Mortality and Exploitation Rates of Challawa Gorge Dam Fishes, Kano State, Nigeria

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Abstract
Analyses were done on length-frequency data to study the mortality and exploitation rates of fish species of Challawa gorge dam. The species were: Bagrus bayad macropterus, Synodontis schall, Oreochromis niloticus, Pollimyrus isidori, Marcusenius senegalensis, Schilbe uranoscopus, Clarias lazera, Lates niloticus, Brycinus nurse and Auchenoglanis occidentalis. The total mortality (Z), the fishing mortality (F), the natural mortality (M), the current exploitation rate (E), Probabilities of Capture and their Biological Reference Points were all assessed. Bagrus b. macropterus, Synodontis schall, Clarias lazera, Lates niloticus, Schilbe uranoscopus and Auchenoglanis occidentalis were over-exploited. Oreochromis niloticus was optimally harvested. While Pollimyrus isidori, Brycinus nurse and Marcusenius senegalensis were underexploited.

Keywords: Mortality; Exploitation; Fish; Challawa; Dam

Introduction
Livelihoods and food security of millions of people across the world are supported by small-scale fisheries that if it is managed appropriately, it can make tremendous contributions to socio-economic development of fishing communities. In Nigeria, fish forms an important part of the diet of many households, especially in rural areas [1,2]. It makes up around 40% of Nigeria’s protein intake, with fish consumption at 13.3 kg/person/ per year [3]. Total fish production per year is close to 1 million metric tons (313,231 metric tons from aquaculture and 759,828 metric tons from fisheries). The majority of this fish is consumed domestically, while around 10% is exported [4].

But inland fish resources, most of the time, seems to be on a steady decrease [5,6]. This can be attributed to overexploitation of the resources, illegal fishing methods [7], minimal conservation commitments and majorly lack of review, compliance or enforcement of fishery management policies and laws [8]. It has been noticed that inland fishery resources are often over-exploited because of the fishing pressure and the fact that bigger aquatic resources – Seas, Oceans, Estuaries, Lagoons etc. – which produce the bulk of fish resources are far from the inland areas, therefore the pressure on the inland freshwaters [9,10].

Fish mortality is a parameter used to infer the loss of fishes through death. Mortality in exploited fisheries is either natural or fishing mortality. Natural mortality is all causes of death that are not as a result of anthropogenic harvest. These include; Diseases, predation, unfavourable environmental conditions (such as pollution), senescence, competition, cannibalism or any other factor(s) that might cause death in fisheries.

On the other hand, fishing (harvest) mortality is the removal, from fish stock, of fishes using any fishing methods [11]. Fish mortality may account for the shrinkage of fish population overtime. Mortality in fishes is highest at the egg/larval stages due to vulnerability to predation, starvation and unfavourable conditions [12] and decreases as the fish progresses in their life history [13].

Many fisheries are being direly over-exploited, including those in countries with well-developed fishery management institutions. Example the Canadian cod fisheries have not recovered from a collapse
Materials and Methods

The study was carried out in Challawa garge dam, Kano state, Nigeria with coordinates 8°06’58.04”E 11°41’21.95”N. The dam was completed in 1993 on the Challawa River. It is the 2nd largest of the 3 dams along Hadejia-Jama’are River Basin [24]. It is 42 m high and 7.8 km in length. The dam has a full storage capacity of 904,000,000 m³. The direct catchment area is 3857 km². Apart from irrigation and township water supply, the dam was constructed with hydropower potential of around 3 MW.

Data collection

Fish samples were collected from three of the seven landing sites of the dam from artisanal fishermen, on a monthly basis. The 3 landing sites were - TURAWA: 11° 40’52.4”N 008°02’31.9”E, SAKARMA: 11° 39’543”N 08°06’611”E and PEGINMA: 11° 39’28.1”N 007°581’18.9”E. The Total lengths and Weights of the fish samples were measured using a measuring tape and a digital weighing balance (Sarturius T630) to the nearest 0.1 cm and 0.1 g respectively. The study was conducted from March – August, 2017.

The fish were identified to species level and Olaosebikan and Bankole [3]. The sampling sites were chosen based on a reconnaissance survey and responses of the fishermen that the 3 sites have the largest landings by volume. The fishermen use non-motorized canoes and the predominant fishing gears were gill net and hook and line. The data were analysed using the FAO-ICLARM fish stock assessment software, FISAT II.

