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POPULATION PARAMETERS AND EXPLOITATION RATE OF *ENGRAULICYPRIS SARDELLA* AND *RHAMPHOCHROMIS SPECIES* IN SOUTHERN LAKE MALAWI: CASE OF LIGHT ATTRACTION FISHERY

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ABSTRACT

Growth parameters (L_∞ and K) and mortality coefficients (Z, M and F) were estimated for *Engraulicypris sardella* and *Rhamphochromis species* caught in southern Lake Malawi using light attraction *(kauni)* fishery. The number of recruitment peaks, growth performance index (ø') and exploitation ratio ($E = F/Z$) was also assessed for each species. Routines in the FAO-ICLARM Stock Assessment Tools (FISAT II), Length Frequency Distribution Analysis (LFDA) software and Excel SOLVER were used to estimate the parameters from length distribution data collected from March to November 2000. The key parameters were used in relative yield (Y'/R) and biomass per recruit (B'/R) analyses to derive reference points and evaluate the exploitation status of the two species caught by light attraction fishery (chilimira nets). Relatively high K and low $L\infty$ values, typical of short-lived tropical fishes, were obtained, combined with high Z, M and F estimates, these results imply low annual survival and high turnover rates. Both *Engraulicypris sardella* and *Rhamphochromis species* exhibited year-round recruitment, with *Rhamphochromis* having two recruitment peaks. The values of current exploitation rates for *Engraulicypris sardella* from light attraction fishery in Southern Lake Malawi seem to be sustainable. However, *Rhamphochromis* values were very high compared to the estimated reference points of E_{max}, $E_{0.1}$ and $E_{0.5}$. Overall, the results indicate that *Engraulicypris sardella* was fished at maximum sustainable yield in 2000 and for *Rhamphochromis* there was over-fishing. The results provide preliminary baseline information (as well as reference points) that can be incorporated into wider reference systems relevant to current fisheries assessment and management in Lake Malawi.

ACRONYMES

ELEFAN:	Electronic Length Frequency Analysis
FAO:	Food Agriculture Organisation
FISAT:	FAO and ICLARM Stock Assessment Tools
ICLARM:	International Centre for Living Aquatic Resources Management (now called World Fish Centre)
LFDA:	Length Frequency Distribution Analysis
NSO:	National Statistical Office
SEA:	South East Arm
SLCA:	Shephard Length Composition Analysis
SWA:	South West Arm

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1 INTRODUCTION

1.1 Environment and biodiversity of Lake Malawi

Lake Malawi is the southernmost lake of the East African Rift Valley lakes, lying from 9° 30' S to 14° 30' S between three riparian countries Malawi, Tanzania and Mozambique (Figure 1). According to Duponchelle and Ribbink (2000) Lake Malawi is one of the oldest (many million years) and largest lakes in the world. Its mean area (29 000 km², Bootsma and Hecky 1993) makes it the 9th largest lake in the world and third largest lake of Africa after Lakes Victoria and Tanganyika (Lowe-McConnell 1993). Lake Malawi is located 472 m above sea level, its maximum depth is 785 m and average depth about 292 m (Bootsma and Hecky 1993). An important characteristic is that more than 80% of the lake is deeper than 200 m (Thompson *et al.* 1996), below which it is permanently stratified and anoxic (Eccles 1974). This basically means that the living space available for the fish and the other components of the food chain is only about 20% of the lake volume. About one third of Lake Malawi's shoreline is steep and rocky whereas two thirds are gently sloping sandy beaches or swampy river estuaries (Lowe-McConnell 1994).

The well known characteristic of the lake is its exceptional fish species richness (Duponchelle and Ribbink, 2000). It harbours more fish species than any other lake in the world (Fryer and Iles 1972). It was estimated that between 500 and 1000 different fish species were present in the lake (Konings 1995), although only about a third were presently described or catalogued by a cheironym (Ribbink *et al.* 1983). Most of these fishes belong to a single family, Cichlidae, apart from 44 species which belong to nine other families (Ribbink *et al.* 1983, Ribbink 1988). With the exception of chambo (*Oreochromis spp.*), all cichlids are closely related species, possibly descended from a single common ancestor (Meyer 1993, Moran *et al.* 1994). This tremendous cichlid fish diversity (Greenwood 1984) has evolved in a very short evolutionary time period, which may have been within the last 200 to 300 years for some species (Owen *et al.* 1990). More than 99% of these cichlid fish species are endemic to Lake Malawi (Ribbink 1991, Turner 1996). Moreover, there is a high degree of intra-lacustrine endemicity, i.e., many species belonging only to particular islands or stretches of shoreline within the lake (Ribbink and Eccles 1988, Eccles and Trewavas 1989). These peculiarities of the lake fishes have led to great interest by the scientific community, challenged by understanding what constitutes the most striking example of rapid vertebrate species radiation known to this day (Turner 1998).

Lake Malawi provides water for drinking, irrigation and domestic use for people living on the lakeshores, and also fish. The value of the lake fishes does not lie only in their scientific interest, but also in their primordial nutritional status (Mkoko B.J. *et al.* 1997, Duponchelle and Ribbink, 2000). The most important resource of the lake is the fish and water itself, which are part of a complex ecosystem that needs to be preserved as a whole if it is to be used in a sustainable way. The fish and the other components of the food chains in the lake rely heavily on the water quality of the lake. Bootsma and Hecky (1993) discussed in detail the physical characteristics (depth, small outflow, and long flushing time) of Lake Malawi and the implications for pollution retention and ecosystem fragility. They pointed out that Lake Malawi's great depth allows the various pollutants to go undetected for many years and its low flushing rate makes the elimination process very long (several centuries). Although the lake is still in rather pristine condition, the first signs of changes have already been observed, as phytoplankton species characteristic of eutrophic systems, which were formerly rare, are becoming progressively more abundant (Hecky and Bootsma 1999).

In Malawi most of the people rely directly on natural resources through agriculture, fisheries and associated activities. The demographic context, shows one of the highest population densities of Africa and the human population has been steadily growing at about 2% per annum (NSO 1998). Two main threats to the fish communities can be distinguished and both are related to changes in the use of natural resources.

Fishing activities are the more direct human influences on fish communities. In the absence of alternative employment, the rapidly growing human population exerts an increasing demand for fish, which entails an increased pressure on the already overexploited stocks (Turner 1995). Despite their huge economical and scientific interests, very little is known about Lake Malawi cichlid fishes. As emphasised previously, only about one third of the fish are described or catalogued and new species are discovered regularly. Paradoxically, the most studied fish are the colourful rock-dwelling haplochromines, which are not exploited except for the ornamental trade (Turner 1995). The fish exploited for food purposes are those that inhabit the shallow and deep sandy shores. They sustain a highly diversified traditional fishery and a localised commercial mechanised fishery that has expanded over the years (Tweddle and Magasa 1989) and, which are according to the most recent assessments, already fully or overexploited (Turner 1995). Fisheries scientists have already shown the critical effects of overexploitation, such as reduction in population size, modification of size structure and some local extinction of the larger cichlid species (Turner 1995). However, while it is believed that cichlid populations are likely to recover from overexploitation, given their life-history characteristics (Ribbink 1991), it has also been suggested that cichlid fisheries may be more resilient than previously thought (Tweddle and Magasa 1989). Nevertheless, "it is essential to distinguish between the resilience of a multi-species fish stock and the vulnerability of individual species" (Turner 1995), because the fishery's resilience might be achieved through the unnoticed disappearance of several species (Duponchelle and Ribbink 2000).

However, Duponchelle and Ribbink (2000) indicated that the present state of knowledge lacks important information concerning the notion of “population” for the exploited species. For example, the same species in two distant parts of the lake could belong to different populations, presenting different life history and/or genetic variations and also morphological differences. In such cases the disappearance of one of these populations would be critical as it would lead to a loss of diversity. As most of the fishing activities occur in the southern part of the lake, studies aiming to determine the population status of the exploited species should be carried out there in order to assess the exploitation rate and potential re-colonisation from less exploited parts of the lake (Duponchelle and Ribbink 2000).

Another environmental threat is related to farming. Together with fishing, agriculture is the most important human activity in Malawi. The steadily increasing human population is a key factor with respect to the degradation of lands in the river catchments, such as deforestation, burning of vegetation, destruction of wetlands on the river banks for agricultural purposes and the cultivation of marginal areas (Duponchelle and Ribbink 2000). All these activities, by removing the vegetation cover, weaken the soil, which is carried away with its nutrients directly in the rivers by the rains and ultimately arrive in the lake. The land clearance burning is also suspected to strongly contribute to the atmospheric phosphorus deposition in the lake. Bootsma and Hecky (1999) reported increased loads of sediments and nutrients received by the lake from rivers and the atmosphere as the main threat to the water quality. Over-fishing and siltation resulting from deforestation have strongly diminished the abundance of potadromous fish species in Lake Malawi (Duponchelle and Ribbink 2000, Tweddle 1992).

1.2 Engraulicypris sardella *(Usipa)*

There is a single biological stock *Engraulicypris sardella* in Lake Malawi and in economic and ecological terms, it is the most significant cyprinid species in the lake. This small shoaling zooplankton feeder is an important component of the pelagic ecosystem in the lake (Turner 2004). Eccles (1992) reported a maximum length of adults being 13 cm (5 inches) in total length, and that it rarely exceeds 10 cm or 4 inches. FAO (1993) indicated that *Engraulicypris sardella* is very important in the economy of the lakeshore communities. It is highly valued by natives both for food and bait. It also forms one of the chief preys for the predators in the open water, such as *Rhamphochromis* and other cichlids. *Engraulicypris sardella* is believed to be an annual species, but relatively little is known of the biology of this ecologically and commercially important fish (Thompson *et al.* 1996).

According to Morioka and Kaunda (2004), hatching in *Engraulicypris sardella* is observed almost throughout the year and growth of juvenile hatched in the rainy season (November to February) is faster than the those hatched in dry season (June and July). The growth rate of *Engraulicypris sardella* in the rainy season was more than 0.70 mm TL per day but less than 0.50 mm TL in the dry season (Morioka and Kaunda 2004). Long breeding periods of *Engraulicypris sardella* strongly suggest the existence of plural stocks, that is, different stocks adapting to the different optimum temperature for reproduction (Morioka and Kaunda 2004).

Engraulicypris sardella is mainly taken by light attraction fishery in chilimira nets in the traditional fishery (58.8% of recorded traditional catches 1976-96), mosquito nets (28.5%) and kambuzi seines (12.3%). Annual catch was less than 3000 tons during the late 1970s and the early 1980s. The largest catch (19 thousand tons) was recorded in 1996 and the catch per unit effort has fluctuated heavily without a trend. High catch per unit effort values were observed in the late 1990s (Bulirani *et al.* 1999).

1.3 Rhamphochromis species *(Ncheni)*

Rhamphochromis are fast swimming predatory haplochromine cichlids endemic to Lake Malawi. They are important members of the pelagic and sometimes deep water communities (Allison *et al.* 1996, Thompson and Allison 1997) and are becoming increasingly important in commercial and subsistence fisheries (Turner *et al.* 2000). There are more than six species of pelagic cichlids of the genera *Rhamphochromis.* The systematics of this group is very confused. Different species appear to have different habitat preferences, some preferring inshore waters while others inhabit the surface layers of open waters and some appear to be largely demersal. Large numbers of small *Rhamphochromis* are caught in shallow waters by light attraction fishery in chilimira nets in the lake and it is not known if all of the offshore or deep water species have inshore-living young or if these represent different species (Turner *et al*. 2002).

