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Original Article

Growth aspects of grey mullet *Mugil cephalus* Linnaeus, 1758 from Kilifi creek, Kenya

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Growth, M. cephalus, Length-weight, Kilifi, Age.

ABSTRACT

Mullets form a major component of pelagic fish landings in tropical areas. M. cephalus Linnaeus, 1758 were collected from Kilifi creek between October 2002 and September 2004 using gillnets and a cast net. The sampling sites were Nkoma, Mazioni, Kidundu and Kombeni sites in the southern arm while the northern arm had Sea Horse, Fumbini, Konjora and Rare sites chosen based on observed physical characteristics. The total length (mm), total weight (g) was recorded and the abdomen dissected for gonad identification. From 765 specimens obtained, length-weight relationship (Regression and test of isometry), relative condition factor (Kn), age and growth (Von Bertalanffy Growth Equation VBGE) were performed. In 537 males, length ranged between 57mm and 480mm, the weight between 3g and 1169g. The regression line fitted for length on weight was $Log10\ W = 1.7457 + 2.8658\ Log10\ L$ and the test of isometry (b=2.8658) was significantly different from 3 (t^ = 21.2138; $P < 0.05$). The length ranged between 61mm and 507mm, weight between 3.8g and 1385g in 228 females. The regression line fitted for length on weight being $Log10\ W = 1.7973 + 2.8955\ Log10\ L$ and the test of isometry (b=2.8955) was significantly different from 3 (t^ = 13.5536; $P < 0.05$). Low monthly variations in the relative condition factors between the sexes as well as during the different seasons was observed, however, the males had higher relative condition factors than females. Asymptotic length (VBGE) was calculated for M. cephalus at each site with largest fishes caught at Sea Horse, Nkoma, Fumbini and Mazioni while the smallest fishes were from Kombeni and Kidundu. In females, the asymptotic length $L\infty$ (51.48 cm) was higher than in males (48.3 cm) and no notable difference was observed in K (growth coefficient) between females (0.83) and males (0.79) respectively. Kilifi creek needs conservation as source of juveniles for stocking in ponds for future culture.

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INTRODUCTION

The finfish family Mugilidae (the mullets), are widely distributed in all tropical, subtropical, and temperate seas forming part of coastal marine species landed (Asish et al., 2016). Jacot, (1920) pioneered growth and development studies on mullets of the Atlantic coast of United States with an aim of artificial propagation having noted that their supply continually falls short of the demand. Growth is the measurable increase of an organic system in weight or length produced by its assimilation of materials obtained from its environment and is widely dependent on external factors (von Bertalanffy, 1938).

In the study of fish populations, growth and age structure are essential features, with many researchers using annuli (Weatherly and Rogers, 1978), while others have used length-weight relationships to estimate growth (Kraiem et al., 2001, Ilkyaz et al., 2006). The mullets are more difficult to age than majority of marine fishes because of widespread distribution and considerable commercial importance (Kennedy and Fitzmaurice, 1969). Researchers in temperate regions have different estimates for length at age, attributed to differences in interpretation of scales, otoliths or other structures used for age determination (Grant and Spain, 1975, Ibanez et al., 1999, Moura and Gordo, 2000, Kraiem et al., 2001,).

Morato et al., (2001) reported that length and weight data are useful and standard results of fish sampling programs essential for a wide number of studies including estimating growth rates, age structure and aspects of fish population dynamics. The determination of length-weight relationship in fish, is important both for practical and biological points of view (Bagenal and Tesch, 1978). The length-weight relationships are used in the calculation the standing stock biomass, condition indices, the analysis of ontogenetic changes and several aspects of fish population dynamics. Treasurer, (1976) noted that length has less annual fluctuation hence a more reliable indicator of growth than weight. Moura and Gordo, (2000) identified five species of mullets at Obidos lagoon, Portugal, estimated their age from otoliths and length frequency analysis, reporting no significant differences between the growth curves obtained using the two methods.

Assessment of fish population health has always used condition indices (Hartman and Margraf, 2006). Chan and Chua, (1980) reported that in *Liza subviridis* (Valenciennes, 1836), the relative condition factors varied between the juvenile males and females. Nzioka (1981) observed higher condition factor for females than males which he attributed to the fact that, ovaries constituted 4% of the total body weight in ripe females compared to 0.7% total body weight of ripe testes. The condition factor indicates feeding, spawning and other aspects related to the wellbeing of the fish (Soumendra et al., 2017).

Thomson (1966) observed that in sub-tropical and temperate waters, growth of mullet ceases in winter but reaches its maximum at mid-summer while in tropical waters, no regular formation of annuli occurs on scales and otoliths. Age and growth have been estimated from length-weight relationships by various researchers to establish the age of the largest possible length (asymptotic length) in fish after being incorporated in the von Bertalanffy equation (Wootton, 1998). The asymptotic length of *Liza aurata* (Risso, 1810) from Homa lagoon, Izmir Bay was estimated as L_∞ = 43.2 cm (Ilkyaz et al., 2006). Ibanez et al., (1999) reported differences in the asymptotic lengths in *M. cephalus* (females L_∞ = 622.9 mm and males L_∞ = 603.9 mm) and *M. curema* Valenciennes, 1836 (females L_∞ = 454.6 mm and males L_∞ = 411.8 mm) from the Gulf of Mexico.