Mortality parameter

Total mortality rates (Z) of each of the species were estimated using Length-converted catch analysis taking 26.1°C as the mean annual surface temperature of the dam. The Natural mortality rates (M) were estimated using Pauly M’s equation (Pauly and Morgan, 1987):

\[ \ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T) \]

Where;

- \( L_\infty \): Asymptotic length
- \( K \): VBG growth constant
- \( T \): Mean annual surface temperature

The Fishing mortality rates were derived from the difference between the Total and Natural mortality rates

\[ F = Z - M \]

The exploitation ratio (E) were arrived at using the function, \( \frac{F}{Z} \)

Growth Performance indices were calculated as explained by Gayanilo et al. (2005) using:

\[ \log(W) = \log\left(\frac{L}{L_\infty}\right) + 2.5 \log\left(\frac{L}{L_\infty}\right) - 1 \]

Where \( K \) is the VBG growth constant and \( L_\infty \) is the asymptotic length. From the length-converted catch curve, Probabilities of Capture (\( L_{Z50}, L_{Z75} \) and \( L_{Z75} \)) 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.

Exploitation parameters

Employing Beverton and Holt Y/R analysis [25,26], the relative biomass per recruit (B/R) was estimated as \( B/R = \frac{(Y/R)}{F} \) [27]. The parameters needed for this routine are: Length-frequency data with constant class sizes, \( M/K, L_\infty/L_\infty, a \) and \( b \) values. The output gives the values of the following parameters:

- \( E_{\max} \) which shows exploitation rate that produces maximum yield [28],
- \( E_{\min} \) highlights exploitation rate at which the marginal increase of \( Y/R \) is 10% of its virgin population;
- While \( E_{\max} \) implies exploitation rate under which the population is reduced to half its virgin biomass, were all computed using the procedure incorporated in the FiSAT program.

The "selection ogive" option was employed instead of "Knife - edge" because according to [26,29,30] while Knife-edge assumes that species that are \( <L_{50} \) are not caught by fishing gears, the "selection ogive" procedure assumes that the probability of capturing any species is the function of their length, therefore it was more realistic for this study (Figure 1).

Results

A total of 10 species of fishes, belonging to 9 families were identified during the period under study and they are presented below in Table 1, including their English names and the local names (in Hausa language).

As reported from the fishermen, about 13 fish species belonging to 9 different families were available before in Challawa garge dam. Table 2 below presents some with their English and Local names.

Mortality rates

Below in Figures 2a–2j, are the length-converted catch curves of the species. The mortality parameters: Total mortality (Z), Natural mortality (M), Fishing mortality (F) and Exploitation rate (E) were estimated from length-converted catch curves by inputting the corresponding \( L_{Z50} \) and \( K \) values.

Probabilities of capture

The probabilities of capture of the species were determined from the length-converted catch curves. Length-frequencies of the species were used to extrapolate the length at which they might be vulnerable to fishing gears. It is given in percentages of 25, 50 and 75. They are presented below in Figures 3a–3j.

In Table 3 below, the values of \( Z, Z/K, M, F, E \) and Probabilities of capture are presented. Clarias lazera had the highest total mortality followed by Late niloticus. From the Z/K values [31] The Population of B. nurse and P. sidori had growths that dominated their mortality. S. schall and M. senegalensis mortality lightly dominated growth. While the population of B. macropeterus, Oreochromis niloticus, Clarias lazera, Lates niloticus, Schilbe uranoscopus and Aschenoglanis occidentalis all had mortality that dominated growth greatly (Over-exploitation). M. senegalensis had the highest natural mortality while S. uranoscopus had the lowest natural mortality. Lates niloticus was the most fished species in Challaw dam, whereas B. nurse was the least fished species. Lates niloticus was the most exploited fish species followed by C. lazera. B. nurse was the least exploited species followed by P. sidori. The probabilities of capture of the species show that fingerlings of all the species with the exception of M. Senegalensis were caught and retained.