Turner *et al.* (2002) stated that nothing had been published on *Rhamphochromis* taxonomy since the 1930s, apart from a few notes in Eccles and Trewavas's big revision of the haplochromine genera in 1989 (Eccles and Trewavas 1989). It seems that there may be several species not described, while a few of the named forms are probably synonyms. Turner (2004) described *Rhamphochromis species* with the following characteristics: *Rhamphochromis longiceps* matures at around 12-15 cm standard length, young ones often found in shallow swampy bays and lagoons, but adults found all over the lake, even in the open pelagic habitats. *Rhamphochromis esox* grows very large to at least 42 cm standard length, living in inshore surface waters and with its juveniles often found in shallow rocky areas. *R. leptosoma* and *R. melanotus* are synonyms. *R. woodi* is one of the largest *Rhamphochromis* reaching to around 40 cm SL, but is more heavily built than *R. esox*. Its juveniles are often caught in bottom trawl catches in the southern part of the lake in fairly deep water (around 50-100 m), but adults seem to live in the open water and are often caught near rocky shores. In rocky habitats, the most common *Rhamphochromis* is the one presently identified as *R. lucius*, which is another species with a big mouth and large teeth like *R. esox.* Turner (2004) concluded that other *Rhamphochromis* species appear to live in deep water over sandy or muddy bottoms while at least one non-described species seems to breed in deep water near rocky shores and it is possible that there is one or more similar-looking species amongst the group (Turner 2004). Juveniles of *Rhamphochromis* species seem to prey on zooplankton switching to fish when it grows larger (Turner 2004).

1.4 Scope of study

This study focuses on light attraction fishery by mid water seines (chilimira nets) and their effects on *Engraulicypris sardella* (Usipa) and *Rhamphochromis* (Ncheni) in southern Lake Malawi. Catches from chilimira nets landing at Mwawa (Kela) beach in the southeast arm and Msaka beach in the southwest arm (Figure 1) were examined for almost one-year to determine the potential effects of the fishery on the stocks.

All stock assessment models are based on rates and the measure of rate is time, which is why the age of the fish caught is needed. However, direct estimation of the age of fish in tropical environments is difficult so stock assessment models for tropical fisheries, especially those in developing countries, are usually implemented in terms of length in which case growth, or the relation between length (size) and time (age) is needed (Mosepele and Kolding unpublished). While length may not be a desirable variable from a mathematical/statistical modelling perspective due to its non-linear relationship with time, it is an attractive measurement from a sampling point of view because it is easily taken in the field. Although requiring a substantial amount of data (Kolding 1996), a length based stock assessment is therefore a convenient method to study fish stocks within a narrow temporal scale assuming a constant parameter system to make the approach valid (Sparre and Venema 1998). The aim of this paper is to make a detailed analysis of the population parameters and exploitation rates of *Engraulicypris sardella* and *Rhamphochromis* in the southern part of Lake Malawi, in this particular case in 2000. The length frequency distributions were analysed to determine growth and mortality rates of an exploited stock, which then provides the basis for long-term potential yield prediction under steady-state assumptions with regard to the biological processes.

This study contributes to the biological and fishery information pool on estimated growth parameters, mortality and exploitation rates, recruitment pattern, yield and biomass per recruit of *Engraulicypris sardella* and *Rhamphochromis* in Lake Malawi

2 MATERIALS AND METHODS

2.1 Data collection

Length frequency data, was collected by the Malawi Department of Fisheries enumerators at Mwawa /Kela beach in southeast arm and Msaka beach in southwest arm (Figure 1). All fish samples (Table 1a and 1b) in the study were collected from traditional fishermen, landing their catches at nearby beaches for local marketing and consumption. The fishes were caught using light attraction fishery in chilimila nets (open water seines). A total of 1393 and 5562 *Engraulicypris sardella* were sampled in the southeast arm and southwest arm, respectively whereas 3865 and 3652 *Rhamphochromis* were sampled in the southeast and southwest arms, respectively for length frequency data. Each landing site was sampled for three consecutive days per month during the sampling period. Within each month, the three-day sampling period was randomised and length frequency data was taken only from a sub-sample of the catch (Weyl *et al*. 2004).

Table 1: *Engraulicypris sardella* and *Rhamphochromis* monthly samples indicating total number of fish sampled each month and length ranges observed.

(a) - *Engraulicypris sardella*

	Southeast arm		Southwest arm	
Month	Number of fish sampled	Length range (cm)	Number of fish sampled	Length range (cm)
April	-	-	1001	5 -11
May	213	5 - 11	1156	5 -11
June	144	5 - 11	-	-
July	42	9 - 12	431	8 - 13
Aug	-	-	1549	3 - 18
Sept	111	4 - 16	722	3 – 14
Oct	631	4 - 16	612	4 – 15
Nov	252	7 - 13	91	4 – 14
TOTAL	1393	4 - 16	5562	3 – 18

(b) - *Rhamphochromis*

	Southeast arm		Southwest arm	
Month	Number of fish sampled	Length range (cm)	Number of fish sampled	Length range (cm)
March	139	8 - 32	-	-
April	223	10 - 47	88	9 – 34
May	324	5 - 26	133	11 – 30
June	88	12 - 32	-	-
July	174	10 - 34	174	12 – 40
Aug	231	11 - 41	225	10 – 38
Sept	1438	5 - 46	803	9 – 26
Oct	812	9 - 46	1252	8 – 38
Nov	436	8 - 42	977	8 – 38
TOTAL	3865	5 - 47	3652	8 – 40

2.2 The study area

The sampling period was March to November 2000, all the information related to catches are based on this period and from two locations, one in the southeast arm (Mwawa/Kela) and another from southwest arm (Msaka). For more details on the sampling procedure see Weyl *et al.* (2004).

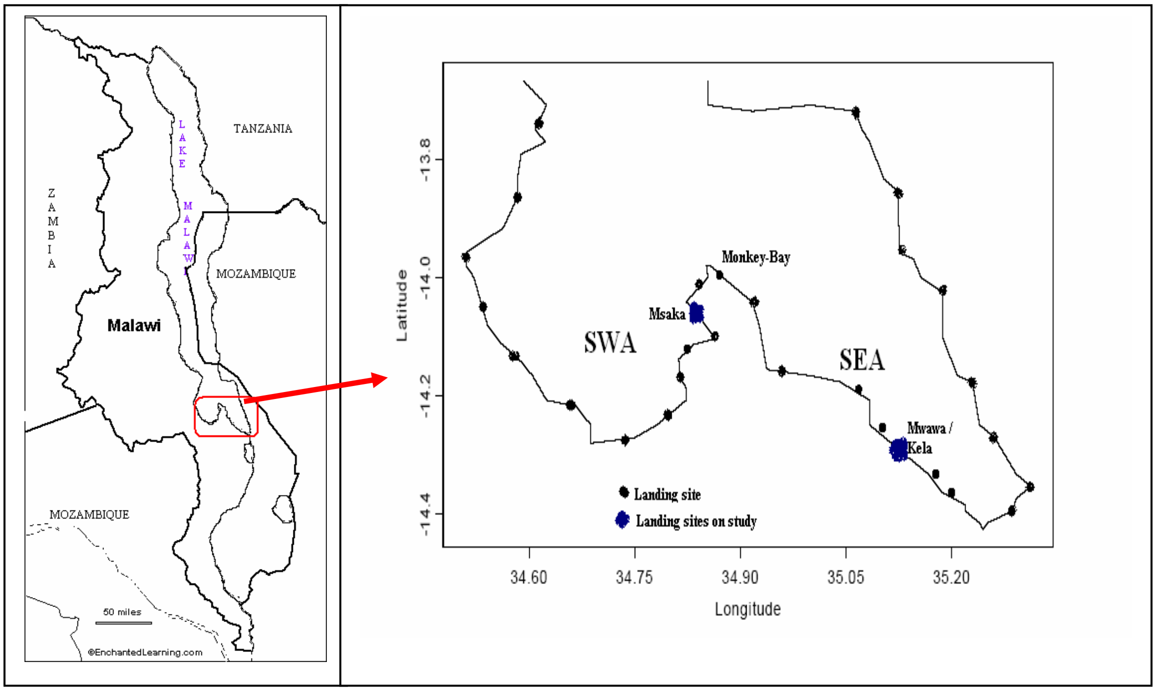

Figure 1: Map of Malawi showing the study areas Mwawa/Kela in the south-eastern arm (SEA)and Nsaka in the south-western arm (SWA).

2.3 Light attraction fishery using open water seines

The pelagic fish in the south of Lake Malawi are mainly taken by mid-water seines locally known as chilimira seine nets operated at night using light from paraffin lamps to attract the fish (Weyl and Banda 2001). Light attraction fishery occurs in both arms of the lake.

The chilimira net is an open-water seine net which has been recorded only in Lake Malawi (Weyl and Banda 2001). It has a conical appearance. The bunt mesh size ranges from mosquito netting to 50 mm and the headline length is from 20 to 90 m. The vertical opening of the net ranges from 5 to 50 m, with a head rope almost always twice as long as the footrope. The net is operated from two dugout canoes and one planked boat with a total crew of nine. The planked boat and the larger dugout are involved in the casting and hauling operations (Weyl and Banda 2001). At night the headman, located in the smaller dugout canoe equipped with a brightly shining kerosene pressure lamp, directs the actions of the crew in the other craft. When a fish school (usually *Engraulicypris sardella*) appears, the fishermen are told to shoot the net. The net is towed in the opposite direction to the movement of the fish. When the fish are caught, the head of the crew joins in hauling the net into the boat and the larger dugout (Weyl and Banda 2001). During the day the net is used for other fish species like the *Copadichromis* (zooplanktivorous, schooling cichlids) as it can quickly be prepared for this by removing the mosquito-net lining, which is needed for catching *Engraulicypris sardella.*

2.4 Catch composition

Light attraction fishery in both the south-eastern and south-western arms of Lake Malawi in 2000 were multi-species, including many different species, many of which were cichlids (Weyl *et al.* 2004). A total of 62 species from 28 cichlid genera and 13 species from nine non-cichlid genera were identified from the samples. Sixty different species were identified from catches sampled in the southeast arm and 51 species from catches sampled in the southwest arm. Of these, 36 species were recorded from both arms, 24 species were recorded only from southeast arm and 15 species were recorded only southwest arm. Of the 37 genera identified, only five, *Copadichromis*, *Dimidiochromis*, *Engraulicypris sardella*, *Oreochromis* and *Rhamphochromis*, contributed more than 5% to the total catch in either arm and their combined contribution to the annual catch was in excess of 85 % in both arms (Weyl *et al.* 2004).

2.5 Definition of length / age cohorts

In order to come up with meaningful cohorts, monthly length-frequency data was fitted with normal distribution curves in Excel. This gave mean monthly lengths and standard deviation using the formula:

$$f(x) = \frac{N.dl}{SD.\sqrt{2\pi}}.\exp\left(-\frac{(x-\bar{X})^2}{2.SD^2}\right)$$

Where *N* is the number in the distribution, S^2 is the variance or standard deviation, *x* bar is the mean value and *dl* is the step length or length interval of frequencies.

