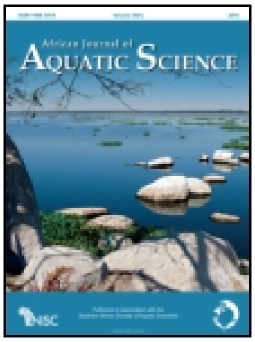

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An assessment of a light-attraction fishery in southern Lake Malawi

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This study provides the first quantitative assessment of the light-attraction component of a small-scale purse seine, locally known as a *chilimira* net, fishery in two areas of southern Lake Malawi. For monitoring purposes the shoreline of Lake Malawi is divided into a number of statistical strata. Two strata ('2.1' in the southeast arm and '3.1' in the southwest arm of the lake) were selected for this study. Catch per unit effort in stratum 2.1 was generally lower than that recorded in stratum 3.1 but nets in stratum 2.1 fished more frequently, leading to similar annual catches in the two strata. Annual catch was estimated as 19.4 (CI = 15.9–23.5) tons net^{-1} year^{-1} in stratum 2.1 and 23.5 (CI = 19.5–28.1) tons net^{-1} year^{-1} in stratum 3.1 respectively. A total of 62 species from 28 cichlid genera, and 13 species from nine non-cichlid genera, were identified from the samples. Of the 37 genera identified, only five; *Copadichromis*, *Dimidiochromis*, *Engraulicypris*, *Oreochromis* and *Rhamphochromis*, contributed more than 5% to the total annual catch in either stratum. Their combined contribution to the annual catch was in excess of 85% in both strata. Comparisons showed that catch-composition was dependent on area. Length-frequency distributions of major target species in the catch showed that the fishery targeted juveniles in stratum 2.1, while in stratum 3.1 most individuals were harvested after reaching their length-at-maturity. The dependence of catch-composition and size-selection on area indicates that management interventions for this fishery need to be area-specific. Since the fishery targets a diverse species assemblage, effort limitation or area closure may be the only viable management options, until such time as additional biological and fisheries data are available for the application of stock assessment models.

Keywords: *chilimira* net, CPUE, length-frequency, species composition

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Introduction

Lake Malawi (9°30'S–14°30'S) is a 28 800km^2 freshwater lake located in the East African Rift Valley bordered by Malawi, Tanzania and Mozambique. The lake supports a highly diverse ichthyofauna with more than 500 endemic fish species (Turner 1995). The fish are exploited by a fishery that includes both large-scale and small-scale components (Allison *et al.* 2002). In the Malawian section of the lake, these fisheries yield c. 30 000 tons per annum (Tweddle and Magasa 1989, Ngochera 2001). Small-scale fishers utilising beach seines, pelagic seines, gill nets, longlines, handlines and traps land more than 90% of the catch (Banda *et al.* 2001).

These fisheries target predominantly inshore species, many of which have declined as a result of over-fishing (Turner 1994, 1995, Bulirani *et al.* 1999, Allison *et al.* 2002). In contrast, the offshore fish stocks of Lake Malawi are considered unexploited or only lightly exploited (Thompson and Allison 1997, Turner *et al.* 2000). For this reason, developing fisheries that redirect fishing effort from overexploited inshore to unexploited pelagic species is a high priority (Allison *et al.* 2002). However, the economic exploitation of offshore species is hampered by their dispersed nature (Menz and Thompson 1995).

Concentrating dispersed pelagic fishes using light-attraction is commonly applied in African fisheries (Balon 1971, Coulter 1976, Van Zwieten *et al.* 2002) to increase the catch rate. On Lake Malawi the only small-scale gear currently used to harvest offshore species, using light-attraction, is a pelagic purse seine locally known as the *chilimira* net. The *chilimira* net is fished either, during the day when semi-pelagic cichlids of the genus *Copadichromis* are targeted near submerged rocky outcrops (Smith 1998, Jackson 2000), or at night with the aid of light-attraction, when the small 'sardine-like' cyprinid *Engraulicypris sardella* is targeted (FAO 1993, Smith 1998).

The *chilimira* net has a headline length of 70m and is typically constructed of 36-ply multifilament netting with mesh size ranging from 6mm to 25mm. The cod-end is sometimes lined with mosquito netting (Weyl *et al.* 2000). The operation of *chilimira* nets at night using light attraction is well-described (Coulter and Znamensky 1971, FAO 1993). On Lake Malawi a typical *chilimira* crew comprises nine members using two dugout canoes and one larger plank boat. The plank boat is powered by a small outboard motor (9–15hp), which generally transports the dugout canoes to the fishing grounds. One of the dugout canoes is equipped with between one and three pressurised paraffin lamps. On reaching the fishing grounds, the dugout canoe with the pressurised paraffin lamps is stationed, with one crew member, away from the remaining vessels. After a sufficient quantity of fish is attracted the fishing vessels are summoned. The *chilimira* net is then deployed simultaneously from the plank boat and the second dugout canoe in a semi-circle around the attracted fish. On sinking, the net takes on the shape of a quarter sphere (Coulter and Znamensky 1971). The canoe with the lamps is then rowed slowly towards the net, drawing the attracted fish with it. The other canoe and plank boat come together and the net is hauled by hand into the plank boat.

Most fishing trips commence in the late afternoon (16h00) and end between 04h00 and 08h00. The catch is landed at well-defined landing sites and auctioned to buyers. The fishing periods are, however, highly dependent on weather and may be curtailed by storms. During full moon periods *chilimira* nets fish for limited periods before the rise of the moon.

The *chilimira* net was developed on Lake Malawi (Jackson 2000) and in the 1960s its use was confined to the steep, rocky shorelines of northern Lake Malawi and to isolated areas in the southeast and southwest arms of the lake (Howard 1961). Since then, the fishery expanded rapidly and in 1999 more than 2 500 *chilimira* nets (Weyl *et al.* 2000) accounted for more than 50% of the annual landings from the Malawian section of the lake (Malawi Department of Fisheries unpublished fisheries statistics).

While catch and effort in the *chilimira* net fishery has been monitored since 1976 (FAO 1993), this monitoring system aggregates both diurnal and nocturnal catches (Weyl *et al.* 1999). Lewis and Tweddle (1990) showed that night catches from the *chilimira* fishery were underrepresented in catch assessments and hypothesised that a considerable amount of *E. sardella* captured by this fishery may have been unrecorded.

There is a general lack of published information on the species composition of *chilimira* catches, as well as on the size selectivity of the gear. These factors are vital for the derivation of management advice for the fishery and this study represents the first specific assessment of the light-attraction component of the *chilimira* net fishery in southern Lake Malawi.

