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Reflecting onto the population dynamics of *Hydrocynus brevis* from Dadin: Kowa Reservoir

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Abstract
The population dynamics of *Hydrocynus brevis* from Dadin-Kowa reservoir were studied. Population dynamic parameters such as growth, mortality and recruitment patterns were analyzed using length frequency data over 12-month period employing FiSAT II software. Findings revealed that $K = 1.7^{-yr.}$, $L\infty = 33.33$ cm and $T_{max} = 1.76$ years. Mortality indices revealed that the fish is slightly above exploitation threshold ($F > Eopt \leq 0.5$). However; the major source of population decay is associated with natural factors ($M = 2.87^{-yr.}$). Bimodal recruitment pulses were observed with $Lm = 22.9$ cm, $Lc/ L\infty = 0.29$. Restocking program is suitable to ensure its continuous existence as it seems to have low population, and experiencing recruitment overfishing.

Keywords: Fish population dynamics, *Hydrocynus brevis*, FiSAT II, natural mortality, Dadin-Kowa reservoir

1. Introduction

Fish population is subject to natural control processes and a renewable resource if they are exploited in a planned manner [1]. Despites its' benefits and tremendous species diversity; fish resources have witnessed various changes in stock diversity and abundance resulting from structural changes in habitat, food composition and uncontrolled exploitation [2]. Fish population dynamics indicates the fluctuations or changes in number of fish in a given population and the factors responsible for these changes including the rate of loss (death) and replacement of individuals (recruitment) in the population and any other regulatory forces tending to keep the number in the population steady at least to prevent excessive changes [3]. Data obtained from fish population changes describe the rate of reproduction, rate of growth, rate of mortality, rate of recruitment, change in size and number that occur to fishery resources overtime. Population dynamics further describes the ways in which a population increases and decreases that affect optimal harvesting rates.

Fish population dynamics is used by fisheries scientists to determine sustainable yields [4]. Fish populations have a unique set of dynamics (these are: Recruitment, Growth, and Mortality) that influence their current and future status [5]. Tropical fishes exhibited high level of dynamism compared to temperate ones as they are characterized by faster growth with shorter lifespan unlike temperate counterparts. They also support multispecies fisheries where a large number of species can be caught in the same ground with some important gears example trawl in every haul [6]. As a consequence, broadly the indicators of fish stock dynamics as illustrated by Renjithkumar (2014), as supported by [7] indicated that mortality, recruitment and exploitation rates are the cardinal driving forces that causes fish population dynamics, whereas catch per unit effort, mean length in catch, length at first maturity are also supportive indicators of fish population changes [6, 8, 9].

Accordingly, fish resources are renewable but as well exhaustible [6], which indicates human reliance [10]. As such, their estimation of life traits, how they vary with habitats and population factors are crucial for understanding of population dynamics and risk of extinction {11].

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Therefore, fish resources stock assessment is paramount to aid management practices, predict changes in size of stock, size of yields as a function of both fishery independent and dependent factors, formulate fishing strategy to obtain maximum sustainable yield (MSY) sustainable yield (MSY) without distorting the equilibrium of fish stock, evaluating natural as well as human forces acting upon fish population and fitting them into yield models so as to moderate their dynamic forces [12]. Hence; management of fisheries should be viewed as a dynamic effort not only at preserving fisheries resources, environmental conditions but as well has an economic impacts on the society [6, 11, 13] including most tropical countries [14].

Therefore successful management of fish resources is needed for maintaining equilibrium of the fish between additive and destructive forces acting on the population [12, 15]. Therefore the advancement of fishery resources lies in the intimate utilization of fishery science, globally extensive studies were conducted by many researchers with regards to fish species population dynamics, this includes works of [16-25]. In Nigeria, prominent researchers contributed to the development and understanding of fishery biology such as (Abowei, 2009; Ekundayo, Sogbesan, & Haruna, 2014; Essien-Ibok & Isemin, 2020; Famoofo & Abdul, 2020; Francis & Erondu, 2010; Udoh, Ekpo, & Essien, 2013; Udoh, Ukpatu, & Udoidiong, 2015; Vincent, 2015).