The Z/K values for the species indicate the extent of mortality in relation to growth, for the given species in a year:

- Z/K values of <1 indicates Growth dominates Mortality;
Figure 1: Map of the study area.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>English name</th>
<th>Local name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagridae</td>
<td>Bagrus b. macropterus</td>
<td>Bayad, Silver catfish</td>
<td>Ragon ruwa, Doza, Misko</td>
</tr>
<tr>
<td>Mochokidae</td>
<td>Synodontis gambiensis</td>
<td>Wahrindi</td>
<td>Karaya</td>
</tr>
<tr>
<td>Cichlidae</td>
<td>Oreochromis niloticus</td>
<td>Nile Tilapia</td>
<td>Karfasa</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>1. Marcusenius isidori</td>
<td>Baby whale,</td>
<td>Lusa</td>
</tr>
<tr>
<td>Cichlidae</td>
<td>Synodontis schall</td>
<td>Stonebasher</td>
<td></td>
</tr>
<tr>
<td>Mormyridae</td>
<td>2. Gnathonemus senegalensis</td>
<td>Marcusenius senegalensis</td>
<td></td>
</tr>
<tr>
<td>Claridae</td>
<td>Clarias lazera</td>
<td>African catfish</td>
<td>Tarwad’a</td>
</tr>
<tr>
<td>Cetopomidae</td>
<td>Lates niloticus</td>
<td>Niger/Nile Perch</td>
<td>Giwan ruwa, Barya</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>1. Marcusenius isidori</td>
<td>Baby whale,</td>
<td>Lusa</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>2. Gnathonemus senegalensis</td>
<td>Marcusenius senegalensis</td>
<td></td>
</tr>
<tr>
<td>Claridae</td>
<td>Alestes nurse</td>
<td>Silversides</td>
<td>Kawara, Jan wutsiya</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>1. Marcusenius isidori</td>
<td>Baby whale,</td>
<td>Lusa</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>2. Gnathonemus senegalensis</td>
<td>Marcusenius senegalensis</td>
<td></td>
</tr>
<tr>
<td>Bagridae</td>
<td>Auchenoglanis occidentalis</td>
<td>Bubu, Armored catfish</td>
<td>Buro</td>
</tr>
</tbody>
</table>

*Illustrates latest names.

Table 1: Fish species identified at Challawa gorge dam during the study.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>English name</th>
<th>Local name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malapteruridae</td>
<td>Malapterus electricus</td>
<td>Electric catfish</td>
<td>Minjirya</td>
</tr>
<tr>
<td>Cichlidae</td>
<td>1. Sarotherodon galilaeus</td>
<td>Mango tilapia</td>
<td>Gargaza</td>
</tr>
<tr>
<td></td>
<td>2. Other tilapia spp.</td>
<td>Tilapia</td>
<td>Karfasa</td>
</tr>
<tr>
<td>Osmeridae</td>
<td>Heterotis niloticus</td>
<td>Heterotis</td>
<td>Bari</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>Heterobranchus spp.</td>
<td>Catfish</td>
<td>Mari</td>
</tr>
<tr>
<td></td>
<td>1. Mormyrus hasselquisti</td>
<td>-</td>
<td>Taku, Fura</td>
</tr>
<tr>
<td></td>
<td>2. Mormyrus rume</td>
<td>Bottlenose</td>
<td>Milligi</td>
</tr>
<tr>
<td></td>
<td>3. Mormyrus deliciosus</td>
<td>Trunkfish</td>
<td>Sangwani</td>
</tr>
<tr>
<td>Cyprinidae</td>
<td>1. Labeo senegalensis</td>
<td>African carps</td>
<td>Data</td>
</tr>
<tr>
<td></td>
<td>2. Other labeo spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characidae</td>
<td>Hydrocynus spp.</td>
<td>Tiger fish</td>
<td>Tsege, Zawai</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>Synodontis spp.</td>
<td>Squeker</td>
<td>Kurungu</td>
</tr>
<tr>
<td>Gymnarchidae</td>
<td>Gymnarchus niloticus</td>
<td>-</td>
<td>Dan-sarki</td>
</tr>
</tbody>
</table>