Methods

Study area

At its southern end Lake Malawi splits into two arms; the 1 210km^2 southwest arm (SWA) and the 1 820km^2 southeast arm (SEA), which together produce c. 60% of the fish yield taken from the lake (Ngochera 2001). This study focussed on this southern section of the lake. For monitoring purposes the shoreline of Lake Malawi is divided into a number of statistical areas, here termed 'strata', (FAO 1993). Within each of these strata there are a number of well-defined landing sites at which fish catches are landed by small-scale operators on the completion of fishing trips. Two strata (2.1 and 3.1) were selected for this study.

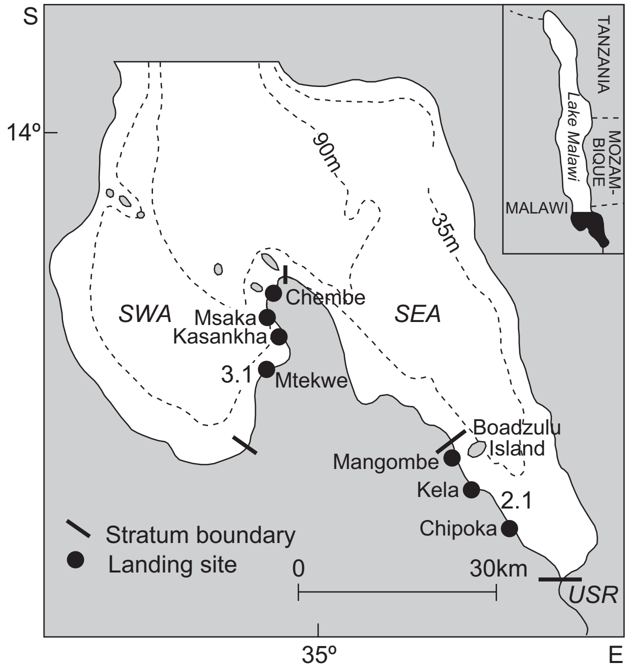

Figure 1: Map of southern Lake Malawi showing the landing sites in strata 2.1 and 3.1 where catch samples were collected between March 2000 and February 2001. SEA = southeast arm, SWA = southwest arm, USR = Upper Shire River

Stratum 2.1 is situated south of Boadzulu Island, on the western shore of the southern part of the SEA (Figure 1). In this area the lake bottom slopes gently from c. 2m deep at its outflow into the Upper Shire River to a maximum of c. 50m near Boadzulu Island. The shoreline and lake bottom are predominantly sandy, with a high mud content (Turner 1996). A monitoring survey conducted in 2001 enumerated 94 *chilimira* nets in this stratum (Weyl *et al.* 2002). Of these, 62 were landed at two adjacent landing sites, Kela and Chipoka (Figure 1). The main fishing ground for these nets is south of Boadzulu Island (Figure 1).

Stratum 3.1 is situated on the eastern shoreline of the SWA. The northeast coast of the SWA is steep and rocky and the lake bottom slopes rapidly to depths exceeding 50m and the maximum depth of the SWA is some 100m. In the southern part of stratum 3.1, the lake is relatively shallow, encompassing extensive swamps. In 2001, a total of 142 *chilimira* nets were enumerated in the stratum (Weyl *et al.* 2002). Eighty-two of these were recorded at two adjacent villages, Msaka and Chembe (Figure 1). The nets operating from these villages generally fish the deeper offshore waters (>50m in depth) around the islands of the Cape MacClear peninsula (Figure 1).

Sampling procedure

Due to the susceptibility of the fishery to weather conditions and the highly diverse nature of the multi-species catch, a bipartite approach was taken in this assessment.

First, catch and effort data, aggregated for all species in the catch, were collected by Malawi Department of Fisheries enumerators at three beaches, Chipoka, Mangombe and Kela in stratum 2.1, and four beaches, Chembe, Mtekwe, Kasankha and Msaka in stratum 3.1 (Figure 1). Both the sampling day and landing site were randomised within the period commencing in March 2000 and ending in February 2001.

On each sampling day the number of *chilimira* nets present at each particular landing site, together with the proportion of those nets actively fishing, were recorded. Of the nets that were fishing on a particular sampling day, a random sample was chosen for assessment. The total catch of these nets was weighed to the nearest kilogram, irrespective of species composition. Catch and effort data were collected on 77 days in stratum 2.1 and on 108 days in stratum 3.1. A total of 217 and 320 catches were sampled in stratum 2.1 and 3.1, respectively.

Second, the most active landing site in each area (i.e. Kela in stratum 2.1 and Msaka in stratum 3.1 (Figure 1)), was used for the determination of the species- and length-frequency composition of their catches. 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. A random sample of nets landing at each site was selected and the total catch of that net was weighed at the completion of the fishing trip. A sub-sample of the catch from the selected nets was taken. All fish in the sub-sample were identified to genus or species level and each component was weighed to the nearest gram and measured for total length (TL) to the nearest millimetre.

Species identifications 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). Turner (1996) lists fairly well-established informal species names for many of the undescribed haplochromine genera of Lake Malawi. In this study the formal names were used when possible, whereas Turner's informal species name was assigned to any species lacking a formal description. If a species lacked an informal name but could be identified to genus level it was categorised as an undescribed species within that genus. If a cichlid species could not be identified to genus level, as was the case with some juvenile cichlids <40mm TL, it was assigned to the category 'unidentified juvenile cichlid'. Due to difficulties in the accurate identification of juveniles of the *Oreochromis* '*Nyasalapia*' group (Turner *et al.* 1989), all species within this group were lumped.

Catch rate

The procedures outlined by Pollock *et al.* (1994) were used to determine catch per unit effort (CPUE). Since all *chilimira* nets were similar in construction and their total catch was recorded only on the completion of the fishing trip, daily effort units were standardised on a 'per net per trip' basis. All catch samples collected during this study were used in the analysis and mean CPUE for each net fished in period p and stratum s was then calculated as:

$$\overline{\text{CPUE}}_{p,s}(\text{kg net}^{-1}\text{ trip}^{-1}) = \frac{1}{n}\sum_{i=1}^{n}\frac{C_{i,p,s}(\text{kg})}{E_{i,p,s}(\text{trip})}$$

(Equation 1)

where $C_{i,p,s}$ is the i^{th} catch of n sampled during the p^{th} period in stratum s, and $E_{i,p,s}$ the effort (equal to one trip) expended to obtain $C_{i,p,s}$.

Due to marked seasonal variations, CPUE was calculated separately for six bimonthly periods: March–April 2000; May–June 2000; July–August 2000; September–October 2000; November–December 2000 and January–February 2001. These periods correspond to the main seasons; a dry winter from May to August, characterised by south-easterly winds that may reach force eight on the Beaufort Scale and average daily air temperatures of 20–22°C; a dry summer from September to November with a daily average air temperature of approximately 28°C; and a rainy season from late November to April, characterised by northerly winds and average daily air temperatures of 25°C (FAO 1993).

