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Growth, and Stock Status Assessment of African Catfish, *Clarias anguillaris* (Linnaeus, 1758) from Burkina Faso Newly Man-Made Lake Samandeni

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Abstract

The Samandeni reservoir in Burkina Faso, impounded in 2017, hosts a significant diversity of fish, including the Clariidae family. The fish stocks have been exploited since 2019, when the reservoir was opened to fishermen. However, no assessment of the status of these stocks has been conducted. The present study focused on the dynamics of *Clarias anguillaris* exploitation in order to have reliable information that can contribute to the planning of its sustainable exploitation. Length-frequency data on 323 individuals were sampled from commercial catches from March 2021 to February 2022. The growth parameters were determined using ELEFAN method and the stock assessment was done using the Bayesian Length-Based Biomass (LBB) method. The growth analysis showed isometry for both male and female fishes with allometric coefficient value of 3.03, 3.01 and 3.17 respectively for mixed sexes, male and female. Estimates values (0.6 and 0.4) of the growth oscillation intensity indicate the existence of seasonal growth. The relative biomass (B/B_0) estimated for *C. anguillaris* was less than the relative biomass that produces the maximum sustainable yield (B_{MSY}/B_0) indicating biomass overfishing. In addition, the length at first capture was less than the optimal length at first capture indicating a growth overfishing status. Therefore, it would be desirable to increase the mesh size of the fishing gear so that juveniles are not caught, which will ensure an ecological sustainability of the exploitation of the Clariidae.

Keywords

Growth, Stock Status, *Clarias anguillaris*, Samandeni Reservoir, Burkina Faso

1. Introduction

Global fisheries, including freshwater, marine, and capture fisheries, as well as aquaculture, provide about 17% of the total animal protein consumed by humans, and about 59.5 million people derive their livelihoods from fishing [1]. Then, the fish populations dynamics and the stocks assessment are essential for the management of fisheries resources. Indeed, the stock assessment of a fishery is necessary to know if the fishing pressure has to be alleviated towards the sustainability of the fishery. As such, the fishermen and the management officers must take measures based on stock status [2] and scientific approaches [3]. However, most global stocks and especially fish stocks in inland fisheries are still not assessed due to data limitations, in addition to the lack of expertise that is a major constraint in fisheries management [2] [4]. In this context, biological parameters, such as the growth and status of fish stocks, need to be studied in order to better understand the population biology of inland fishes and then to better ensure sustainable fisheries for the benefit of the fishing communities that substantially depend on them for their livelihood.

The waters of Burkina Faso are very productive and support a large biodiversity. As a result, a wide variety of fishing gears is used to exploit this biodiversity, including longlines, gillnets, cast nets, traps, etc. The multispecies feature of Burkinabe fisheries renders their biological management complex. In this line, the landings record experiences the challenge of species-specific catch and effort details, which are required for regular stock assessment using conventional stock assessment models. Although the situation of fisheries in Burkina Faso is widely perceived as highly problematic, only a few fish stocks have been assessed [5] [6] [7]. Recently, [8] assessed the population dynamics of *Clarias anguillaris* in Samandeni reservoir before the reservoir was opened to fishing and farming. Although this study addressed the parameters of *C. anguillaris* dynamics, it did not take into account the effect of ecological changes and fishing pressure on fish population growth parameters after the reservoir was opened to fishing. Indeed, several studies have shown that environmental changes and fishing pressure can influence life history parameters and therefore fish population dynamics [9] [10] [11] [12]. Moreover, the opening of the reservoir to exploitation, characterized on the one hand by the influx of fishermen using various fishing gear and on the other by market gardening on the reservoir banks, has certainly modified the reservoir's environmental conditions, hence the importance of this study in the Samandeni reservoir five years after it was opened to exploitation. Thus, in the light of the evolution of fishing pressure on the reservoir, the need to assess the parameters of the biology, such as growth, of the various species present, and particularly those of the reservoir's ecologically and economically important species, is more than essential.

