Growth, Mortality Rates and Exploitation of Cichlids in Anthropological Coastal Zone in the North of Lake Tanganyika

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Abstract

Population parameters of main cichlids species from the anthropological coastal zone of the north of Lake Tanganyika were investigated using length-frequency data sampled tri-monthly (between February 2011 and September 2012) and analysed using the FiSAT software package. Extreme values estimated were L_∞ = 35 cm (K= 0.2 year^{-1}) for Boulengerochromis microlepis (Boulenger, 1899) and $L\infty$ = 11 cm for Auronocranus dewindti and Callochromis pleurospilus (with K-values of 1.1 and 1 respectively). Extreme Φ'-values were 2.1 and 2.5 for C. pleurospilus and Limnotilapia dardennii respectively. Except for C. pleurospilus with M/K<2, M/K > 2 noticed for other species indicated that species have short longevity. The high natural mortality rate M recorded could be attributed to the prohibited fishing practices in use and to the environment degradation. Moreover, the Z/K>2.9 recorded for all species and the E- values calculated (E=F/Z) higher than 0.5, E_{50} and E_{max} (predicted maximum exploitation rate) indicated that fishes are overexploited.

Keywords: population parameters, fish cichlids, coastal zone, Lake Tanganyika

1. Introduction

In Africa, aquatic ecosystems biodiversity is threatened by increasing subsistence and commercial fishing activities (Daget 1988; Lévêque & Paugy 1999). The degradation of the aquatic environment due to siltation, erosion, deforestation, and also possibly to water supply shortage, associated with limited rainfall, are also a matter for concern. The enormous diversity of Lake Tanganyika with its cichlid and non-cichlid fish species flocks and its importance as cradle and reservoir of ancient fish lineages seeding other radiations has resulted in a significant body of literature in the fields of biodiversity and evolution. The lake also contains several invertebrate taxa that underwent radiation *in situ* (Vanhove *et al.*, 2013). According to Lowe Mac Connel (1995), the Lake Tanganyika is known for its endemic fauna. Indeed, on about 1500 species of vertebrate and invertebrate already inventoried, 600 of them are endemic. About 70% of endemic species are fishes and close to 90% of them belong to the family of Cichlids. Devos & Snoeks (1994) had recorded 22 fish families distributed in 101 genera with 337 species among who 247 species are cichlids. According to Fermon and Nshombo (2013), the Lake Tanganyika is an important animal protein resources area and close to 30 million people live in its watershed. However, due to conflicts and movements of populations, several facts have led to a depletion of fish stocks.

According to Naiman *et al* (1990) cited by Bigirimana (2005), the coastal zones are very rich in nourishing sources at all trophic levels and serve to the reproduction sites, shelter against predators and growth for many species including pelagic species. In spite of this coastal zone importance in the biodiversity maintenance and in the ecosystems production, those of the north zone of the Lake Tanganyika appear very vulnerable to all shapes of human influence (spontaneous districts birth on Lake sides, urbanization, industrialization, increase of sediment from the pouring basins, etc.). The various shapes of degradation (pollution, destruction of banks that are privilege places of fishes reproduction, intensive fishing with inappropriate fishing gears, etc.) observed in this zone are due especially to the presence of the Bujumburas cities (capital of Burundi) and Uvira (in D.R. Congo, situated of the west side) implanted close to the lake. According to Devos and Snoeks (1994), the most abundant Cichlids species in the Lake Tanganyika belong notably to the genera of *Bathybateses, Boulengerochromis, Callochromis, Cyathopharynx, Hemibates, Trematocara, Xenotilapia, Oreochromis, Limnotilapia.* Some of them, generally coastal, are more interesting for consumers. Those are *Boulengerochromis, Bathybates, Oreochromis, Limnotilapia,* etc.

In spite of this cichlids abundance in the coastal zones and their importance both in food security and as source income, little is known on their dynamics population. Indeed, the majority of available studies concern either biodiversity (Devos & Snoeks, 1994, Allison *et al.*, 2000) or fishing practices or production estimate and evolution of the main and commercial interest species (Evert, 1989; Cohen, 1999; Petit, 2000; etc.). Actually, it is noticed that no survey on the human activities impact (fishing practices, pollution of anthropological origin, etc.) on the population dynamics of cichlids fish has not been carried out yet. Unfortunately, these informations are very important in conservation plans and management sustainable particularly on the coastal anthropological zones in the north of Lake Tanganyika. The aim of this paper is to bridge this gape in knowledge by providing information on the reproduction, growth, mortality and yield of some cichlids of coastal anthropological zone on the north of Lake Tanganyika.