Bi-monthly CPUE data were compared with a non-parametric Kruskal-Wallis test. The Dunn's pairwise test was used for multiple comparisons. A 95% confidence level was used in all tests.

Effort

To determine mean bi-monthly fishing effort, in contrast to daily effort, a standard fisheries monitoring procedure (FAO 1993) was utilised. Fishing effort in stratum s during a two-month period p, comprising 60 possible fishing days, was calculated from the mean proportion of nets from a landing site fishing on any day ($\overline{pf}_{p,s}$) as:

$$\overline{E}_{p,s}(\text{net}^{-1}\text{ trips}) = 60(\text{days}) \times \overline{pf}_{p,s}(\text{net trips day}^{-1})$$

(Equation 2)

Total catch

Total catch for each net during period p in stratum s was calculated as:

$$TC_{p,s}(\text{tons}) = \frac{\overline{\text{CPUE}}_{p,s}(\text{kg net}^{-1}\text{ trip}^{-1}) \times \overline{E}_{p,s}(\text{net trips})}{1000}$$

(Equation 3)

and total annual catch for each net per stratum for six bi-monthly periods as:

$$\text{AC}_s(\text{tons}) = \sum_{p=1}^{6}\text{TC}_{p,s}(\text{tons})$$

Estimating variance

Non-parametric bootstrap resampling (Efron and Tibshirani 1986) was conducted to estimate CPUE, effort and total catch variability. For each sampling period, a large number (1 000 in this case) of pseudo-values (x_i) were drawn with replacement from the observed data. For example, in the case of CPUE the average of the pseudo-values, $\bar{x}_i$, would be the average of any random set of $C_{i,p,s}/E_{i,p,s}$ estimates drawn with replacement from the sample. Mean effort (Equation 2) was similarly estimated, and total catch (Equation 3) calculated as the product of the two. For all estimates, the bootstrap was conditioned on sample size, i.e., the number of resampled pseudo-values was the same as the number of values in the sample.

Variance was then estimated by:

$$\mathrm{Var}\,(x) = \frac{1}{1000}\sum_{i=1}^{1000}[\bar{x}_i - \bar{x}]^2$$

where $\bar{x}$ is the arithmetic mean of the pseudo-values. In the CPUE example, after a large number of resamples of $\bar{x}_i$ (in this case 1 000), $\bar{x}$ would converge asymptotically to Equation 1.

The percentile method was used to estimate 95% confidence intervals, where the 2.5% and 97.5% quartiles from the sorted $\bar{x}$ values were chosen to represent the upper and lower 95% confidence intervals respectively (Buckland 1984).

Species composition

The catch composition at genus/species level was determined by raising the mass of the species in each subsample to the mass of the sample.

Proportional species composition for any species/genus during each period *p* was then obtained by dividing the mass of the species/genus in all catches by the mass of all sampled catches.

The total catch of each species/genus was calculated by multiplying the proportional composition by the total catch in period *p*, and annual catch of each species/genus by summing over all periods.

Results

Catch

Bi-monthly CPUEs in strata 2.1 and 3.1 are illustrated in Figure 2A. In stratum 2.1 mean CPUE decreased significantly from 124 (95% CIs = 76–176)kg net^{-1} trip^{-1} during March/April to a July/August low of 38 (30–47)kg net^{-1} trip^{-1}. After July/August CPUE increased to 94 (78–109)kg net^{-1}. trip^{-1} in November/December, whereafter it decreased to 60 (51–69)kg net^{-1} trip^{-1} in January/February (Figure 2A). In stratum 3.1 CPUE fluctuated widely, with peaks of 187 (160–219)kg net^{-1} trip^{-1} during March/April, and 195 (156, 234)kg net^{-1} trip^{-1} in September/October. The lowest CPUE, 93 (70–120)kg net^{-1} trip^{-1}, was recorded during May/June (Figure 2A). CPUE in stratum 3.1 was significantly higher than that in stratum 2.1 during the periods March/April, July/August, September/October and January/February.

Bi-monthly effort is shown in Figure 2B. Effort differed significantly between periods in both strata. In stratum 2.1 effort fluctuated between 31 (11–51) trips in March/April to 55 (51–59) trips. In stratum 3.1, bi-monthly effort decreased from 38 (31–44) trips in March/April to nine (3–16) trips in May/June and then increased steadily to 46 (36–54) trips in January/February (Figure 2B). Bi-monthly effort in stratum 2.1 was similar to that in stratum 3.1 during March/April and January/February but was significantly higher during all other periods.

Bi-monthly estimates of the total catch per net in stratum 2.1 and 3.1 are shown in Figure 2C. In stratum 2.1, the estimated bi-monthly catch ranged from 2.1 (1.7–2.6) tons net^{-1} for the period July/August to 4.9 (4.0–5.8) tons net^{-1} in November/December. In stratum 3.1, bi-monthly catch ranged from 0.8 (0.3–1.5) tons net^{-1} during July/August to 7.2 (5.1–9.7) tons net^{-1} during January/February. Annual catch estimates for the two strata were similar; 19.4 (15.9–23.5) tons net^{-1} year^{-1} in stratum 2.1 and 23.5 (19.5–28.1) tons net^{-1} year^{-1} in stratum 3.1, respectively.

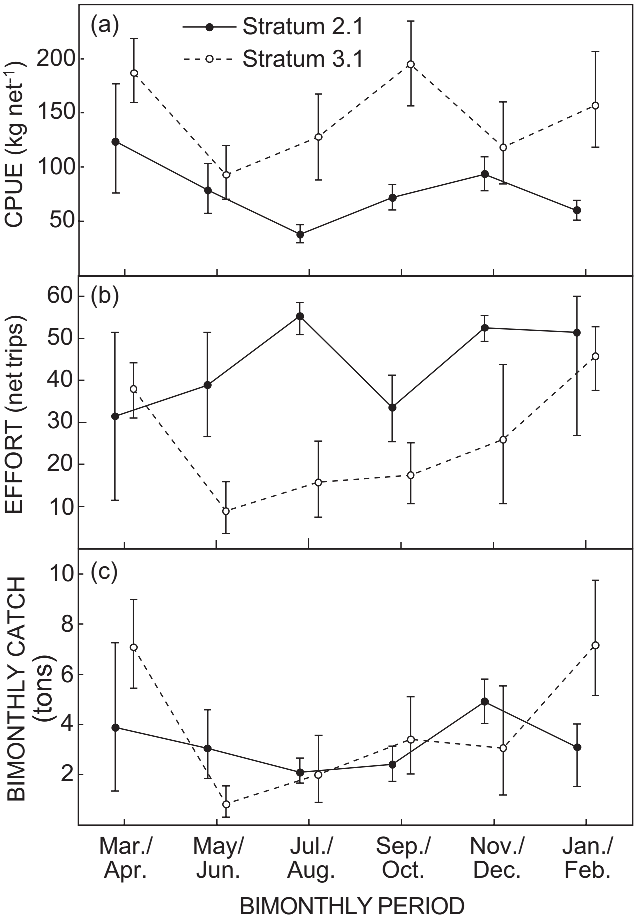

Figure 2: (a) Catch per unit effort (CPUE), (b) effort, represented by proportional fishing days and (c) catch per net in the *chilimira* net fishery during six bimonthly periods from March 2000 to February 2001 in strata 2.1 and 3.1 in southern Lake Malawi

Catch composition

A total of 62 species from 28 cichlid genera, and 13 species from nine non-cichlid genera, were identified from the samples (Table 1). Sixty different species were identified from catches sampled in stratum 2.1 and 51 species from catches sampled in stratum 3.1. Of these, 36 species were recorded from both strata, 24 species were recorded only from stratum 2.1 and 15 species were recorded only in stratum 3.1.

