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Growth and mortality of the catfish, *Hemisynodontis membranaceus* (Geoffroy St. Hilaire), in the northern arm of Lake Volta, Ghana

P. K. OFORI-DANSON

Water Research Institute, Council for Scientific and Industrial Research, Achimota, Ghana

C. J. VANDERPUYE

Department of Oceanography and Fisheries, University of Ghana, Legon, Ghana

G. J. de GRAAF

NEFISCO, Amsterdam, and EUROCONSULT, Arnhem, the Netherlands

Abstract Estimates of growth and mortality of the catfish, *Hemisynodontis membranaceus* (Geoffroy St. Hilaire), in Lake Volta were obtained from length composition data compiled in 1995 and 1996. The von Bertalanffy growth function (VBGF) estimates were: $L_\infty = 44.5$ cm standard length; $K = 0.62$ year^{-1}; and $t_0 = -0.23$ years. Natural mortality rate, M, was 1.20 year^{-1}. Total mortality rate, Z, was computed as 4.39 year^{-1} and the exploitation ratio ($E = F/Z$) was 0.72. Although the fish is estimated to have longevity of about 5 years, those exploited are normally less than 2 years of age, which is indicative of growth over-fishing. In order to arrest over-exploitation of the species, there is a need to establish 'lake reserves'. In addition, the fisheries management should be devolved from the state to the local level to compel fishermen to take greater responsibility for the sustainability and conservation of the fisheries.

KEYWORDS: growth, *Hemisynodontis membranaceus*, Lake Volta, mortality, over-fishing.

Introduction

The River Volta is the second largest river in West Africa after the Niger. It has four major tributaries: the White, Black and Red Volta and the Oti (Fig. 1), the catchment areas of which cover roughly two-thirds of Ghana. A dam at Akosombo led to the creation of Lake Volta in 1964.

During the last three decades, the lake has undergone great changes in its ecology, limno-chemistry and socio-economy. For instance, increased pressure on land along the

Correspondence: P. K. Ofori-Danson, Water Research Institute, Council for Scientific and Industrial Research, P.O. Box 38, Achimota, Ghana. Fax: +233 21 777665/761030 (e-mail: wri@ghana.com)

banks has led to high rates of deforestation. This has resulted in increased soil erosion leading to the transportation of high loads of silt and nutrients through rivers into the lake, thereby contributing to its eutrophication. Furthermore, wetlands bordering the lake are being converted into agricultural land or land for grazing cattle, and therefore may not be able to act as natural filters for nutrients and silt, and now do not provide breeding grounds for many fish species.

In anticipation of these problems, multi-disciplinary studies under the Volta Lake Research and Development Project (VLR&DP) were undertaken mainly under the aegis of the Food and Agricultural Organization/United Nations Development Programme (FAO/UNDP) during the first decade of the lake's existence (FAO/UNDP 1971, 1979). These studies came to an end when the VLR&DP was phased out in 1978. Since then, systematic data collection from the lake's natural resources has been lacking. There have been calls for renewed studies to facilitate their management due to declining catches with possible stabilization of the lake's ecology after 30 years of impoundment.

This paper focuses on catfish, *Hemisynodontis membranaceus* (Geoffroy St. Hilaire), which is one of the five major commercially important species encountered in the northern arm of the lake. This zone currently constitutes the heaviest fish landing sectors