2.6 Growth

Analysis and processing of length data were conducted using the Length Frequency Distribution Analysis (LFDA Version 5.0, Kirkwood *et al.* 2001) together with FAO-ICLARM Stock Assessment Tools (FISAT II, FAO packages 2002). It was assumed that the growth of *Engraulicypris sardella* and *Rhamphochromis* conforms to the von Bertalanffy growth model. Estimation of growth parameters ($L\infty$, K, t_o) of the von Bertalanffy growth curve was done by defining grid boundaries using SLCA (Shepherd's Length Composition Analysis) and ELEFAN (Electronic Length Frequency Analysis). When several pairs of $L\infty$ and K parameter estimates were identified by the LFDA (1992) programme the pair with the value of $L\infty$ and K that were giving maximum score per chosen defined grid after several trials and iterations was chosen. These values were taken to be near the maximum observed length of the particular species (Kirkwood *et al.* 2001).

In addition, parameters were estimated using Excel SOLVER by least squares minimization. The use of a sum-of-squares residual function (RSS) to estimate some parameters is known as least squares analysis, a method that can be used for linear and non-linear functions. The method of least-squares therefore estimates the required model parameter values by minimising the squared residuals. SOLVER in the Excel Tools menu was the one used in this study. An assumption was made that both *Engraulicypris sardella* and *Rhamphochromis* of 0.1 year old were 1 cm in length, in order to have the best fitted von Bertalanffy curve from the origin. Growth parameters *L*∞ and *K* were used in fitting the von Bertalanffy growth equation:

$$Lt = L\infty\left[1 - \exp\left(-K\left(t - t_0\right)\right)\right]$$

Where *L (t)* is the length of the fish at time *t*, t_0 is the "age" of the fish when *L* is equal to zero, *L*∞ is the asymptotic length and *K* is the rate at which the L_t approaches *L*∞ (Munro 1982).

Growth performance index (ø'), a way of comparing the growth rate of a species in a particular fishery to the standard growth rate of the species, was also performed. The growth performance index, $\phi' = \ln K + 2\ln L\infty$ (Munro and Pauly 1983), was computed using the *L*∞ and *K* values derived for each species.

2.7 Mortality and exploitation rates

The total mortality coefficient, Z (year^{-1}), was estimated using the linear length-converted catch curve method incorporated in FiSAT, using the final estimates *of L*∞ and *K* and the length distribution data for the species (Gayanilo and Pauly 1997). Assuming constant recruitment and constant mortality the length converted catch curves takes the form:

$$\ln\left(\frac{N_i}{dt_i}\right) = a + Z_i$$

Where *N* is the number of fish in length class *i*, dt_i is the time needed for the fish to grow through length class *i*, t_i age of the mid-length of length class *i* corresponding to the mid length of class *i*, and where *Z*, with sign changed, is an estimated total mortality. The von Bertalanffy growth parameters derived as described in the previous section were used as input data for the estimation.

Natural mortality rate (*M*) is usually a difficult parameter to estimate in an exploited resource (FAO 1993). Most of the procedures rank no higher than 'qualified' guesses (Sparre *et al.* 1989). The natural mortality, *M* (year−1), for each species was estimated using Pauly's (1980) empirical equation relating *M, to, L*∞*, K* and mean environmental temperature (taken as 23 °C in this study) given temperature ranges from 20 to 27 °C.

$$\ln M = -0.0152 - 0.279\ln L_\infty + 0.6543\ln K + 0.463\ln T$$

Where *T* is the average annual temperature at the surface in °C. Fishing mortality rate (*F*) was calculated as *Z - M*. Differences in temperature are likely to have a minimal effect on estimates of *M* for these species, given the narrow temperature ranges. The exploitation rate, *E*, was computed by dividing *F* by *Z* (*F/Z*). The parameter *E* expresses the proportion of a given cohort/population that ultimately dies due to fishing given existing exploitation pressure (Beverton and Holt 1966). The length-based methods within ELEFAN are similar to "non-parametric" statistical methods and therefore do not provide measures of confidence intervals or uncertainties (Silvestre *et al*. 2004).

2.8 Recruitment pattern

ELEFAN in FiSAT II was further used to obtain expressions of the seasonal changes in recruitment patterns displayed in graphical form. The seasonal recruitment pattern of the fish was reconstructed using the entire length−frequency data set and was subdivided into normally distributed recruitment pulses, suggestive of the recruitment seasons for an arbitrary year. This involved projecting backward along a trajectory described by the computed von Bertallanffy growth formula, all restructured length−frequency data onto a 1-year time scale (Pauly 1987). Then, employing the maximum likelihood method, the distribution was resolved into its Gaussian components using the NORMSEP (normal separation) procedure of Hasselblad and Tomlinson (1971). Growth parameter estimates $L\infty$ and K and t_0 were used as inputs. Recruitment pattern was presented in terms of the percentage of recruitment versus time (months). The number of recruitment peaks for each species in each location was examined using recruitment patterns.

2.9 Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) models

The main reason why fisheries scientists study the growth of fishes and describe it in the form of the von Bertalanffy growth function is to perform stock assessment using the yield-per-recruit (*Y/R)* model of Beverton and Holt (1966). E_{max} is the value of the exploitation ratio (E) associated with the highest *Y/R* value that is possible with a given value of length at first capture (L_c). $E_{0.1}$ the value of the exploitation ratio at which the slope of the *Y/R* is one tenth of its value at the origin and $E_{0.5}$ the value of the exploitation ratio associated with a fifty percent reduction of the spawning biomass (per recruit) in the unexploited stock.

Yield per-recruit (*Y/R*) and biomass per-recruit (*B/R*) analysis to obtain reference points and evaluate the exploitation status of the species was conducted. The *Y/R* model is a principal steady state model that describes the state of stock and the yield in a situation when the fishing pattern has been the same for a long time so that all fish are vulnerable to capture after recruitment (Sparre *et al*. 1989). The model of Beverton and Holt (1966), as modified by Pauly and Soriano (1986), was used to predict the relative yield per recruit (*Y'/R*) of the species to the fisheries:

$$Y'/R = EU^{M/K}\left[1-\left(\frac{3U}{1+m}\right)+\left(\frac{3U^2}{1+2m}\right)+\left(\frac{3U^3}{1+3m}\right)\right]$$

Where $E = F/Z$ is the current exploitation rate, i.e. the fraction of mortality caused by fishing activity, F is the instantaneous fishing mortality coefficient, $U = 1- (Lc/L\infty)$ is 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:

$$B'/R = \frac{(Y'/R)}{F}$$

Then, $E_{\max}$ (exploitation rate producing maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of Y'/R is one tenth of its 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 the Beverton and Holt (1966) function. Yield contours were plotted to assess the impact on yield of changes in exploitation rate E and critical length ratio L_c/L_∞.

Computations of Y'/R and B'/R were made using the equations given by Pauly and Soriano (1986), as implemented in FISAT II (Gayanilo and Pauly 1997), knife-edge selection was used in the Y'/R and B'/R calculations. A decision was made to use the lowest lengths of capture on each species from the locations (i.e for *Engraulicypris sardella*, $L_c = 3$ and 4 cm for the south-eastern and south-western arm respectively and *Rhamphochromis* $L_c = 5$ and 8 cm for the south-eastern and south-western arm respectively). This was also due to the fact that the type of gear used in this study and its mesh sizes are assumed to sweep everything that is found in its way when hauling.

3 RESULTS

3.1 Identification of length-age cohorts

Length distribution of the two species indicated length-age cohorts that can be followed over time (Figures 2, 3, 4 and 5). The mean total length of *Engraulicypris sardella* in the first cohort from the south-eastern arm varied from 6.87 cm ± 2.45 in September to 8.33 cm ± 1.23 in November and the second cohort increased from 9.82 cm ± 0.54 in May to 12.05 cm ± 0.60 in November. For the southwest arm the monthly mean of the first cohort was 8.16 cm ± 1.17 in September and declined to 7.71 cm ± 0.75 whereas the second cohort increased from 9.11 cm ± 0.69 in April to 11.96 cm ± 0.60 in November (mean ± std dev). In general, the shift of cohorts in time indicates a clear, though relatively slow, growth (Figures 2 and 3).

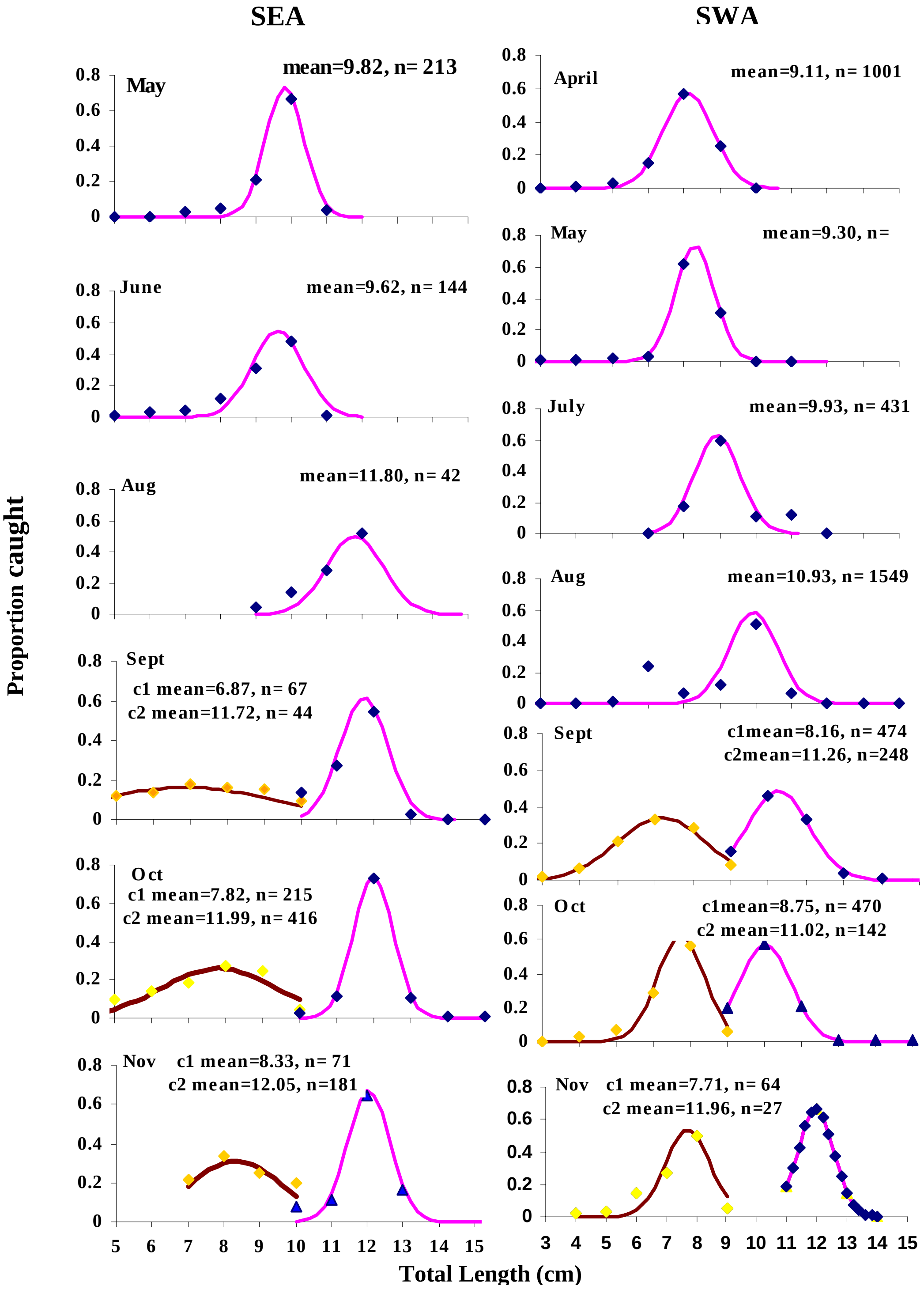

Figure 2: Monthly length frequency of *Engraulicypris sardella* caught in light attraction fishery in Lake Malawi South.

