Short Communications

Detritus and energy consumption and conversion efficiency of \textit{Sarotherodon melanotheron} (Cichlidae) in a West African lagoon

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Summary

The growth, standing stocks and production of tilapia \textit{Sarotherodon melanotheron} (Cichlidae) in the 1 km\textsuperscript{2} Sakumo Lagoon near Tema, Ghana, are estimated by application of recently developed models to previously published data. The new estimates are used to obtain values of food (i.e. sediment) consumption, some related statistics, and to assess bioturbation as caused by \textit{S. melanotheron}.

Introduction

A detailed account of the biology and ecology of the detritivorous tilapia, \textit{Sarotherodon melanotheron} (Ruppel), in Sakumo Lagoon (Ghana, West Africa) was presented in Pauly (1973, 1975, 1976), based on field data collected in 1971. In the present contribution, a few gaps in this account are filled through reanalysis of some of the data presented earlier, using various recently developed methods and models.
Growth, mortality and biomass estimation

Table 1 summarizes growth parameter estimates in *S. melanotheron*. Their quality being highly variable, we have estimated a set of mean values of $L_{oo}$ and $K$, parameters of the von Bertalanffy growth function or VBGF (Bertalanffy 1938) based on the $\overline{\theta}'$-method of Paul and Munro (1984). This approach, demonstrated to apply in tilapias by Moreau et al. (1986) states that the quantity $\overline{\theta}'$, defined by

$$\overline{\theta}' = \log_{10} K + 2 \log_{10} L_{oo}$$ 

has within species a very narrow normal distribution (CV < 10%). The estimates in Table 1 thus lead to a simplified form of the VBGF, i.e.

$$L_{oo} = 22.3 \left(1 - \exp -0.736 \overline{t}' \right)$$

which predicts (total) length (in cm) as a function of relative age ($t' = t - t_o$) as will be seen below, absolute ages are not needed for this contribution, and hence no attempt was made to estimate the third parameter (i.e. $t_o$) of the VBGF.

The version of the VBGF for growth in weight corresponding to (2) is, given the means in Table 1,

$$W_{oo} = 215 \left(1 - \exp -0.736 \overline{t}' \right)^3$$

Equation (2) suggests that the lone specimen of 19 cm collected by the first author, the largest of 1605 specimens sampled in Sakumo Lagoon, had a relative age $t'_{max} = 2.60$ years. All other specimens ranged between 5 and 16 cm, with the lower value corresponding to a relative age of $t'_{min} = 0.34$ years.

Hoening and Lawing (1982, see also Paul 1984) proposed for the estimation of the coefficient of instantaneous mortality ($Z$) of fish the equation

$$Z = 1 / \left(C_1(t'_{max} - t'_{min}) \right)$$

where $t'_{max}$ is the maximum age observed in a sample of size n (here n = 1605), and where $C_1$ is a table value. Using $t'_{max} - t'_{min} = 2.26$ years and a value of $C_1 = 0.12$ (obtained by

<table>
<thead>
<tr>
<th>#</th>
<th>Sex</th>
<th>$W_{oo}$ (g)</th>
<th>$T_{Loo}$ (cm)</th>
<th>$K$ (y^-1)</th>
<th>$\overline{\theta}'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>143</td>
<td>19.4</td>
<td>1.73</td>
<td>2.81</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>200</td>
<td>21.8</td>
<td>1.37</td>
<td>2.81</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>146</td>
<td>19.6</td>
<td>1.65</td>
<td>2.80</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>173</td>
<td>20.9</td>
<td>2.19</td>
<td>2.98</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>330</td>
<td>25.9</td>
<td>1.68</td>
<td>3.05</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>367</td>
<td>26.6</td>
<td>0.30</td>
<td>2.32</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>338</td>
<td>25.9</td>
<td>1.24</td>
<td>2.92</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>115</td>
<td>18.2</td>
<td>2.55</td>
<td>2.93</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>131</td>
<td>19.0</td>
<td>2.93</td>
<td>3.02</td>
</tr>
<tr>
<td>10</td>
<td>F &amp; M</td>
<td>73</td>
<td>15.2</td>
<td>7.25</td>
<td>3.23</td>
</tr>
<tr>
<td>11</td>
<td>F &amp; M</td>
<td>679</td>
<td>33.0</td>
<td>0.16</td>
<td>2.24</td>
</tr>
</tbody>
</table>

**Means:**

- $W_{oo} = 215$ (g)
- $T_{Loo} = 22.3$ (cm)
- $K = 0.736$ (y^-1)
- $\overline{\theta}' = 2.83$
extrapolation of the second column of Table 5.2 in PAULY 1984) gives $Z = 3.7 \text{ year}^{-1}$ (s.e. = 0.6), which corresponds to an estimate of production/biomass ratio ($P/B$) if steady-state conditions are assumed (ALLEN 1971).