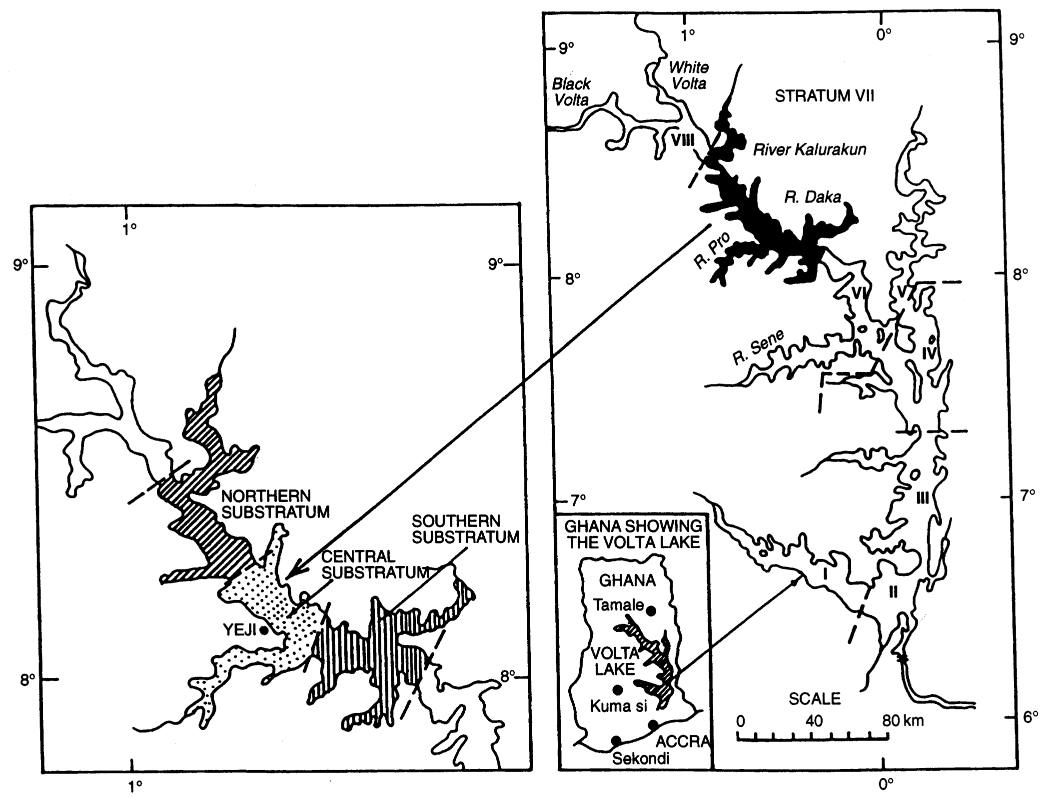

Figure 1. Map of Lake Volta, Ghana.

of the lake, and boasts the largest fish market on the lake at Yeji (Agyenim-Boateng 1989).

Management of the fisheries sector in the country has so far been inadequate, with issues of equity and sustainability only recently being addressed. The sector is facing major problems such as over-exploitation of some fishery resources, inadequate information for planning and management, destructive fishing practices, habitat damage, conflicts between fisheries and post-harvest losses. The primary objective of the study is to provide information that is relevant to the management of synodontid catfish in Lake Volta.

Materials and methods

Sampling and data source

Two-stage stratified sampling method was implemented. In the first stage, the water areas in stratum VII, the Yeji region, were geographically divided into three minor strata, namely: northern sub-stratum; central sub-stratum; and southern sub-stratum (Fig. 1). Further stratification was based on the size of the fishing site or village as follows: small site (having 0–10 canoes); medium site (having 11–50 canoes); and large site (having more than 50 canoes). The canoe catch and fishing effort were recorded in a specific catch assessment survey (CAS). For this, three fish landing sites were selected in the northern and southern sub-strata, respectively, and four sites were selected in the central sub-stratum.

Length composition of the catch

Monthly length frequency (standard length, *SL*, to the nearest centimetre) data were compiled from sample length measurements during experimental fishing with a purse seine (locally called winch-net), and the distributions determined at 1.0-cm length intervals. Appropriate routines of FISAT (Gayanilo, Sparre & Pauly 1995) were employed to correct the length frequency data for possible selectivity of the purse seine.

Growth parameters

Fish growth was assumed to follow the von Bertalanffy growth function (VBGF), which has the basic form: $L_t = L_\infty[1 - \exp(-K(t - t_0))]$

Estimates of the von Bertalanffy growth parameters, the asymptotic length (L_∞) and the growth coefficient (K), were derived using the ELEFAN routine in the FISAT suite of programs (Gayanilo *et al.* 1995). The theoretical age at length zero (t_0) was obtained from Pauly's (1979) equation:

$$\log_{10}(-t_0) = -0.392 - 0.275 \log_{10} L_\infty - 1.038 \log_{10} K$$

Longevity and growth performance index (φ')

Longevity was calculated from Pauly's (1984) equation: $t_{max} = 3/K$. Pauly and Munro's (1984) growth performance index (or phi-prime index) φ' was computed from the equation: $\varphi' = \log_{10} K + 2 \log_{10} L_\infty$.