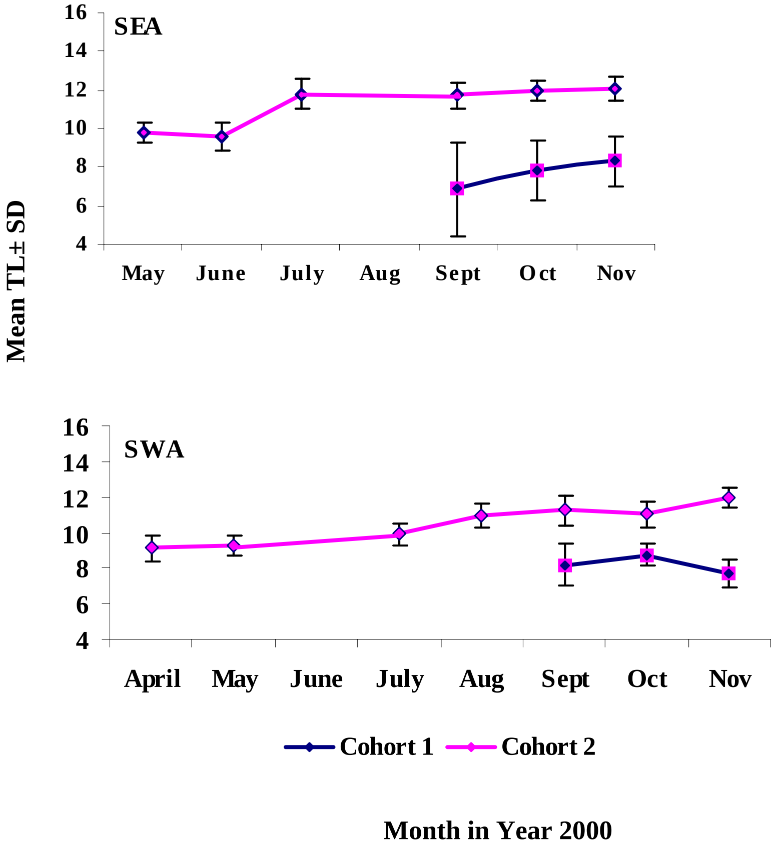

Figure 3: Monthly average total length and standard deviation in observed cohorts of *Engraulicypris sardella*.

For *Rhamphochromis* three cohorts were identified from the south-eastern arm samples. The first cohort increased from 10.44 cm ± 1.30 in May to 13.57 cm ± 1.39 in October and declined to 10.83 cm ± 1.38 in November. The second cohort ranged between 19.71 cm ± 1.61 and 20.83 cm ± 2.89. The third ranged between 30.12 cm ± 5.79 in April to 39.80 cm ± 2.63 in September and declined to 30.14 cm ± 6.43 in November. The third cohort is rather confusing as it doesn't fulfil the cohort properties. It can be assumed that there might be some emigration of distant stocks into the area. For the south-western arm only two cohorts were identified and the monthly mean of the first cohort ranged from 11.68 cm ± 1.75 to 15.00 cm ± 0.58. The second cohort varied between 18.73 cm ± 2.68 and 21.93 cm ± 4.24 (mean ± standard deviation) (Figures 4 and 5). Overall, the increase in length seems marginal in both areas. The number of measurements behind the first the third cohort are very limited in most months and therefore the findings should be interpreted with caution.

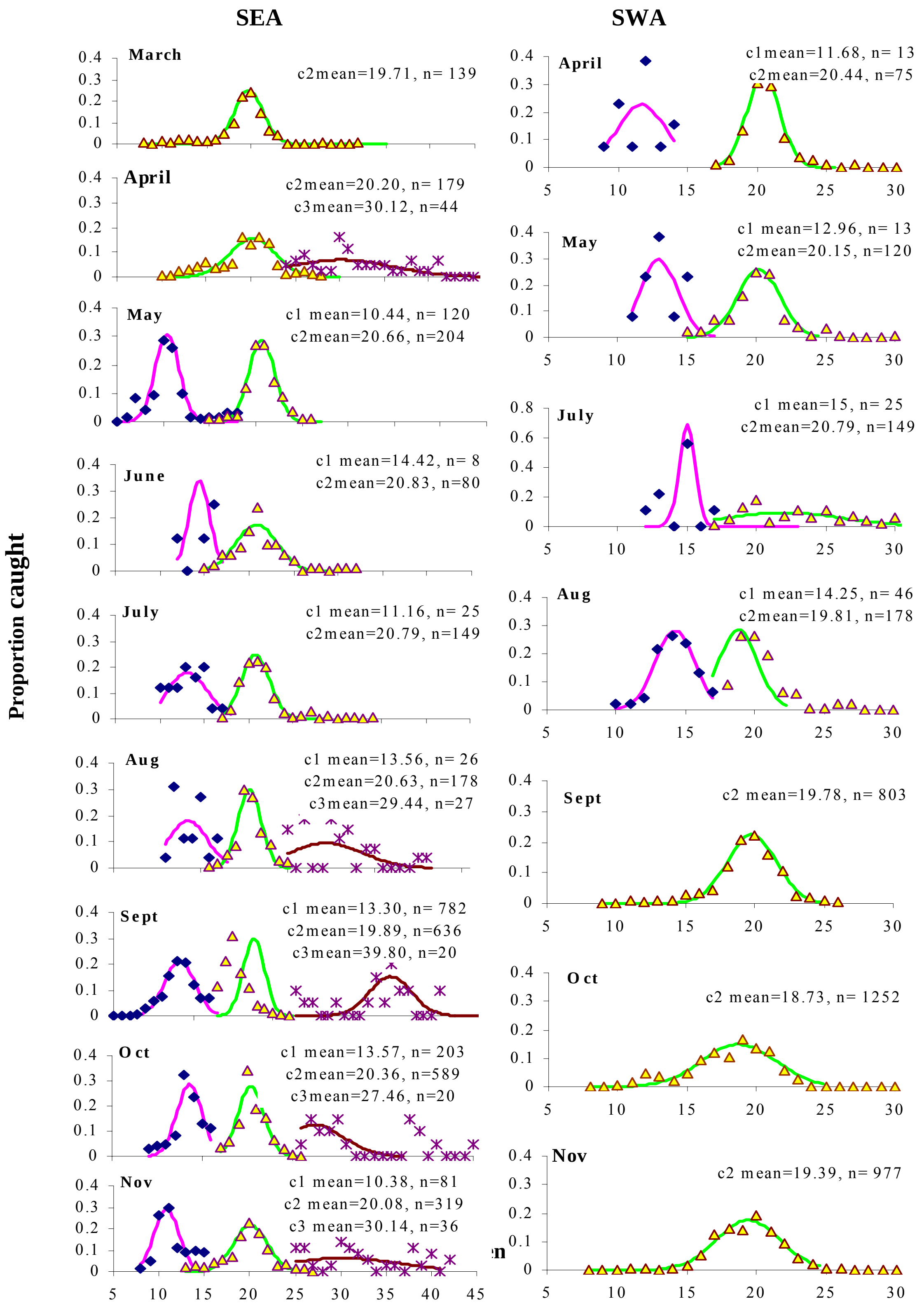

Figure 4: Monthly Length frequency of *Rhamphochromis* caught in light attraction fishery in Lake Malawi South.

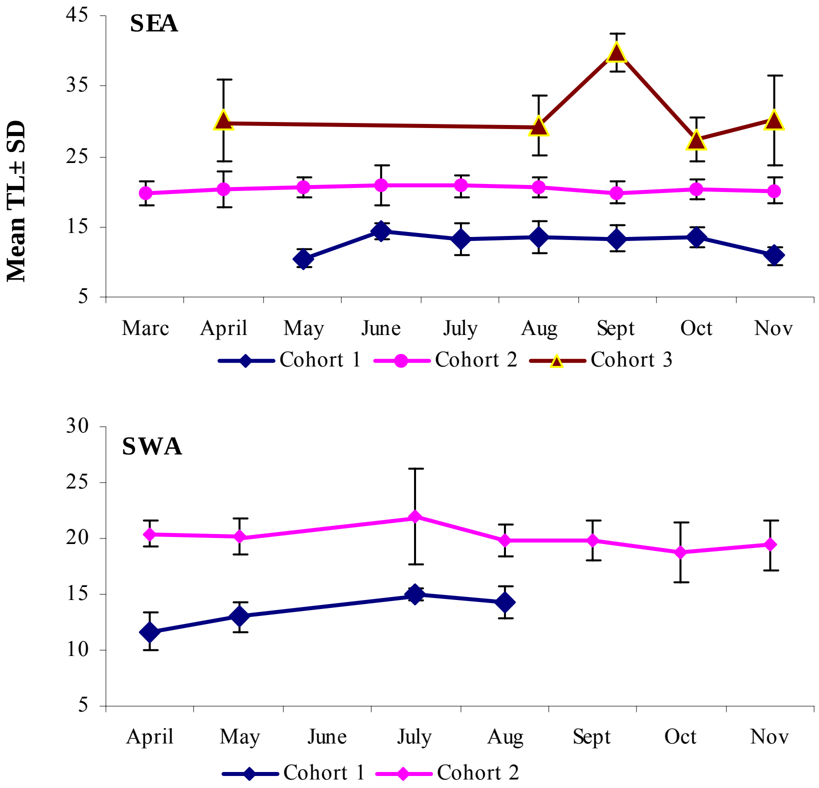

Figure 5: Monthly average total length and standard deviation in observed cohorts of *Rhamphochromis.*

3.2 *Population dynamics of* **Engraulicypris sardella** *and* **Rhamphochromis**

3.2.1 Engraulicypris sardella

Growth parameters

Initial parameter estimates by LFDA (ELEFAN and SLCA) showed lower values of *K* estimated for *Engraulicypris sardella* in both methods (Table 2 and Figure 6) as compared to the results from sum of square minimisation (Table 3 and Figure 7). Taking the mean values obtained from LFDA into FiSAT II for ELEFAN *K* scanning $L\infty$ ranged from 13.77 - 14.67 cm and *K* from 0.8-1.5 yr^{-1} for the southeast arm and $L\infty$ between 12.62 - 14.73 cm and *K* values of 0.89-2.6 yr^{-1} for the southwest arm (Figure 6).

Table 2: Initial parameters from LFDA (1992) for *Engraulicypris sardella* in the southeast and southwest arms of Lake Malawi.