Growth is often represented by mathematical models of which the von Bertalanffy model is the most used to describe tropical fish. For stock assessments of tropical species, the analysis of length frequency data coupled with a small number of age readings by counting daily rings is recommended [13]. However, methods using daily ring structures require expensive specialized equipment and large numbers of personnel, making them unlikely to be used in some locations [13]. Thus, the most widely used method for estimating biological parameters is that involving length frequency data that are quick and less expensive to collect [13]. Reference [14] listed the scarcity of data and the lack of stock assessment methods suitable for use in sparse data situations as one of the reasons why exploited fish stocks are still not assessed in developing countries and regions. Several methods have now been developed to meet the needs of fisheries with limited data. Among these methods, the length-based biomass estimation (LBB) method [14] is the most employed in the study of the biology and dynamics of exploited stocks. In order to provide the information required for sustainable exploitation of fishery resources in the Samandeni reservoir in Burkina Faso, the present study was conducted to: 1) estimate individual growth parameters, 2) identify length-weight relationship parameters and 3) determine the level of biomass depletion of *C. anguillaris*.

2. Material and Methods

2.1. Study Site and Fish Sampling

The newly created reservoir of Samandeni is located in the Volta catchment of Burkina Faso between latitudes 11˚23' and 11˚19' North and longitudes 4˚34' and 4˚46' West (**Figure 1**). This water was allocated the status of Ramsar site in October 2020 and is 153 km^2 wide with a storing capacity of more than one billion m^3 of water. The fish specimens were procured on a monthly basis from March 2021 to February 2022 from the catch of local fishers on the nine sampling sites shown in **Figure 1**. The species of fish were identified using the standard identification key given by [15]. In the Samandeni reservoir, the fishers are known to use a variety of fishing methods such as gillnets with a mesh size of 10 to 40 mm, longlines, traps and cast net.

2.2. Sample Measurements

Fish were randomly sampled from several fishers to ensure a good representation of size classes in the samples. A monthly collection trip of 7 days is carried out over 12 months, for a total of 84 sampling sessions. Each specimen was examined on the same day of collection to avoid error in the morphometric measurements posed by fixation. The total length (TL in cm) of each fish was measured to the nearest 0.1 cm, to calculate size-frequency distributions according to [16] empirical approach and to estimate growth parameters. The body weight (W) in g of each specimen was also measured to the nearest 0.1 g using an electronic balance.

Length-weight relationship

The morphometric relationship between length and body mass (LWR) was calculated using the power regression Equation (1) given by Le Cren [17] as:

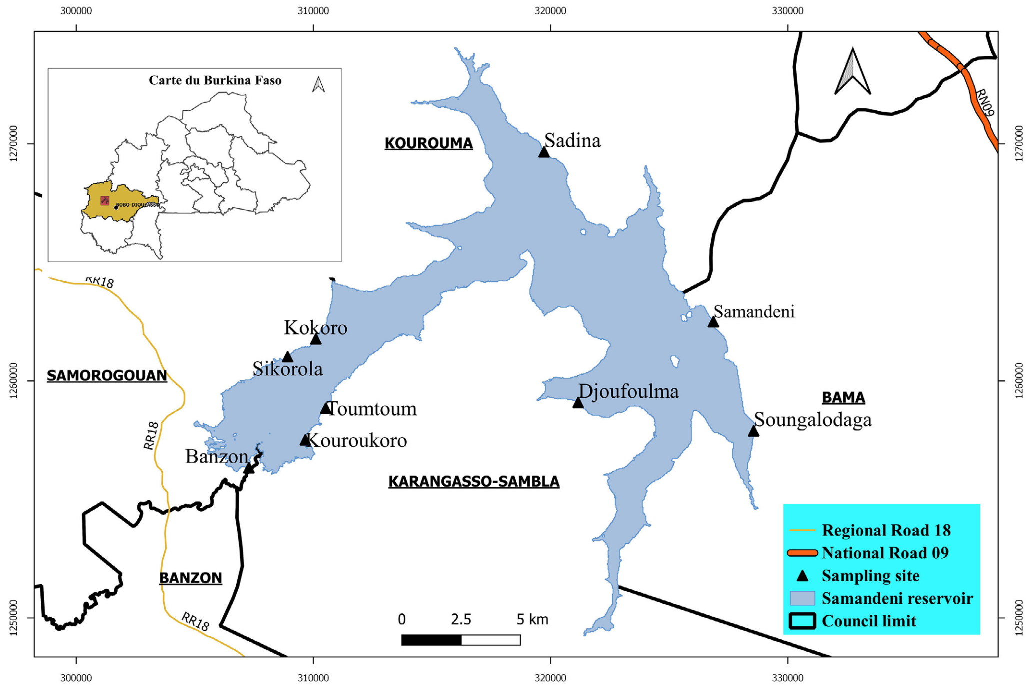

Figure 1. Map of Samandeni reservoir showing the sampling stations.

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

where TL, is the total length in cm and W, the total weight in g, "a" and "b" represent the intercept and slope parameters of the regression respectively. The value of parameter "a" and "b" were calculated using the linear regression of the log-transformed Equation (2):

$$\ln W = a + bTL \quad (2)$$

The two-tailed t-test was used to conclude the growth pattern [Isometric ($b = 3$) vs. allometric ($b < 3$ or $b > 3$)].

2.3. Estimation of Growth Parameters

A monthly collected values of TL, grouped into classes intervals of 2 cm according to Wang *et al.*, [16] empirical approach, was used to estimate the population demographic parameters. The asymptotic length (L_{inf}), the coefficient of growth (K), the amplitude of the growth oscillations (C), and the fraction of a year where the first sinusoidal growth oscillation begins (t_s) were estimated using TropFishR, an R package ver. 3.5.1 for tropical fisheries analysis [18]. Since we had collected length-frequency (LF) data, the electronic length frequency analysis method (ELEFAN) was used to estimate the population demographic parameters [19]. A bootstrapped ELEFAN with genetic algorithm optimization function developed by [20] was applied to the LF data, allowing assessment of the uncertainties around the growth parameters estimates. Growth was modeled based on Von Bertalanffy growth function (VBGF) and a seasonally oscillating VBGF was used to assess the growth parameters, which are attributed to changes in water temperature, precipitation and to the availability of food [21]. The seasonally oscillating von Bertalanffy growth function [22] used is given by the Equation (3) as:

$$L_t = L_\infty \left[1 - e^{-(K(t-t_0)+s(t)-s(t_0))}\right] \quad (3)$$

With $S(t) = (CK/2\pi)\sin 2\pi(t - t_s)$, $S(t_0) = (CK/2\pi)\sin 2\pi(t_0 - t_s)$, and L_t is the length-at-age t, L_{inf} is the asymptotic length, K is the von Bertalanffy growth constant, and t_0 is the theoretical age when length equals zero, C is a constant indicating the amplitude of the oscillation, typically ranging from 0 to 1, and t_s is the fraction of a year where the sine wave oscillation begins (turns positive). A value of $C = 1$, growth stops completely once a year at a point in the annual cycle while values of C between 0 and 1 result in slowed but not stopped, growth [23].