2. *Materials and Methods*

2.1. Study area and Sampling Sites

Situated between latitudes 03°20 ' and 08°48'S and longitudes 29°03' and 31°12'E, the Lake Tanganyika is a stretched international lake (Kelly, 2001; Langenberg, 2008) and shared between four countries (Burundi, Democratic Republic of Congo, Tanzania and Zambia (Figure 1). With time, big agglomerations have been erected around this lake. It is about Bujumbura in Burundi, Uvira, Kalemie and Moba in D.R.Congo, Kigoma and Kipili in Tanzania and Mpulungu in Zambia. These places of population are scattered in the basin pouring the Lake Tanganyika and shelter a variety of industries and potentially polluting activities (Bakevya *et al*., 1998). Measuring 673 km to its main axis, the Lake Tanganyika is the longest of the world, and account between 12 and 90 km of width with an inshore perimeter of 1.838 km (Hanek *et al*., 1993 in Kelly, 2001). With a surface of 32800 km², a maximal depth of 1470 m and a volume of 1880 km^3, he is among the world lakes the more voluminous and deepest (Branchu *et al*., 2005). According to Hassan (2006), sources of pollution susceptible to cause some serious problems are notably the domestic garbage, the culture with manures and pesticides, harbors, embankments and the traffic on lake, the industrial enterprises and the small industrial activities.

The survey was led in the coastal zones of the Lake Tanganyika situated close to the Uvira (D.R - Congo) and Bujumbura (Capital of Burundi) cities. The ambient temperatures vary between 23°C and 24°C. To the extremity of the North of the lake the layer of water oxygenated is thin enough and limit himself to 100 m of depth. In the South basin this concentration reaches 2 mg/l sometimes at 300 m of depth (Plisnier *et al*., 1999). The pH-water varies between 8.5 and 9.2. For the purpose of this study, six areas were considered: three on the Burundian coast (Mouth of the Rusizi River, Bujumbura Port and Nyamugari) and three on the Congolese coast (Kilomoni, Maendeleo and Kalimabenge) on other hand. On all sites, fish species undergo strong pressure of fishing and negative effects of various shapes of aquatic environment deterioration due to human activities.

2.2. Fish Sampling and Data Analysis

From February 2011 to September 2012 and tri-monthly fish samples were obtained from the study area with the assistance of artisanal fishermen using various fishing gears (lines, seine nets, gill nets, etc.). In order to complete artisanal fishing data, experimental fishing was simultaneously. So, fishing was done with multi-meshed nylon gillnets (15-35 mm mesh sizes). The total length (TL) of each specimen was measured to the nearest 0.1 cm.

Length frequency data were analysed using the FiSAT software package (Gayanilo *et al.* 2002). The eleven fish species concerned by this study are those with sufficient data for a better use of FiSAT Software. Those are *Auronocranus dewindti* (Boulenger, 1899), *Bathybates minor* Boulenger, 1906, *Boulengerochromis microlepis* (Boulenger, 1899), *Callochromis pleurospilus* (Boulenger, 1906), *Cardiopharynx dewindti* (Poll, 1942), *Limnochromis auritus* (Boulenger, 1901), *Limnotilapia dardennii* (Boulenger, 1899), *Trmatocara variabile* (Poll, 1953), *Triglachromis otostigma* Regan, 1920, *Xenotilapia flavipinnis* (Poll, 1985) and *Xenotilapia sima* Boulenger, 1899. ELEFAN I was used to estimate the growth parameters based on the von Bertalanffy growth formula (VBGF) expressed in the form (Pauly 1979): $Lt = L\infty$ [1-e – K (t-to)] where Lt: the predicted length at age t; $L\infty$ (cm) is the asymptotic length; K (per year) is a growth constant (Pauly 1980). The overall growth performance index Φ' was quantified using the model of Munro & Pauly (1983): Φ' = 2 log $L\infty$ + log K. The potential longevity of the fish was estimated according to equation: $t_{max} \approx 3/K$ (Pauly 1980). The parameters, $L\infty$ and K, obtained were used as input to length –converted catch curves to obtain estimates of total mortality (Z), following Pauly (1983). Natural mortality (M) was estimated using the empirical formula of Pauly (1980); viz.: log M = 0.0066 log K + 0.279 log $L\infty$ + 0.4634 log T where T is the mean annual environmental temperature (°C). In Lake Tanganyika area, it is around 28°C. The fishing mortality rates, F, were calculated as Z-M.

