International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 6 Issue 2, February - 2022, Pages:204-211

Weight-length relationships, Condition factor and Hepatosomatic index of goby fish *Acentrogobius nebulosus* and *Asterropteryx semipunctata* in coastal ecosystems of Zanzibar.

Shaib S. Mnemba[1,2*], Saidi S. Bakari[1] and Haji M. Haji[1]

[1]The State University of Zanzibar, P.O.Box 146, Zanzibar, Tanzania

***Abstract**: Weight-length relationships, Condition factor and Hepatosomatic index of 480 mangrove gobies (Acentrogobius nebulosus and Asterropteryx semipunctata) were investigated. Fish samples were caught using shrimp and mosquito nets during the low tides. The regression coefficient "b" was determined by using $TW = aTL^b$, condition factor by $CF = 100TW/TL^3$ and Hepatosomatic index by HIS = 100LW/TW. The Acentrogobius nebulosus had regression coefficient "b" of 3.1154 and Asterropteryx semipunctata was 2.9744. Both Acentrogobius nebulosus (t –test, $p < 0.05$) and Asterropteryx semipunctata (t –test, $p < 0.05$) had significantly positive allometric growth compared to isometric regression coefficient. The overall mean condition factor for Acentrrogobius nebulosus was 1.265±0.137 and in Asterropteryx semipunctata was 1.297±0.078 depicting good fish condition. The HSI in Asterropteryx semipunctata was significantly higher than in Acentrogobius nebulosus (t-test, $p < 0.05$) contrary to HSI values across the sampling points (ANOVA, $p > 0.05$). The values of regression coefficients "b", CF and HSI in gobies provides an impression that the marine and coastal ecosystems of Zanzibar are promising to Zanzibar blue economy as they could support fish biomass production. However, the authorities need to consider protection of marine ecosystems health and function for the sustainable blue economy.*

Keywords — Condition factor, cube law, *Acentrogobius nebulosus*, *Asterropteryx semipunctata*, Hepatosomatic index, Zanzibar

1. Introduction

Investing on blue economy is considered as a blueprint for rapid and sustainable economic development in Zanzibar (Zanzibar Vision 2020-2050). Fishery sector in particular, contributed to over 4.8% of GDP in 2019 (Blue Economy Policy, 2020). It also supports the livelihoods of Zanzibar population to about 25% (Zanzibar Research Agenda, 2015). However, the coastal and marines resources especially mangrove areas are prone to anthropogenic inputs of untreated wastes that could directly impact the ecosystem health and functions and subsequently to fish stocks. Current studies (Moynihan et al., 2012; Juma et al., 2017; Mahugija et al., 2017; Staehr et al., 2018; Koleleni and Haji, 2015; Issa, 2017 and Bravo et al., 2021), show that there is unprecedented levels of chemical and nutrient pollution along the coastal and marine environment of Zanzibar. This could increasingly put the considerable stresses and pressures to the sustainability of Zanzibar blue economy especially based on not only fishery sector but also tourism. One of the determinants of sustainability of fishery sector is the assessment of fish biomass productivity and the general well-being of the fish stock. Among the important tools in fishery assessment are Length – weight relationships (LWRs), Condition factors – CF (Froese, 2006; Das and Biswas, 2016; Nehemia et al., 2012) and Hepatosomatic indices – HSI (Marado et al., 2017; Bawuro et al., 2018). WLRs is determined by $TW = aTL^b$ where parameters ***a*** and ***b*** are regression constants (Froese 2006). Fish growth pattern can either be symmetric (isometric) or asymmetric (allometric). The regression constant b = 3 reflect isometric, b > 3 positive and b < 3 negative allometric growth (Romdhani et al., 2013; Froese, 2006). WLRs can be used to estimate the biomass of fish from its length (Froese, 2006) whilst the Condition factor ($CF=100W/L^3$) is regarded as physiological index of fish growth (Andrade et al., 2015) and measures how well is fish doing in the ecosystems. They both help in estimation and evaluation of fish stock for comparison of fish population over time (Khristenko and Kotovska, 2017). Furthermore, HSI is an important parameter in assessing fish health due to physiological effects resulted from environmental stress caused by either unavailability of food or pollution. The indices can therefore help in predicting the dynamics of fish population, growth and mortality rates (Osho and Usman, 2019). They integrate several physiological levels such as molecular, cellular or organ systems and hence are useful tools for fishery science and management (Khristenko and Kotovska, 2017). The data on these three parameters in Zanzibar coastal and marine environment are scanty. This paper provides basic information on CF, LWRs and HSI of goby fish (*Acentrogobius nebulosus* and *Asteropteryx semipunctata*) in coastal waters. The parameters help to ascertain the status of fish growth and condition in marine and coastal environment for the sustainable marine resources management toward blue economy in Zanzibar. .

2. Materials and methods

2.1 Study area

The study was carried out in six selected coastal areas (Fig. 1) which are described in Table 1. The sampling stations were further divided into two substations denoted as 1 &2.