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Williams (1996) was more concerned with global fish supply, which are becoming scarce and more subject to human influences but will only be improved by better management of fishery resources. She further noted that aquatic resources make up 19 % of the total animal protein consumed and also provide environmental cultural values and services. Williams and Corral (1999) observed that monitoring has a key role to play in all aspects of fisheries management including those related to sustainable management of the resource.

In Kenya, Mullets form a major component of pelagic fish landings which was highest (698 Mt) in 2019, has been decreasing steadily and in 2023, 585 metric tons was landed, a major improvement from 2022. Most mullets were landed from Lamu County (260 Mt), followed by Kwale (183 Mt), and least from Tana River County (39 Mt) explained by improved data collection (Kenya Fisheries Service, 2023). This study examined length-weight relationship, condition factor and relative age determination of *Mugil cephalus in situ* within Kilifi creek as an important component of fishery monitoring in Kilifi County for its future mariculture programmes.

MATERIALS AND METHODS

Study site

Kilifi creek (39º 50'E and 3º 38'S) (Fig. 1) is approximately 55 km north of Mombasa Island along the Kenyan coast. The open water creek area, Bahari ya Wali, is separated from the ocean by approximately four kilometres and 500 m wide channel. The entire area of Kilifi creek is approximately 22.4 km^2 (Ong'anda, personal communication). Different mangrove tree species extensively cover the western side of the creek. The southern arm water channel is shorter, has Kombeni stream while the northern arm water channel is longer with two streams, Ndzovuni and Rare, which join up forming the Konjora channel that leads to Bahari ya Wali. These streams originate at about 300 metres above sea level on the eastern side of the Nyika plateau facing the Kenyan coast. Kilifi creek has an estimated mangrove area of 360 ha (Kokwaro, 1985).

Continuous fishing goes on within the creek throughout the year. There are several smaller landing beaches for fishery products within the creek as far as where sampling occurred. Four sampling sites in the northern arm and other four sampling sites in the southern arm were chosen based on physical characteristics i.e., water depth and distance from the nearest site. The chosen sites ensured the coverage of the entire creek to determine sites used the Mugilidae. These were Sea horse, Fumbini, Konjora and Rare within the northern arm channel and Nkoma, Mazioni, Kidundu and Kombeni in the southern arm channel. Sampling took place for four days around neap tides every month from October 2002 to September 2004. Each site was sampled twice and the samples were pooled every month per site giving a sample size. During neap tides fish access shallow areas for feeding and the tide strength is reduced as opposed to spring tides when shallow areas are exposed and the tide strength is high which interferes with fishing activity. Fish landings are higher within the creek during neap tides. The sampling sequence among the study sites was constant during the entire period starting at the creek entrance and ending in the northern and southern arm channels, respectively. This choice was made because movement to sampling sites started two hours before the lowest neap tide and this enabled access to all sites two hours after lowest neap tide. These sites were also chosen to establish how far *M. cephalus* utilize the creek areas.

The physico-chemical parameters of sampling sites investigated were water temperature, dissolved oxygen, salinity, water depth, water transparency and nutrients (inorganic phosphate (PO_4^{3-}) and nitrate (NO_3^-)). The different equipment used were water temperature (Thermometer), dissolved oxygen (water fixed and titrated in the laboratory), water depth (Calibrated string with a sinker), water transparency (Secchi disc), Nutrients (inorganic phosphate (PO_4^{3-}) and nitrate (NO_3^-) were fixed and taken to the laboratory for analysis according to methods described by described by Grasshoff, (1972) and Parsons et al, (1984)).