2. Materials and Methods

The study area: The Dadin-Kowa is located in Yamaltu-Deba Local Government area, Gombe State in the north east of Nigeria. Dadin-kowa town is located between Latitudes 10°19′19″N and 10.32194°N; Longitude 11°28′54″E and 11.48167°E. It shares common boundary with Akko Local Government area, to the South and West, Yamaltu-Deba to the East and Kwami to the North. Dadin-kowa has an altitude of about 370 meters above sea level [34].

2.1 Data Collection

Fish samples were collected from three prominent landing sites on a monthly basis for the period of 12 months (January - December, 2020) from the catches of artisanal fishermen. The three landing sites were: *Almakashi*: 10°44’40.584’’N, 11°30’32.574’’E, *Dadin-Kowa*: 10°92’14.142’’N, 11°28’43.956’’E and *Malleri*: 10°18’ 38.539’’N, 11°9’13.582’’E. The study area has bordered three local government areas of Gombe State each with at least a town having intensive fishing activities, therefore, the aforementioned landing sites were selected reflecting the entire Reservoir coverage, and the local government areas includes Funakaye (Almakashi); Yamaltu-Deba (Dadin-Kowa) and Kwami (Malleri) accordingly.

Fish samples were sampled from the population and their morphometric measurements (Standard length & weight) were measured using a measuring tape and a digital weighing balance (Sartorius) to the nearest 0.1cm and 0.1g respectively. The standard lengths of each of the fish species measured from the three landing sites was pooled monthly [35] and grouped into classes of 2-cm constant class sizes using the FiSAT_II software for subsequent analyses.

2.2 Fish Species Length-Weight relationship (*LWR*) Determination

Using MS Excel, the incurred morphometric data (length and weight precisely) from the fish species studied was transformed into their natural logarithm numbers using the “*LN*” function. Thereafter, “*Regression*” function of the same MS Excel was employed to determine the length-weight relationship ($W=aL^b$) [36, 37]. Equations of the graph was generated thereafter. These gave the functions and the constants of the intercepts and slopes (a & b) of the corresponding graphs [38].

2.3 Fish Species Growth Parameter Determination

The length frequency data was used to plot *Powell-Wetherall Plot* [39] which was then used to obtain the initial asymptotic length (L∞) – Which is the hypothetical length a fish will reach if it were to grow forever - and Z/K. The value of asymptotic length was then fitted into ELEFAN 1 to obtain growth coefficient (K) of Von Bertalanffy Growth Formula (VBGF) and the best growth curve for better estimation of asymptotic length. Also the length frequency distribution was obtained using ELEFAN I [40].

Where:

L∞ = Asymptotic length

Z/K = the ratio between total mortality and growth speed towards L∞

Also, fish species hypothetical longevity or T_{max} was determined for each species using the function Longevity (T_{max})= 3/(K) (Gosavi *et al.*, 2019; Wehye & Amponsah, 2017) (1)

Where

K = VBGF growth constant, or coefficient of growth.

Growth Performance index was calculated as explained by Ahmad *et al.*, (2018) using the function

$$ø' = \log10(K) + 2\log10(L∞) \quad (2)$$

Where:

K is the VBGF growth constant and L∞ is the asymptotic length.

2.4 Fish Species Recruitment Patterns Determination

The recruitment rate of the fish species was estimated by backward projection, as illustrated in the FiSAT routine, along a trajectory defined by the VBGF; of the length-frequencies onto the time axis of a time-series of samples using the original data, as described in the FiSAT II routine. Inputs for the recruitment determination includes growth parameters such L∞, K and t_0 (if available). Recruitment pulses were obtained, which is/are the month(s) with the highest percentages of recruitment as an output (Asriyana *et al.*, 2020).

Where;

L∞ = Asymptotic length

K = Growth speed

t_0 = growth of fish at age zero

Also, the length at first maturity (Lm) was determined employing the function:

Lm = L∞ *2/3, (Wehye *et al.*, 2017) (3)

Where,

L∞ = Asymptotic length.