Table 2: Fish species that were available before.
Figure 2: Length-converted catch curves used to estimate Total mortality, Natural mortality, Fishing mortality and Exploitation rate. A (Bagrus b. macropterus), B (S. schall), C (O. niloticus), D (P. isidori), E (C. lazera), F (L. niloticus), G (M. senegalensis), H (B. nurse), I (S. uranoscopus) and J (A. occidentalis).
Figure 3: Probabilities of capture. A (Bagrus b. macropterus), B (S. schaff), C (O. niloticus), D (C. lazera), E (L. niloticus), F (M. senegalensis), G (B. nurse), H (S. uranoscopus), I (A. occidentalis) and J (P. isidori).
• Z/K value of 1 indicates population is in equilibrium (Where mortality balances growth).
• Z/K values of >1 indicate mortality domination; and
• Z/K values of ≥2 indicates the fish population is highly exploited [31]. These values are relative to the population size, fecundity and the exploitation rate for a given species.

The growths of B. nurse and P. isidori dominated their mortalities. The mortalities of S. schall and M. senegalensis dominated their growths. While, Bagrus b. macropterus, O. niloticus, C. lazeria, L. niloticus, S. uranoscopus and A. occidentalis were highly exploited more than their growth could replace their biomass.

Exploitation status of Challawa fishery

Using the FISAT_II software, the exploitation status of the individual species studied from Challawa dam were estimated. The required inputs for this function are: M/K, Lc/L∞, “a” and “b” values (from length-weight relationships). Below are the outputs (graphs) generated for each of the species in Figures 4a–4j.

Lc/L∞ of less than 0.5 indicates that small-sized fishes are exploited. M/K and Lc/L∞ were used as inputs for the Beverton and Holt exploitation analysis. The Selection ogive was preferred because it was more practical to the fishery of the area under study. Because fishes caught below the Lc(L50) are retained and never returned to the water. When Ecurrent=0.5, that is the optimum level of exploitation. Therefore when F=M, then E=0.5.

From Table 4 below, Lc/L∞ of less than 0.5 indicates that small-sized fishes are exploited. M/K and Lc/L∞ were used as inputs for the Beverton and Holt exploitation analysis. The Selection ogive was preferred because it was more practical to the fishery of the area under study. Because fishes caught below the Lc(L50) are retained and never returned to the water. When Ecurrent=0.5, that is the optimum level of exploitation. Therefore when F=M, then E=0.5.

**Bagrus b. macropterus:** Bagrus b. macropterus population in Challawa dam are overly exploited. The Maximum Sustainable Yield (MSY) was 0.398, but the current exploitation rate was 0.64. The Maximum Economic Yield (MEY) which is the value that will ensure maximum economic return to the fishermen was (E50) 0.320. It was slightly below the MSY which shows that the Bagrus population is highly sought after by the fishermen, but its exploitation is highly unsustainable. Hence the probable reason for its rapid decline. At current exploitation rate the Y/R and B/R stand at 0.011 and 0.049, respectively, which is far lower for replenishing depleting stocks, considering the exploitation rate (Figure 4a).