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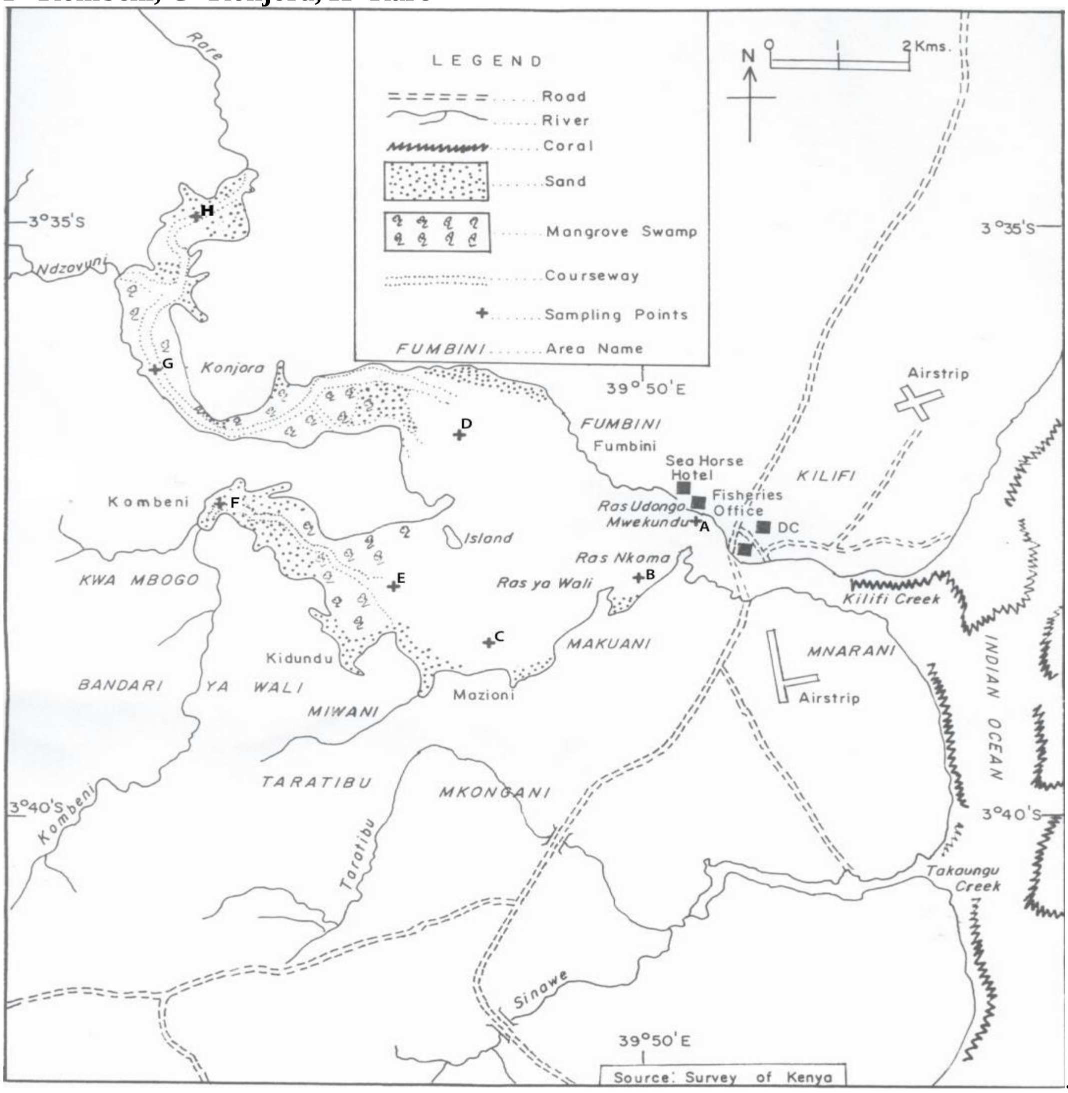
A canoe, used for fishing at each sampling site was towed by a motorboat with an outboard engine (45 HP) because of the long distances between the sampling sites. Bahari ya Wali of Kilifi creek is the only deep area which progressively becomes shallow towards the western side. Five of the sampling sites on the western end of the creek were shallow channels and most fishes caught were small in size. The most suitable gears were gill nets and cast nets used by fishers. Gill nets (50.8, 63.5 and76.2 mm mesh sizes, 166 cm depth and 100 m long each) were used for fishing because the channels are narrow and shallow. A cast net (19.1 mm mesh size, 7.6 m^2) was used in areas the gill nets could not be used by being extremely shallow.

The fishes were taxonomically classified using Smith's Sea Fishes (Smith and Heemstra, 1986), Biology and Ecology of Fishes in Southern African Estuaries (Whitfield, 1998) and FAO Species Identification Sheets for fishery purposes (Thomson and Luther, 1984). At the laboratory, fresh *M. cephalus* the total length (cm), using a fish measuring board (to the nearest 1 mm), total weight of the un-gutted fish (to the nearest 0.1 g) using a triple beam balance (Ohaus capacity 2610g) were recorded, then dissected for identification of sexes.

Figure 1. Kilifi creek study sites, A- Sea horse, B- Nkoma, C- Mazioni, D- Fumbini, E- Kidundu, F- Kombeni, G- Konjora, H- Rare



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Data analysis

The length-weight relationship was determined using the formula 1 **(**Bagenal and Tesch, 1978):

$W = aL^b$ (1)

W = the total body wet weight (g); L = the total length (cm); *a* = a constant on the y-axis and *b* = an exponent describing the slope of the regression. This equation gives a parabolic line.

A straight line was fitted by plotting logarithmic transformation of observed lengths against the observed weights.

A test of isometry was done to test whether the regression coefficients '*b'* of the monthly length-weight relationships calculated was significantly different from the expected isometric 3. This test is based on calculating the statistic (t^) using the Pauly, (1984) formula 2:

$$t\hat{} = [(sd_x/sd_y)\ (b-3/\sqrt{(1-r^2)}]\ \sqrt{(n-2)} \qquad (2)$$

sd_x = standard deviation of Log_{10} of monthly lengths; sd_y = standard deviation of Log_{10} of the monthly weights; n = number of fish examined and r^2 = coefficient of determination from the regression analysis.

The statistic (t^) is significantly different from 3, if its value is greater than the tabulated value of t (t-table) at n-2 degrees of freedom.

Relative condition factor was calculated using the formula 3 (Bagenal and Tesch, 1978):

$Kn = 100\ w/l^b$ (3)

w = observed total weight; *l* = observed total length of a fish; *b* = an exponent calculated from the length- weight equation. Relative condition factor was related to sex and season.

The Von Bertalanffy Growth Formula (VBGF) was used to estimate length at infinity and relative age from length measurements (Bagenal and Tesch, 1978; King, 1995; von Bertalanffy, 1938) expressed as:

$$L_t = L_\infty (1 - \exp[-K (t - t_o)]) \qquad (4)$$

L_t = length at age t, L_∞ = asymptotic length (when catabolism equals anabolism); K = the rate of change of length increment; t_o= the hypothetical time at which the fish length would have been zero.

The constant *a* and exponent *b* calculated in part (a) above was used to estimate length at infinity (L_∞) based on the Electronic Length Frequency Analysis (ELEFAN I) computer programme incorporated in Food and Agricultural Organization-International Center for Living Aquatic Resources Management (FAO-ICLARM) Stock Assessment Tool (FISAT) (Gayanilo et al., 1996).