2.2 Fish sample collection and processing

The total of 480 goby fish consisting of two species (*Acentrogobius nebulosus* and *Asteropteryx semipunctata*) were collected from the rivers inside mangrove ecosystems and intertidal areas along the coast of Zanzibar. *Acentrogobius*

International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 6 Issue 2, February - 2022, Pages:204-211

nebulosus were 223 and *Asterropteryx semipunctata* were 257. The fish were caught using the shrimp and mosquito nets during the low tides, collected into pre-labeled plastic bags and immediately into the ice box full of cooling elements. They were then transported to SUZA laboratory (The State University of Zanzibar, Beit el raas campus) for biometrical measurements (total weight, total length and liver weights).

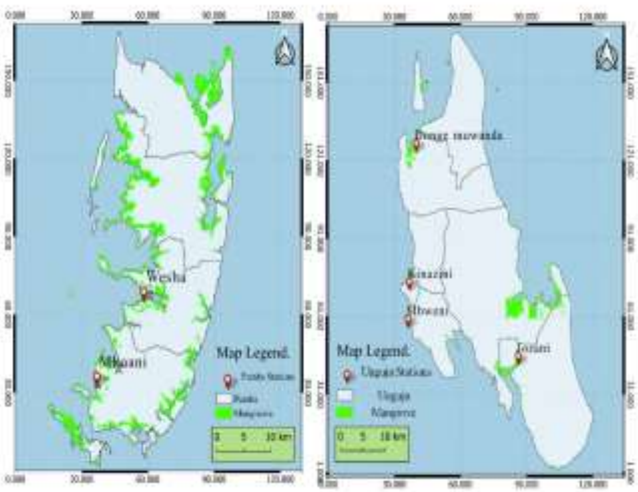


Fig. 1: The maps of Zanzibar islands (Unguja and Pemba) showing the sampling locations

Table 1: The descriptions of sampling stations.

Sampling stations	Descriptions
Kinazini (K1 & K2) and Mbweni (M1 & M2)	Located in Urban West region characterized with high population growth rate, urbanization and tourist activities contributing to the coastal pollution through sewage outfalls, city garages, boats and ship traffics at Malindi port and Mtoni deport of petroleum products.
Donge Muwanda (DM1& DM2)	Located in North "B'' district of North Region, Unguja. It is close to Mahonda sugar factory, sugar farms and a small harbor with some boat traffics. It also receives water from runoffs through river Mwanakombo which drain water from different rice fields.
Jozani (J1 & J2)	Located in Chwaka bay, South region of Unguja Island. It is Government protected forest with an immerse mangroves. The forest is used for tourist activities.
Mkoani (MK1 & MK2)	Mkoani is located in Mkoani district within South region of Pemba. The site is in close proximity to Mkoani port which is prone to various shipping and boating activities characterized with oil spills and waste discharges, and adjacent to Mkoani municipality which generate untreated solid and liquid wastes which eventually contaminate the site through sewage systems and runoffs.
Wesha (W1 & W2)	Located at South region, Chake-Chake District of Pemba. During the time of sampling, the station was characterized with a loss of mangrove forests which is believed to be caused by severe oil spills from power plants and boat traffics and Wesha oil deport.

2.3 Determination of Condition factor (CF), Length – weight relationships (LWRs) and Hepatosomatic index (HSI):

The fish length was measured from the tip of the snout to the end of the caudal fin on the measuring board to a nearest 0.1 cm and weight at 0.1 g. The Condition Factor (CF) was calculated using the formula adopted from Froese (2006):

$$CF = (100TW)/(TL^3)$$

Where CF is Condition Factor, TL is total length in centimeter , TW is total weight in gram of each goby fish, whilst the Length – weight relationships were determined by using the formula adopted from Jin et al (2015), Romdhan et al, (2013) and Panicker et al, (2013):

$$TW = aTL^b$$

Where TW is total weight in gram, TL is total length of each goby fish in cm, ***a*** and ***b*** are Constants estimated by linear regression of log transformed varieties. The b-values of selected goby fish species from every station was tested to verify their levels of significance from the isometric growth (b = 3). It should be noted that the LWRs estimations were considered only as a mean annual values because, the data were collected over extensive period of time and are not representative of a particular season. This approach has also been used by Jisr et al. (2018).

The HSI was determined using the formula adopted from Hismayasari et al, (2015) and Dewi and Rosi, (2017):

HIS = 100LW/TW

Where HSI is hepatosomatic index, LW is liver weight in gram and TW is total (body) weight of each goby fish in gram.

