stock status of *Badis badis* in a wetland ecosystem (NW Bangladesh): Insights from new recorded maximum length. Heliyon, e22777.

Rahman O, Laboni TA, Khatun MS, Rahman MA, Islam MA, Rahman MM, Parvin MF, Abedin MJ & Hossain MY (2024). Estimating the growth parameters, exploitation rate, biomass and maximum sustainable yield of long whisker catfish *Mystus gulio* (Hamilton, 1822) in the coastal waters from southwestern Bangladesh. Heliyon, 10(8).

Rainboth WJ (1996). FAO species identification field guide for fishery purpose. Fish of the Cambodian Mekong, Rome, 265.

Ranjan JB, Herwig W, Subodh S & Michael S (2005). Study of the length frequency distribution of sucker head, *Garra gotyla gotyla* (Gray, 1830) in different rivers and seasons in Nepal and its

applications. Kathmandu University Journal of science, engineering and Technology, 1(1), 1-14.

Roy A, Dutta S, Podder A & Homechaudhuri S (2020, March). Variation in population characteristics and harvesting pressure influencing recruitment pattern of an economically important fish, *Osteomugil cunnesius* of Indian Sundarbans. In Proceedings of the Zoological Society, 73(1), 5-15.

Rypel AL & Richter TJ (2008). Empirical percentile standard weight equation for the blacktail redhorse. North American Journal of Fisheries Management, 28(6), 1843-1846.

Sabbir W, Hossain MY, Rahman MA, Hasan MR, Khan MN, Mawa Z, ... & Habib KA (2020). Growth pattern of the Hooghly Croaker *Panna heterolepis* Trewavas, 1977 in the Bay of Bengal (Bangladesh) in relation to eco-climatic factors. Egyptian Journal of Aquatic Biology and Fisheries, 24(7), 847-862.

Talwar PK & Jhingran AG (1991). Inland fishes of India and adjacent countries (Vol. 2). CRC press.

Tanjin S, Rahman, MA, Uddin M, Sarker BK, Sarmin MS, Mawa Z, ... & Hossain MY (2021). Estimation of condition factor of bengal tongue sole (*Cynoglossus cynoglossus*) in the Bay of Bengal, Bangladesh. Pakistan Journal of Marine Sciences, 30(2), 127-133.

Tesch FW (1968). Age and growth. In: Ricker WE, (ed.), Methods for Assessment of Fish Production in Fresh Waters. Blackwell Scientific Publications, Oxford, 93-123.

How to cite this article: Laboni TA, Khatun MS, Rahman O, Sarmin MS, Ratry YA, Uddin MM, Likhon TR, & Habib KA (2024). First report on population parameters of Bengal tongue sole (*Cynoglossus cynoglossus*): Suggestion for optimum catchable length in the Bay of Bengal, Bangladesh. Aquatic Resource Sciences, 01, 01-11.