The von Bertalanffy growth curves were then drawn on Excel spread sheet and the relative age of fish was determined by plotting the calculated L_t against t.

RESULTS

Physico-chemical parameters of Kilifi creek

The physico-chemical parameter with the largest mean variation (Table 1) was nitrates being highest at Rare and lowest at Mazioni. The mean phosphate concentration was high at Rare and lowest at Kidundu. The variation in means among sites was low in salinity, temperature and dissolved oxygen. Both Sea Horse and Nkoma were the deepest sites and also with the highest water transparency while lowest was at Kombeni. F-test was carried out to establish if there was significant difference in the physico-chemical parameters during the North East Monsoon and South East Monsoon seasons. Significant difference was observed in phosphate concentration and water temperature ($F_{1,184}$ = 22.51, P=0.00; $F_{1,184}$ = 48.06, P = 0.00) respectively while no significant difference was observed in nitrates, dissolved oxygen, salinity, water transparency and depth ($F_{1,184}$ = 0.71, P = 0.4; $F_{1,184}$ = 0.88, P = 0.35; $F_{1,184}$ = 0.10, P = 0.74; $F_{1,184}$ = 1.20, P = 0.27 and $F_{1,184}$ = 1.16, P = 0.028) respectively.

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Length – weight relationships

A total of 765 *M. cephalus* obtained during the sampling period from all the eight sites was used. 537 males were obtained and used in the Length–weight relationship analysis. The length and weight ranged between 57mm weighing 3g and 480 mm weighing 1169.3g (Fig. 2). The calculated mean length and weight were 193mm and 214.4g, respectively. The regression line fitted for length on weight was Log_{10} W = 1.7457 + 2.8658 Log_{10} L. The exponent (b = 2.8658) indicated negative allometric growth. The test of isometry for the monthly length-weight relationship in males is given by Table 2. The overall exponent (b=2.8658) was significantly different from 3 (t^ = 21.2138; P < 0.05), however, the monthly exponents were not significantly greater than 3 in only five months but significantly greater than 3 in nearly all months. The exponential value of 2.8658 shows that length increases with increase in weight and the regression coefficient was found to be highly significant (t = -22.524; df = 536; P < 0.05).

Table 1: Means of Physico-chemical parameters and finfish at the study sites (± = SE; n=24 months).

Parameters	Sea horse	Nkoma	Mazioni	Fumbini	Kidundu	Kombeni	Konjora	Rare
Phosphates (µM)	0.65±0.029	0.72±0.036	0.63±0.023	0.7±0.032	0.58±0.021	1.06±0.060	0.65±0.035	1.11±0.064
Nitrate (µM)	1.37±0.055	1.27±0.038	1.21±0.045	1.28±0.047	1.32±0.048	1.49±0.037	7.08±0.124	11.1±0.344
Dissolved Oxygen (mg/l)	6.50±0.024	6.29±0.018	6.24±0.017	6.34±0.027	6.19±0.021	5.32±0.018	6.02±0.035	6.19±0.044
Temperature (º C)	28.0±0.061	28.2±0.062	28.6±0.073	28.4 ±0.07	27.8±0.073	30.1±0.085	29.6±0.082	30.1±0.083
Salinity (‰)	35.2±0.058	35.2±0.059	35.5±0.072	35.3±0.076	35.5±0.062	37.5±0.16	33.2±0.172	29.9±0.231
Depth (m)	8.67±0.08	8.05±0.08	3.76±0.021	1.61±0.013	1.96±0.017	1.37±0.017	3.87±0.031	2.22±0.034
Water transparency (m)	2.92±0.029	2.55±0.033	1.57±0.015	1.21±0.008	0.95±0.009	0.43±0.005	0.92±0.012	0.62±0.006

Figure 2. **Length-weight relationships in male *M. cephalus* (Pooled totals obtained during the study period used).**

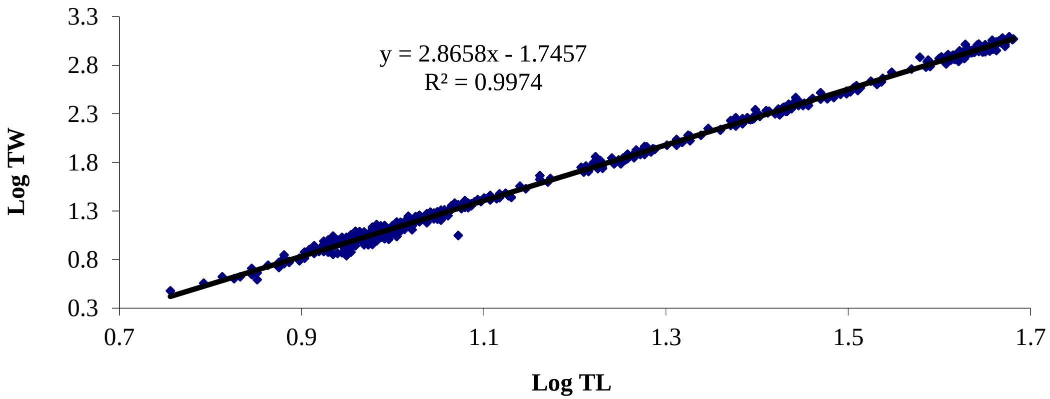

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Table 2: Test of isometry (t^) for the monthly length-weight regression for male *M. cephalus* (*Significant at 5 % level).