Mortality parameters

Total annual instantaneous mortality rates, Z, were estimated for each year separately by constructing linearized length–converted catch curves (Sparre & Venema 1992). Natural mortality rates, M, were computed by the empirical equation of Pauly (1980), using a mean annual temperature of 29.8 °C. The fishing mortality rates, F, were calculated as $Z - M$. The exploitation ratio, E, was calculated as equal to the fraction of death caused by fishing (Ricker 1975): $E = F/Z$.

Results

Length–weight relationship

The length–weight relationships for *H. membranaceus* in Lake Volta are as follows: $W = 0.0223SL^{2.9368}$ ($r = 0.9596$) for males and $W = 0.0067SL^{3.2205}$ ($r = 0.9740$) for females. The exponent b is closer to 3 in males indicating that weight growth is isometric.

Growth and mortality parameters

The length frequency distribution for the two successive years from FISAT analyses is shown in Figure 2. A summary of the parameters that describe growth in length (K, L_∞ and t_0) and derived growth performance index (φ') is provided in Table 1.

Using the estimated value of the average growth coefficient ($K = 0.62$ year^{-1}), the longevity, $t_{max} = 3/K$, was calculated as about 4.84 years and the von Bertalanffy growth model for *H. membranaceus* is described as $L_t = 44.1[1 - \exp(-0.62(t + 0.23))]$. From the length–weight relationships and the estimated L_∞, the asymptotic weights (W_∞) were calculated as 1.55 and 1.36 kg, respectively, for males and females. These values are significantly different ($P < 0.05$) and suggest that there are differences between the growth in weight of males and females.

The average instantaneous total mortality rate, Z, was estimated in 1995/96 (Fig. 3) for fish ranging between 14.8 and 30.0 cm SL as 4.39 year^{-1} and the average instantaneous natural mortality coefficient, M, was calculated as 1.20 year^{-1} (Table 1). The reliability of the estimated M was ascertained using the M/K ratio because this ratio has been reported to be within the range of 1.12–2.5 for most fishes (Beverton & Holt 1966). The values of M/K were 1.88 and 2.02 in 1995 and 1996, respectively (Table 1). Thus, the average instantaneous fishing mortality coefficient ($F = Z - M$) was calculated as 3.19 year^{-1} and the exploitation ratio ($E = F/Z$) as 0.72.