3. RESULTS AND DISCUSSION

3.1. Variation of fish weights, lengths and parameters of length – weight relationships

The biometrical measurements (total weight and total length) of *Asterropteryx semipunctata* and *Acentrogobius nebulosus* are presented in Table 2 and 3 respectively. The total weight in *Asterropteryx semipunctata* varied from 2.4 g in fish from J1 to 36.2 g in DM1 with a highest average of 11.72±6.17 g in fish from DM1 while the total length varied from 5.2 cm in fish from J1 to 11.5 cm in K2 with a highest average of 9.45±0.19 cm in fish from DM1. The total weight in *Acentrogobius nebulosus* varied from 1.3 g in fish from W2 to 21.2 g in K1 with a highest average of 21.04±1.77 g in fish from M1 while the total length varied from 4.5 cm in fish from W2 to 13.8 cm in M2 with a highest average of 11.78±0.35cm in fish from M1.

Table 2: The biometrical measurements (Range and Mean ± SE for the TL and TW) of *Asterropteryx semipuncta*

Substation codes		K2	DM1	DM2	J1	J2	MK2
n		40	57	57	50	40	13
Range	TL_cm, min-max	7.1-11.5	6.7-14	6.5-13.9	5.2-8.4	6.1-11.1	5.5-10.5
	TW_g, min-max	4.5-16.5	3.8-36.2	4.0-29.8	2.6-9.4	3.9-20.6	2.4-9.9
Mean±SE	TL_cm	8.68±0.40	9.45±0.19	8.28±0.17	6.86±0.10	8.40±0.17	7.85±0.35
	TW_g	8.17±0.44	11.72±6.17	7.91±0.55	4.53±0.18	8.46±0.54	5.89±0.67

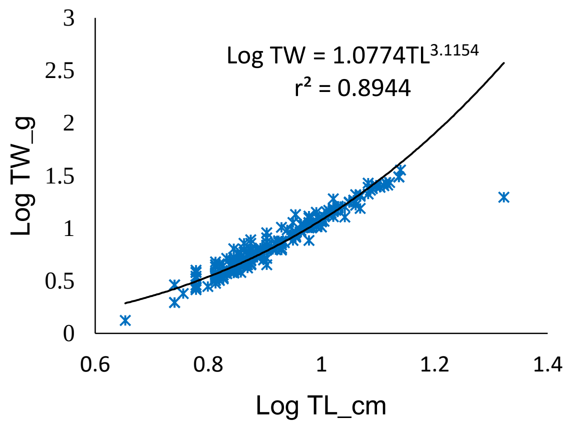
Table 3: The biometrical measurements (Range and Mean ± SE for the TL and TW) of *Acentrogobius nebulosus*

Substation codes		K1	W1	W2	MK1	M1	M2
n		38	22	15	26	19	104
Range	TL_cm, min-max	5.7-21	5.5-13.5	4.5-9.6	8.4-11.0	8.4-13	8.5-13.8
	TW_g, min-max	2.4-21.2	2.9-9.5	1.3-11.4	6.7-14.8	7.3-27.3	7.5-35.9
Mean±SE	TL_cm	9.45±0.15	7.60±0.30	9.70±0.19	10.90±0.23	11.78±0.35	7.73±0.17
	TW_g	6.07±0.38	5.72±0.61	10.60±0.58	17.38±1.08	21.04±1.77	6.03±0.34

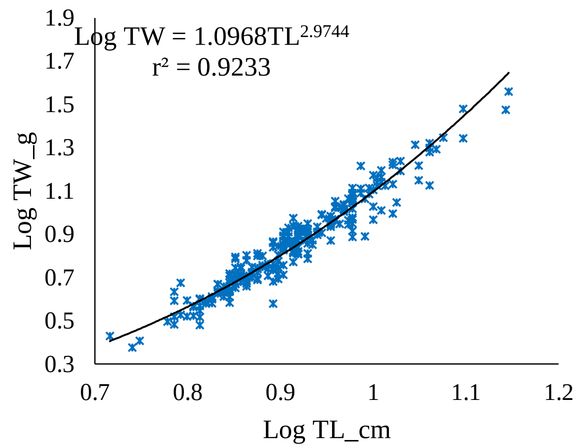
The variation in total length (ANOVA, $p < 0.05$) and total weight (ANOVA, $p < 0.05$) across the stations among both *Asterropteryx semipunctata* and *Acentrogobius nebulosus* were significant. The literature search has revealed that the regression coefficient for the isometric growth in fish is always equal to 3 (Jisr et al., 2018; Froese 2006; Le Cren 1951). The results in the present study has showed significant positive allometric growth in both *Asterropteryx semipunctata* ($b = 3.227$, $r^2 = 0.914$, $p < 0.05$) and *Acentrogobius nebulosus* ($b = 3.276$, $r^2 = 0.863$, $p < 0.05$) depicting good correlation between the weight and length of Zanzibar gobies. That, gobies in Zanzibar are generally become thicker with increasing length, contrary to b – values reported in King (1996) that fish with $b < 3$ become thinner as they grow larger. However, the regression coefficient (b – values) in gobies from the individual sampling substations varied from 2.7182 to 4.6542 in *Acentrogobius nebulousus* (Table 4) across the sampling stations with negative allometric ($b < 3$) growth behaviors in gobies from M1, M2 and MK1 while isometric growth ($b = 3$) was recorded in fish from K1 and positive allometry ($b > 3$) being in fish from W1 and W2. The negative growth ($b < 3$) in *Asterropteryx semipunctata* was recorded in goby fish from J1 and K2 while isometric growth was in goby fish from DM2 and positive allometry was in goby fish from DM1, J1 and MK2. The negative allometric growth in fish are associated with relative slow growth rate and fish become thinner as they grow larger throughout the year (Jisr et al., 2018). Similar results have also been reported elsewhere (Chukwu and Deekae, 2011; Abdoli et al., 2009). It was also reported in 73 fresh water fish populations in Nigeria (King, 1996) and in 152 specimens of combined sex of *Clarius gariepinus* which were reared in indoor water recirculation systems tanks (Anyanwu et al., 2007). The isometric growth on the other hand, reflect good environmental condition of the habitat (Tsoumani et al., 2006; Jisr et al., 2018).