The ascending left arm of the non-seasonalized length-converted catch curve was used to compute the probability of capture (P) of each size class *i*. This involves dividing the number of fishes actually sampled by the expected numbers (obtained by extrapolation of the straight portion, i.e. the ascending part of the catch curve) in each length class of the ascending part of the catch curve. By plotting the cumulative probability of capture against class midlength, a resultant curve was obtained from which the length at first capture L_c was taken as corresponding to the cumulative at 50 %. The seasonal recruitment pattern of the fish was reconstructed using the entire restructured length-frequency data set. This involved projecting backward, along a trajectory described by the computed VBGF, all restructured length-frequency data onto a 1-year time scale (Pauly 1987). Then, employing the maximum likehood method, the distribution was resolved into its Gaussian components using the NORMSEP (normal separation) procedure of Hasselblad (1966). The model of Beverton & Holt (1966), as modified by Pauly & Soriano (1986), was used to predict the relative yield per recruit (Y'/R) of the species to the fisheries. (Y'/R)= E^{UM}/K [1-(3U)/ (1+m) + (3U²)/ (1+2m)-(U^3)/ (1+3m)]; where, E=F/Z= current exploitation rate, i.e., the fraction of death caused by fishing activity, F = the instantaneous fishing mortality coefficient, U= 1-(L_c/ $L\infty$) = the fraction of growth to be completed by the fish after entry into the exploitation phase, m = (1-E)/ (M/K) = K/Z. The relative biomass per recruit (B'/R) was estimated as: B'/R= (Y'/R)/F. Then, E_{max} (exploitation rate producing maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of Y'/R is 10% if it's virgin stock) and $E_{0.5}$ (the exploitation rate under which the stock is reduced to half its virgin biomass) were computed through the first derivative of Beverton & Holt (1966) function.

3. Results and Discussion

3.1 Growth Parameters and Recruitment

The estimated growth parameters ($L\infty$, K), potential longevity (t_{max}) and growth performance index (Φ') are summarized in table I. The length frequency distributions and the estimated VBGF curve are shown in figure 2. The Rn value obtained in the present evaluation is 0.314. The Rn-values obtained vary between 0.232 and 0.972 respectively for *Trematocara variabile* and *Auronocranus dewindti*. The table 1 shows small $L\infty$-values with high K-values. The smallest $L\infty$-value ($L\infty$ =11 cm, TL) were recorded for *A. dewindti* and *Callochromis pleurospilus* (with K-values of 1.1 and 1 respectively). The highest $L\infty$-value (35 cm, TL) with K-value of 0.2 $year^{-1}$ was noticed for *Boulengerochromis microlepis*. On the all fish cichlids concerned by the present study, the only one species which it is possible to find $L\infty$ and K-values in literature (Iles, 1971) is *Boulengerochromis microlepis* in south of the Lake Tanganyika (Tanzania coast). $L\infty$ (=52.9 cm, TL) and K (=0.56 $year^{-1}$) found were higher than $L\infty$ and K-values obtained during this study.

The overall growth performance indexes Φ' recorded in this study vary between 2.1 and 2.5 for *Callochromis pleurospilus* and *Limnotilapia dardennii* respectively. The mean Φ'-value for the all studied cichlids is 2.3 with a weak variation coefficient (V.C= 6.3%). Indeed, Pauly *et al.* (1998) have shown that closely related species have similar values of Ø', even if their $L\infty$ and K-values differ. As for $L\infty$ and K-values, previous studies for Ø'-values are very scarce, except for *Boulengerochromis microlepis* for which Ø'=3.2 recorded in the south of Lake Tanganyika (Tanzania coast) (Iles, 1971) was very higher than Ø' obtained in the present study.

The Φ'-values obtained in the present study are lower than those of other cichlids in tropical aquatic ecosystems as showed by Niyonkuru *et al.* (2007), Niyonkuru (2007), Niyonkuru *et al*. (2012) for *Sarotherodon melanotheron* Rüppel, 1852, *Tilapia guineensis* (Bleeker in Günther, Dokouin, 1862) and *Hemichromis fasciatus* Peters, 1852 in brackish water like Nokoué and Ahemé lakes where Φ'-values for the three species exceed 2.5. About the recruitment patterns the figure 4 analyses showed that some species such as *Triglachromis otostigma, Xenotilapia sima, Limnochromis auritus* and *Boulengerochromis microlepis* have only one peak situated between June and August corresponding on dry season. For other species such as *Limnotilapia dardennii, Trematocara variabile, Xenotilapia flavipinnis, Callochromis pleurospilus Cardiopharynx dewindti* and *Bathybates minor it appears* two peaks periods which are not clearly separated. These results show that there is no marked recruitment seasonality of cichlid fishes in the study area.

3.2. Mortality Rates and Related Parameters

The length converted catch curves are presented in figure 3. Instantaneous mortality rates M, Z and F as well as M/K and Z/K ratios are given in table 2. The natural mortality M seems very high for all studied species and varies between 0.52 to 2.3 $year^{-1}$ respectively for *Boulengerochromis microlepis* and *Auronocranus dewinndti*. According to Sparre & Venema, (1992), if M is high, the fish reach early in their life the age where loss due to natural mortality exceeds the gain in biomass due to growth. Therefore, the size of first capture would allow the fish to be caught before they experience high natural mortalities. Indeed, the high natural mortality rate recorded could be attributed on one hand to the fishing practices in use an on other hand to environment degradation. Concerning fishing practices, it was noticed during sampling data that all cichlids are caught in the most case by prohibited by fishing gears such mosquito nets or gillnets and seine nets with meshes sizes varied between 10 and 30 mm knot to knot. Two techniques of use cast nets were noted. About aquatic environment degradation, as evoked above, water polluted from shapes localities of town are generally drained in the town without in pretreatment. Indeed, due to that pollution, the only source of drinking water catchment in the Lake Tanganyika which was at 800 m from the beach in 1981 has been displaced to 3.500 m by the water and electricity production and distribution, REGIDESO, in acronym.