The bi-monthly and annualised catch composition at genus level in the two strata is summarised in Table 2. Of the 37 genera identified, only five; *Copadichromis*,

Table 1: List of all taxa sampled from *chilimira* net catches in strata 2.1 and 3.1 of southern Lake Malawi between March 2000 and February 2001. Superscript text denotes whether a species was recorded from stratum 2.1 (a), 3.1 (b) or from both strata (ab)

CICHLIDAE
Alticorpus mentale ^{a}
Aulonocara sp. 'gold' ^{b}
Aulonocara sp. 'blue orange' ^{a}
Aulonocara macrochir ^{a}
Buccochromis atritaeniatus ^{a}
Buccochromis lepturus ^{ab}
Buccochromis nototaenia^{a}
Buccochromis rhoadesi ^{ab}
Cheilochromis euchilus ^{b}
Copadichromis chrysonotus ^{ab}
Copadichromis conophoros ^{b}
Copadichromis pleurostigma ^{a}
Copadichromis quadrimaculatus ^{ab}
Copadichromis trimaculatus ^{ab}
Copadichromis virginalis ^{ab}
Corematodus taeniatus ^{a}
Ctenopharynx intermedius ^{a}
Ctenopharynx pictus ^{b}
Dimidiochromis kiwinge ^{ab}
Diplotaxodon argenteus ^{ab}
Diplotaxodon bigeye ^{b}
Diplotaxodon greenwoodi ^{ab}
Diplotaxodon limnothrissa ^{ab}
Fossochromis rostratus ^{ab}
Hemitaeniochromis insignis ^{ab}
Lethrinops alta ^{a}
Lethrinops auritus ^{a}
Lethrinops lethrinus ^{a}
Lethrinops longimanus ^{b}
Lethrinops longipinnis ^{a}
Lethrinops parvidens ^{ab}
Mylochromis anaphyrmus ^{ab}
Mylochromis semipalatus ^{a}
Naevochromis chrysogaster^{a}
Nimbochromis livingstonii ^{b}
Nimbochromis venustus ^{b}
Nyassachromis argyrosoma ^{ab}
Nyassachromis eucinostomus ^{b}
Oreochromis karongae ^{ab}
Oreochromis lidole ^{a}
Oreochromis squamipinnis ^{ab}

CICHLIDAE
Otopharynx argyrosoma ^{ab}
Otopharynx auromarginatus ^{a}
Otopharynx speciosus ^{ab}
Placidochromis subocularis ^{ab}
Protomelas similes ^{a}
Protomelas taeniolatus ^{b}
Pseudotropheus elegans ^{ab}
Pseudotropheus livingstonii ^{ab}
Rhamphochromis esox ^{ab}
Rhamphochromis ferox ^{ab}
Rhamphochromis longiceps ^{ab}
Rhamphochromis macrophthalmus ^{ab}
Scaenochromis ahli ^{a}
Sciaenochromis benthicola ^{ab}
Stigmatochromis woodi ^{a}
Taeniochromis holotaenia ^{b}
Taeniolethrinops praeorbitalis ^{a}
Tramitichromis lituris ^{b}
Trematocranus brevirostris ^{a}
Trematocranus microstoma ^{a}
Trematocranus placodon ^{a}

CYPRINIDAE
Barbus eurystomus ^{ab}
Barbus johnstoni ^{ab}
Barbus litamba ^{b}
Engraulicypris sardella ^{ab}
Labeo cylindricus ^{b}
Labeo mesops ^{b}
Opsaridium microcephalum ^{ab}
Opsaridium microlepis ^{ab}

MORMYRIDAE
Mormyrus anguilloides ^{ab}

SILUROIDEI
Bagrus meridionalis ^{ab}
Bathyclarias spp. ^{ab}
Clarias gariepinus ^{a}
Synodontis njassae ^{ab}

Dimidiochromis, *Engraulicypris*, *Oreochromis* and *Rhamphochromis*, contributed more than 5% to the total annual catch in either stratum. Their combined contribution to the annual catch was in excess of 85% in both strata (Table 2).

The genus *Copadichromis* occurred in 68% and 64% of all catches assessed in strata 2.1 and 3.1, respectively. In stratum 2.1, the contribution of this genus to the total catch ranged from less than 2% during March/April and May/June to more than 10% during November/December and January/February (Figure 3a). In stratum 3.1, the genus contributed less than 5% during March/April, May/June and July/August and more than 40% during November/December. (Figure 3b). As a proportion of the total annual catch, *Copadichromis* contributed 7.5% and 11.6% to the annual catch in strata 2.1 and 3.1 respectively (Table 2).

Six *Copadichromis* species (*C. chrysonotus*, *C. conophoros*, *C. pleurostigma*, *C. quadrimaculatus*, *C. trimaculatus* and *C. virginalis*) were identified in the catch. Of these, *C. chrysonotus* and *C. virginalis* dominated the catch composition, with each species contributing in excess of 40% to the total *Copadichromis* catch in both areas. *C. quadrimaculatus* contributed 12.5% and 10.5% to the total *Copadichromis* catch in stratum 2.1 and 3.1, respectively. *C. conophoros, C. pleurostigma* and *C. trimaculatus* were considered incidental catches.