Location	ELEFAN			SLCA			Mean L_∞ for K scanning
	L_∞	K	t_0	L_∞	K	t_0	
SEA	14.54	0.496	-0.85	15.21	0.295	-0.32	14.88
SWA	13.62	0.453	-0.64	14.93	0.238	-0.43	14.28

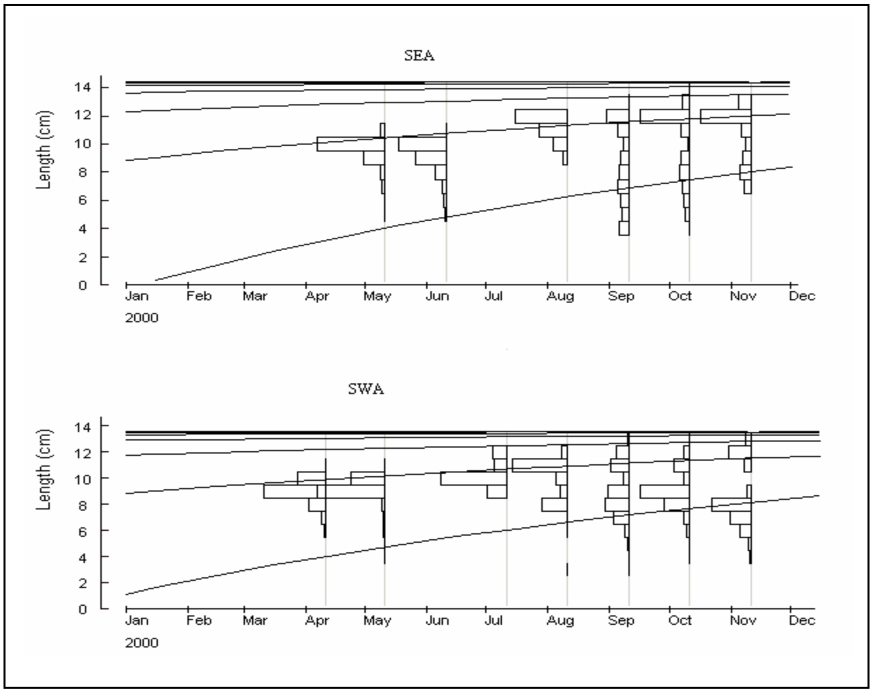

Figure 6: *Engraulicypris sardella* length frequency and fitted von Bertalanffy growth curves (*L*∞ = 14.5 cm TL, *K*= 0.96 year $^{-1}$, t_0 = 0) for the southeast arm and (*L*∞ = 13.6 cm TL,*K*= 1.09 year $^{-1}$, t_0 = 0) for the southwest arm.

The estimated von Bertalanffy growth parameter of *Engraulicypris sardella* after sum of square minimisation using solver in Excel for the southeast and southwest arms are *L*∞ = 14.5 cm and 13.6 cm, respectively, and *K* = 0.96 yr-1 and 1.09 yr-1, respectively (Table 3 and Figure 7). The Munro's growth performance index (ø) estimated was the same (2.3) in both locations, which gave an indication that the parameters estimated conformed the von Bertallanffy condition (Munro 1983). The *L*∞ and *K* found using this process were within the ranges estimated in FiSAT. However the *K* values are higher than the initial estimates in LFDA.

Table 3: Growth parameters from Excel minimisation, Growth index, Mortality and Exploitation rates of *Engraulicypris sardella.*

Location	L_∞	*K*	t_0	Φ'	*Z*	*M*	*F*	*E*
SEA	14.5	0.96	-0.030	2.30	2.47	1.95	0.53	0.21
SWA	13.6	1.09	-0.055	2.31	4.17	2.15	2.02	0.48

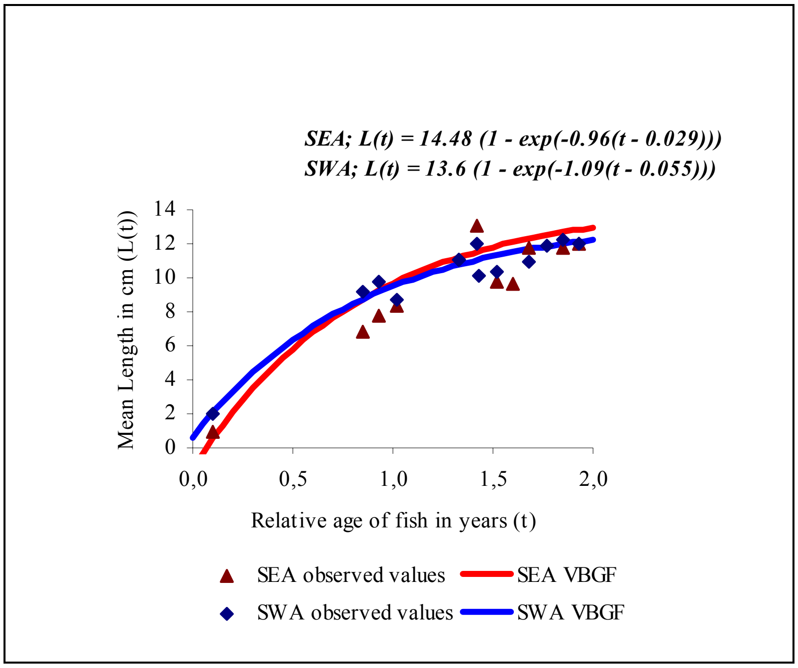

Figure 7: von Bertalanffy growth curves for *Engraulicypris sardella* after sum of square minimisation.

Mortality and exploitation rate

The length converted catch curve analysis for *Engraulicypris sardella* in the southeast arm produced lower total mortality estimates of *Z* = 2.47 yr-1 as compared 4.17 yr-1 for the southwest arm in different relative age ranges (Figure 8). The natural mortality (*M*) calculated using Pauly's empirical formula (Pauly 1980), was high but relatively close in both locations. The calculated fishing mortality (*F*) was higher in the southwest arm than that in the southeast arm (Table 3). The same was true for the exploitation rate (*E* = *F/Z*).

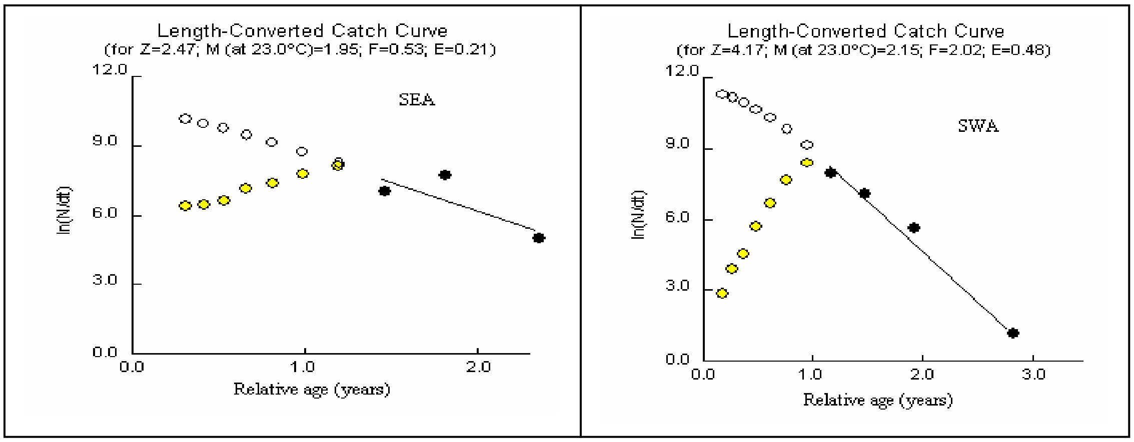

Figure 8: Length converted catch curves for *Engraulicypris sardella* caught by light attraction fishery in the south-eastern and south-western arms of Lake Malawi.

Recruitment pattern

The FiSAT plot of the percentage recruitment of *Engraulicypris sardella* into the fishery from the southeast arm and the southwest arm showed more or less continuous recruitment from January to November with a peak (≈ 23 %) in July for the southeast arm. Two pulses in May (≈12 %) and between August and September of (≈15 %) were apparent in the southwest arm (Figure 9).

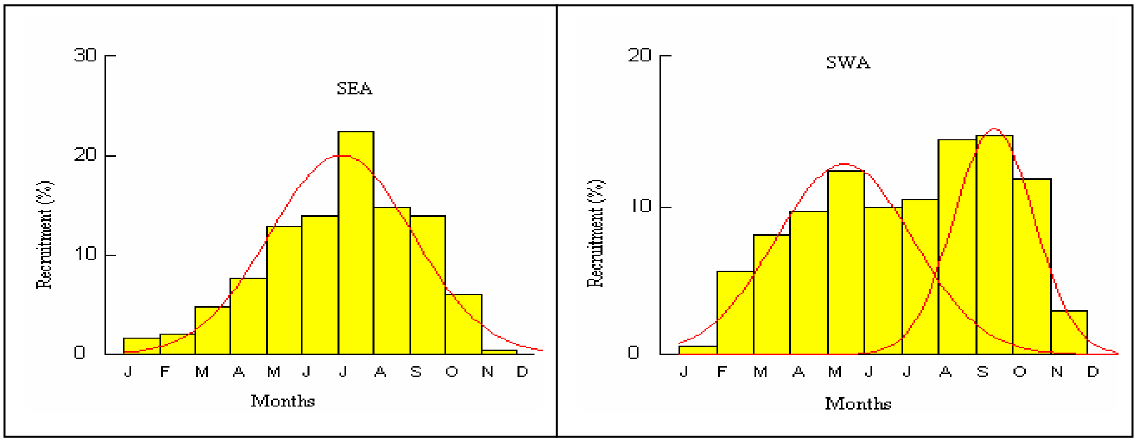

Figure 9: Recruitment pattern of *Engraulicypris sardella* caught in the south-eastern and south-western arms of Lake Malawi (year 2000).

Relative yield and spawning biomass per recruit (Y'/R, B'/R)

The yield per recruit model of *Engraulicypris sardella* with input parameters M/K and $Lc/L\infty$ are given in Table 4. Using knife edge selection criteria in FISAT II and assuming constant recruitment, levels of optimum exploitation rates were calculated. The E_{max}, $E_{0.1}$ and $E_{0.5}$ values estimated by the relative yield per recruit analysis were 0.51, 0.42 and 0.30 respectively for the southeast arm and 0.46, 0.36 and 0.28 respectively for the Southwest arm (Figure 10). The exploitation rate (E) for light attraction fishery was 0.21 and 0.45 in the southeast arm and the southwest arm respectively (Table 5). Thus the exploitation rate in the southeast arm was below maximum acceptable limits ($E_{max} = 0.51$) and biological optimum ($E_{0.1} = 0.42$). Whereas in the southwest arm the exploitation rate of this fishery was slightly below the maximum acceptable limit ($E_{max} = 0.46$) and higher than biological optimum ($E_{0.1} = 0.36$). This suggests that the *Engraulicypris sardella* population in both locations is being exploited around maximum sustainable yield by chilimira nets.

Table 4: *Y'/R* and *B'/R* optimum values of *Engraulicypris* in the south-eastern and south-western arms of Lake Malawi.