The positive growth of gobies in Zanzibar could be associated with fish localities, sexes, maturity (Le Cren, 1951), stoutness (Kayombe et al., 2015) and optimum condition for fish growth (Jisr et al., 2018). These results are in agreement with *Clarius gariepinus* from lake Naivasha of Kenya (Kayombe et al., 2015), *Oreochromis niloticus* of Esperanza lake of Philippines (Cuadrado et al., 2019) and in marble gobies (*Oxyeleotris marmorata*) reported in Setyobudi et al, (2020), *Neogobius syrman, Neogobius fluviatilis* and *Neogobius melanostomus*

International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 6 Issue 2, February - 2022, Pages:204-211



Plot A: LWR for *Acentrogobius nebulosus*



Plot B: LWR for *Asteropteryx semipunctata*

Figure 2: Length – weight relationships of *Acentrogobius nebulosus* (Plot A) and *Asterropteryx semipunctata* (Plot B).

Table 4: Length – weight relationships for *Acentrogobius nebulosus* coastal waters of Zanzibar.

Species: *Acentrogobius nebulosus*				
Substation	n	r^2	LWRs equation	Growth behavior
K1	104	0.9026	Log TW = Log ($1.0523TL^{3.0344}$)	Isometry
W1	22	0.9738	Log TW = Log ($1.1901\ TL^{3.1035}$)	Positive allometry
M1	26	0.9796	Log TW = Log ($1.1037\ TL^{2.7182}$)	Negative allometry
M2	19	0.9752	Log TW = Log ($1.0811\ TL^{2.6178}$)	Negative allometry
MK1	13	0.9812	Log TW = Log ($1.0562\ TL^{2.9215}$)	Negative allometry
W2	38	0.9504	Log TW = Log ($1.2233\ TL^{4.6542}$)	Positive allometry

collected from two wetlands (Gomishan and Miankale) in Southeastern Caspian sea basin of Iran (Abdoli et al., 2009). In the present study, the difference in regression co-efficient "b" of gobies to the isometric regression co-efficient b – values was not significant (t-test, p > 0.05). Similar to the difference in regression co-efficient b – values between the *Acentrogobius nebulosus* and *Asteropteryx semipunctata* (t-test, p > 0.05). The correlation coefficient (r^2 – values) for the *Acentrogobius nebulosus* (Table 4) varied from 0.9026 to 0.9812 and *Asterropteryx semipunctata* (Table 5) from 0.9318 to 0.9784 and their difference between the species was not significant (t-test, p > 0.05) and therefore, reflect high degree of positive correlation between the log TW versus log TL of Zanzibar gobies. This signifies high levels of fish growth in the ecosystems and this is linked with rapid increase in length and weight and so be in good condition (Le Cren, 1951). The results here are in agreement with various goby fish species caught from Southeastern Caspian Sea basin of Iran (Abdoli et al., 2009), freshwater fish species from Ebonyi River (Ude et al., 2011) and commercial fish species collected from the river Nile, Sudan (Raheam et al., 2017).

The Condition factor reflects the physiological index of fish growth and is related to the availability of important growth requirements in the ecosystems (Andrade et al. 2015). It can either be regarded as the organism-level response to factors such as nutritional status, pathogen effects and exposure of the individual fish species to toxic chemicals which in turn, could result into less than or greater than normal fish weights (Andu and Kangur, 1996) and therefore, the parameter indicate the general wellbeing of fish (Azmat et al. 2007). Fish is determined to have the isometric growth and of good health if its values of Condition factor > 1 (Van der Oost et al. 2003). In our study, the overall mean condition factor for *Acentrrogobius nebulosus* was 1.265±0.137 and in *Asterropteryx semipunctata* was 1.297±0.078 across the stations. The mean Condition factors for the *Acentrogobius nebulosus* (Figure 3, Plot C) and *Asterropteryx semipunctata* (Figure 3, Plot D) per TL class interval depict significant good fish condition in Zanzibar coastal waters for each species (ANOVA, p < 0.05). It is recognized that physiological and biological conditions such as food availability (Jin et al., 2014; Le Cren, 1951; Marado et al., 2017), parasite infections (Le Cren, 1951), trophic positions (Cossa et al., 2012), temperature (Bloomfield et al., 2011), chemical pollution (Van der Oost et