The genus *Dimidiochromis* was represented by a single species, *D. kiwingae*, which contributed 6.0% and 6.9% to the annual catch in strata 2.1 and 3.1 respectively. Despite its relatively large contribution to the total catch, this genus was represented in only 33% of the catches in stratum 2.1, and in 18% of the catches in stratum 3.1. The contribution of this species to the catch composition varied considerably between periods. In stratum 2.1 the contribution of *D.*

Table 2: Percent contributions of cichlid and non cichlid genera to the *chilimira* net catches sampled in strata 2.1 and 3.1 in southern Lake Malawi during six bi-monthly periods: March/April 2000 (P1); May/June 2000 (P2); June/July 2000 (P3); September/October 2000 (P4); November/December 2000 (P5) and January/February 2001 (P6), and an annual estimate (A) of the contribution of each genus to the annual catch of each net. Missing values denote the absence of the genus from the sample; 0.0 denotes that the genus contributed <0.05% to the catch

Period	Stratum 2.1							Stratum 3.1						
Genus	P1	P2	P3	P4	P5	P6	A	P1	P2	P3	P4	P5	P6	A
Cichlids														
Alticorpus		0.2					0.0							
Aulonocara	0.5		0.0	0.0		0.0	0.1			0.0				
Buccochromis	2.5	0.2	0.4	0.4	1.0	3.3	1.5	3.1					2.8	2.0
Cheilochromis										0.0				
Copadichromis	1.3	1.3	8.7	3.3	16.2	11.0	7.5	1.8	2.4	4.8	11.2	41.5	9.8	11.6
Corematodus			0.8	0.3	0.1	0.3	0.1							
Ctenopharynx	0.1				0.4		0.1			0.0				
Dimidiochromis	0.8	2.4	1.9	1.7	16.5	2.9	6.0	3.0	0.6	0.1	0.6	0.0	17.4	6.9
Diplotaxodon	0.2	0.4	9.9	5.5	0.4	3.5	1.6	0.2	0.0	0.7	4.4	12.0		2.4
Fossorochromis			0.3	1.0	1.9		0.7				0.1		0.4	0.2
Hemitaeniochromis				0.0			0.0			0.0				
Lethrinops	0.9	0.2	0.3	0.1	0.0	0.0	0.2			0.0			0.0	0.0
Maravichromis	0.1	0.0		0.0			0.0			0.0				
Naevochromis					0.0		0.0							
Nimbochromis									0.0	0.0				0.0
Nyassachromis	0.0		0.0				0.0	0.0	0.0	0.0				0.0
Oreochromis	74.6	74.9	38.1	18.2	26.0	29.7	45.1	0.3		0.1	0.8	0.2	1.4	0.7
Otopharynx		0.4	0.3	0.7		0.1	0.2		0.4	0.0		0.0		0.0
Placidochromis	0.1	0.0		0.0	0.0		0.0		0.1	0.0			0.0	0.0
Protomelas				0.3	0.0		0.0			0.0				
Pseudotropheus	0.2	0.3	0.3	0.1	0.0	0.0	0.1			0.0	0.0			0.0
Rhamphochromis	10.1	9.1	26.1	54.3	29.7	30.1	25.2	55.8	49.5	21.6	72.7	44.8	57.6	57.3
Sciaenochromis	0.0	0.0					0.0			0.0				
Stigmatochromis	0.1	0.2	0.0	0.4	0.1		0.1							
Taeniochromis											0.0			0.0
Taeniolethrinops	0.1	0.0					0.0							
Tramitichromis									0.1	0.0				0.0
Trematocranus	0.5	0.1	0.1		0.1		0.2							
Unidentified juvenile cichlids						0.0	0.0							
Non-Cichlids														
Bagrus	1.9	0.1	9.8	0.4	1.6	6.0	2.0			0.7	0.5	0.4		0.1
Barbus	0.5			5.8	0.2	0.3	1.0	0.3	0.1	0.2	0.6	0.1	0.6	0.4
Bathyclarias	4.6	7.2		1.4		6.3	3.6	1.1		1.1	2.3		4.8	2.3
Clarias	0.7	0.3	2.7	1.9			0.5							
Engraulicypris		1.1	0.4	2.5	5.3	5.7	3.1	31.8	42.1	68.0	4.2	0.5	1.9	13.4
Labeo											0.2	0.1		0.0
Mormyrus				0.0		0.6	0.1			1.1				
Opsaridium	0.2	1.3		1.7	0.6	0.4	0.7	2.6	4.8	1.5	2.3	0.3	3.2	2.5
Synodontis	0.1	0.4					0.1				0.0			0.0

kiwingae to the total catch ranged from <1% during March/April to >16% during November/December (Figure 3). In stratum 3.1 it contributed <3% to the catch during all periods except January/February, when it contributed >17% to the catch (Figure 3).

The genus *Engraulicypris* is monotypic, with a single species, *E. sardella*, which was a major contributor to the catch in stratum 3.1 (>13%) but contributed only 3% to the annual catch in stratum 2.1 (Table 2). *E. sardella* was present in 78% of the catches in stratum 3.1, but in only 34% of the catches from stratum 2.1. Consequently, *E. sardella* contributed less than 6% to the catch during all periods in stratum 2.1, while in stratum 3.1 its contribution to the catch varied from <4.2% from September/October to January/February, to between 31% and 68% from March to July (Figure 3). The total annual catch of this species was estimated at 0.5 tons net^{-1} year^{-1} in stratum 2.1 and 4.2 tons net^{-1} year^{-1} in stratum 3.1.

The genus *Oreochromis 'Nyasalapia'* was the most important component of the fishery in stratum 2.1, occurring in more than 75% of all catches and contributing between 18% and 75% to the catch composition during all periods (Figure 3). *Oreochromis 'Nyasalapia'* contributed 45.1% to the annual *chilimira* catch in stratum 2.1 (Table 2) which corresponded to an annual catch of more than 8.5 tons net^{-1} year^{-1}. In stratum 3.1, the contribution of this genus to the total annual catch was negligible (<1%). Of the three *Oreochromis 'Nyasalapia'* species, two species *O. karongae*