Location	M/K	Lc / L_∞	E_{max}	$E_{0.1}$	$E_{0.5}$	$E_{Current}$
SEA	2.03	0.28	0.51	0.42	0.30	0.21
SWA	1.97	0.22	0.46	0.36	0.28	0.48

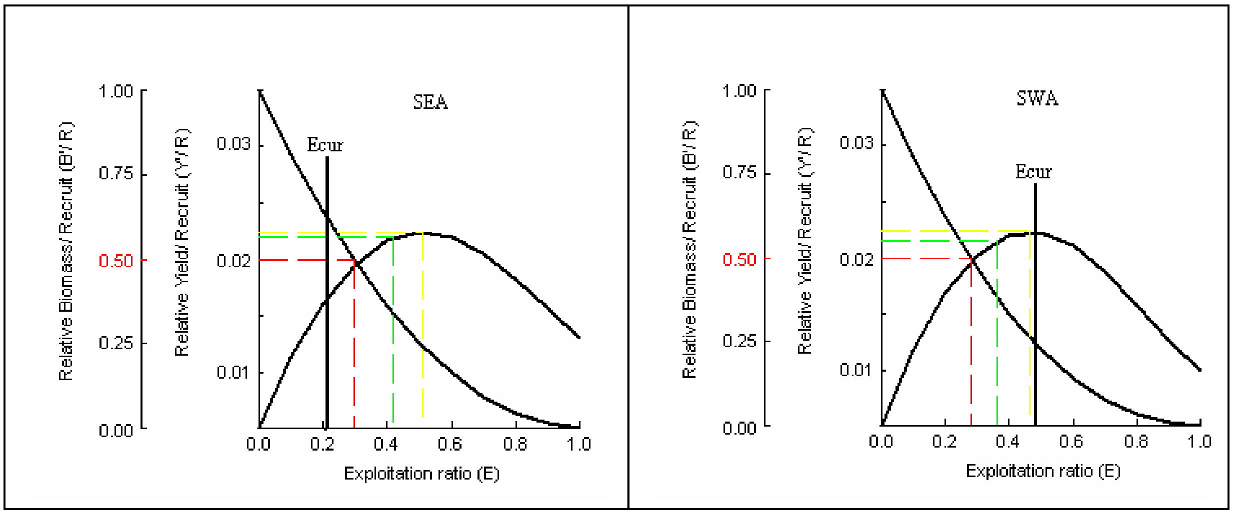

Figure 10: *Engraulicypris sardella* knife edge relative *Y'/R* and *B'/R* curves in the south-eastern and south-western arms of Lake Malawi.

3.2.2 Rhamphochromis

Growth parameters

The estimated von Bertalanffy growth parameter of *Rhamphochromis* after taking the mean values obtained from LFDA into FiSAT II for ELEFAN *K* scanning gave $L\infty$ values ranging from 27.9 - 49.35 cm and *K* values of 0.3-0.89 yr^{-1} for the Southeast arm and 21.25 – 42.5 cm and *K* values of 0.28-1.98 yr^{-1} for the southwest arm (Table 5 and Figure 11). These ranges of $L\infty$ and *K* values were obtained after taking *Rhamphochromis* as genera without specific species.

Table 5: Initial parameters from LFDA (1992) for *Rhamphochromis* in the south-eastern and south-western arms of Lake Malawi.

Location	ELEFAN			SLCA			Mean L_∞ for K scanning
	L_∞	K	t_0	L_∞	K	t_0	
SEA	41.5	0.389	-0.75	40.40	0.419	0.796	40.95
SWA	41.53	0.323	-0.11	43.111	0.326	-0.988	42.32

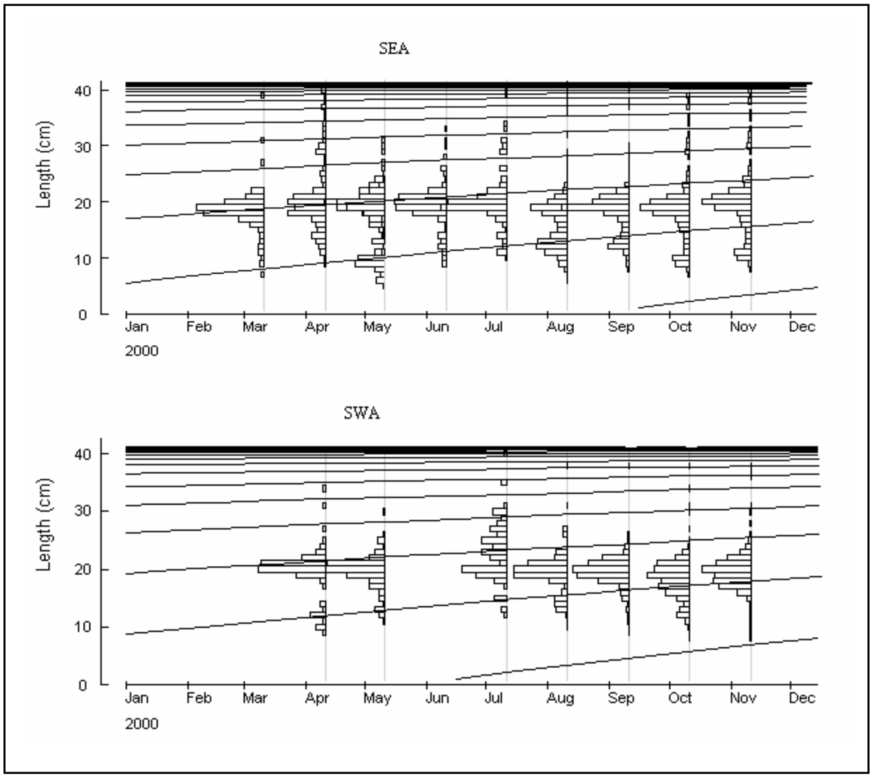

Figure 11: *Rhamphochromis* length – frequency and fitted von Bertalanffy growth curves. ($L\infty$ = 41.2 cm TL, K= 0.39 year $^{-1}$, t_0 = 0) for the Southeast arm and ($L\infty$ = 40.5 cm TL, K= 0.41year $^{-1}$, t_0 = 0) for the Southwest arm.

The estimated von Bertalanffy growth parameters by sum of square minimisation was $L\infty$ = 41.2 cm and K = 0.39 yr^{-1} with t_0 = 0.096 (Table 6 and Figure 12). This was only done for samples from the Southeast arm, as it was not possible to fit a von Bertalanffy growth curve to monthly mean values observed from the Southwest arm. The Munro's growth performance index (ø) ranged between 2.83 and 2.77.

Table 6: Growth parameters from Excel minimisation, Growth index, Mortality and Exploitation rates **of *Rhamphochromis*.**

Location	L_∞	K	t_0	Φ'	Z	M	F	E
SEA	41.2	0.39	-0.096	2.8	4.71	0.81	3.90	0.83
SWA	-	-	-	-	5.16	0.81	4.35	0.84

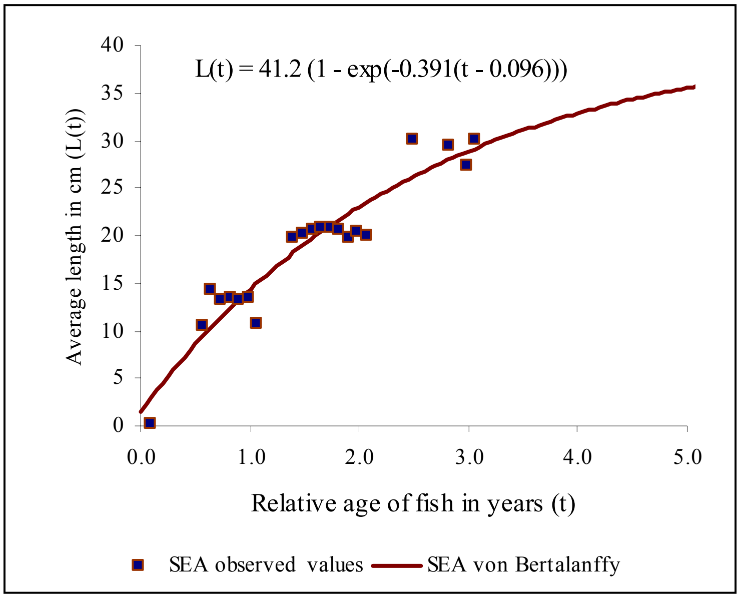

Figure 12: von Bertalanffy growth curves for *Rhamphochromis* after sum of square minimisation.

Mortality and exploitation rates

The length converted catch curve analysis for *Rhamphochromis* produced high estimates of total mortality in both locations. Total mortality of 4.71 yr^{-1} and 5.16 yr^{-1} in the same relative age range were estimated for the southeast arm and southwest arms respectively (Figure 13). Since the $L\infty$ and K values used were those from the sum of square minimisation results from samples of the southeast arm, the natural mortality (M), calculated using Pauly's empirical formula (Pauly 1980), from both locations was the same (M = 0.81 yr^{-1}). Fishing mortality was very high in both locations, F = 3.9 yr^{-1} for the Southeast arm and 4.35 yr^{-1} in the southwest arm (Table 6). The exploitation rate ($E = F/Z$) of chilimira nets was high in both locations, 0.83 in the southeast arm and 0.84 in the southwest arm (Table 6).

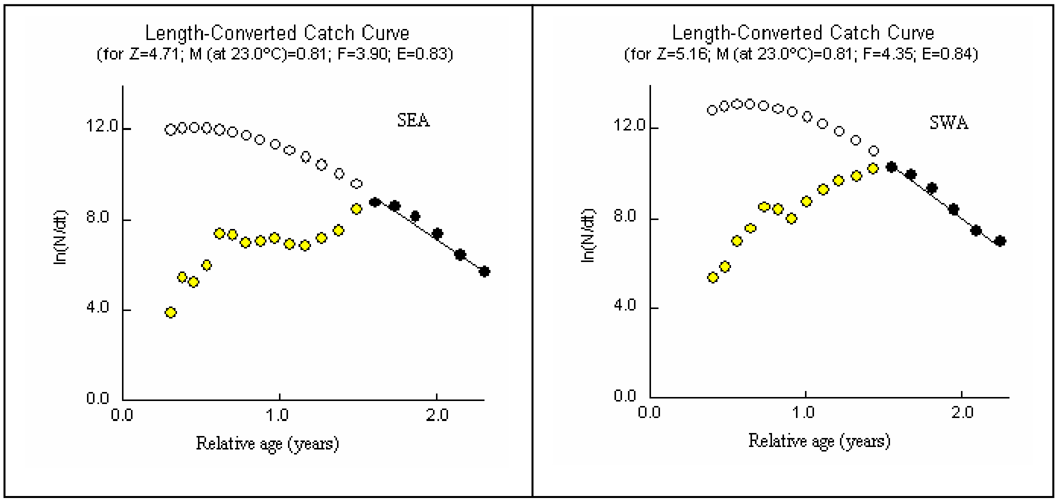

Figure 13: Length converted catch curves for *Rhamphochromis* caught by light attraction fishery in the South-eastern and South-western arms of Lake Malawi.

Recruitment pattern

FiSAT II plots of the percentage recruitment of *Rhamphochromis* into the fishery from the southeast arm showed a continuous recruitment from January to November with two pulses. The first peak between April and May (≈19 %) and a second one in September (≈ 9 %) in the southeast arm. For the southwest arm two pulses of recruitment were also evident, the stronger one (≈ 17 %) around February to March and a weaker one (≈ 12 %) between July and August (Figure 14).

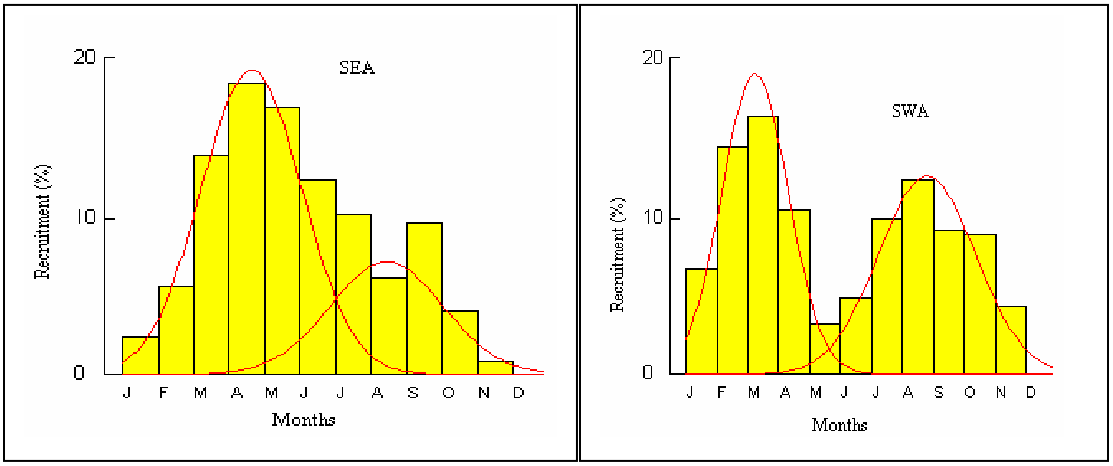

Figure 14: Recruitment pattern of *Rhamphochromis* in the south-eastern and south-western arms of Lake Malawi (year 2000).