Large predators capable of consuming $S. \text{melanotheron}$ of 5–19 cm total length were absent from (the semi-closed) Sakumo Lagoon during the period of study. Thus, the overwhelming part of production can be assumed to have gone into the fishery catch, consisting of 90% $S. \text{melanotheron}$ and estimated at 15 tonnes year$^{-1}$ km$^{-2}$ (PAULY 1976). The average biomass of $S. \text{melanotheron}$ in Sakumo Lagoon, which has an area of precisely 1 km$^{-2}$ can thus be estimated from

$$\text{mean annual biomass} = \frac{\text{annual catch}}{Z}$$

or $15 \times (0.9/3.7) = 3.65 \text{ tonnes}.$

**Food consumption and conversion efficiencies**

PAULY (1976) estimated that $S. \text{melanotheron}$ of 20 g ingested 1.5 g (dry weight) of bottom mud per day, containing 1200 cal g$^{-1}$, of which 50% were assimilated. The growth rate of $S. \text{melanotheron}$ of 20 g can be estimated from the first derivative of equation (3), i.e.

$$\frac{\text{dw}}{\text{dt}} = 3 \times K W [(W \omega / W)^{1/3} - 1]$$

corresponding here to 53.3 g year$^{-1}$ or 0.146 day$^{-1}$. This corresponds, assuming 1 g wet weight = 1000 cal, to 146 cal day$^{-1}$.

With gross food conversion efficiency ($K_1$, IYLEV 1939) defined as

$$K_1 = \frac{\text{growth increment}}{\text{food ingested}}$$

$K_1$ can be computed from the above data, i.e. $K_1 = 146/1800 = 0.8811$. PAULY (1986) defined the parameter beta through a model relating $K_1$ and body weight

$$K_1 = 1 - (W/W \omega)^{\beta}$$

Using 0.0811,20 and 215 as estimates of $K_1$, W and $W \omega$, respectively (see above) leads to an estimate of $\beta = 0.0356$.

The value of $\beta$ completes the set of values needed to estimate the food consumption per unit biomass of an age-structured fish population ($Q/B$) using the model of PAULY (1986), which can be expressed as

$$Q/B = \frac{\int_0^\infty \left( \frac{\text{dw}}{\text{dt}} \exp -Zt' \right) \text{dt}}{\int_0^\infty (W \exp -Zt') \text{dt}}$$

and which, given the above inputs, suggests that the investigated $S. \text{melanotheron}$ population consumed annually 35.1 times as many calories as it itself contained. Due to active selection by feeding $S. \text{melanotheron}$, the diatom and detritus-rich mud fraction that is actually ingested has a higher calorific content than the surface sediment itself, i.e. 1200 vs 327 cal g$^{-1}$, respectively (PAULY 1973). The 3.65 tonnes population of $S. \text{melanotheron}$ in Sakumo Lagoon thus stirred up $3.65 \times 0.0962 (1200/327) = 1.3$ tonnes of bottom sediments per day, corresponding to a bioturbation rate (CLIFTON and HUNTER 1973) of 470 g m$^{-2}$ year$^{-1}$.

The mean of available estimates of primary production in Sakumo Lagoon is 352 mg C m$^{-2}$ day$^{-1}$ (see PAULY 1975). This corresponds, for the lagoon as a whole to a primary production of 128 tonnes of carbon per year. Given the fish yield estimate presented above,
of which about 10% can be assumed to consist of carbon (Marten and Polovina 1982), a primary production-fish yield efficiency of 0.0117 can be estimated. This lies on the upper end of the range of 0.0008 to 0.0100 reported by Marten and Polovina (1982) for tropical and subtropical lagoons and estuaries. One can thus conclude that the short food chain which characterizes small West African lagoons (i.e., phytoplankton-detritus-S. melanotheron) is rather efficient, compared to the more complex food webs of other tropical lagoons and estuaries.

References

Pauly, D., 1984: Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies and Reviews 8, Manila, Philippines.

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