Month	Total number	df	b	r^2	t^	$t_{0.05}$, n-2
Oct 02	53	51	2.9806	0.9984	1.1611	2.008
Nov	20	18	2.8869	0.9984	4.1519*	2.101
Dec	29	27	2.8706	0.9967	4.0706*	2.052
Jan 03	46	44	2.8326	0.9964	6.5216*	2.015
Feb	17	15	2.9499	0.9975	1.3139	2.131
Mar	28	26	2.8916	0.9982	4.5014*	2.056
Apr	30	28	2.873	0.9958	3.6018*	2.048
May	1	0				
Jun	6	4	2.7239	0.9989	6.1101*	2.776
Jul	3	1	2.7303	0.9975	1.9731	12.706
Aug	8	6	2.8763	0.996	1.6623	2.447
Sep	4	2	2.5467	0.9978	5.3609*	4.303
Oct	23	21	2.8354	0.9992	9.4017*	2.08
Nov	30	28	2.7974	0.9812	2.7686*	2.048
Dec	24	22	2.9254	0.9978	2.6045*	2.069
Jan 04	21	19	2.8457	0.9989	7.1221*	2.093
Feb	17	15	2.8964	0.9984	3.4604*	2.131
Mar	12	10	2.8654	0.9974	2.9094*	2.228
Apr	41	39	2.8438	0.9975	6.7633*	2.024
May	43	41	2.8355	0.9974	7.2759*	2.02
Jun	29	27	2.8752	0.9955	3.3546*	2.052
Jul	16	14	2.9576	0.9426	0.2174	2.145
Aug	11	9	2.7886	0.9998	16.0797*	2.262
Sep	25	23	2.7643	0.9982	9.6296*	2.069
Overall	537	535	2.8658	0.9974	21.2138*	1.96

In females (Fig. 3), the length and weight ranges were between 61mm weighing 3.8g and 507mm weighing 1385g with mean length and weight of 277mm and 432.6g, respectively, from 228 observations. The regression line fitted for length on weight was Log_{10} W = 1.7973 + 2.8955 Log_{10} L. The test of isometry for the monthly length-weight relationship in females is given by Table 3. The overall exponent (b=2.8955) was significantly different from 3 (t^ = 13.5536; P < 0.05) however, the monthly exponents were significantly greater than 3 in only seven months but not significantly greater than 3 in the remaining months. The exponential value of 2.8955 indicates that length increases with increase in weight (negative allometric growth) and the regression coefficient value was found to be highly significant (t = -20.990; d.f. = 227; P < 0.05).

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Figure 3. Length-weight relationships in female M. cephalus (Pooled totals obtained during the study period used).

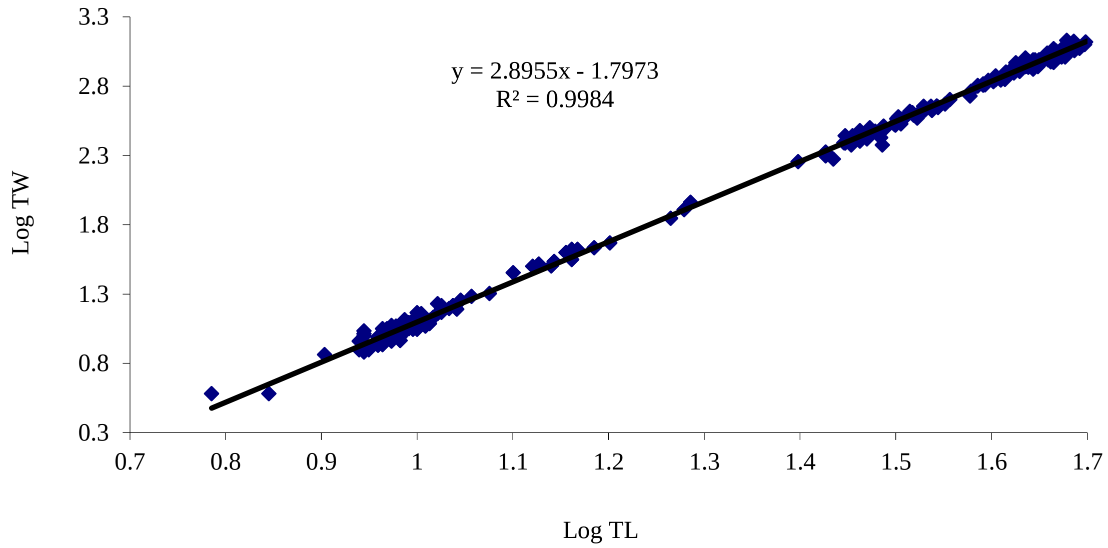

Table 3: Test of isometry for the monthly length-weight regression for female *M. cephalus* (*Significant at 5 % level).