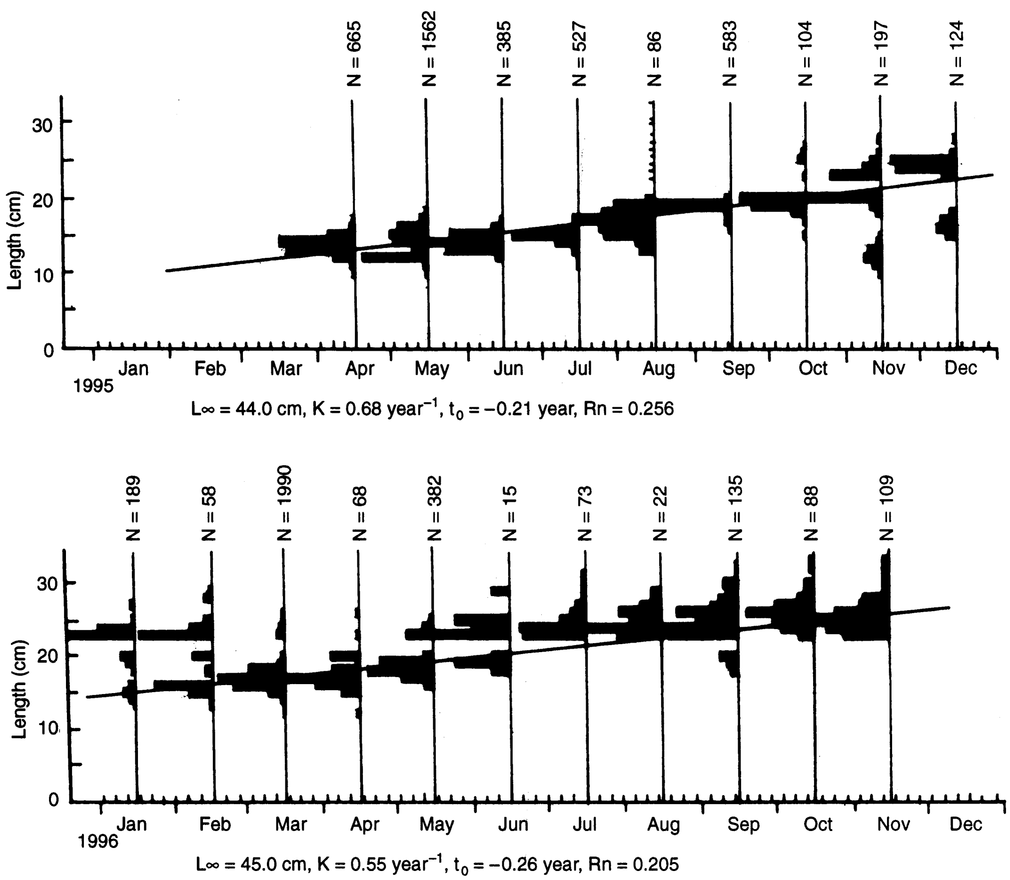

Figure 2. Length frequency distribution output from FISAT for *H. membranaceus* caught in 1995 and 1996 with a superimposed growth curve.

Discussion

The maximum observed size ($SL = 33.0$ cm) for *H. membranaceus* is among the relatively large mochokid species found in the Sahelian waters (Entsua-Mensah, Osei-Abunyewa & Palomares 1995; Machena 1995). Machena (1995) estimated the asymptotic length (L_∞) for *Synodontis zambezensis* (David & Poll) and *Synodontis nebulosus* (Peters) in Lake Kariba as 32.6 cm *TL* and 14.7 cm *SL*, respectively, which further supports the assertion that *H. membranaceus* is among the relatively large mochokid species found in the sub-region.

Baijot & Moreau (1997) estimated that the range of φ' mean values for some important fishes in Africa ranged between 2.65 and 3.32, and considered these as low growth rates. In this study, the φ' mean estimate for *H. membranaceus* was 3.09 which falls within this range; thus, the fish might also be considered to exhibit a slow growth rate in Lake Volta. This slow growth rate in Lake Volta and in some similar water bodies in Africa might be induced by important changes in the physical and chemical characteristics of the waters, accentuated by persistent drought and poor rains over recent years.

The exploitation ratio of the purse seine for *H. membranaceus*, ranging between 14.8 and 30 cm *SL*, was beyond the expected optimal exploitation level, $E_{opt} = 0.5$, indicating over-exploitation by the purse seine. The estimated longevity (t_{max}) for *H. membranaceus* is about 5 years indicating that it is short-lived. However, the fish caught were mostly less than 2 years of age, implying that they are normally caught before they grow large enough to contribute substantially to the stock biomass; this is indicative of growth over-fishing. This was expected because the number of canoes has increased by about 300% between 1975 and 1995 (Coppola & Agadzi 1977; Ofori-Danson 1999). This is in