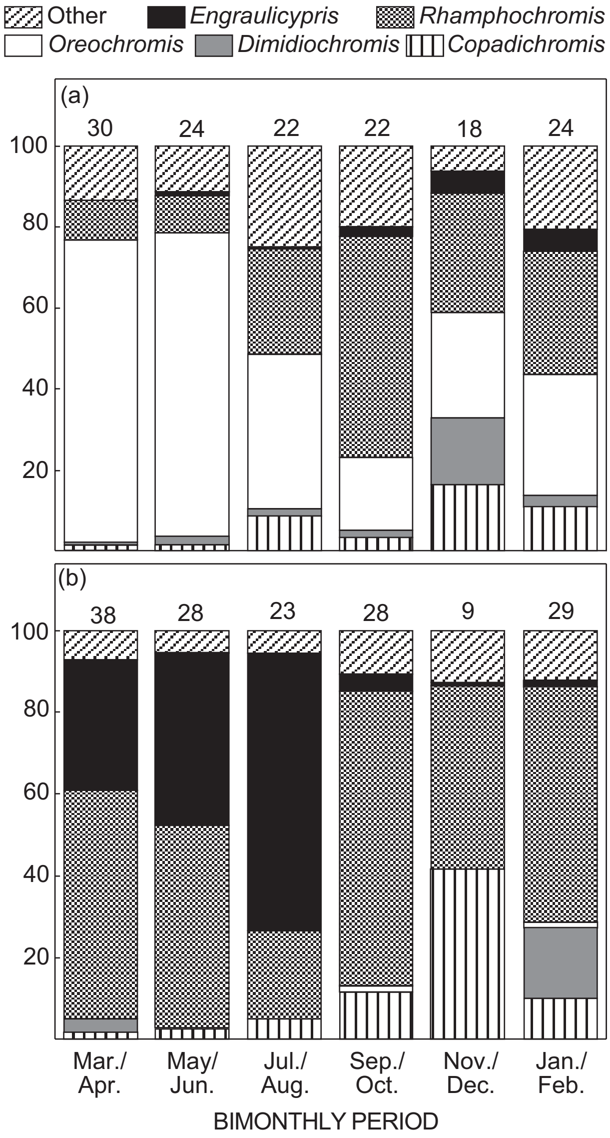

Figure 3: Percent catch composition by *Copadichromis*, *Dimidiochromis*, *Engraulicypris*, *Oreochromis* and *Rhamphochromis* species in the chilimira net fishery sampled in (a) stratum 2.1 and (b) stratum 3.1 in southern Lake Malawi from March 2000 to February 2001. All other species were lumped into the group 'other'. Numbers above bars represent the number of catches sampled during each period

and *O. squamipinnis* were recorded in both strata, while *O. lidole* was only recorded in stratum 2.1. Due to the inherent difficulty in identifying immature individuals of the three species, the species composition within the genus was not assessed further.

Rhamphochromis species contributed between 9% and 54% to the catch in stratum 2.1 and between 21% and 77% to the catch in stratum 3.1 during all periods (Figure 3). On an annual basis, the genus was represented in more than 86% and 92% of all catches assessed in strata 2.1 and 3.1, respectively. As a percentage of the annual *chilimira* catch, this genus comprised 25% and 54% of the total annual catch in strata 2.1 and 3.1, respectively.

Due to complications with the accurate identification of species belonging to the genus *Rhamphochromis*, identification to species level was performed on a sub-sample comprising 14% and 27% of all *Rhamphochromis* samples in strata 2.1 and 3.1, respectively. Within these sub-samples, four *Rhamphochromis* species, *R. esox*, *R. ferox*, *R. longiceps* and *R. macrophthalmus* were identified in both strata. *R. macropthalmus* was a minor component (<0.3%) of the *Rhamphochromis* catch in both areas. In stratum 2.1, the relative contributions of *R. esox*, *R. ferox* and *R. longiceps* to the total *Rhamphochromis* catch were 3.2%, 7.1% and 89.5% respectively. In stratum 3.1, the relative contribution of *R. esox*, *R. ferox* and *R. longiceps* to the total *Rhamphochromis* catches were 15.6%, 66.4% and 17.8% respectively.

The combined annual contributions of five other genera, *Bagrus, Bathyclarias*, *Buccochromis, Opsaridium* and *Diplotaxodon*, were 11% and 9% in strata 2.1 and 3.1 respectively (Table 2). Therefore, these genera constitute an important by-catch in the fishery.

The genus *Bagrus* was represented by a single species, *B. meridionalis*, which contributed 2% and 0.1% to the total catch and which occurred in 12% and 4% of all catches assessed in strata 2.1 and 3.1 respectively. *Bathyclarias* comprised 3.6% and 2.3% of the annual catch and occurred in 19% and 9% of all catches in strata 2.1 and 3.1, respectively.

The genus *Buccochromis* comprised 1.5% and 2.0% of the total catch and occurred in 21% and 5% of all catches in strata 2.1 and 3.1, respectively. Four species were identified; *B. atritaeniatus*, *B. lepturus*, *B. nototaenia* and *B. rhoadesi*. All four species were represented in stratum 2.1, with *B. atritaeniatus* (45.8%) and *B. lepturus* (44.5%), dominating the *Buccochromis* catch. In stratum 3.1, only *B. lepturus* (98.8%) and *B. rhoadesi* (1.2%) were identified.

The genus *Diplotaxodon* contributed 1.6% and 2.4% to the annual catch and occurred in 28% and 42% of all catches sampled from strata 2.1 and 3.1 respectively. Four species, *D. argenteus*, *D. bigeye*, *D. greenwoodii*, and *D. limnothrissa,* were identified. *D. limnothrissa* was the most important species within this genus, comprising 69.1% and 92.3% of annual *Diplotaxodon* landings.

Despite occurring in 17% of the catches, the genus *Opsaridium* was a minor component of the fishery by mass in stratum 2.1 (<1%). In stratum 3.1 it was present in 35% of all catches sampled and contributed 2.5% to the annual catch. Two *Opsaridium* species, *O. microlepis* and *O. macrocephalus* were present in approximately equal proportions in the catch.

The remaining 27 genera contributed <4% to the catch in stratum 2.1 and <1% in stratum 3.1 and were considered a minor by-catch in the fishery. For this reason, they are not discussed further.

Length-frequency analysis

Length-frequency histograms of the major target species, illustrated in Figure 4, differed considerably between strata. The length frequency distributions for *C. quadrimaculatus, C. virginalis, D. limnothrissa, R. ferox* and *R. esox* were bimodal in stratum 2.1, with the first mode before the length-at-maturity. In stratum 3.1, the length frequency distribution