2.5 Fish Species Mortality Rates Determination

Employing the *Pauly M's Equation*; the Total mortality rate (Z) of the fish species was estimated using *Length-Converted Catch Analysis* taking 25 °C as the mean annual surface temperature of the Reservoir. The Natural mortality rates (M) were estimated using Pauly M's equation. Outputs of the process besides Z and M; includes the Fishing mortality (F) and Exploitation ratio (E).

$$\ln(M) = -0.0152 - 0.279\ \ln(L\infty) + 0.6543\ \ln(K) + 0.463\ \ln(T) \qquad (4)$$

Where;
$L\infty$ = Asymptotic length
K = VBGF growth constant
T = Mean annual surface temperature (Temperature measurements were taken in-situ using Hanna portable thermometer)

Also, Optimum fishing (F_{opt}) which is directly related to the natural mortality (M) was calculated for the selected fish species using the expression below:

$$F_{opt} = 0.4*(M) \qquad (5)$$

But (M) is coefficient of natural mortality (Wehye *et al.*, 2017).

The length at optimum yield (L_{opt}) for the fish species was analyzed employing the function

$$L_{opt} = \frac{3}{3+M/K} * L\infty \qquad (6)$$

Where, M/K = is ratio between natural mortality (M) and growth constant (K), but $L\infty$ is asymptotic length [45].

The exploitation ratios (E) were arrived at using the function, F/Z. From the *Length-Converted Catch Curve*, Probabilities of Capture (L_{25}, L_{50}, and L_{75}) were estimated using running average. These parameters indicate the length at which 25%, 50% and 75% of the fish population will be vulnerable to a fishing gear. And L_{50} was taken as the length at first maturity or recruitment (Udoh & Ukpatu, 2017).

2.6 Fish Species Virtual Population Analysis (VPA)

This is where the population of each of the species is reconstructed to obtain the estimated catches, biomass/kg, the exploitation level of the various length classes and the assumed total population. Inputs for the computation of VPA were; Length-weight relationship constants, *a* and *b*, Fishing mortality (F), Natural mortality (M), Fishing mortality (Ft) and growth parameters – asymptotic length ($L\infty$) and growth rate (K). *Length-structured option* of the VPA was used [47].

3. Results

3.1 Growth parameters

Data obtained for the parameters of growth for *Glyptothorax exodon* indicated that asymptotic length ($L\infty$) = 33.33 cm, growth speed (K) is $1.7^{-yr.}$, growth performance index (ø') = 3.27 and potential longevity (T_{max}) is 1.76 years accordingly (Figure 1).

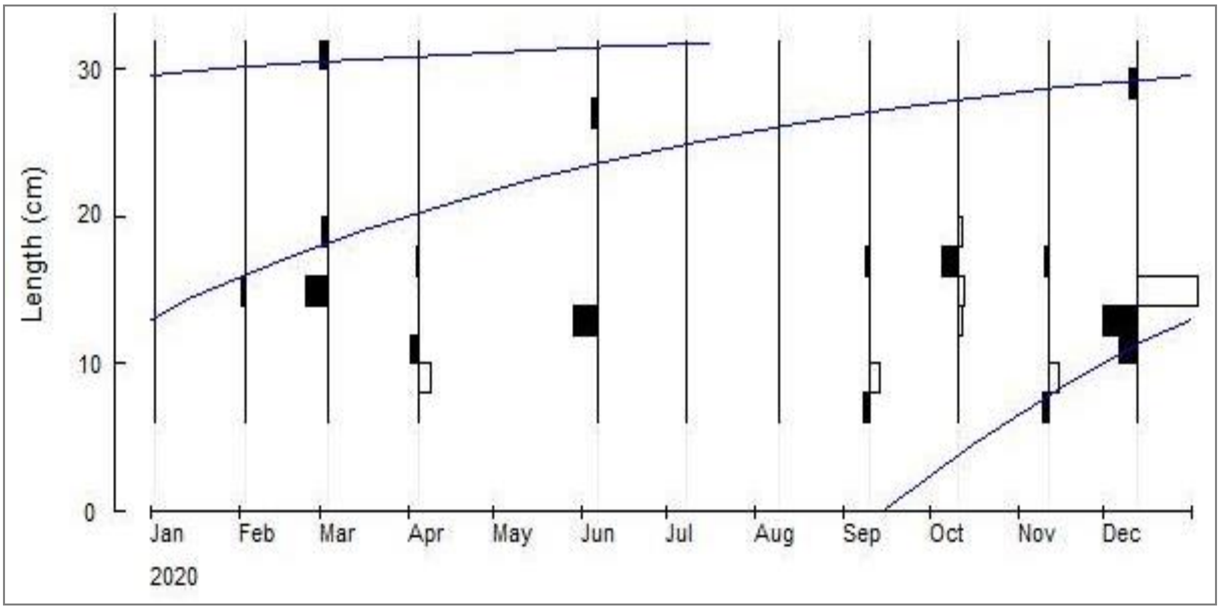

Fig 1: Length frequency histograms superimposed with growth curve of *Hydrocynus brevis*