2.4. Stock Status Assessment

The stock status was estimated using the LBB method that is a recently approach developed by [24] to access fisheries, which uses LF data as input and applies a Bayesian Monte Carlo Markov Chain (MCMC) method to estimate indicators of stock status. The LBB model is suitable for species that grow throughout their lives, such as most economic fish and invertebrates [24]. It estimates the asymptotic body length (L_{inf}), the first catch body length (L_c), the relative natural mortality (M/K) and the relative fishing mortality (F/M) in the age range represented by LF samples. With these parameters as input, standard fisheries' equations can be used to estimate the depletion or the current exploited biomass relative to unexploited biomass (B/B_0). These parameters also allow the estimation of the length at first capture that would maximize catch and biomass for the given fishing effort (L_{c_opt}), and the estimation of a proxy for the relative biomass capable of producing maximum sustainable yields (B_{MSY}/B_0). The method uses a prespecified set of priors, but users can manually incorporate priors for asymptotic length (L_{inf}), length at first capture (L_c), and relative natural mortality (M/K) from local studies. The L_{inf} priors were estimated from the median maximum length rather than the absolute maximum length. The M/K prior is set as 1.5, and L_c is estimated from the catch curve generated from the input LF data. We used our first maturity body length (L_m) estimates (Da, personal communication) and computed the numeric percentage of specimens in the catches larger than L_m. The details of the LBB method and underpinned formulas are given in [21]. **Table 1** represents the basic information and priors (L_{inf}, L_c, Z/K, M/K, F/K, and α) for the LBB analysis. All the analysis presented here was done using R code (LBB_33a. R), downloaded from http://oceanrep.geomar.de/44832/ following the guidelines provided in the new user guide of the code.

Table 1. Basic information of *C. anguillaris* and prior for the LBB method.

Length (cm)			Prior					
Min	Mean	Max	L_{inf} (cm)	Z/K	M/K	F/K	L_c (cm)	alpha
15	33.9	72	73.1	4.1	1.5	2.6	23.8	15.1

The relative biomass able to produce maximum sustainable yields (B_{MSY}/B_0) and the relative fishing mortality (F/M) are the major stock status indicators estimated using this method. According to [14] [24], a stock is underexploited if $B/B_{MSY} > 1.2$, fully exploited if $0.8 \le B/B_{MSY} \ge 1.2$, and over-exploited if $B/B_{MSY} < 0.8$. Moreover, the overexploited stocks have relative fishing mortality (F/M) of over 1.2. The fully exploited and under-exploited stocks have F/M respective values of 0.8 - 1.2 and <0.9 [14]. The ratio of L_{mean}/L_{opt} and L_c/L_{c_opt} less than unity, accounting for the fishery's capture of too tiny individuals and truncated length structure. Similarly, the ratios of the 95th percentile length and L_{95th}/L_{inf} close to unity (>0.9) indicate the minimum presence of the large individuals.

3. Results

3.1. Morphometric Relationship

To study length-weight relationships and growth, measurements were taken on 323 C. anguillaris individuals. Total length ranged from 15 cm to 72 cm, while total weight varied from 11.9 g to 2900 g. **Figure 2** illustrates the length-weight relationship (RLW). The parameters of the LWR regression show an isometric growth in female and male and mixed sexes of *C. anguillaris* in Samandeni reservoir. The coefficients of determination are greater or equal to 0.9 indicating that there was a strong correlation between the total length and the total weight of fish.

3.2. Growth Parameters

The growth parameters are presented in **Table 2**. The mean annual length in male (33.6 cm) was higher than the females (31.6 cm). This means that male fishes are on average larger than female fishes. Estimates of asymptotic length (L_{inf}) also show that male fishes reach a much greater asymptotic length compared to female fishes. The estimates values of growth rate (K) were 0.30 and 0.31 yrs^{-1} for male and female respectively. This indicates that growth of *C. anguillaris* in Samandeni is slow. The growth oscillation parameter (C) was greater than zero. It is 0.5 and 0.4 for male and female individual respectively, indicating seasonalized growth. Since the parameter t_s reflects the fraction of the year in which the growth becomes positive, the values of t_s (0.5 and 0.6) indicate that the revival of growth of *C. anguillaris* in Samandeni reservoir occurs in the months of July and August.

Table 2. Estimated growth parameter.