### Table 3: Mortality Rates Parameters.

<table>
<thead>
<tr>
<th>Species</th>
<th>Z’</th>
<th>Z/K</th>
<th>M’</th>
<th>F’</th>
<th>E</th>
<th>Lc/L∞</th>
<th>Lc/L∞</th>
<th>Lc/L∞</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagrus b. macropterus</td>
<td>1.56</td>
<td>2.19</td>
<td>0.56</td>
<td>1</td>
<td>0.64</td>
<td>7.76</td>
<td>9.3</td>
<td>16.18</td>
</tr>
<tr>
<td>Synodontis schall</td>
<td>2.27</td>
<td>1.92</td>
<td>0.79</td>
<td>1.48</td>
<td>0.65</td>
<td>8.56</td>
<td>10.08</td>
<td>11.92</td>
</tr>
<tr>
<td>Oreochromis niloticus</td>
<td>1.87</td>
<td>2.36</td>
<td>0.91</td>
<td>0.96</td>
<td>0.51</td>
<td>10.32</td>
<td>12.24</td>
<td>14.3</td>
</tr>
<tr>
<td>Pollimyrus isidori</td>
<td>1.68</td>
<td>0.1</td>
<td>0.98</td>
<td>0.7</td>
<td>0.42</td>
<td>8.43</td>
<td>9.29</td>
<td>10.13</td>
</tr>
<tr>
<td>Clarisida lazeria</td>
<td>3.43</td>
<td>2.67</td>
<td>0.79</td>
<td>2.64</td>
<td>0.73</td>
<td>12.13</td>
<td>13.76</td>
<td>15.41</td>
</tr>
<tr>
<td>Lates niloticus</td>
<td>3.35</td>
<td>4.66</td>
<td>0.44</td>
<td>2.92</td>
<td>0.87</td>
<td>13.5</td>
<td>15</td>
<td>16.5</td>
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<tr>
<td>M. senegalensis</td>
<td>1.82</td>
<td>1.4</td>
<td>1.03</td>
<td>0.79</td>
<td>0.42</td>
<td>7.39</td>
<td>8.18</td>
<td>8.99</td>
</tr>
<tr>
<td>Brycinus nurse</td>
<td>1.31</td>
<td>0.66</td>
<td>1</td>
<td>0.31</td>
<td>0.24</td>
<td>6.7</td>
<td>7.58</td>
<td>8.52</td>
</tr>
<tr>
<td>Schilbe uranoscopus</td>
<td>1.35</td>
<td>2.71</td>
<td>0.42</td>
<td>0.93</td>
<td>0.69</td>
<td>7.45</td>
<td>8.24</td>
<td>8.99</td>
</tr>
<tr>
<td>A. occidentalis</td>
<td>2.22</td>
<td>2.03</td>
<td>0.73</td>
<td>1.49</td>
<td>0.67</td>
<td>10.75</td>
<td>11.5</td>
<td>12.25</td>
</tr>
</tbody>
</table>

Where: Z=Total instantaneous mortality, M=Natural mortality, F=Fishing mortality, E=Exploitation rate
Lc/L∞=Length at which 75% of the population will be vulnerable to fishing gear.

### Table 4: Exploitation Parameters.

<table>
<thead>
<tr>
<th>Species</th>
<th>Emax</th>
<th>E10</th>
<th>E50</th>
<th>Ecurrent</th>
<th>M/K</th>
<th>Lc/L∞</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagrus b. macropterus</td>
<td>0.4</td>
<td>0.32</td>
<td>0.25</td>
<td>0.64</td>
<td>2.08</td>
<td>0.12</td>
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<tr>
<td>Synodontis schall</td>
<td>0.66</td>
<td>0.47</td>
<td>0.28</td>
<td>0.6</td>
<td>2.14</td>
<td>0.32</td>
</tr>
<tr>
<td>Oreochromis niloticus</td>
<td>0.64</td>
<td>0.51</td>
<td>0.33</td>
<td>0.51</td>
<td>2.33</td>
<td>0.37</td>
</tr>
<tr>
<td>Pollimyrus isidori</td>
<td>0.7</td>
<td>0.56</td>
<td>0.34</td>
<td>0.42</td>
<td>2.65</td>
<td>0.42</td>
</tr>
<tr>
<td>Clarisida lazeria</td>
<td>0.62</td>
<td>0.52</td>
<td>0.32</td>
<td>0.77</td>
<td>2.33</td>
<td>0.36</td>
</tr>
<tr>
<td>Lates niloticus</td>
<td>0.45</td>
<td>0.37</td>
<td>0.27</td>
<td>0.87</td>
<td>2.45</td>
<td>0.2</td>
</tr>
<tr>
<td>M. senegalensis</td>
<td>0.75</td>
<td>0.61</td>
<td>0.37</td>
<td>0.42</td>
<td>3.01</td>
<td>0.53</td>
</tr>
<tr>
<td>Brycinus nurse</td>
<td>0.65</td>
<td>0.52</td>
<td>0.2</td>
<td>0.24</td>
<td>3.03</td>
<td>0.48</td>
</tr>
<tr>
<td>Schilbe uranoscopus</td>
<td>0.56</td>
<td>0.46</td>
<td>0.22</td>
<td>0.69</td>
<td>3.5</td>
<td>0.26</td>
</tr>
<tr>
<td>A. occidentalis</td>
<td>0.54</td>
<td>0.45</td>
<td>0.67</td>
<td>2.43</td>
<td>0.29</td>
<td></td>
</tr>
</tbody>
</table>