Month	Total number	d.f	b	r^2	t^	$t_{0.05}$, n-2
Oct 02	42	40	2.9489	0.9991	3.6514*	2.021
Nov	3	1	3.024	0.9962	0.1287	12.706
Dec	17	15	2.843	0.9995	9.5622*	3.131
Jan 03	9	7	2.9297	0.9988	1.8316	2.365
Feb	9	7	2.8767	0.9983	2.7480*	2.365
Mar	21	19	2.7583	0.9947	5.2325*	2.093
Apr	3	1	0.2498	0.8503	2.3898	12.706
May	1					
Jun	5	3	2.8721	0.9933	0.9391	3.182
Jul	3	1	3.0613	0.9999	2.0024	12.706
Aug	4	2	2.831	0.999	2.6758	4.303
Sep	2	0	0.1559	1		
Oct	3	1	3.2299	0.9526	0.3191	12.706
Nov	26	24	3.0068	0.9837	0.0861	2.064
Dec	17	15	2.9081	0.9989	3.6883*	3.131
Jan 04	8	6	2.904	0.9985	2.0891	2.447
Feb	14	12	2.8618	0.9996	8.3625*	2.179
Mar	2	0	0.0416	1	0	
Apr						
May	11	9	2.8967	0.9988	3.0865*	2.262
Jun	9	7	2.2005	0.6789	1.3977	2.365
Jul	10	8	2.8198	0.7276	0.2954	2.306
Aug	3	1	2.8442	0.9994	2.2357	12.706
Sep	6	4	3.2057	0.9926	1.4863	2.776
Overall	228	226	2.8955	0.9984	13.5536*	1.96

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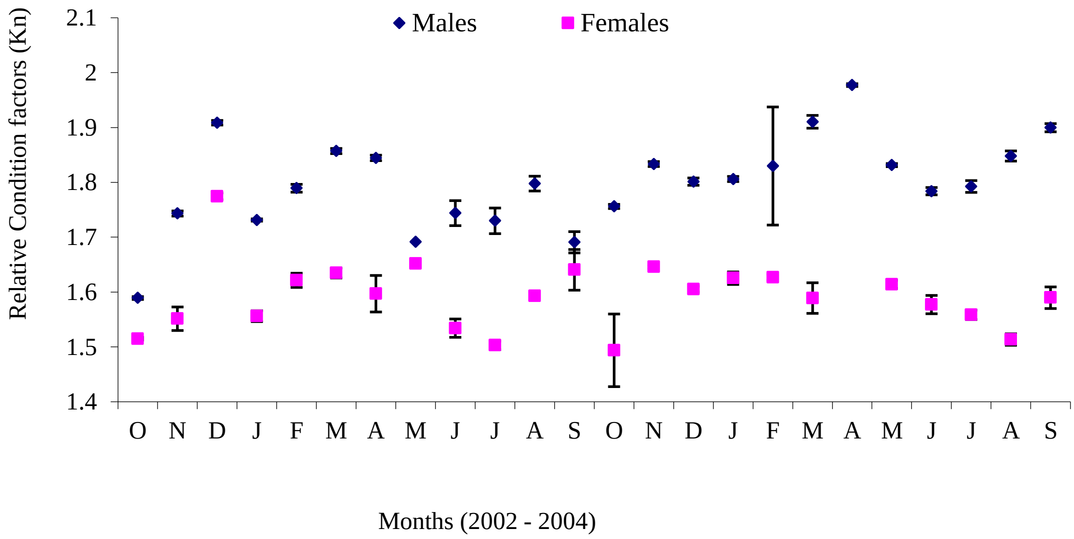
Relative condition factors

In *M. cephalus* (Fig. 4), the relative condition factors were observed to be higher during the NE monsoons than during the SE monsoons in both sexes. The males had higher relative condition factors than females although both sexes exhibit higher relative condition factors (above 1.5). The standard error bars show very small variation in relative condition factors in both sexes of *M. cephalus* except in October 2003 (females) and February 2004 (Males) when the samples sizes were very small.

Figure 4. Relative condition factors (Kn) of M. cephalus (Bars represent SE).



Length at infinity (L_∞) and relative ages

In *M. cephalus* females, the calculated value of asymptotic length from the von Bertallanfy Growth Equation (VBGE) length at infinity (L_∞) 51.48 cm is higher than in males (48.3 cm) and no notable difference was observed in K (growth coefficient) between females (0.83) and males (0.79) respectively. Combined asymptotic length of both sexes calculated for each site is shown in Table 4. Fishes caught in the northern arm of the creek were larger than those of the southern arm. Fumbini, Sea Horse, Nkoma and Mazioni were deep sites within Bahari ya Wali hence had the largest fishes. The smallest fishes were caught at Kombeni and Kidundu within the southern arm which were shallow sites. The growth coefficient (K) was lowest at Rare followed by Kidundu and Kombeni.

Table 4:Asymptotic lengths of *Mugil cephalus* (combined sexes) at the study sites (TL – total length).

Sites	Length	L_∞ (mm)	K
Sea horse	TL	474.8	0.88
Fumbini	TL	476.6	0.80
Konjora	TL	310	0.89
Rare	TL	292.2	0.66
Nkoma	TL	458	0.88
Mazioni	TL	455	0.89
Kidundu	TL	214.8	0.77
Kombeni	TL	168	0.82

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Relative age in *M. cephalus*

Fig. 5 shows the theoretical growth curves for *M. cephalus* determined graphically from the von Bertalanffy's equation for ages 0 – 10 years. By the third year, growth rate has declined giving a plateau. During the first two years of life (Table 5), *M. cephalus* grew rapidly in length with average increases of 132.8 and 118.3mm in the first year and 60.4 and 51.9mm in the second year in males and females respectively. However, from the third to the tenth year, growth decreased to 0.2mm, though, males grew faster than females throughout with a clear distinction.

Figure 5. Von Bertalanffy growth curve of M. cephalus at relative age.