3.2 Mortality parameters

The parameters of mortality with respect to the said fish species revealed that Total mortality (Z) stood at 2.87^{-yr}, Natural mortality (M) is 2.33^{-yr} and Fishing mortality (F) is 0.54^{-yr}. However, the Exploitation ratio (E) is 0.19^{-yr} L_{opt} = 22.9 cm, L_{50} = 8.94 cm, and $Lc/L\infty$ = 0.29 (Figures 2 and 3).

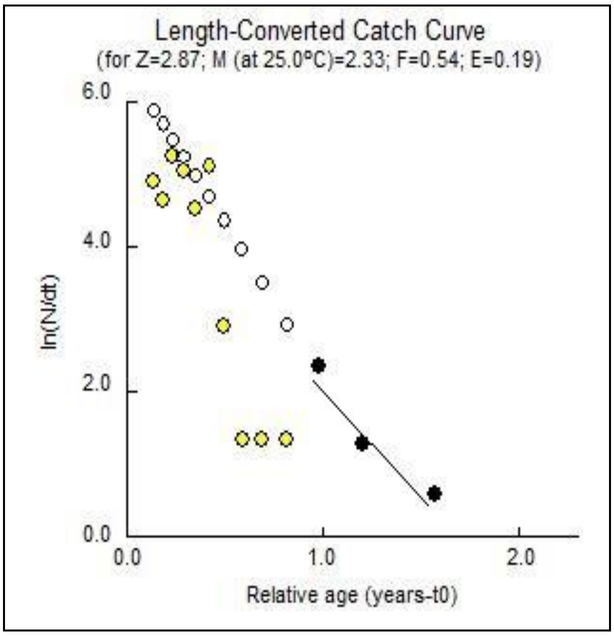

Fig 2: Mortality parameters of *Hydrocynus brevis*

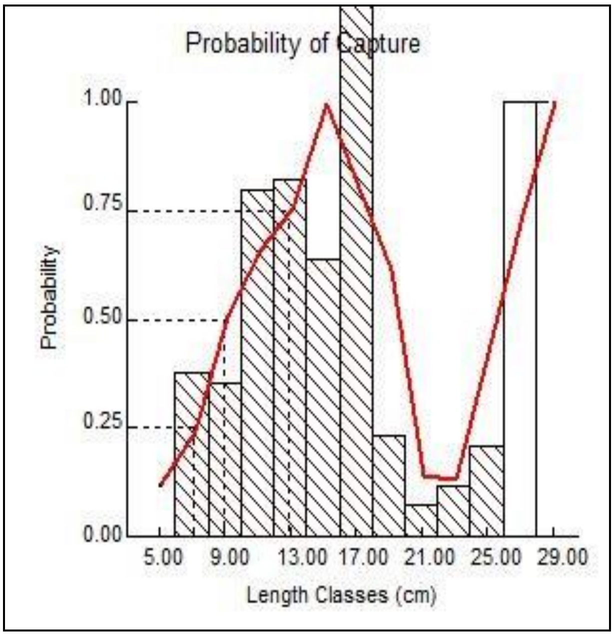

Fig 3: Probability of capture of *Hydrocynus brevis*

3.3 Recruitment patterns

Reflecting on the recruitment pattern of the said fish indicates a bimodal recruitment peak occurring in January (16.4%) and September (26.6%), whereas the month of November recorded the least recruitment output with 3.26% of the fish's population. However, the Lm obtained was 12.8 cm accordingly (Figure 4).