International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 6 Issue 2, February - 2022, Pages:204-211

Table 5: Length – weight relationships for *Asterropteryx semipunctata* from coastal waters of Zanzibar.

al., 2003) and seasons (Giosa et al., 2014) may tempt

Species: *Asterropteryx semipunctata*				
Substation	n	r^2	LWRs equation	Growth behavior
DM1		0.9715	Log TW = 1.1025 TL $^{3.107}$	Positive allometry
DM2		0.9784	Log TW = 1.1117 TL $^{2.9948}$	Isometry
J1		0.9586	Log TW = 1.2114 TL $^{3.5473}$	Positive allometry
J2		0.968	Log TW = 1.1318 TL $^{2.929}$	Negative allometry
MK2		0.9318	Log TW = 1.05 TL $^{3.2375}$	Positive allometry
K2		0.9735	Log TW = 1.0452 TL $^{2.4784}$	Negative allometry

variability in Condition factor for various ecosystems.

3.2. Variations in Liver Weights and Hepatosomatic Indices (HSI) for the goby fish

The data for Liver weight (LW) and Hepatosomatic index (HIS) are presented in Table 6 and 7 for both *Acentrogobius nebulosus* and *Asterropteryx semipunctata* respectively. LW in *Acentrogobius nebulosus* varied from 0.04 g (K1) to 1.33 g (M2) with a highest average (0.607±0.086) being recorded in fish from M2. The LW in *Asteropteryx semipunctata* on the other hand, varied from 0.003 g (K2) to 1.3 g (DM2) with a highest average (0.375±0.034 g) being recorded in fish from DM2. The difference in LW across the substations in *Acentrogobius nebulosus* was significant (ANOVA, $p < 0.05$) and was similar to *Astrropteryx semipunctata* (ANOVA, $p < 0.05$). The range of HSI for *Acentrogobius nebulosus* was between 0.49 (K1) to 8.22 (K1) with the highest average of 3.15±0.26 whilst the range of HSI in *Asterropteryx semipunctata* was 0.09 to 6.15 (K2) with the highest average of 3.09±0.41. The statistical analysis revealed that the levels of HSI was significantly high in *Asteropteryx semipunctata* than *Acentrogobius nebulosus* (t-test, $p < 0.05$). The difference in HSI between the species which is associated with the size differences in hepatocytes have also been reported elsewhere (Leão et al., 2021). The difference in HSI in the

Table 6: Liver weights and Hepatosomatic indices (Min – Max, Mean ± SE) in *Acentrogobius nebulosus* Zanzibar mangrove ecosystems.

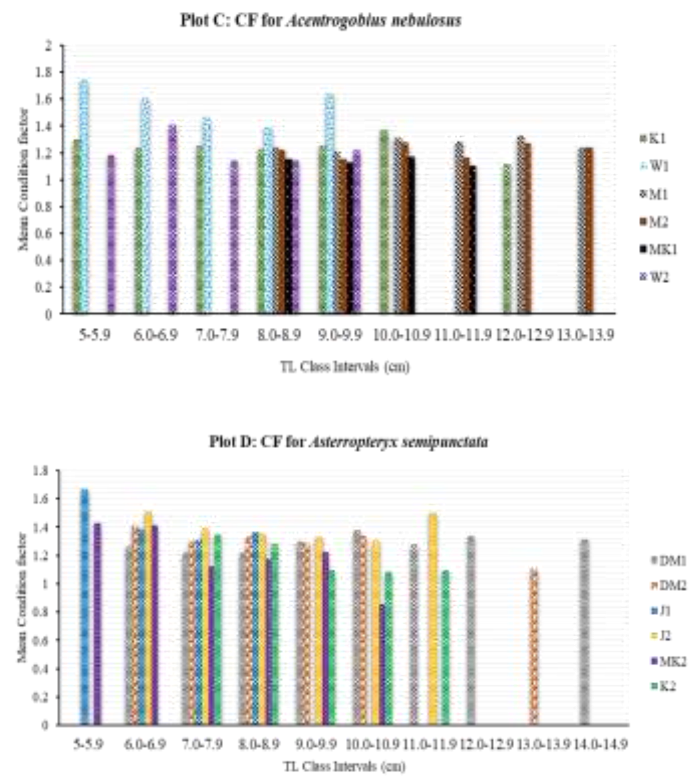


Figure 3: Mean Condition factors of (Plot C) *Acentrogobius nebulosus* and *Asterropteryx semipunctata* (Plot D) per TL class interval.