For populations with weak longevity, the M/K ratio is often very elevated (M/K>2). In the present study, except for *Callochromis pleurospilus* in which M/K ratio is 0.79 (viz. less than 2), M/K > 2 was noticed for all other studied fish species. It means that these species have short longevity in the study area. High values of M and K indicate that these fishes have high biomass renewal rates (P: B). At fishes, the natural mortality has been found greatly correlated with the biomass renewal success (Gunderson, 1997). According to Sparre & Venema (1992), high growth coefficients, small $L\infty$ and high natural mortality M indicate that fishes ripen early and have short longevity. According to these authors, if natural mortality M is high, fishes reach age where the loss due to natural mortality exceeds biomass gain due to growth. So, fishing mortality should be more raised to capture fishes before they die for natural reasons. Fish populations are considered to be below the optimal exploitation when fishing mortality is lower to the natural mortality.

The table 2 shows also that, for all species, Z/K varying between 2.9 to 11.5. According to Barry & Tegner (1989), if Z/K <1, there is predominance of the growth on the population mortality and when Z/K <1, then mortality predominates on the growth. But, if Z/K =1, the population is in a state of balance and then mortality equilibrates itself with growth. In the population where mortality predominates on the growth, if Z/K≈2, then it is a slightly exploited population. During our investigation the Z/K ratio is everywhere higher than 2.9, meaning that all fish species could be slightly exploited in study area.

3.3. Exploitation Level

The table 3 shows that the exploitation level varies in function of each species. Indeed, for some of them E-values are higher than 0.5, meaning that they are over exploited. Those are *Auronocranus dewinndti* (E=F/Z=0.53 with E_{max}=0.453), *Boulengerochromis microlepis* (E= 0.75 with E_{max}= 0.348), *Limnochromis auritus* (E=0.60 with E_{max}= 0.375), *Limnotilapia dardennii* (E=0.64 with E_{max}=0.401) *Xenotilapia sima* (E=0.60 with E_{max} =0.385). For each of them, the E-values calculated (viz. F/Z) are both higher than 0.5, E_{50} and $E_{max.}$ The E_{50} (exploitation rate under which the stock is reduced of half of its virgin biomass) and $E_{max.}$ (Exploitation rate producing the maximum yield) have been calculated from the derivative Beverton & Holt (1966) function. For other species such as *Bathybates minor, Callochromis pleurospilus, Cardiopharynx dewindti, Trematocara variabile, Triglachromis otostigma* and *Xenotilapia flavipinnis,* E-values calculated are smaller than 0.5 traducing that they are not over exploited. The table 3 presents also L_{25}, L_{50} and L_{75} values for each fish cichlid studied.

The table analysis shows small sizes of first capture Lc or L_{50} which vary according to species from 5.5 cm, TL for *Bathybates minor* to 11.13 cm, TL for *Trematocara variabile*. The first capture size, Lc or L_{50}, is, indeed, the size on which 50% of fishes are selected by the fishing gear. These results prove globally that, even if E <0.5 is recorded for some fish species; the majority of different fishes species studied are caught at very small sizes.

Conclusion

During this survey, it has been revealed that the various human activities have negative impacts on the life history of fish populations in general and of fish cichlids in particularity. Indeed, M/K> 2 was globally noticed for all studied fish species, meaning that fishes have shorts longevity in study area. High M and K- values indicate that these fishes have high biomass renewal rates (P: B). The overall growth performance indexes Φ' recorded in this study which vary between 2.1 and 2.5 show that ecological conditions are not favorable for better growth. The various forms of pollution and the prohibited fishing practices could explain high natural and total mortalities rates recorded. All E- Values calculated (viz. F/Z) were both higher than 0.5, E_{50} and E_{max} (predicted maximum exploitation rate) meaning that next to the pollution attributable to the human activities, fishes are also overexploited. Thus, planning and rational management measures in the study area should be considered.