Estimates parameters	Males			Females		
	Mode	Lower	Upper	Mode	Lower	Upper
L_{inf} (cm)	63.34	35.00	78.89	54.82	36.8	70.85
K (yrs^{-1})	0.30	0.09	0.90	0.31	0.11	0.74
t_{anchor}	0.50	0.11	0.86	0.59	0.14	0.88
C	0.60	0.17	0.86	0.40	0.13	0.88
t_s	0.56	0.01	0.88	0.47	0.008	0.88

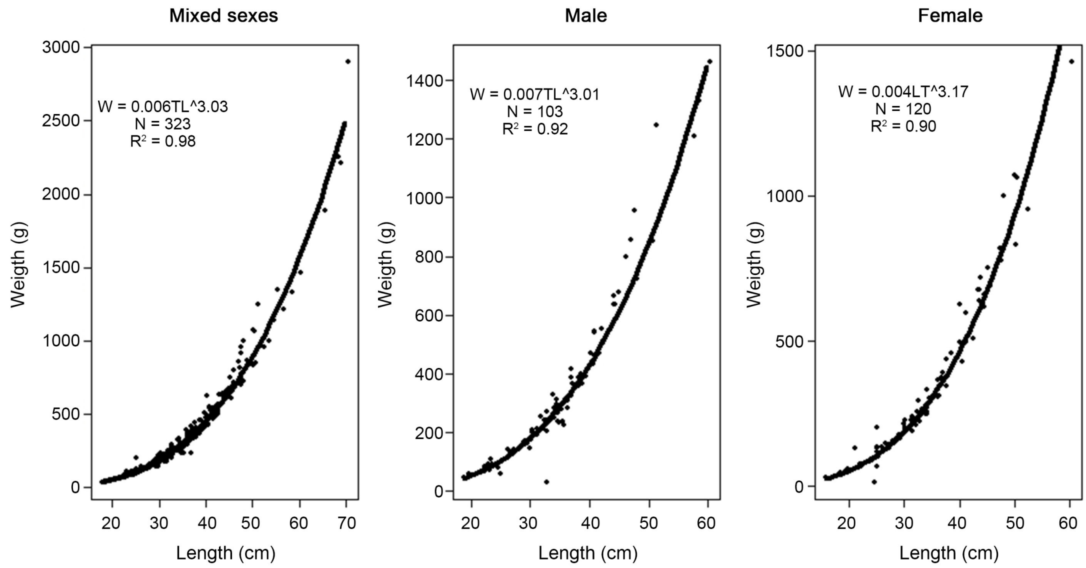

Figure 2. Length-weight relationship graph of *Clarias anguillaris* in Samandeni reservoir.

3.3. Length Base Stock Assessment

The specific evaluation results of LBB method are shown in **Figure 3**. The blue line in the figure represents the fit of the data and the LBB estimation, and the red line is the evaluation from the LBB method of population resources. The parameters L_{mean}/L_{opt}, L_c/L_{c_opt}, L_{95th}/L_{inf}, B/B_0, B/B_{MSY}, B_{MSY}/B_0 and F/M were obtained (**Table 3**). The estimated B/B_0 (0.3) was below the reference limit (0.4) which indicated a depletion rate of 70% due to overfishing. Furthermore, the relative B/B_0 was lower than the B_{MSY}/B_0 (0.36), and the F/M was 0.93 which suggests a fully exploited status. The estimated L_{mean}/L_{opt} (0.78) and L_c/L_{c_opt} (0.64) were less than unity, suggesting a truncated length structure and overfishing of small fish. The estimated $L_{95\text{th}}/L_{inf}$ (0.91) was close to unity, suggesting that at least some large fish were still present in the *C. Anguillaris* stock of Samandeni reservoir. In addition, a smaller estimate was observed for L_c (23.4 cm) than L_{c_opt} (36 cm), indicating growth overfishing.