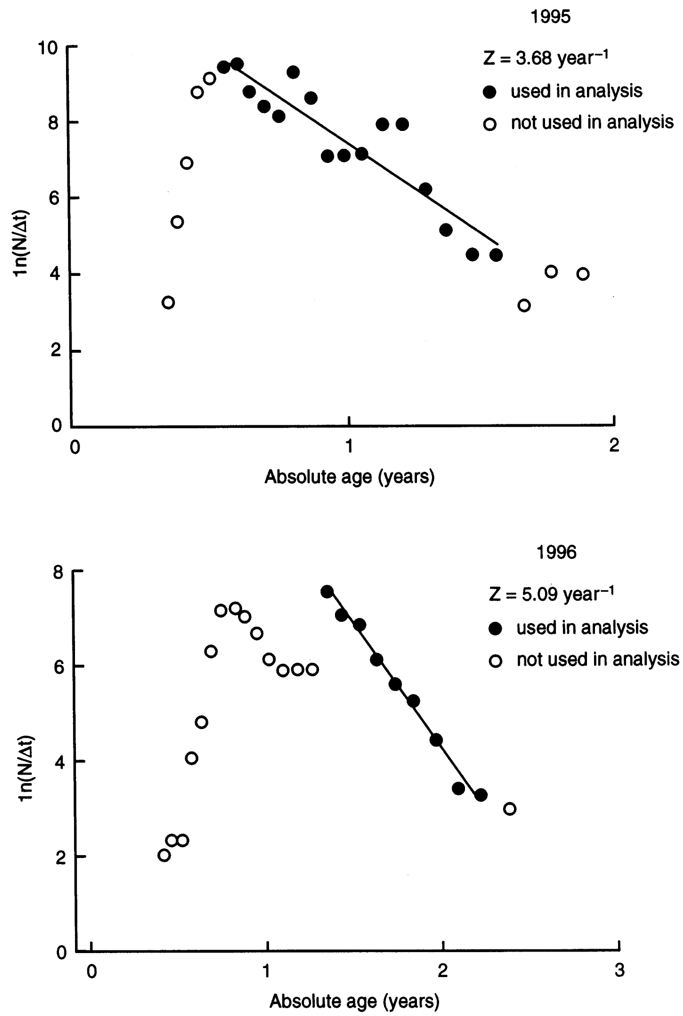

Figure 3. FISAT output of linearized length–converted catch curves for *H. membranaceus* caught from the Yeji area of Lake Volta during 1995 and 1996.

Table 1. Estimated population parameters of *H. membranaceus* caught in the Yeji area of Lake Volta

Parameters	1995	1996	Mean
L_∞ (SL, cm)	44.0	45.0	44.5
K (year^{-1})	0.68	0.55	0.62
t_0 (years)	−0.21	−0.26	−0.23
t_{max} (years)	4.42	5.45	4.84
φ'	3.12	3.05	3.09
M (year^{-1})	1.28	1.11	1.20
M/K	1.88	2.02	1.95
F (year^{-1})	2.40	3.98	3.19
Z (year^{-1})	3.68	5.09	4.39
$E = F/Z$	0.65	0.78	0.72

contrast with findings from the fish stock assessment programme carried out between 1969 and 1977 by the VLR&DP (FAO/UNDP 1979), which reported no sign of over-fishing of the stocks and encouraged increases in fishing effort measured by the number of canoes. It is apparent from the current results that this situation can no longer be recommended for the fishery and that urgent management intervention is required.

The management implication from the results is that the fishery of *H. membranaceus* in Lake Volta is faced with problems of growth over-fishing and economic over-capitalization because effort is increasing without a corresponding increase in catch. It is possible that this situation may apply to the other commercially important fish stocks in the lake (e.g. the Nile tilapia, *Oreochromis niloticus* L., *Chrysichthys* spp., *Labeo* spp. and *Schilbe* spp.). There are simply too many canoes to support the production available.

Currently, fisheries management is solely in the domain of the state working through the Directorate of Fisheries. It is apparent that this system of fisheries management, where access and other development measures are regulated by the state, is now inappropriate. There is therefore a need to devolve fisheries management to the local level to compel fishermen to take greater responsibility for the sustainability and conservation of the fisheries resource. This can be implemented initially through the adoption of a community-based fisheries management (CBFM) approach (Yamamoto 1995; Pomeroy, Pollnac, Predo & Katon 1996). The initial stage would involve the establishment of community-based fisheries management committees (CBFMC), largely composed of members from the fishing villages. The CBFMC would be designed specifically to encourage fishing communities to discuss problems and propose solutions relating to fisheries and the aquatic environment. In addition, the CBFMC must have some control over their adjacent fishing areas, and have the ability to make and enforce their own regulations. The main benefit of the CBFMC to the government is that the conservation actions necessary to exploit the fishery resources on a sustainable basis become the responsibility of the community. The Department of Fisheries would then work to support the undertakings and needs of all fishermen. It is anticipated that ownership of fish resources, access rights to them and adherence to the fisheries management process would gradually be addressed by the CBFMC. In this regard, studies that will elucidate the possibilities for adopting aspects of property rights in fisheries should be commissioned for Lake Volta.

Meanwhile, a more practical means to arrest over-exploitation of the species and contribute to the protection of the fishery as a whole would be the periodic prohibition of fishing in certain areas. This may be achieved through the establishment of 'lake reserves' to protect the spawning stock biomass and through the monitoring of their effects as a management strategy. Unfortunately, preventing fishermen from fishing in certain areas often has intangible benefits to them. Thus, it is necessary to address some of the many social problems in the lake area (e.g. poverty, education, growing population and employment) in order to win the support of fishermen and make changes in behaviour possible. The areas to be delineated as 'lake reserves' should be chosen on the basis of sound research and fishermen collaboration.

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