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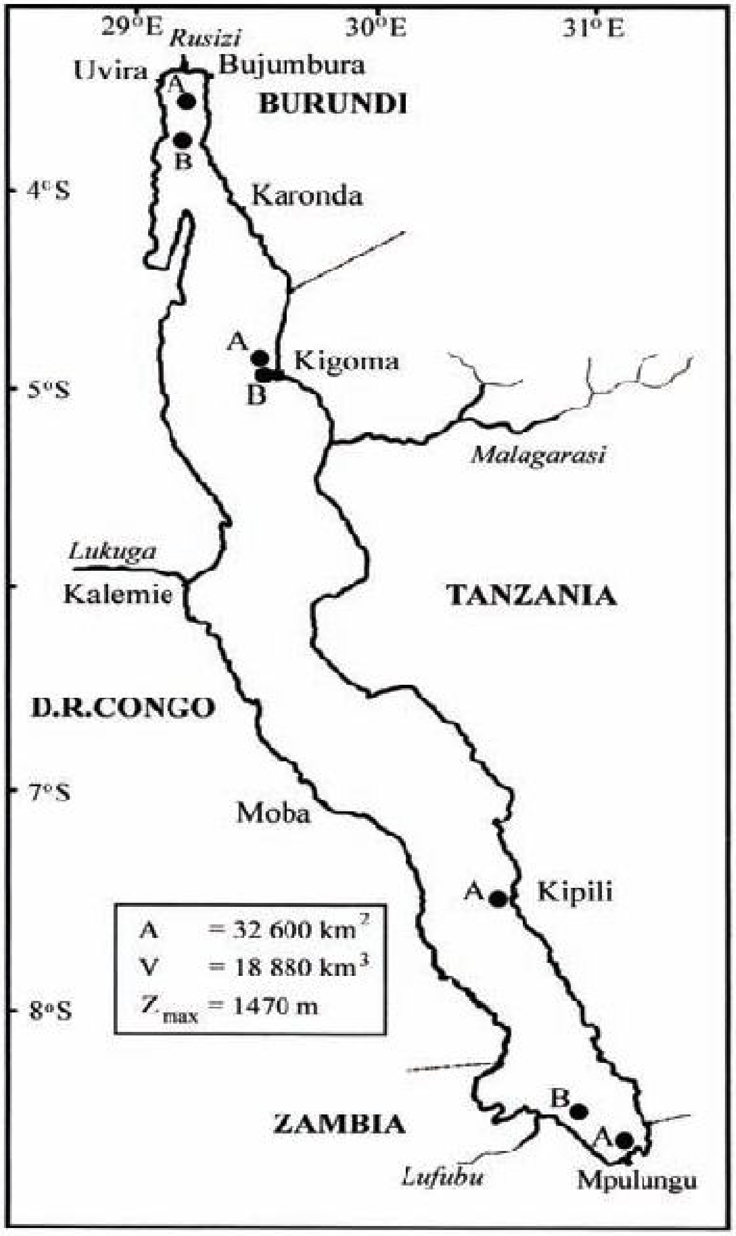
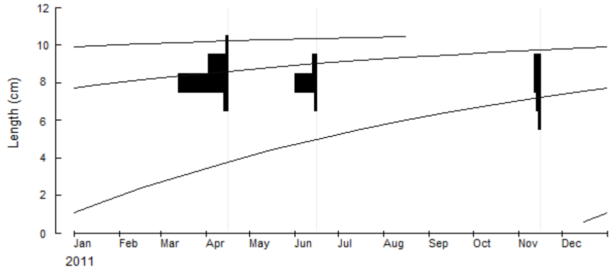
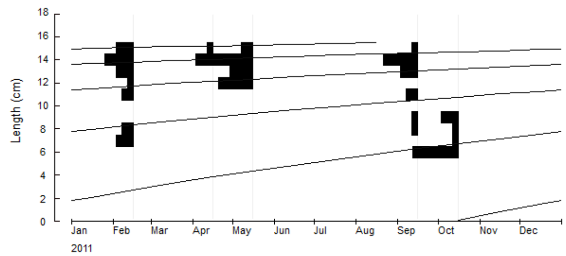


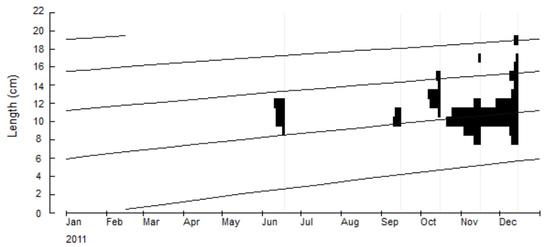
Figure 1: Map of Lake Tanganyika showing the Study Area (North of Lake Tanganyika)