	Asterropteryx semipunctata					
	K2	J1	J2	DM1	DM2	MK2
			Liver weights			
Range	0.003 - 0.8	0.012 - 0.37	0.03 - 0.89	0.03 - 0.9	0.04 - 1.3	0.03 - 0.35
Mean± SE	0.092±0.013	0.094±0.008	0.219±0.023	0.23±0.02	0.375±0.034	0.136±0.026
n	104	50	40	57	57	13
			Hepatosomatic index			
Range	0.09-6.15	0.27-3.93	0.74-4.33	0.59-6.65	0.74-6.9	1.21-3.76
Mean± SE	1.35±0.99	1.98±0.1	2.47±0.13	2.85±0.22	3.09±0.41	2.14±0.22
n	104	50	40	57	57	13

Table 7: Liver weights and Hepatosomatic indices (Min – Max, Mean ± SE) in *Asterropteryx semipunctata* of Zanzibar

	Acentrogobius nebulosus					
	K1	W1	W2	M1	M2	MK1
			Liver weights			
Range	0.04 - 0.76	0.1 - 0.7	0.03 - 0.31	0.06 - 1.2	0.1 - 1.33	0.09 - 0.27
Mean±SE	0.253±0.024	0.15±0.02	0.108±0.018	0.438±0.053	0.607±0.086	0.161±0.014
n	40	14	21	26	19	15
			Hepatosomatic index			
Range	0.49-8.22	1.23-4.69	0.84-2.73	0.82-4.4	0.98-4.76	0.86-2.71
Mean± SE	3.15±0.26	1.84±0.19	1.7±0.13	2.33±0.16	2.63±0.22	1.55±0.14
n	40	18	21	26	19	15

individual species across substations was not significant (ANOVA, $p > 0.05$). Similar statistical results were reported in Leão et al., (2021). Among others, pollution (Marado et al., 2017; Bawuro et al., 2018; El-Moselhy et al., 2014) and high energy reserves (Leão et al., 2021) have direct impact to liver size. Variation in liver size and so to HSI can be due to increase in size (Hypertrophy) or increase in number of hepatocytes (Hyperplasia) resulted from contaminant effects to the liver (Solé et al., 2010). In contrast, the decrease in HSI has been linked with the role of liver in nutrient metabolism resulted from high food abundance (Mohapatra et al., 2015) and cellular activity of protein synthesis during reproduction (Nunes et al., 2011). The difference in HSI between the species and sampling substations in marine environment of Zanzibar could be associated with environmental stresses. Most of the selected sampling substations are in close proximity to allochthonous sources of anthropogenic pollutants.

4. Conclusion

The length – weight relationships of both *Acentrogobius nebulosus* and *Asterropteryx semipunctata* showed variations in growth behavior across the stations. Some were positive (b>3), isometric (b=3) while others were negative allometric (b<3) depicting disparity in environmental conditions for supporting fish productivity in Zanzibar coastal waters. However, the average b-values (b>3) for both *Asterropteryx semipunctata* and *Acentrogobius nebulosus* have generally indicated significant positive allometric growth and good fish conditions. The condition factor (CF > 1) in both two goby fish species and across the stations indicated good goby fish population with reflections to healthy status of gobies with good tissues energy reserves. The values of HSI were significantly higher in *Asterropteryx semipunctata* than *Acentrogobius nebulosus*. However, the difference in HSI across the stations was not significant, reflecting similar conditions of coastal ecosystems and support fish productivity. It is therefore, mangrove ecosystems in Zanzibar could effectively support fish biomass production and are promising to Zanzibar blue economy. However, we would recommend the authorities to consider waste treatment before disposal into marine and coastal environment so as to protect the livelihoods of marine biota.

5. Acknowledgment

We are acknowledging the Building Stronger University Project 2017/2021, Phase Three, Work Package II (BSU III, WP II), which is under DANIDA financial support. The project is a collaboration between The State University of Zanzibar (SUZA), Copenhagen University and Aarhus University, Denmark. We deeply acknowledge Dr. Zhanna Tairova for technical guidance and support without forgetting Mrs. Halima Othman, Mrs. Maneno Ibrahim and Mr. Ali Nassor for their assistance during the field work and laboratory processing of samples.

6. References

[1] Abdel Raheam, H. A. (2017). l."Length-Weight Relationship and Condition Factor of Three Commercial Fish Species of River Nile, Sudan". EC Oceanography, 1, 01-07.

[2] Abdoli, A., Allahyari, S., Kiabi, B.H., Patimar, R., Ghelichi, A., Mostafavi, H., Aghili, S.M. and Rasooli, P., 2009. Length–weight relationships for seven Gobiid fish species in the southeastern Caspian Sea basin, Iran. Journal of Applied Ichthyology, 25(6), pp.785-786.

[3] Aini, R. N., Probosunu, N., & Setyobudi, E. (2020). Length-Weight Relationship, Condition Factor and Otolith shape of Marble Goby (Oxyeleotris marmorata) at Sermo Reservoir, Yogyakarta. In *E3S Web of Conferences* (Vol. 147, p. 02006). EDP Sciences.