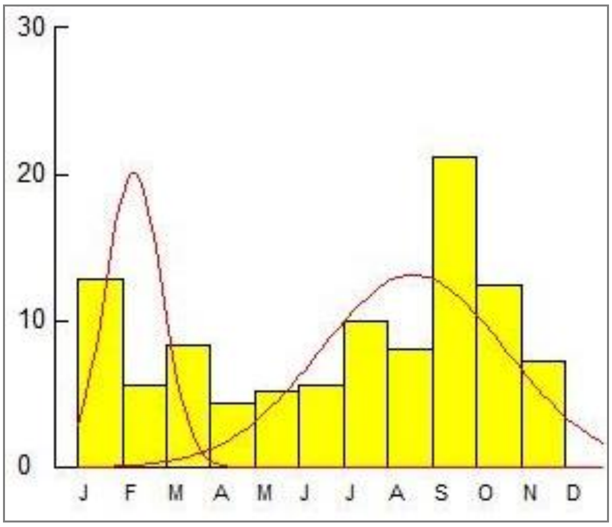

Fig 4: Recruitment pulses of *Hydrocynus brevis*

4. Discussion

4.1 Growth parameters

Asymptotic length ($L\infty$ = 33.3 cm) is relatively lower than Lake Guiers ($L\infty$ = 39cm) and Niger-Benoue ($L\infty$ = 90.6cm) as cited in fishbase.org. *Hydrocynus brevis* has K - value (K = 1.7) from this study which exceeds 0.55 as reported from Lake Guiers (fishbase.org). *Hydrocynus brevis* demonstrated high growth coefficient (K) and performance index (ø'). Growth performance index (ø' = 3.27) for this fish species comes into terms with the records from Sudan (fishbase.org) but relative larger than those of Lake Guiers (Senegal) and Kariba (Zimbabwe) as documented on fishbase.org. According to Chirwatkar *et al.*, (2021) catfishes are typically carnivorous and voracious in feeding habits and are likely to grow at a faster rate. But minimal lifespan of 1.76 years, Potential longevity is inversely proportional to growth constant (K – score), therefore tropical fishes with high K – value tend to have low lifespan with high mortality [48, 49]. In addition; this could be due to heavy exploitation; whereas high growth coefficient and performance is attributable to their efficient protein digestion and mineral retention. Mouth size has been reported to influence the predatory ability of fish species through feeding behavior (Luiz, Crook, Kennard, Olden, and Saunders, 2019), this phenomenon has been aiding the said fish species to attain such unique growth potentials. Low potential longevity is associated with high growth performance index.

4.2 Mortality and Recruitment Indices

The exploitation status (E = 0.19) of this fish species inferred under-exploitation because ($E < E_{opt} = 0.5$). But natural mortality (M = 2.33) has been the major source of mortality of this fish species and this statement is supported by slight mortality dominance index ($Z/K > 1$). The highest M – value documented in this study is 2.33 against *Hydrocynus brevis* per year; this M – value exceeds the records of *Selaroides leptolepis* (1.7 per year) from Ternate Island [51] and *Saurida tumbil* [52]. It was observed that disease burden, poor competitive abilities, senescence, diet deficiencies, anthropogenic activities emanating from different geographical locations [53] can influence natural mortalities of fish species including those from this study.

Recorded length at first capture (L_C) is less than length at first maturity (Lm = 22 cm) and length at optimum exploitation (L_{opt} = 22.9cm) indicating growth and recruitment overfishing characterized by small-sized fishes in the landings. The aforementioned statement was strengthened by low value of $L_C/L\infty$ (0.29), this is lesser than 0.5 obtained against *Brycinus nurse* (7). The fish species is one of the most sought for; because $Z/K > 1$, indicating mortality domination and exploitation rate is above the threshold of 0.5. Although Lm (22.2 cm) is relatively larger than L_C (9 cm), recruitment is all year round with major peaks occurring in the months of January (16.4%) and September (26.6%). This bimodal recruitment peaks enable the fish to replenish its lost population via mostly natural losses (M = 2.23). Bimodal recruitment pattern is assumed to be plasticity of tropical fishes with diverse ecological flexibility [54].

5. Conclusion

The current findings indicated that *Hydrocynus brevis* from Dadin-Kowa Reservoir had good growth coefficient, but bears setbacks resulting from low lifespan and greatly ravaged by natural causes of population decay.

5.1 Compliance with ethical standards

5.2 Acknowledgments

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5.3 Disclosure of conflict of interest

The authors declared that there is no conflict of interests.

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