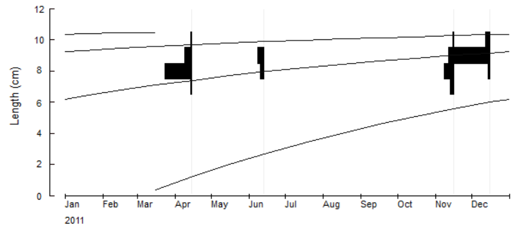
Auronocranus dewinndti



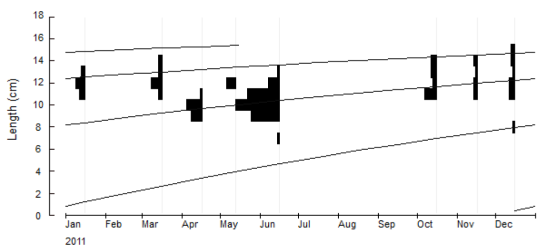
Bathybates minor



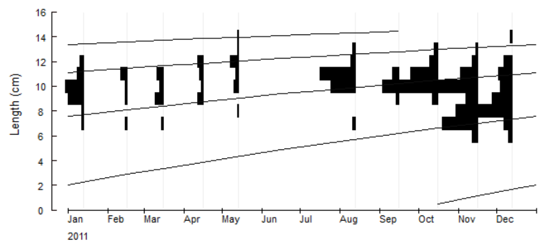
Boulengerochromis microlepis



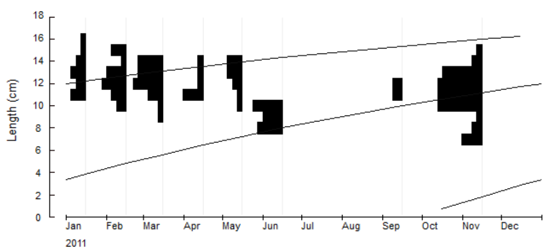
Callochromis pleurospilus



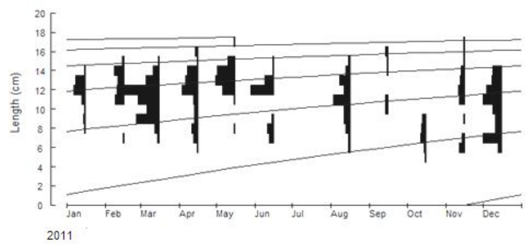
Cardiopharynx dewindti



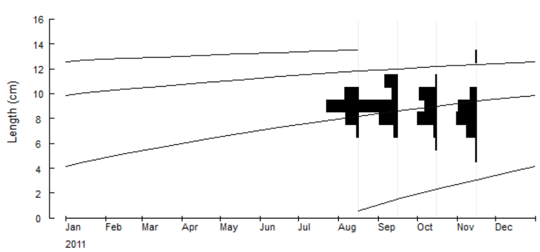
Limnochromis auritus



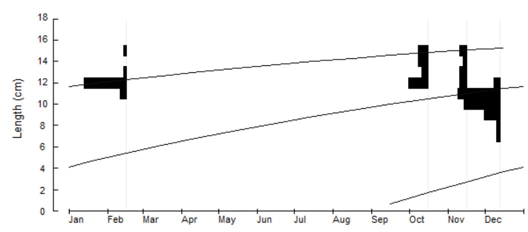
Limnotilapia dardennii



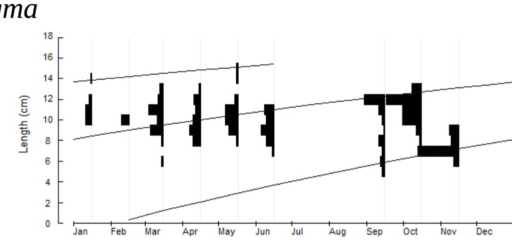
Trematocara variabile



Triglachromis otostigma



Xenotilapia flavipinnis



Xenotilapia sima

Figure 2: Von Bertalanffy growth Curves Using FiSAT. Lines Superimposed on the Histograms Link Successive Peaks of Growing Cohorts as Extrapolated by the Model