4. Discussion

The analysis of the length-weight relationship of *Clarias anguillaris* revealed an isometric growth for male and female fishes as well as for the combined sexes. This means that they grow well in weight as well as length. Reference [25] was used to compare estimated parameters with data from other reservoirs and rivers in Africa. The observed values of b are consistent with those accepted by the literature and are in the same order as those obtained for the same species in four major tributaries of the Volta River in Burkina Faso [26]. In the central Niger Delta in Mali, [27], on the other hand, observed positive allometry in male while female had isometry. A comparison of the allometry coefficient b of the length-weight relationship shows that females have a higher b-value than male and sexes combined in *C. anguillaris*. Although this is true to some extent, the

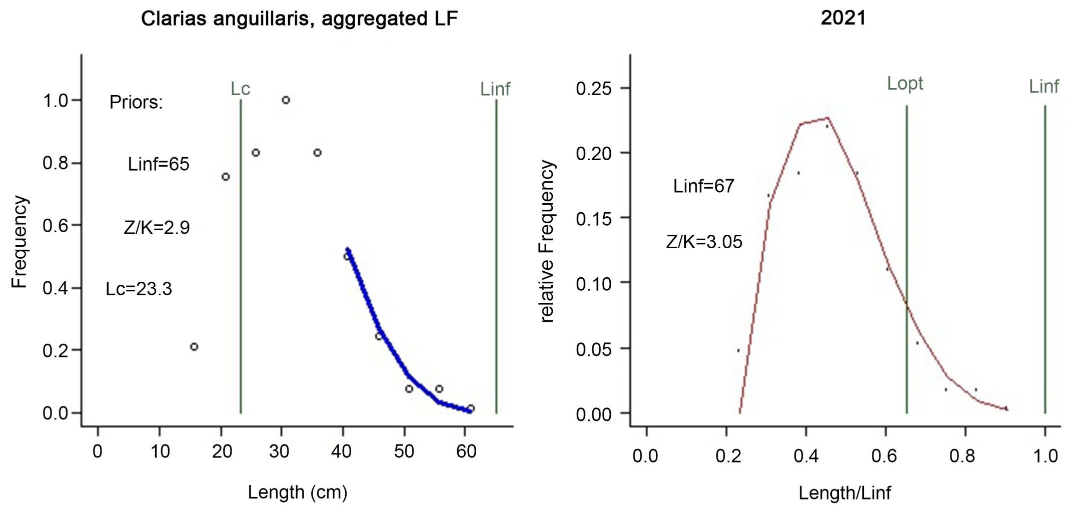

Figure 3. The length and frequency results of the length-based Bayesian biomass estimator (LBB) analysis of *Clarias anguillaris* in the Samandeni reservoir.

Table 3. Estimated LBB results of *C. anguillaris* using length frequency (LF).

L_c (cm)	L_{c_opt} (cm)	L_{mean}/L_{opt}	L_c/L_{c_opt}	L_{95th}/L_{inf}	B/B_0	B_{MSY}/B_0	B/B_{MSY}	F/M
23.1	36	0.78	0.64	0.91	0.30	0.36	0.84	0.93

inability to separate sex in small fishes therefore indicates that the result of b for all specimens combined best represents the length-weight relationship in *C. anguillaris*. Estimates of b also suggest that *C. anguillaris* has good growth in the Samandeni reservoir during the study period. This relatively good growth and well-being could be explained by the food availability [28] that characterizes the newly impounded reservoirs, as is the case of the Samandeni reservoir. Indeed, [29] notes that the creation of dams generates from the first moments an excessive proliferation of foods favorable to a good growth of fish.