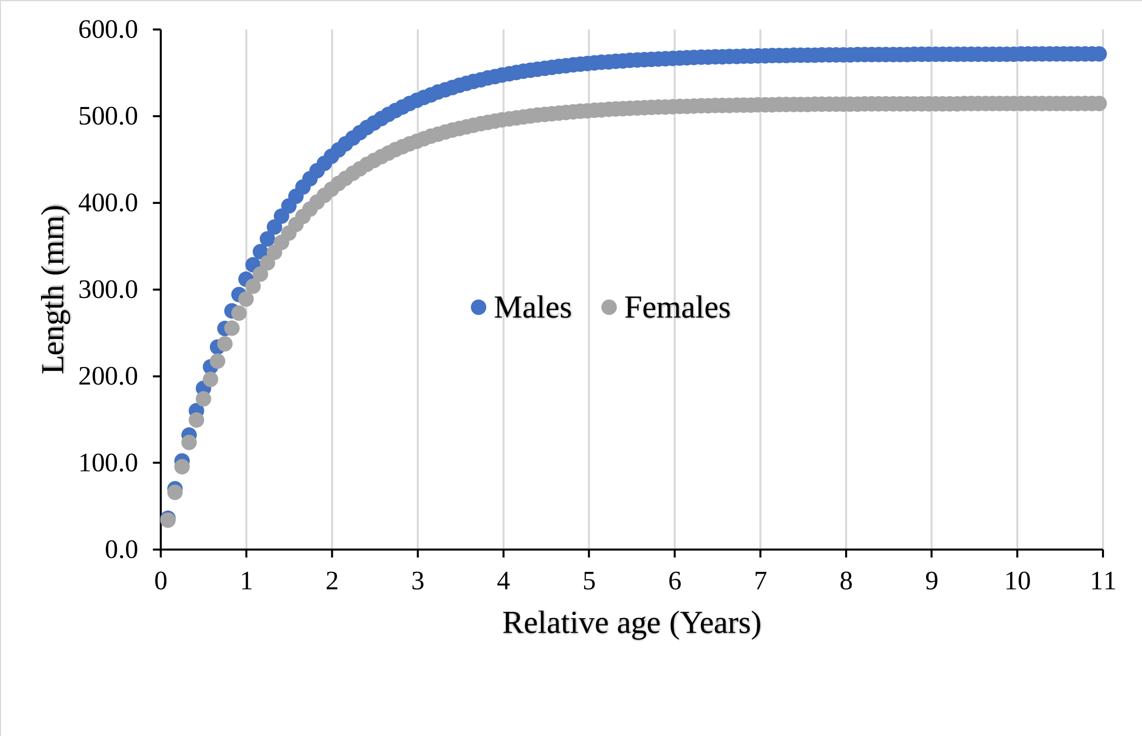

Table 5: Growth differences in relative TL with increase in relative age in *M. cephalus*.

	Relative length (mm)	
Year	**Males**	**Females**
1	328.5	304.0
2	461.3	422.3
3	521.7	474.2
4	549.1	497.0
5	561.6	507.0
6	567.3	511.4
7	569.9	513.3
8	571.0	514.1
9	571.6	514.5
10	571.8	514.7

Discussion

Variations in the physico-chemical parameters of Kilifi creek were comparable to those from other parts of the Kenyan coast (Ohowa et al., 1997, Uku & Bjork, 2001, Uku & Kitheka, 2002) indicating that the Kenyan coast is still pristine and naturally supports development of fishery resources. Mullets are pelagic fishes commonly landed hence the interest in its growth performance at Kilifi creek (Kenya Fisheries Service, 2023).

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In the length-weight relationship, the values of parameter *b* i.e., the rate of growth, which is also the slope of the growth curve, are usually between 2 and 4. When the value of *b* is equal to 3, fish are said to show isometric growth while values less than or greater than 3 show allometric growth (Bagenal and Tesch, 1978; Verdiell-Cubedo et al., 2006). Allometric growth is whereby unequal growth of different body parts compared to the overall growth rate is observed while isometric growth is whereby equal growth of different body parts compared to overall growth rate is reported. In this study, males and females of *M. cephalus* of Kilifi creek exhibited negative allometric growth ($b < 3$) as was reported by Ibanez et al., (1999) and Durairaja et al., (2020). Positive allometric growth ($b > 3$) for *M. cephalus* was reported from Adriatic estuarine system, (Dulcic and Glamuzina, 2006) and western Mediterranean Sea (Verdiell-Cubedo et al, 2006). Giarrizzo et al., (2006) observed negative allometry in *Mugil curema*, *Mugil gaimardianus* and *Mugil incilis* from Curuca estuary in northern Brazil. Ilkyaz et al., (2006) also observed negative allometric growth in the males and females of *Liza aurata* in Homa lagoon. The length-weight relationship in fishes observed among different localities can be affected by several factors including habitat, season, food availability, health, number of specimen and differences in the observed length ranges (Bagenal and Tesch, 1978; Wootton, 1998).

Some authors have reported that there are no growth differences between sexes for *M. cephalus* (Cech and Wohlschlag, 1975; Grant and Spain, 1975), but other workers have shown that there are significant differences in growth between the sexes (Ibanez et al., 1999). Differences in growth between sexes was observed in *M. cephalus* during this study. Sometimes the females grow slightly faster (Cech and Wohlschlag, 1975), live longer than the males or at least are predominant among older fish (Hickling, 1970), an observation made on *M. cephalus* in this study because there many larger females in older class sizes than males. In general, the values of the relationship between length and weight obtained in this study are similar to those expressed by authors reporting on other Mugilidae species (Giarrizzo et al., 2006; Ilkyaz et al., 2006). The test of isometry for the monthly length-weight relationship proved significant differences in both male and female *M. cephalus* studied at Kilifi creek.