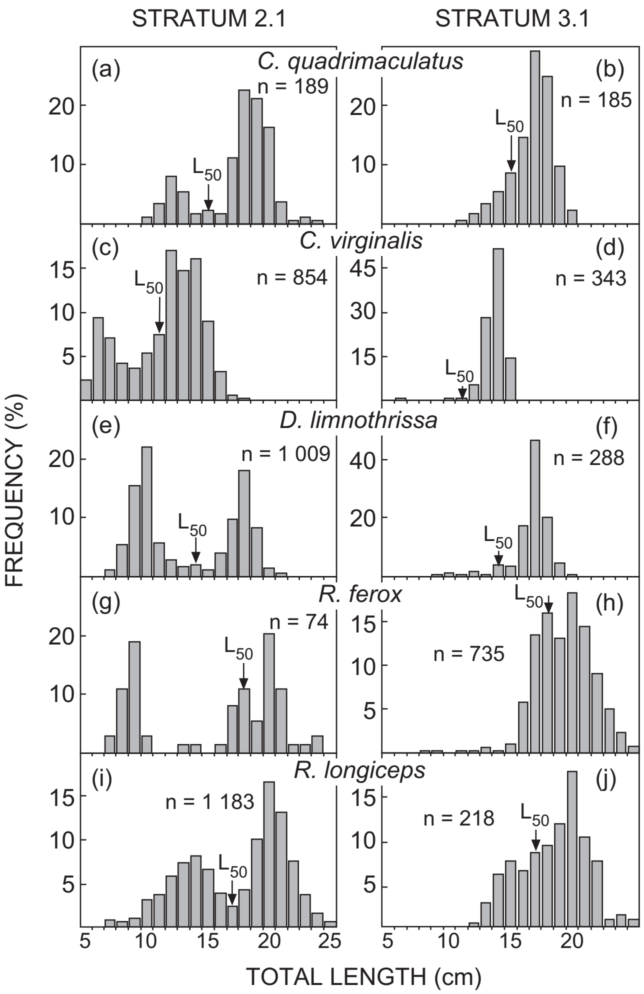

Figure 4: Length-frequency for *Copadichromis quadrimaculatus* (a, b), *Copadichromis virginalis* (c, d), *Diplotaxodon limnothrissa* (e, f), *Rhamphochromis ferox* (g, h) and *Rhamphochromis longiceps* (i, j) sampled from the chilimira net fishery in strata 2.1 and stratum 3.1 in southern Lake Malawi between March 2000 and February 2001. Length-at-maturity (L_{50}) was derived from the literature (Tweddle and Turner 1977, Thompson *et al.* 1996b, Turner *et al.* 2000)

was unimodal with the mode occurring after the length-at-maturity (Figure 4).

Insufficient *Oreochromis 'Nyasalapia'* were present in the catch samples in stratum 3.1 for meaningful comparison between strata. The length frequency distribution of *Oreochromis 'Nyasalapia'* in catches from stratum 2.1 is presented in Figure 5. *Oreochromis 'Nyasalapia'* in the catch ranged from 100–400mm TL and their length-frequency distribution is skewed, rising rapidly to 200mm TL and then declining gradually to 400mm TL. The length-frequency distribution of *Oreochromis 'Nyasalapia'* of the catch can therefore be described as unimodal with the mode occurring before maturity.

The length-frequencies of other major species in the *chilimira* net catch were unimodal with no discernible differences between strata (Table 3).

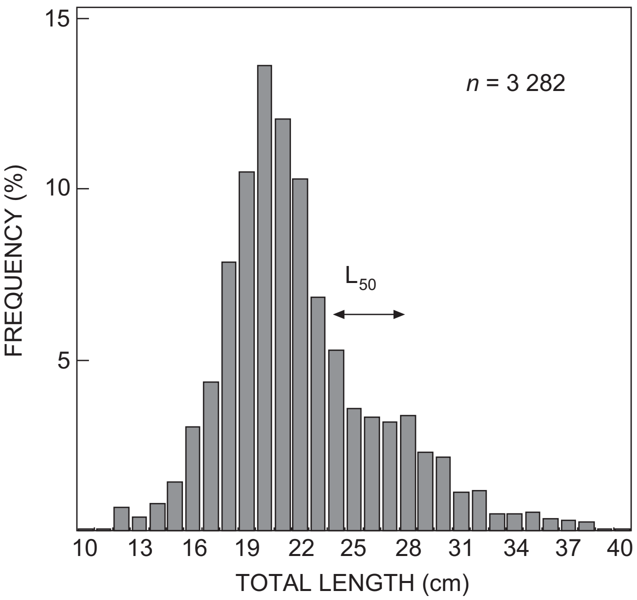

Figure 5: Length-frequency for *Oreochromis 'Nyasalapia'* species sampled from the *chilimira* net fishery in stratum 2.1 in southern Lake Malawi between March 2000 and February 2001. The length-at-maturity (L_{50}) range represents the ranges at maturity for *O. karongae*, *O. lidole* and *O. squamipinnis* derived from Trewavas (1983)

Table 3: Mean length at capture ± standard deviation (mm total length) of species (in genera contributing >4% to the catch composition) with unimodal length-frequency distributions in the *chilimira* net catch in southern Lake Malawi

Species	Mean length at capture (mm TL ± SD)
Bagrus meridionalis	432 ± 141
Bathyclarias spp.	493 ± 165
Buccochromis spp.	220 ± 45
Copadichromis chrysonotus	142 ± 29
Copadichromis conophoros	85 ± 11
Copadichromis pleurostigma	143 ± 22
Copadichromis trimaculatus	136 ± 17
Dimidiochromis kiwingae	204 ± 40
Diplotaxodon argenteus	184 ± 34
Diplotaxodon greenwoodii	206 ± 33
Engraulicypris sardella	92 ± 16
Opsaridium microlepis	233 ± 74
Opsaridium microcephalus	212 ± 64
Rhamphochromis esox	269 ± 84
Rhamphochromis macrophthalmus	260 ± 7

Discussion

Smith (1998) attempted to disaggregate catch data by assessing fishing groups targeting the *Copadichromis* species or *E. sardella* separately, but did not focus specifically on the light-attraction fishery. The current study is, therefore, the first assessment of the light-attraction component of the *chilimira* fishery. Estimates of CPUE and effort for stratum 3.1 compared favourably with previous estimates (Smith 1998) but differed considerably from those derived from stratum 2.1. CPUE in stratum 2.1 was generally lower than that recorded in stratum 3.1 but nets in stratum 2.1 fished more frequently; this led to similar annual catches being made in the two strata (Figure 2). Environmental differences in the two strata might explain the different CPUE and effort.

Fishers in stratum 3.1 generally operate offshore where large, south-easterly wind-generated waves in winter (May to August) may curtail or even cause fishing trips to be cancelled. Consequently, a distinct reduction in fishing effort was observed over this period in this stratum (Figure 2). Due its proximity to the southernmost shoreline of the lake and thus the reduced wave-generation capacity during windy periods, effort in the fishery of stratum 2.1 was relatively stable throughout the year (Figure 2).

As was the case with previous assessments of the *chilimira* net fishery (Lewis and Tweddle 1990, Smith 1998), *Copadichromis* and *E. sardella* were well-represented in the catch, sometimes occurring in great quantities (Table 2). However, their combined contribution to the total annual catch in the fishery was only 11% in stratum 2.1% and 25% in stratum 3.1 (Table 2). While the low contribution of *Copadichromis* to night catches of this fishery was a feature also documented by Smith (1998), the low contribution of *E. sardella* was surprising.

E. sardella is a fast-growing species with a large reproductive output, a high natural mortality rate, density-dependent larval survival and widely fluctuating stocks (Tweddle and Lewis 1990, Thompson and Allison 1997). Hence, the low contribution of *E. sardella* to the total catch in both areas may be a consequence of poor recruitment in the previous year.

Despite relatively low *E. sardella* catches, predatory pelagic cichlids of the genus *Rhamphochromis* and *Dimidiochromis* made up a considerable portion of the catch (Tables 2 and 3). The presence of predators as a major component of light-attraction fisheries is well documented (Cochrane 1976, Coulter 1976, Van Zwieten *et al.* 2002). In Lake Tanganyika the predatory centropomid *Lates stappersii* makes up a considerable proportion of the catch of the light-attraction fishery targeting the clupeids *Stolothrissa tanganyikae* and *Limnothrissa miodon* (Van Zwieten *et al.* 2002). Similarly, the predatory characid *Hydrocynus vittatus* constitutes a considerable by-catch in the light-attraction fishery for *L. miodon* in Lake Kariba (Cochrane 1976).