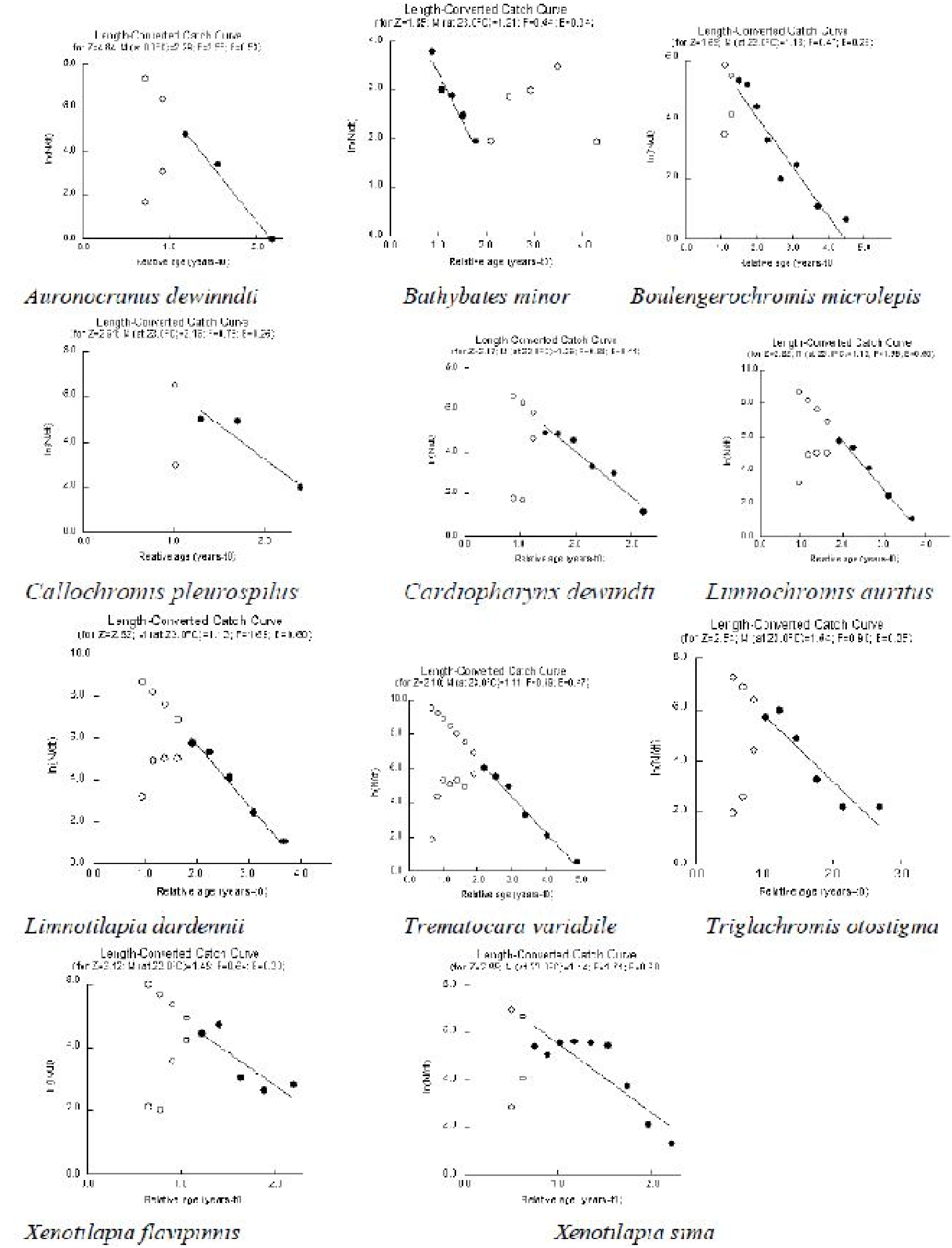


Figure 3: Length-Converted Catch Curves for Different Fish Species

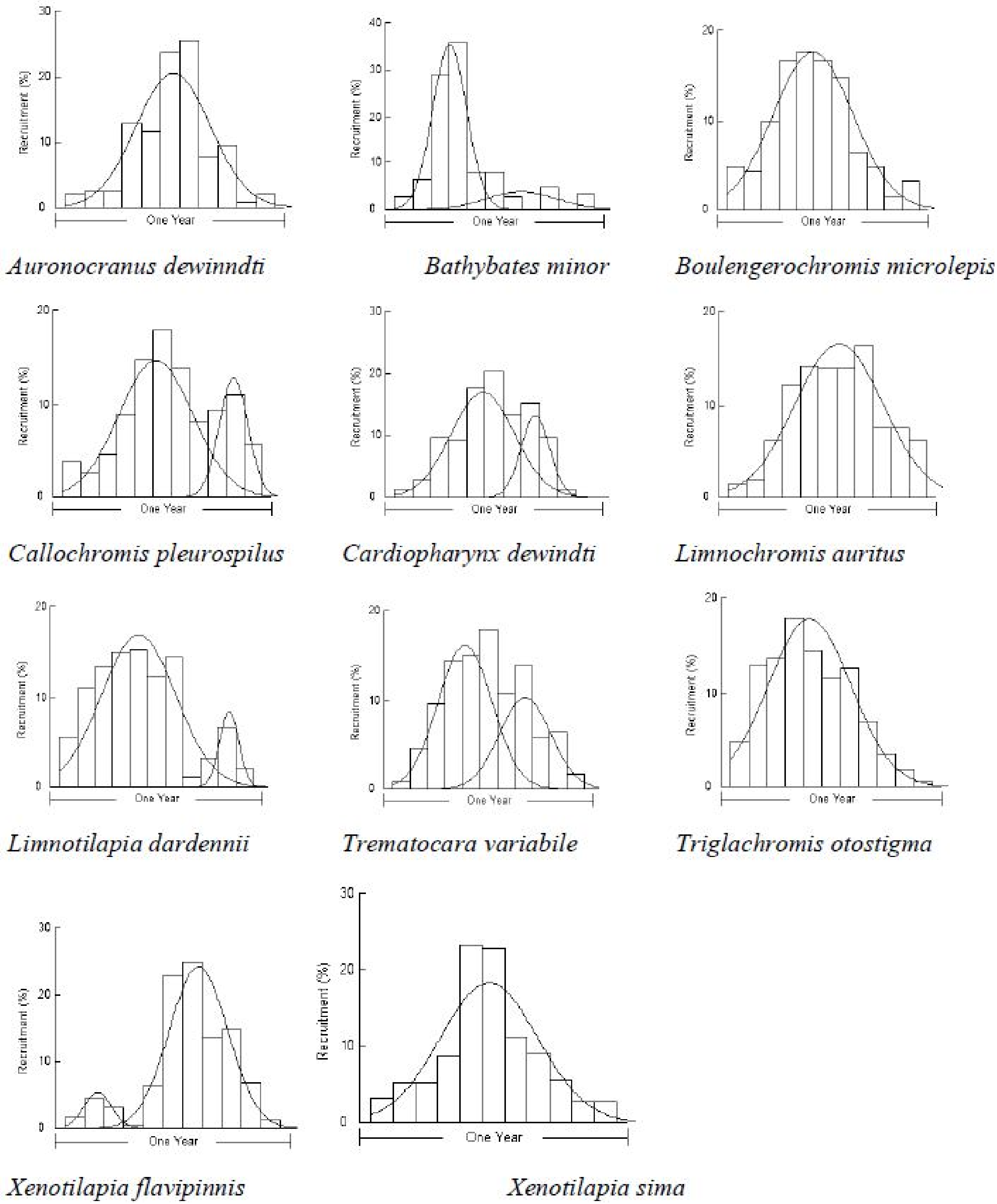


Figure 4: Recruitment Patterns for Different Species

Table 1: Estimates of Growth Parameters

Species	L∞ (TL, cm)	K (year^{-1})	Rn	t_{max} (years)	Φ'
1. *Auronocranus dewindti*	11	1.1	0.972	2.73	2.12
2. *Bathybates minor*	17	0.5	0.648	6	2.12
3. *Boulengerochromis microlepis*	35	0.2	0.476	15	2.4
4. *Callochromis pleurospilus*	11	1	0.413	3	2.1
5. *Cardiopharynx dewindti*	18	0.56	0.365	5.4	2.3
6. *Limnochromis auritus*	17.3	0.45	0.313	6.7	2.13
7. *Limnotilapia dardennii*	21	0.67	0.331	4.5	2.5
8. *Trematocara variabile*	19	0.46	0.232	2.7	2.22
9. *Triglachromis otostigma*	15	0.75	0.398	4	2.23
10. *Xenotilapia flavipinnis*	19	0.71	0.412	4.2	2.4
11. *Xenotilapia sima*	22.2	0.51	0.441	7	2.4

Table 2: Instantaneous Mortality Rates and Related Parameters

Species	M (year^{-1})	M/K	Z (year^{-1})	F (year^{-1})	Z/K
1. *Auronocranus dewinndti*	2.3	2.1	4.85	2.55	4.4
2. *Bathybates minor*	1.21	2.4	1.85	0.64	3.7
3. *Boulengerochromis microlepis*	0.58	2.9	2.3	1.72	11.5
4. *Callochromis pleurospilus*	2.2	0.71	2.91	0.75	2.9