In this study, seasonal fluctuation in the relative condition factor is small in *M. cephalus*. This can be attributed to feeding at the same rate throughout the year as observed by Siddiqui, (1977). *M. cephalus* males have higher relative condition factor than females, this contrasts observation in Rabbitfish, *Siganus sutor* (Valenciennes, 1835) and Sea Bream, *Scolopsis bimaculatus* (Ruppell, 1828) in the same region where females had higher relative condition than males (De Souza, 1988; Nzioka, 1981). Some investigators ascribe fluctuations in condition factor to gonad weight (Le Cren, 1951; Nzioka, 1981; Ntiba, 1986; Ntiba and Jaccarini, 1990; Mwatha, 1997), others attribute it to feeding rate of fish (Siddiqui, 1977). In *Sillago sihama* (Forsskal, 1775), relative condition factor is related to both gonad weight and feeding (Reddy and Neelakantan, 1993). *M. cephalus* at Kilifi creek have high relative condition which may be attributed only to the high feeding intensity throughout the year.

The constancy of the environment and non-seasonal breeding habits of fishes in tropical areas ensures that annuli marks are being laid down at any time of the year and in any number, therefore, many studies have been carried out to find a method of age determination (Weatherly and Rogers, 1978). Researchers in different areas have employed different methods of aging mullets (Jacot, 1920, Cardona, 1999, Ilkyaz et al., 2006). In this study the estimated asymptotic lengths in mullets were determined from the length-weight relationships. These were 483mm and 514.8mm in male and female *M. cephalus,* respectively, and the growth coefficient values ($K = 0.79$ in males and 0.83 in females) indicating that male fishes approach asymptotic length earlier than female fishes in the study area.

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Ibanez et al., (1999) reported higher values in *M. cephalus* (females L_∞ = 622.9 mm and males L_∞ = 603.9 mm) while Grant and Spain, (1975) calculated L_∞ = 604.6 mm in *M. cephalus* (unsexed) and L_∞ is higher in all those sites outside the tropics than is observed in this study. However, the asymptotic length of *M. cephalus* is decreasing probably because earlier workers calculated bigger values from large fishes, which are not available currently in the catch. The asymptotic length for Mugilidae at each site confirms that fry for stocking in aquaculture farms can be obtained from Kombeni, Kidundu and Rare.

Gerking, (1966) in (Cech and Wohlschlag, 1975) reported that explanations for age-specific growth differentials depend on physiological-ecological variables as effective length of growing season, food availability, feeding rates, food utilization rates, efficiency of food utilization and comprehensive metabolic requirements. Besides these, less than optimal conditions of temperature, dissolved oxygen levels, salinity, photoperiod and general water quality place metabolic stress on fishes reducing their scope for activity (Fry, 1971). During this study, food for *Mugil cephalus* was abundant in the creek because the physico-chemical parameters of sea water were pristine throughout the year hence the high growth rates observed. It is also important to consider that differences between growth rates are important even in very close areas. These differences could be explained by the different methods applied for age determination (Oren, 1981) by world-wide distribution of the species and its different survival strategies and on the other hand, the differences between growth rates can also occur because of commercial exploitation. When fishing is very intense, the commercial size of fish decreases and the variation of the K coefficient increase (Ibanez, et al., 1999).

Charisiadou et al., (2022) reported that mariculture in the East African coast is underdeveloped due to technical, economical and institutional limitations despite the natural environmental capacity. There is also absence of traditional knowledge, however polyculture of mullets and milk fish has been practiced in Zanzibar and Kenya in small experimental scale (Mirera, 2011). De Silva, (1980) observed that Mullets have a potential as cultivable species in the tropics however, the source of fingerlings for stocking is the natural environment. There is also lack of sufficient biological and physiological information on juveniles and this hampers the culture of mullets world-wide. In this study, the areas for fingerling collection for stocking in ponds were Kombeni, Kidundu and Rare. This study has established growth of mullets *in situ* at Kilifi and sites used by different class sizes. The fishery managers should encourage conservation of the entire creek especially the specific sites as sources of fingerlings for future pond stocking.

CONCLUSIONS

- In this study, negative allometric growth was observed in both male and female *M. cephalus* in which different body parts grew at different rates maintaining proportionality.
- Relative condition factors were high throughout the sampling period with low seasonal fluctuation in both sexes, however males had higher relative condition factors.
- *M. cephalus* males reach asymptotic lengths earlier than females. This difference in growth rate where males grow faster than females because all food is used for growth only while in females, the food is for both gonadal development and growth.
- *M. cephalus*, females persist in the population than males which tend to be larger than females at all sizes.

RECOMMENDATIONS

- There is decline in mullet fish landings in all parts of the world including Kenya and mullets can be cultured in cages or earthen ponds to improve food security in Kenya.
- From this study, Kilifi creek is pristine, is feeding ground for all sizes of Mullet hence any industrial development around it with effect on water quality should be discouraged.

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- Results from length-weight relationships have shown sites used by juvenile fish as feeding grounds and fishing in such areas (Kombeni, Rare and Kidudndu) should be discouraged.

Scope of the study

This study was limited only to growth aspects of *Mugil cephalus* from Kilifi creek and not any other species.

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