[4] Andrade, T., Afonso, A., Pérez-Jiménez, A., Oliva-Teles, A., de las Heras, V., Mancera, J. M., and Costas, B. (2015). Evaluation of different stocking densities in a Senegalese sole (Solea senegalensis) farm: implications for growth, humoral immune parameters and oxidative status. *Aquaculture*, *438*, 6-11.

[5] Anyanwu, P. E., Okoro, B. C., Anyanwu, A. O., Matanmi, M. A., Ebonwu, B. I., Ayaobu-Cookey, I. K., and Afolabi, S. E. (2007). Length-weight relationship, condition factor and sex ratio of African mudcatfish (*Clarias gariepinus*) reared in indoor water recirculation system tanks.

[6] Bawuro, A. A., Voegborlo, R. B., and Adimado, A. A. (2018). Bioaccumulation of heavy metals in some tissues of fish in Lake Geriyo, Adamawa State, Nigeria. *Journal of Environmental and Public Health*, *2018*.

[7] Bloomfield, A. L., Elsdon, T. S., Walther, B. D., Gier, E. J., and Gillanders, B. M. (2011). Temperature and diet affect carbon and nitrogen isotopes of fish muscle: can amino acid nitrogen isotopes explain effects?. *Journal of Experimental Marine Biology and Ecology*, *399*(1), 48-59.

[8] Chukwu, K. and Deekae, S., 2011. Length-weight relationship, condition factor and size composition of Periophthalmus barbarus (Linneaus 1766) in New Calabar River, Nigeria. *Agriculture and Biology Journal of North America*, *2*(7), pp.1069-1071.

[9] Cossa, D., Harmelin-Vivien, M., Mellon-Duval, C., Loizeau, V., Averty, B., Crochet, S., and Cadiou, J. F. (2012). Influences of bioavailability, trophic position, and growth on methylmercury in hakes (Merluccius merluccius) from Northwestern Mediterranean and Northeastern Atlantic. *Environmental science and technology*, *46*(9), 4885-4893.

[10] Cuadrado, J. T., Lim, D. S., Alcontin, R. M. S., Calang, J. L. L., and Jumawan, J. C. (2019). Species composition and length-weight relationship of twelve fish species in the two lakes of Esperanza, Agusan del Sur, Philippines. *FishTaxa*, *4*(1), 1-8.

[11] Das, K., and Biswas, S. P. (2016). Length-weight relationship and condition factor of a hillstream fish (Garra gotyla) gotyla (gray) from Noa-dihing river, Arunachal Pradesh. *Int. J. Eng. Technol. Sci. Res.*, *3*.

[12] De Giosa, M., Czerniejewski, P., and Rybczyk, A. (2014). Seasonal changes in condition factor and weight-length relationship of invasive Carassius gibelio (Bloch, 1782) from Leszczynskie Lakeland, Poland. *Advances in Zoology*, *2014*.

[13] Dewi, N. K., and Rosi, P. (2017). Determination of liver somatic index (LSI) and gonadosomatic index (GSI) value of crap (Cyprinus carpio) and Nile tilapia (Perca fluviatilis). *International Journal of Scientific and Research Publication*, *7*(6).

[14] El-Moselhy, K. M., Othman, A. I., Abd El-Azem, H., & El-Metwally, M. E. A. (2014). Bioaccumulation of heavy metals in some tissues of fish in the Red Sea, Egypt. *Egyptian journal of basic and applied sciences*, *1*(2), 97-105.

[15] Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of applied ichthyology*, *22*(4), 241-253.

[16] Hismayasari, I. B., Marhendra, A. P. W., Rahayu, S., Saidin, S. D., & Supriyadi, D. S. (2015). Gonadosomatic index (GSI), hepatosomatic index (HSI) and proportion of oocytes stadia as an indicator of rainbowfish Melanotaenia boesemani spawning season. *International Journal of Fisheries and Aquatic Studies*, *2*(5), 359-362.

[17] Issa, M. A. (2017). Organochlorine Pesticides (OCPs) and Polycyclic Aromatic Hydrocarbons (PAHs) in Marine Sediments and Worms from Coastal Area of Zanzibar Town (Doctoral dissertation, The State University of Zanzibar (SUZA).

[18] Jin, S., Yan, X., Zhang, H. and Fan, W., 2015. Weight–length relationships and Fulton's condition factors of skipjack tuna (Katsuwonus pelamis) in the western and central Pacific Ocean. *PeerJ*, *3*, p.e758.

[19] Kayombe, J. L., Waithaka, E., & Obegi, B. (2015). Length–weight relationship and condition factor of Clarias gariepinus in Lake Naivasha, Kenya. *International Journal of Fisheries and Aquatic Studies*, *2*(6), 382-385.