Coulter (1976), working on *L. stappersii* in Lake Tanganyika, suggested that the predators were drawn to the lamps from a wider radius than were their clupeid prey. The concentration of prey would also account for the presence of other, less abundant pelagic piscivores (Thompson and Allison 1997) such as *Bathyclarias* and *Opsaridium*, as well as for the catch of typically benthic predators (Tweddle 1975, Lovullo *et al.* 1992, Turner 1996) belonging to the genera *Buccochromis* and *Bagrus*.

Of the more than 500 species in the lake, few are considered truly pelagic (Thompson and Allison 1997). Within the family Cichlidae, all species in the genera *Rhamphochromis* and *Diplotaxodon* are pelagic (Thompson and Allison 1997). In addition, a single *Copadichromis* species, *C. quadrimaculatus,* is considered pelagic, because it migrates from inshore rocky areas into the pelagic zone at about 130mm TL and then returns only during the breeding season (Iles 1960, Thompson *et al.* 1996a). Two cyprinid genera, *Engraulicypris* and *Opsaridium*, and two siluroid genera, *Bathyclarias* and *Synodontis*, have been recorded in considerable quantities in the pelagic zone (Thompson *et al.* 1996b). Pelagic species contribute 79% to the annual catch in stratum 3.1% and 35% to the catch in stratum 2.1.

The annual pelagic species catch is c. 6.8 tons net^{-1} year^{-1} and c. 18.6 tons net^{-1} year^{-1} in strata 2.1 and 3.1, respectively. With a total of 94 *chilimira* nets in stratum 2.1 and 142 in stratum 3.1 (Weyl *et al.* 2002), the total annual pelagic species catch in these two strata could exceed 3 000 tons. The assumption that the pelagic stock of the lake is unexploited (Thompson and Allison 1997) is therefore no longer valid. However, due to the lack of lake-wide data, the total extent of this harvest is unknown.

A considerable portion of the catch in stratum 2.1 comprised semi-pelagic species belonging to the cichlid genera *Copadichromis*, *Dimidiochromis* and *Oreochromis ‘Nyasalapia’* (Table 2). While *Oreochromis ‘Nyasalapia’* has been recorded as an occasional by-catch in the *chilimira* fishery in the SWA (Smith 1998), a rapid assessment undertaken by the Malawi Department of Fisheries in 1996 showed that juvenile *Oreochromis ‘Nyasalapia’* contributed significantly to the catch in the fishery south of Boadzulu Island (Banda 1996). The findings of the rapid assessment are supported by this study (Figure 3). However, the low contribution of the genus to catches in stratum 3.1 indicates that the presence of this genus in the catch is area specific. Lowe (1952) hypothesised that the *Oreochromis ‘Nyasalapia’* stocks were localised. This hypothesis was further confirmed by Kanyerere (2001), who showed that the chambo stock of the SEA was concentrated south of Boadzulu Island. It is therefore possible that the substantial contribution of *Oreochromis ‘Nyasalapia’* to the catch in stratum 2.1 was a result of a localised concentration. Alternatively, this genus is more vulnerable to the fishing gear in the shallower fishing grounds. Unfortunately, data limitations prevented testing these hypotheses.

The multi-species nature of the light attraction fishery complicates its management as each target species differs in body shape, growth and maturity (Iles 1960, Tweddle and Turner 1977, Trewavas 1983, Thompson *et al.* 1996a, 1996b, Turner *et al.* 2000, Smith 2000). It has long been recognised that, when a fishery harvests a number of species, it is impossible to manage each species at its optimum level (Murawski 1984) because harvest levels appropriate for one species may not be suitable for another. In such cases one possible option is to base management on the least-resilient target species in the multi-species fishery.

This study has shown that less than six genera contribute more than 80% to the catch, and thus management measures should focus on these genera. The pelagic *Rhamphochromis* and *Diplotaxodon* stocks are considered widespread and not in immediate danger of localised overexploitation (Turner *et al.* 2000) and *E. sardella* numbers are considered to be driven by environmental factors rather than by fishing mortality (Thompson and Allison 1997). These three genera are therefore not a management priority here. Although *D. kiwingae* is distributed throughout the lake (Turner 1996), no published information is available on the status of its stock. Species of the genus *Copadichromis* and *Oreochromis 'Nyasalapia'* are more limited in distribution (Lowe 1952, Trewavas 1983, Turner 1996) and locality-specific overfishing has been documented (Lowe 1952, FAO 1993, Tweddle *et al.* 1994, Weyl 2000, 2001). These two genera should therefore be the focus of management in this fishery.

The predominance of juveniles in the *Oreochromis 'Nyasalapia'* catch in stratum 2.1 (Figure 5) is cause for concern. The three main species within this genus, *O. karongae*, *O. lidole* and *O. squamipinnis*, are schooling phytoplanktivores which use the inshore littoral zone as nursery areas and migrate offshore prior to attaining maturity at lengths exceeding 220mm TL (Trewavas 1983, Lewis 1990). The mode of the skewed length-frequency distribution prior to the length at maturity (Trewavas 1983) indicates that the light-attraction fishery may contribute towards both growth overfishing (by capturing young fish before they have grown sufficiently to contribute significantly to overall biomass) and recruitment overfishing (by excessive reduction of spawner biomass). Since the contribution of this genus to catches in stratum 3.1 was negligible, management interventions for this genus need to be area-specific.

Furthermore, it was interesting to note that, while the majority of the other target species in the fishery of stratum 3.1 were mature, a considerable proportion of the *R. ferox*, *R. longiceps*, *C. virginalis*, *C. quadrimaculatus* and *D. limnothrissa* harvested in stratum 2.1 were juveniles (Figure 3).

Although the *Rhamphochromis* and *Diplotaxodon* stocks are considered widespread and not susceptible to localised overexploitation, little is known about the use of nursery areas by pelagic and semi-pelagic cichlid species (Turner *et al.* 2000). Since the bimodal length frequency structure in stratum 2.1 indicates that this fishery may operate in a nursery area for *R. ferox*, *R. longiceps*, *C. virginalis*, *C. quadrimaculatus* and *D. limnothrissa*, expansion of the fishery in this area must be viewed with caution.

The dependence of catch-composition and size-selection on area indicates that management interventions for this fishery need to be area-specific. Since the fishery targets a diverse species assemblage, effort limitation or area closure may be the only viable management options, until such time as additional biological and fisheries data are available for the application of stock assessment models.

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