Where: Emax=Exploitation rate that will produce maximum sustainable yield;
E10=Exploitation rate at which the marginal increase in Y/R is 10% of its virgin population.
E50=Exploitation rate under which the population is reduced to half of its virgin population.
M/K=Indicates the health of the habitat of the fish
Lc/L∞=The growth rate of fish at Lc relative to the Lc.
Figure 4: Relative Y/R and B/R using selection Ogive. A (Bagrus b. macropterus), B (S. schall), C (O. niloticus), D (P. isidori), E (C. lazera), F (L. niloticus), G (M. senegalensis), H (B. nurse), I (S. uranoscopus) and J (A. occidentalis).
**Synodontis schall**: *Synodontis schall* exploitation in Challawa dam can be said to be within safe limits because the difference between the current exploitation rate and the \( E_{opt} \) is small. It’s \( MEY (E_{opt}) \) indicates catches should be reduced by 10%. But according to the Virtual Population Analysis (VPA) fishing pressure to the juvenile stock might cause decline of the population. The \( Y/R \) & \( B/R \) was 0.019 and 0.211 (Figure 4b).

**Oreochromis niloticus**: *Oreochromis niloticus* population are exploited at par with the Maximum Economic Yield 0.51 (Table 4). Their exploitation even if upped by 13% might not affect the Tilapia population. It might be as a result of the fact that they are prolific breeders and they are lower on the food chain. Though the juvenile of the Tilapia are exploited there was no reason for concern. The \( Y/R \) and \( B/R \) were estimated at 0.020 and 0.30, respectively (Figure 4c).

**Pollimyrus isidori**: *Pollimyrus isidori* population are very abundant in the Challawa dam considering its high \( E_{opt}=0.70 \) compared to current exploitation rate of 0.42 (Table 4). Therefore they under-exploited probably because of their low market demand. *Pollimyrus isidori* exploitation might be increased by about 28%. The \( Y/R \) & \( B/R \) were estimated at 0.017 and 0.33 respectively (Figure 4d).

**Clarias lazera**: *Clarias lazera* are highly exploited in Challawa fishery. If the fishing pressure on *Clarias population* might be reduced by 15%, the Maximum Economic Yield (MEY) might be increased by about 10%. The Optimum exploitation rates \( E_{opt} \) – 0.32 (Table 4) was doubled by \( E_{current} \) – 0.77 indicating that it is one of the highly sought after species. The \( Y/R \) & \( B/R \) were found to be close to 0.02 and 0.07, respectively(Figure 4e).

**Lates niloticus**: *Lates niloticus* was the most exploited species in Challawa dam with an exploitation rate of 0.87 (on a scale of 0-1) (Table 4). It has the highest fishing mortality of 2.92 (Table 4) with a length at first capture as small as 15.00 cm (Table 3). Whereas the MSY was 0.45 the Optimum Exploitation rate was as low as 0.27. This indicates that *Lates* are exploited well beyond their replenishing capacity. It was not surprising bearing in mind that the predominant fishing methods were Gill nets & Baited long lines. And almost all the fishers target this species. The \( Y/R \) and \( B/R \) was 0.001 and 0.01 indicating low recruitment yield and biomass return for this species in Challawa dam (Figure 4f).

**Marcusenius senegalensis**: *Marcusenius senegalensis* population is under-exploited probably because of low market return. Their exploitation rates can be raised by about 30% for all the length classes without concern, in fact they had the highest \( Y/R \) of 0.466 (Figure 4g).

**Brycinus nurse**: *Brycinus nurse* population is under-exploited by the fishermen. The low \( E_{opt} \) value of 0.24 suggests that little interest is accorded this specie by the resource users. From the values generated by the FiSAT II software it was apparent that increasing the catches of *Brycinus nurse* won’t negatively affect the population. The \( Y/R \) and \( B/R \) were 0.064 and 0.34, respectively (Figure 4h).

**Schilbe uranoscopus**: *Schilbe uranoscopus* population is over-exploited. Its exploitation rate should be decreased by 19% because further fishing pressure to the juvenile stock will decrease the \( E_{opt} \) (Maximum Economic Yield) by about 10%. The \( Y/R \) and \( B/R \) were found to be about 0.57 and 0.26. These indicate that recruitment into the fishery per outweighed fishing mortality (Figure 4i).