5. *Cardiopharynx dewindti*	1.3	2.3	2.2	0.9	3.9
6. *Limnochromis auritus*	1.13	2.5	2.85	1.69	6.3
7. *Limnotilapia dardennii*	1.39	2.1	3.81	2.42	4.2
8. *Trematocara variabile*	1.11	2.4	2.1	0.99	4.6
9. *Triglachromis otostigma*	1.63	2.2	2.54	0.9	3.4
10.*Xenotilapia flavipinnis*	1.48	2.1	2.12	0.64	2.9
11.*Xenotilapia sima*	1.14	2.23	2.85	1.71	5.6

Table 3: Exploitation Levels

Species	E=F/Z	E_{10}	E_{50}	E_{max}	L_{25}	L_{50}	L_{75}
1. *Auronocranus dewinndti*	0.53	0.363	0.292	0.453	7.91	8.38	8.84
2. *Bathybates minor*	0.343	0.401	0.299	0.468	4.75	5.5	6.25
3. *Boulengerochromis microlepis*	0.75	0.270	0.224	0.348	8.43	9.20	10.2
4. *Callochromis pleurospilus*	0.26	0.308	0.244	0.381	6.72	7.47	8.23
5. *Cardiopharynx dewindti*	0.41	0.305	0.239	0.373	8.43	9.19	9.95
6. *Limnochromis auritus*	0.60	0.306	0.239	0.375	8.5	9.29	10.11
7. *Limnotilapia dardennii*	0.64	0.306	0.259	0.401	9.41	10.21	11
8. *Trematocara variabile*	0.47	0.304	0.238	0.371	10.33	11.13	11.95
9. *Triglachromis otostigma*	0.35	0.315	0.247	0.391	6.59	7.35	8.13
10.*Xenotilapia flavipinnis*	0.33	0.311	0.247	0.387	6.06	9.83	10.70
11.*Xenotilapia sima*	0.60	0.306	0.245	0.385	5.66	6.42	7.19