Relative yield and spawning biomass per recruit (Y'/R, B'/R)

The yield per recruit model of *Rhamphochromis* with input parameters M/K and $Lc/ L\infty$ as indicated in Table 7, using knife edge selection criteria in FiSAT II and assuming constant recruitment, levels of optimum exploitation rates were calculated. The length at first capture (*Lc*) used were the lowest lengths recorded in the catches of chilmira nets per location. The E_{max}, $E_{0.1}$ and $E_{0.5}$ values estimated by the relative yield per recruit analysis were 0.40, 0.32 and 0.25 respectively for the southeast arm and 0.44, 0.36 and 0.27 for the southwest arm (Table 7 and Figure 15).

Table 7: *Y'/R* and *B'/R* optimum values of *Rhamphochromis* in the south-eastern and south-western arms of Lake Malawi.

Location	***M/K***	Lc/L_{∞}	E_{max}	$E_{0.1}$	$E_{0.5}$	$E_{Current}$
SEA	2.07	0.12	0.40	0.32	0.25	0.83
SWA	2.07	0.19	0.44	0.36	0.27	0.84

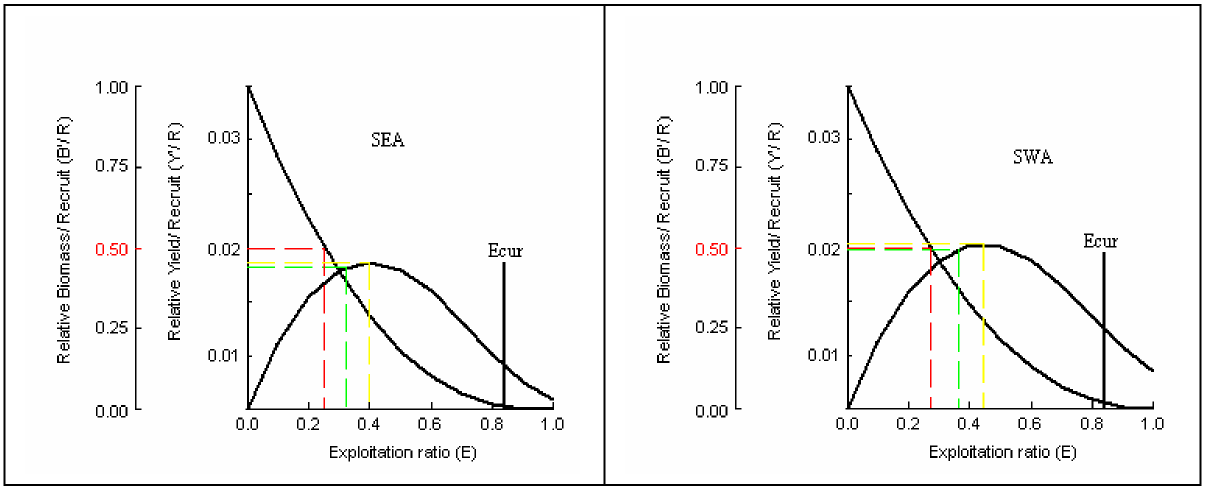

Figure 15: *Rhamphochromis* knife edge relative *Y'/R* and *B'/R* curves in the south-eastern and south-western arms of Lake Malawi.

In both locations, the southeast arm and the southwest arm, the exploitation rate (E = 0.83 and 0.84) of light attraction fishery was far above maximum acceptable limits (E_{max} = 0.40 and 0.44 respectively) and the biological optimum ($E_{0.1}$ = 0.32 and 0.36). The same applied to the $E_{0.5}$ points from the relative spawning biomass as they were seen to be very low in both locations at the current rate at of exploitation (Table 7). This suggests that the *Rhamphochromis* population in both locations is being exploited above the maximum sustainable yield in chilimira nets. However, there is a reason to interpret these results with caution due to severe limitations in the data.

4 DISCUSSION

Owing to inter-species variability of occurrence in the catches of light attraction fishery (chilimira nets), small sample size, improper sampling techniques coupled with inefficiencies in taxonomic identification of *Rhamphochromis species* by officers doing data collection, the outcome of the analysis presented in this work should be regarded as preliminary. Species identification of the haplochromine cichlids of Lake Malawi are complicated by the high diversity and the lack of formal descriptions for many of the species (Turner 1996). Due to the possibility of same species in two distant parts of the lake belonging to different populations and presenting different life history and/or genetic variations, this work tried as much as possible to work with the species from the different locations separately.

The use of modal progression in length-frequency plots of sequentially sampled fish populations is a well-established method of determining growth rates, although precise ages can only be determined if the cohort is followed from first hatching (Pauly and Morgan 1987) . Various growth parameter prediction models were used to estimate $L\infty$ and K. Kohn (1986) suggested that if parameter values were estimated by formal optimization methods, it was essential to show that these estimates were reasonable and reliable for the biological data that the model was depicting. Keeping with this view, the estimates of the von Bertallanffy growth parameters, $L\infty$ should be reasonably close to the maximum fish length observed in the samples (Moreau 1986), t_0 should be smaller than zero so that the fish at age zero could have a positive length (Moreau 1986), and K might vary between zero and one per year for fish species with a long life span (Pauly 1978) and excess one for short lived species. Relevant estimates for *Engraulicypris sardella* and *Rhamphochromis* from Lake Malawi conform to these criteria.

This study estimated a range of $L\infty$ values to be 13.77 - 14.67 cm and K values of 0.8-1.5 year^{-1} for *Engraulicypris sardella* samples from the southeast arm and $L\infty$ values 12.62 – 14.73cm and K values of 0.89-2.6 year^{-1} for the southwest arm. Reported von Bertalanffy parameter estimates of *Engraulicypris sardella* range from $L\infty$=108–135 mm and K = 0·47–1·64 year^{-1} (Menz 1995). According to Rufli and van Lissa (1982), as reported by Menz (1995), the fitted von Bertalanffy growth curve for a cohort followed in Nkhata-bay from May to September 1979 gave $L\infty$ = 137mm and K = 2.95 year^{-1}. The $L\infty$ and the K values of *Engraulicypris sardella* obtained from this study are not very far from the ones in earlier studies except that the L∞ range had higher values as compared to the past studies. This might be attributed to use of Total Length (TL) in this study as opposed to the Standard Length (SL) that the past studies were based on.

Young *Rhamphochromis* (*R. ferox, R. woodi, R. longiceps, etc*) fish could not be accurately distinguished (Olaf Weyl personal communication). The presence of many immature specimens of these species in catches by small-meshed beach seines and chilimila nets makes it difficult to distinguish between species. *Rhamphochromis* taken as a group without specific species gave $L\infty$ values ranging 27.9 - 49.35 cm and K values of 0.3-0.89 year^{-1} for the southeast arm and $L\infty$ values between 21.25 – 42.5cm with K values of 0.28-1.98 year^{-1} for the southwest arm. Few studies have been done on the growth of *Rhamphochromis* and this can be attributed to the problem of identification of young fish. In their paper on the potential yield of unexploited pelagic fish stocks in Lake Malawi, Thompson and Allison (1997) estimated the growth parameter of *Rhamphochromis* from the general equation $\ln K = 2.35 - 0.97 \ln L\infty$ and from this equation they calculated two groups of *Rhamphochromis* (*R. longiceps* and '*other Rhamphochromis spp'*). The values used for *Rhamphochromis longiceps* were 21 cm and 0.55 year^{-1} for $L\infty$ and K respectively while for the other *Rhamphochromis spp*., the values were 50 cm and 0.24 year^{-1}for $L\infty$ and K respectively. The values obtained from this general equation were not very far from the ones that this study has estimated.

A growth index ($ø'$) was used to evaluate the reliability of the $L\infty$ and K estimates. Moreau *et al.* (1986) indicated that in open water environmental conditions (e.g. temperature but also the presence of predators), fish either grow rapidly toward a small size (high K, low $L\infty$), or slowly toward a large size (low K, high $L\infty$). Consequently, the growth performance index ($ø' = \ln K + 2 \ln L\infty$) remains nearly constant among different populations of the same species (Pauly 1991), hence species within the same family are expected to have similar ($ø'$) values, as ø'values are normally distributed. Due to the fact that the species being studied here are endemic to Lake Malawi the growth index ($ø'$) from the two locations, southeast arm and southwest arm, were compared. For *Engraulicypris sardella* the growth index ($ø'$) was 2.30 and 2.31 whereas that of *Rhamphochromis* was 2.83 and 2.77 respectively, the results could be perceived to confirm the pattern suggested by Moreau *et al*. (1986).

Mortality (fishing and natural mortality) rates are important for understanding the rate of population decay. Length converted catch curves were used to estimate the mortality rate of the species under study. The total mortality, Z, for *E. sardella* was found to be 2.47 and 4.17 in the southeast arm and the southwest arm respectively. For *Rhamphochromis* the mortality rates were 4.71 and 5.16 respectively. The natural mortality for *Engraulicypris sardella* (1.95 and 2.15) was higher in both locations compared to that of *Rhamphochromis* (0.81), which can be attributed to biological differences between the two species. *Engraulicypris sardella* are populations of small pelagic and have a great tendency to fluctuate. This is because of their short vital cycle, their dependency on the lowest levels of biological production (phytoplankton and zooplankton) and they are very much influenced by environmental conditions (Marshall 1987). They are fast-growing fish with short life-spans and high rates of reproduction which are features typically associated with r-selected species (Marshall 1987). Their populations fluctuate in abundance over time, even in the absence of fishing, since they respond to short-term changes in the environment that affect recruitment and feeding.

Total mortality was higher in *Rhamphochromis* than *Engraulicypris sardella.* This can be attributed to the fishing mortality, which was very high in *Rhamphocromis* or 3.90 and 4.35 in the southeast and southwest arms respectively. Many reasons can be attributed to the higher fishing mortality such as failure in distinguishing different species within *Rhamphochromis* as *R. ferox* and *R. longiceps* appear to breed for most of the year and were not accurately distinguished from each other during sampling. This was due to the gear type and mesh size that is used, as the probability of larger species escaping is small as well as bias in sampling procedures and the measure of monthly effort (variation in the effort overtime) as this data is fishery dependent. It is believed that these reasons could have led to an over-estimated fishing mortality because some of the assumptions in a linear length catch curve analysis could not be met.