**Auchenoglanis occidentalis**: *Auchenoglanis occidentalis* population is overexploited by about 17%. The exploitation rate of 0.67 shows that it was beyond the \( MSTD \)=0.54 and the \( E_{opt} =0.5 \). As with other species, fingerlings and juvenile overfishing was very high considering the length at first catch and length at first recruitment \( L_{50}=11.50 \) cm (Table 4). The Optimum exploitation level, \( E_{opt}=0.30 \) for this species indicated high fishing pressure. The high instantaneous fishing mortality rate of 1.49 out of 2.22 suggests that it is one of the species that command considerable market value (Figure 4j).

**Discussion**

**Bagrus b. macropterus**

The ideal length at first maturity for *Bagrus* is 17.1 cm (Fishbase. org). The Challawa species’ \( L_{50}=9.30 \) cm. This showed that there is growth and recruitment overshooting, characterised by small-sized fishes in the landings. From the study (Table 4) the value of \( L_{50} \) was 0.12, which was lower than 0.5 [31]. This affirms the presence of many small-sized *Bagrus* spp. in the landing, indicating that small mesh sizes were employed.

The estimated Z/K ratio (Table 3) for *Bagrus* this study was greater than 1, which depicts mortality domination for the targeted species. A Z/K value of ≤ 2 shows that the species are lightly exploited. From Table 4, the \( E_{opt} \) for this species was estimated at 0.64, which was above the \( E_{opt} \) of 0.5. Also, the \( E_{opt} \) (Exploitation level that maximises \( Y/R \) or \( B/R \) was relatively lower at 0.40 (Table 4). In comparison to a similar study conducted in Lake Akata, Benue state, Ikonghbe et al. [32] reported lower total mortality of 1.43 compared to 1.56, lower fishing mortality of 0.381 compared to 1.00, lower exploitation level of 0.266 compared to 0.64. Also, Akombo et al. [33] found out that the population parameters C. auratus (Bagridae) of River Nile, Egypt were \( Z=1.44, M=0.60, F=0.84, E=0.58, Y/R=0.0158 \).

**Synodontis schall**

The length at first capture 10.08 cm (Table 3) was far below the length at first maturity - 21.00 cm (fishbase.org). This indicates serious growth overshooting that does not spare fingerlings. The \( L_{50} \) of 0.32 < 0.5, confirms the fact that smaller sized fishes dominated the catches.

Mospela and Ngunu reported \( L_{50}=30.9 \) cm, \( L_{50}=14.28 \) cm, \( Z=3.57, F=2.17 \) and \( E=0.61 \) for Okavango Basin, Botsswana. Ragheb [34] in another study on *S. schall* in the lower Benue river, got the following values: \( M=1.045, F=2.360, Z=3.405 \) and \( E=0.69 \).

**Oreochromis niloticus**

The estimated length at first capture (12.24 cm). The Z/K ratio (2.36) indicates that Tilapia are mortality dominated, but the E value (0.51) in Table 4, shows that the fish stock are replenished enough to counter the exploitation, and adjusted to optimal level. Abdul et al. [35] studied the Tilapia of Ogun estuary and they got; \( Z=3.93, M=1.46, F=2.47, E=0.63 \) and \( L_{opt}=10.23 \) cm. The asymptotic length and growth rates were higher than this study, but the length at first maturity in this study (12.24 cm) was higher than the Ogun estuary which means Tilapia in the Estuary are recruited earlier than in Challawa dam. The \( L_{50} \) for Lake Timsah, Egypt [36] was even lower at 8.4 cm. But these lower values might be due to differences in fishing gears and mesh sizes employed in the localities [7,26,37]. In a WorldFish Center report [38], on lake Nasser Egypt in 1972 and 1992 showed; \( L_{50}=50.39, 54.73; K=0.16,0.27, Z=1.21,0.83, M=0.42, 0.24; F=0.31,0.97; \) and \( E=0.4,0.8, \) respectively.

**Pollimyrus isidori**

The cut-off length (3.15 cm) being lower than the \( L_{50}=9.29 \) cm proves that all landings catches are retained no matter the size. The \( E \) value of 0.42 (Table 4), shows that it is a less sought-after species. A
Z/K value of 0.10 further illustrates the fact that the species' growth outweighed mortality.