The growth rates k obtained suggest that this species shows slow growth in the Samandeni reservoir during the study period. No growth data is available in [25] for comparison with our results. However, in the same database the values obtained for the sympatric species in Burkina Faso and Africa, *Clarias gariepinus*, oscillate between 0.06 and 0.45 yrs^{-1}. Our results do not deviate much from these values but remain higher than those reported as in [30] (0.19 and 0.14 yrs^{-1}) on the sympatric species in two reservoirs of Burkina Faso. The growth oscillation parameter (C) was greater than zero, indicating that growth was seasonalized in *C. anguillaris* in the Samandeni reservoir. This result is consistent with other studies on the need to take seasonality into account in the assessment of tropical fish stocks [21] [31]. The growth oscillation estimates range from 0 to 1, indicating that to some extent, the growth is slowed in the annual growth cycle. The growth slowing in *C. anguillaris* was also reported in the central Niger Delta of Mali from the study of bone parts [27] in 2012. A comparison of the breeding period, given here, by the t_anchor values and the period of recovery of growth, indicated here by t_s, shows that these periods are nearly the same in the year and correspond to the months of July and August. This suggests that the growth recovery occurs after the spawning; thus, it is thought that the reproductive process slows down the growth of *C. anguillaris*. A similar study also linked seasonal fluctuations in goby growth in Nigeria's Imo River estuary to spawning stress or compromise between breeding and growth [32] to reproduction. In addition, the time of year when growth seems to be accelerating is during the rainy season. This confirms the results of [33] which place the resumption of growth during flood period in the Sahelian zone, which is also the period of food resources maximum availability.

The stock status was given in the LBB model based on the B/B_{MSY} parameter, which had been described in detail in previous studies [24]. In this study, the LBB method was used to assess the state of *C. anguillaris* resources in the Samandeni reservoir. So far, our research could be the first study to assess stocks of this species in the reservoir. The results showed that the assessed stock was overexploited. The B/B_0 ratio was lower than the B_{MSY}/B_0 ratio, suggesting that the *C. anguillaris* stock has low biomass. The relative biomass (B/B_0) for *C. anguillaris* from the Samandeni reservoir assessed was 0.30 on average, indicating a depletion rate of 70%. The L_{mean}/L_{opt} and L_c/L_{c_opt} ratios were all less than one, suggesting a truncated length structure and the capture of juveniles in the fishery. According to Froese [2] the exploitation of a species is only sustainable if the fishes reproduce at least once before being caught, which is not the case in the Samandeni fishery for *C. anguillaris*. Thus, on the one hand, *C. anguillaris* resources are decreasing in the Samandeni reservoir due to long-term overfishing and on the other hand, there is still a growing demand from populations for fish. So, fisheries managers should apply appropriate regulations in a science-based manner to balance catches and recruitments of *C. anguillaris*. The presence of large-sized specimens in the population is known to provide resilience to the stock, which is indicated by the value of L_{95th}/L_{inf}. Despite low observed biomass, the ratio L_{95th}/L_{inf} was 0.9, suggesting that at least a few large individuals of *C. anguillaris* were still present in the reservoir to ensure stock renewal. Reducing fishing pressure, maintaining the temporary closure of the fishery, and restoring habitat could play an important role in conserving the biological resources of this commercial species.

5. Conclusion

This study assessed the growth and stock status of *C. anguillaris* in Samandeni Reservoir, Burkina Faso. The assessment suggested isometric growth. The growth is seasonal with a low growth rate. An overfished status for *C. anguillaris* was observed. The L_{c_opt} values calculated by the LBB method can be used as a reference for exploitation and rebuilding for *C. anguillaris* stock. To assist in the rebuilding of fish populations of this species, fishery managers should maintain species-specific size restrictions and apply specific mesh sizes for fishing gears. Nevertheless, management regulations, such as increasing mesh size, would be difficult to implement. Thus, research suggests that decreasing fishing pressure, reducing the number and type of fishing vessels, and temporal closure of the fishery should be explored to ensure the sustainability of the *C. anguillaris* stock. In addition, it is recommended that continuous collection of LF and catch data be conducted to observe overall changes in stock status. Despite many limitations, this research provides baseline information on the *C. anguillaris* population that will assist the Samandeni Reservoir Fisheries Administration in developing and implementing effective management policy for this and other reservoir fisheries. Further research on gear selectivity and mesh size selectivity will be needed to determine the appropriate gear mesh size for a sustainable fishery in Samandeni Reservoir.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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