In 2000, the recruitment pattern of *Engraulicypris sardella* appeared to be continuous throughout the year, but showed a major peak during July for the southeast arm and two peaks in May and September in the southwest arm. This indicates that *Engraulicypris sardella* spawns throughout the year (Morioka and Kaunda 2004), but with a peak during the rainy season as most of the juveniles are recruited in the fishery around May. The recruitment pattern for *Rhamphochromis* had the same continuous pattern in both locations. There were two pulses in both locations a stronger pulse from March to May in the southeast arm followed by a weaker one in September. In the southwest arm the stronger pulse came in February and the second one in August. Turner *et al*. (2000) observed that *Rhamphochromis* species especially *R. ferox* and *R. longiceps* appear to breed throughout the year.

Length converted catch curves showed a typical form and justified the estimation of (Z) value for these fish species. The exploitation rate for *Engarulicypris sardella* (E = 0.21 for the southeast arm and 0.48 for the southwest arm) are below 0.50 and for *Rhamphochromis* (E = 0.83 for SEA and 0.84 for SWA) are above 0.50. Gulland (1971) suggested that as a rule of thumb a fish stock is optimally exploited at a level of fishing mortality that generates E = 0.50. In the present study $E < Eopt$ for *Engraulicypris sardella*, which means that localised exploitation rates by chilimira nets are within the range required to attain sustainability. For *Rhamphochromis*, $E > Eopt$ in both locations, which means that by using Gulland's rule of thumb, *Rhamphochromis* in these areas are being over- exploited. However, yield per recruit is maximized at low values of E only in the case of large, long lived, low mortality fishes (Silvestre *et al*. 2004). In small tropical fishes with high values of M, the values of F or E, which maximize yield per recruit are generally high (Silvestre *et al*. 2004). Thus, managing a tropical fishery based only on Y/R analysis for a species of small fish (let alone a multi-species fishery) can be misleading. Pauly and Soriano (1986) and Silvestre *et al.* (1991) emphasized that on this account and the additional bias due to the assumption of knife-edge recruitment, if included, the results can be truly misleading.

Gulland (1983) and Pauly and Munro (1984) indicated that for small tropical fishes with high natural mortality, the exploitation rates at maximum sustainable yield (E_{msy}) may be unrealistically high. For these reasons, an agreement emerged to generally limit fishing mortality (F) to the point where the slope of the yield-per-recruit curve has one tenth of its value at the origin of the curve. As indicated in Tables 4 and 7, values of current exploitation rate ($E_{current}$) for *E. sardella* exceeds the values at $E_{0.1}$ in the southwest arm [$E\ (0.48) > E_{0.1}\ (0.36)$]. The same is true for *Rhamphochromis* in both locations, southeast arm [$E\ (0.83)>E_{0.1}\ (0.32)$] and southwest arm [$E\ (0.84)>E_{0.1}\ (0.36)$]. The values of current exploitation rate ($E_{current}$) by chilimira nets on *Rhamphochromis* in both locations are very high, which is a clear indication of over exploitation. Only the current exploitation rate ($E_{current}$) of *E. sardella* in the southeast arm is below $E_{0.1}$ [$E\ (0.21) < E_{0.1}\ (0.42)$]. This is the only location which is below the optimum rate of exploitation ($E_{0.1}$) of *Engraulicypris sardella*, but this might not be the case due to the fewer and limited samples of *Engraulicypris sardella* collected from this location.

The relative biomass per recruit (*B/R* or *B'/R*) curve that is computed along with yield per recruit in FiSAT II has a reference point referred to as $E_{0.5}$, which is defined as the value at which *B'/R* is reduced to half its non-fished level and thus the biomass level that theoretically maximizes surplus production and generates MSY (Gulland 1983, Pauly and Munro 1984). As shown in Table 4, the theoretical $E_{0.5}$ that maximises surplus production using relative biomass per recruit was 0.3 and 0.28 for *Engraulicypris sardella* in the southeast arm and southwest arm respectively. For *Rhamphochromis* they were 0.25 and 0.27 for the southeast arm and southwest arm respectively (Table 7). Except for *E. sardella* in the southeast arm, all the other locations exceeded the optimum level to obtain B'/R ($E_{0.5}$).

It can be taken here that relative spawning biomass per recruit is healthy in the southeast arm [E (0.21) < $E_{0.5}$ (0.30)] for *Engraulicypris sardella*, whereas the level of biomass per recruit is very low and unsustainable in the southwest arm [E (0.48) > $E_{0.5}$ (0.28)], which is an indication of overexploitation. Whereas, for *Rhamphochromis* the situation is worse in both locations the southeast arm [E (0.83) > $E_{0.5}$ (0.25)] and the southwest arm [E (0.84) > $E_{0.5}$ (0.27)]. According to the current exploitation rate ($E_{current}$), *Rhamphochromis* is being exploited above maximum sustainable yield in both locations whereas *Engraulicypris sardella* is exploited fairly in the southeast arm and overexploited in the southwest arm. This indicates that the relative biomass per recruit for *Rhamphochromis* in both locations are below the one required to produce a required amount of recruits.

It has to be noted here that *Y/R* and *B/R* may be equated to actual yield only in situations where recruitment is constant (or varies only randomly). Recruitment is unlikely to remain constant at very high *F* or *E* (Pauly and Munro 1984). However, it has been emphasised by Gayanilo and Pauly (1997) and Pauly and Morgan (1987) that due to equilibrium assumptions in yield per recruit models, only long-term effects are predicted. The values of *F* or *E* needed to produce a maximum yield-per-recruit will tend to generate very low yields, because E_{max} usually reduces the parental stock to a level at which few recruits are produced. In the short term, an increase of fishing mortality or a decrease in size at first capture always results in higher yields, even when yield-per-recruit analyses predict lower yields. Similarly, a decrease in fishing mortality or an increase in size at first capture always results in lower yields in the short term, although, in the long run, higher yields may be reached. The duration of the transition period can be of several years in fish which have a high longevity and are subjected to exploitation over a number of years. In short-lived fish species, like the ones studied here, the transition period will be much shorter. In the case of very short-lived fish like *Engraulicypris sardella*, the distinction between short- and long-term effects does not even apply, because the stocks are never at equilibrium.

5 CONCLUSIONS AND RECOMMENDATIONS

It is often extremely difficult to obtain an unambiguous interpretation of a data set of length-frequencies of tropical fish, in particular when there is only one complex length-frequency sample available and not a time series (Venema *et al*. 1988). Additional information on the biology of the species in question may help a lot in correctly interpreting the data. The objectives of this study were to assess the growth parameters and exploitation rate of *Engraulicypris sardella* and *Rhamphochromis* caught by light attraction fishery in the Southern part of Lake Malawi during the year 2000, and derive reference points of relative yield and biomass per recruit studies of this fishery. Relative to the objectives, estimates of growth parameters ($L\infty$ and K) and mortality coefficients (Z, M and F) were given in addition to a growth index (ø'), a number of recruitment peaks, and an exploitation rate (*E)* for the two species in the two locations of study.

The fishing mortality (*F)* and exploitation rate (*E)* results obtained for *Engraulicypris sardella* show that chilimira (light attraction) fishery is being operated above maximum sustainable yield in the southwest arm, whereas it is fairly exploited in southeast arm. The same indications were shown after comparing the corresponding E_{max}, $E_{0.1}$ and $E_{0.5}$ estimates obtained from *Y/R'* and *B/R'* analyses. For *Rhamphochromis* the fishing mortality (*F)* and exploitation rate (*E)* estimates were very high in both locations and the E_{max}, $E_{0.1}$ and $E_{0.5}$ estimates obtained from *Y/R'* and *B/R'* analyses confirmed that the chilimira (open water seine net) fishery in these locations may have heavily overexploited the resource. However, the cichlids of Lake Malawi have a very low fecundity with a high degree of parental care and in addition with the unknown form of stock-recruitment relationship for most cichlids (Thompson and Allison 1997),. the rates estimated and analysed here may not be very true.

Notwithstanding that this study clearly indicates that exploitation of *Rhamphochromis* by light attraction fishery may not be sustainable, Turner *et al*. (2000) reported that 'due to the wide-ranging nature of the *Rhamphochromis* stocks, they are not considered threatened by local overexploitation'. It should be considered, that the data available in this study is regarded to be confused and weak, especially in the case of *Rhamphochromis,* therefore there is a need for further analysis, pending more comprehensive and reliable data.

It is difficult to make management recommendations for *Engraulicypris sardella* stocks, because this species does experience large fluctuations that appear to be caused by environmental factors (Allison *et al.* 1996). However, the same problem of multi-species arise here and considering the mesh size of chilimira nets that are used by light attraction to harvest *Usipa* can fish down the other important stocks such as *Rhamphochromis, Oreochromis spp*. and other cichlids together with clarids and cyprinids already reported to be overexploited. In general, the exploitation of *Usipa* by light attraction fishery in these two locations seems fairly sustainable and an urgent need for effort limitation is not evident.

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APPENDICES

Appendix 1: Engraulicypris sardella cohorts in southeast arm

		Cohort 1			Cohort 2		
	Range	n	Mean TL	Std Dev	n	Mean TL	Std Dev
May	5 -11	-	-	-	213	9.82	0.54
June	5 -11	-	-	-	144	9.62	0.73
July	9 -12	-	-	-	42	11.80	0.80
Sept	4 -16	67	6.87	2.45	44	11.72	0.65
Oct	4 -16	215	7.82	1.54	416	11.99	0.53
Nov	7 -13	71	8.33	1.28	181	12.05	0.60

Appendix 2: Engraulicypris sardella cohorts in southwest arm

		Cohort 1			Cohort 2		
	Range	n	Mean TL	Std Dev	n	Mean TL	Std Dev
April	5 -11	-	-	-	1001	9.11	0.69
May	3 -12	-	-	-	1156	9.30	0.55
July	8 -13	-	-	-	431	9.93	0.63
Aug	3 -18	-	-	-	1549	10.93	0.68
Sept	3 -14	474	8.16	1.17	248	11.26	0.82
Oct	4 - 15	470	8.75	0.64	142	11.02	0.72
Nov	4 -14	64	7.71	0.75	27	11.96	0.60

Appendix 3: Rhamphochromis cohorts in southeast arm

		Cohort 1			Cohort 2			Cohort 3		
Month	Range	n	Mean TL	Std Dev	n	Mean TL	Std Dev	n	Mean TL	Std Dev
Marc	8-32	-	-	-	139	19.71	1.61	-	-	-
April	10-47	-	-	-	179	20.20	2.56	44	30.12	5.79
May	5-26	120	10.44	1.30	204	20.66	1.39	-	-	-
June	12-32	8	14.42	1.18	80	20.83	2.89	-	-	-
July	10-34	25	13.16	2.23	149	20.79	1.61	-	-	-
Aug	11-41	26	13.56	2.21	178	20.63	1.34	27	29.44	4.20
Sept	5-46	782	13.30	1.87	636	19.89	1.43	20	39.80	2.63
Oct	9-46	203	13.57	1.39	589	20.36	1.42	20	27.46	3.20
Nov	8-42	81	10.83	1.38	319	20.08	1.83	36	30.14	6.43

Appendix 4: Rhamphochromis cohorts in southwest arm

		Cohort 1			Cohort 2		
	Range	n	Mean TL	Std Dev	n	Mean TL	Std Dev
April	9 -34	13	11.68	1.75	75	20.44	1.17
May	11 -30	13	12.96	1.35	120	20.15	1.55
July	12 - 40	25	15.00	0.58	149	21.93	4.24
Aug	10 -38	46	14.25	1.42	179	19.81	1.39
Sept	9 -26	-	-	-	803	19.78	1.77
Oct	8 -38	-	-	-	1252	18.73	2.68
Nov	8 -38	-	-	-	977	19.39	2.27