**Clarias lazera**

The estimated $L_{\infty}$ (13.76 cm) was found to be lower than the $L_{e}$ which was 30.86 cm. This indicates recruitment overfishing. The Z/K and E values of 2.67 and 0.77, respectively show that Clarias are highly exploited in this fishery. In a report on Lake Kainji [39] found $M=0.90$, $F=1.17$, $Z=2.07$, $L_{\infty}=56.6$ cm, $K=0.47$.

In Cross-River floodplain, Mustapha [40] found $L_{\infty}=80.24$ cm, $K=0.49$, $Z=2.54$, $M=0.88$, $E=0.66$. In another research [40] found $L_{\infty}=45.7$ cm, $K=1.67$, $F=2.37$, $M=1.18$, $Z=3.55$, $E=0.67$. And in Gubi dam, Bauchi state [41] $L_{\infty}=43$ cm, $K=0.65$, $F=1.20$, $M=0.22$, $Z=1.44$, $E=0.83$. This shows that Clarias in Gubi dam grow faster than the Challawa species and are exploited much more than Challawa dam.

**Marcusenius senegalensis**

The $L_{\infty}=8.18$ cm. In Bontanga Reservoir, Ghana. Kwarfo-Apegyah et al. [42] found $L_{\infty}=24.68$ cm, $K=0.69$, $Q^\prime=2.4$, $Z=2.4$, $M=1.3$, $E=0.49$, $F=1.24$. B. nurse grow faster and attain bigger sizes than Challawa, but are exploited more in Bontanga Reservoir but less in Lake Nasser. However, they are all sustainably harvested.

**Schilbe uranoscopus**

The estimated length at first capture ($L_{50}$)=7.58 cm. In lake Nasser, $L_{\infty}=20.3$ cm, $Z=0.8$, $M=0.7$, $F=0.1$, $E=0.1$. In Bontanga Reservoir, Ghana. Kwarfo-Apegyah et al. [42] the values obtained were; $L_{\infty}=20.48$ cm, $K=0.52$, $Z=2.54$, $M=1.3$, $E=0.49$, $F=1.24$. B. nurse grow faster and attain bigger sizes than Challawa, but are exploited more in Bontanga Reservoir but less in Lake Nasser. This indicates recruitment overfishing. The Z/K value of 0.10 further illustrates the fact that the species' growth outweighed mortality.

**Lates niloticus**

The estimated length at first capture was 15.0 cm. These point-out growth overfishing. In lake Nasser [38] got $L_{\infty}=180$ cm, $K=0.069$, $Z=0.35$, $M=0.17$, $F=0.18$, $E=0.5$. This indicates that Nile perch in this lake attain bigger sizes and are exploited within safe limits. While at Kainji lake [39] got $L_{\infty}=158.7$ cm, $K=0.25$, $Z=3.61,M=0.49$, $M/k=1.96$, $F=3.12$, $E=0.86$. Kainji lake species attain bigger sizes but are over-exploited despite good yearly growth rate [47].

In lake Victoria, Udoh and Ukpatu [47] reported $L_{\infty}=169$ cm, $K=0.0195$, $Z=0.724$, $M=0.372$, $F=0.352$, $E=0.49$. This means Lake Victoria Nile perch are exploited optimally.

**Auchenoglanis occidentalis**

The estimated length at first capture was 11.50 cm. In Cross River [33] the results obtained were; $K=1.5$, $L_{\infty}=120.23$ cm, $\Theta=4.045$. This indicates better growth performance than Challawa species. In Bontanga Reservoir, Ghana [42] $L_{\infty}=54.08$ cm, $K=0.1$, $Z=1.04$, $M=0.34$, $E=0.68$, $F=0.71$. The Asymptotic length was higher than this study (Table 4). The growth rate was lower, but that is understandable considering the fact that as fish grow older, the annual growth rate slows down [13,48-55]. The exploitation level was higher compared to Challawa dam fishery [56-59].

**Conclusion**

Small-sized fishes are highly exploited in the dam for all the species with the exception of Marcusenius senegalensis probably because their adults are 12-15 cm. As with similar findings, species deemed to be of commercial value were over-exploited and species of lower demand were mostly under-exploited.

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**Conflicts of Interest**

The authors declare no conflict of interest.

**References**