[20] Khristenko, D.S. and Kotovska, G.O., 2017. Length-weight relationship and condition factors of freshwater bream Abramis brama (Linnaeus, 1758) from the Kremenchug Reservoir, Middle Dnieper. *Turkish Journal of Fisheries and Aquatic Sciences*, *17*(1), pp.71-77.

[21] King, R. P. (1996). Length-weight relationships of Nigerian coastal water fishes. *Naga, The ICLARM Quarterly*, *19*(4), 53-581996.

[22] Koleleni, Y. I., and Haji, O. O. (2015). Determination of concentration of heavy metals in fish from sea port of Zanzibar by energy dispersive X-ray fluorescence (EDXRF).

[23] Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *The Journal of Animal Ecology*, 201-219.

[24] Leão, T., Siqueira, M., Marcondes, S., Franco-Belussi, L., De Oliveira, C., and Fernandes, C. E. (2021). Comparative liver morphology associated with the hepatosomatic index in five *Neotropical anuran* species. *The Anatomical Record*, *304*(4), 860-871

[25] Mahugija, J. A., Ahmed, K. N., & Makame, Y. M. (2017). Polycyclic aromatic hydrocarbons (PAHs) contamination in coastal mangrove ecosystems of the Zanzibar archipelago. *Western Indian Ocean Journal of Marine Science*, *16*(1), 25-34.

[26] Mohapatra, S., Chakraborty, T., Shimizu, S., Urasaki, S., Matsubara, T., Nagahama, Y., & Ohta, K. (2015). Starvation beneficially influences the liver physiology and nutrient metabolism in Edwardsiella tarda infected red sea bream (Pagrus major). *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, *189*, 1-10.

[27] Moynihan, M.A., Baker, D.M. and Mmochi, A.J., 2012. Isotopic and microbial indicators of sewage pollution from Stone Town, Zanzibar, Tanzania. *Marine pollution bulletin*, *64*(7), pp.1348-1355.

[28] Nehemia, A., Maganira, J. D., & Rumisha, C. (2012). Length-Weight relationship and condition factor of tilapia species grown in marine and fresh water ponds. *Agriculture and Biology Journal of North America*, *3*(3), 117-124.

[29] Nunes, C., Silva, A., Soares, E., Ganias, K., Nunes, C., Silva, A., & Soares, E. (2011). The use of hepatic and somatic indices and histological information to characterize the reproductive dynamics of Atlantic sardine Sardina pilchardus from the Portuguese coast. Mar. Coast. Fish. 3: 127-144.

[30] Osho, F. E., Usman, R. A. (2019): Length-weight relationship, condition factor and fecundity of African snakehead *Parachanna obscura* from the Anambra River, South East Nigeria. Croatian Journal of Fisheries, 77, 99- 105. DOI: 10.2478/cjf-2019-0011.

[31] Panicker, B., Katchi, V., & Gore, B. (2013). Morphometry and length-weight relationship of goby, *Parachaeturichthys ocellatus* (Day 1873) from Malad creek, Mumbai. *International Journal of Engineering and Science Invention*, *2*(7), 86-91.

[32] Revolutionary Government of Zanzibar, Zanzibar Planning Commission (2020), "Zanzibar Development Vision 2050".

[33] Revolutionary Government of Zanzibar, Zanzibar Planning Commission, Zanzibar Blue Economy Policy 2020.

[34] Revolutionary Government of Zanzibar, Zanzibar Research Agenda 2015 – 2020.

[35] Romdhani, A., Ktari, M.H. and Mahe, K., 2013. Length-Weight relationship and condition factor of Phycis phycis (Linnaeus, 1766) and Phycis blennoides (Brünnich, 1768) [Actinopterygii, Gadiform, Phycidae] in the Gulf of Tunis. *Bulletin de l'Institut National des Sciences et Technologies de la Mer*, *40*, pp.3-13.

[36] Solé, M., Antó, M., Baena, M., Carrasson, M., Cartes, J. E., & Maynou, F. (2010). Hepatic biomarkers of xenobiotic metabolism in eighteen marine fish from NW Mediterranean shelf and slope waters in relation to some of their biological and ecological variables. *Marine environmental research*, *70*(2), 181-188.

[37] Staehr, P. A., Sheikh, M., Rashid, R., Ussi, A., Suleiman, M., Kloiber, U., ... & Muhando, C. (2018). Managing human pressures to restore ecosystem health of zanzibar coastal waters. *J. Aquac. Mar. Biol*, *7*, 59-70.

[38] Ude, E. F., Ugwu, L. L. C., Mgbenka, B. O., & Nwani, C. D. (2011). Evaluation of length-weight relationship of fish species of Ebonyi River, Nigeria. *Nigerian Journal of Fisheries*, *8*(1), 136-144.

[39] Van der Oost R., Beyer J., and Vermeulan N.P.E. 2003. Fish bioaccumulation and biomarkers in environmental risk assessment: a review. *Environmental Toxicology and Pharmacology* 13(2): 57-149.