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Research Article

Combined effects of intestinal parasite infestation and extrinsic stress on the host gross energy in *Malapterurus electricus* (Teleostei: Malapteruridae) host-parasite system in the Lekki Lagoon, Nigeria

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Abstract: This paper describes combined effects of intestinal parasite infestation and extrinsic stress on the host gross energy in *Malapterurus electricus* host-parasite system. Eighty (80) fish samples were procured from the Lekki lagoon, Nigeria. Condition factors, organosomatic indices and hepatic glycogen of the individuals were estimated/measured. Infection status and median condition (K<1.4 and K>1.4) of *M. electricus* were used in grouping the individuals. Histological alterations of the intestines were also observed and scored for Gut-pathological Alteration Index (GAI). Infested individuals harbor *Electrotaenia malopteruri* (a cestode) and *Procamallanus longus* (a nematode). Non-infested individuals of low condition factor had the lowest hepatic glycogen; Mean±SD, 6.59±7.02mg/dl, infested individuals; Mean±SD, 18.94±11.18mg/dl, *P*<0.05, while individuals of high condition factor had higher hepatic glycogen level; infested, Mean±SD, 20.48±34.55mg/dl, non-infested, Mean±SD, 20.69±17.45mg/dl, *P*<0.01. Individuals of low condition factor had parasite load; *E. malopteruri* (0.24) and *P. longus* (0.29), while high condition individuals had; *E. malopteruri* (0.42) and *P. longus* (0.47). The infested individuals of high condition factors had the highest mean body weight, gonadosomatic index (GSI), hepatic triglycerides, cholesterone and low density lipids (LDL). Infested individuals of low condition factor had higher gut-pathological alteration index (GAI, 16.0) compared with high condition individuals (GAI, 8.0). These individuals had from mild to severe ulceration of the mucosa and congestion of the blood vessels. They also had one of the highest HSI, Mean±SD, 2.20±1.31, *P*>0.01 but the lowest GSI, Mean±SD, 4.80±2.9, *P*>0.01. These individuals depleted almost all their hepatic glycogen and signified reduced reproductive potential but had the highest hepatic energy influx to tissues for cellular metabolism. Parasite infestation and extrinsic stresses have significant impact on host gross energy content. Understanding the physiological mechanism in these stress interactions in the host is highly essential.

Keywords: Physiological Stress, Fulton's condition factor, Gut-pathological Alteration Index, Organosomatic indices.

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Introduction

Stress is most commonly defined amongst fish biologists as "a state of threatened homeostasis that is reestablished by a complex suite of adaptive responses" (Chrousos 1998). Fish found in disturbed ecosystems, face a wide variety of stressors; some natural and other anthropogenically-induced. Examples of common stressors that fish and other aquatic organisms face are: predation, parasitism, competition, chemical pollution, and changes in abiotic factors such as temperature, pH, and dissolved oxygen levels. The need for better understanding of the effects of multiple stressors is rapidly becoming one of the most important and challenging areas of research in applied biology (Zeidberg & Robison 2007). The challenge of studying multiple stressors stems from the complex nature of how different stressors interact in various ways with each other and the environment, resulting in "ecological surprises". The effects that multiple stressors exhibit on organisms can be additive or non-additive, i.e., synergistic or antagonistic (Folt et al. 1999).

All parasites utilize host-derived resources for their growth and development, and as such impose an energetic drain on host organisms (Barton 2002; Miller et al. 2007). As a consequence, energetic effects of infection are commonly reported, particularly when the parasites involved are large, rapidly-growing, numerous, or highly pathogenic (Miller et al. 2007). In addition, if infections reduce the competitive ability or foraging success of hosts (for example, as a consequence of infection-induced damage to organs) (Begon et al. 1990), then parasites may limit the nutrient intake of their hosts. Within the host populations, individuals differ in their ability to compete for limited resources (Begon et al. 1990) and the resulting unequal division of nutrients leads to variation in growth rates, body size and nutritional condition (Metcalfe 1986; Westerberg et al.2004). Unequal nutrient intake by competitors is also likely to have consequences for any parasites they may harbor, though it is difficult to predict the direction of such effects. Contrary, because parasites are completely dependent on host derived energy for growth and development (Bush et al. 2001), infecting better competitors might benefit parasites, particularly those with significant energetic requirements. Alternatively, if the best competitors are either in better nutritional condition as a result of their competitive superiority, or of intrinsically higher genetic quality, then they may be poor hosts for parasites if they have better immune systems or are able to limit the availability of nutrients to growing parasites. The former could induce biological stress on the host which reduces physiological energetic, which involves the allocation of acquired energy to the physiological upkeep within the host.

Evidence from laboratory and field studies shows that, during the parasite growth phase, these parasites impose a considerable energetic drain on their hosts. Infected wild caught fish typically have lower somatic body condition and/or liver energy reserves (Arme & Owen 1967; Pennycuick 1971; Tierney et al. 1996) as do experimentally infected fish held under a fixed ration of 8% body weight per day over the parasite growth phase (Barber & Svensson 2003). Furthermore, data on the amino acid composition of Ligula-infected roach are consistent with those of starved fish (Soutter et al. 1980).

Several indicators used for multi-stress responses have been reported by Andu and Kangor (1996) and Azmat et al. (2007). Some of these are condition factor and organosomatic indices. Schmitt & Dethloff (2000) stated that the condition factor is an organism-level response, with factors such as nutritional status, pathogen effects, and toxic chemical exposure causing greater-than-normal and less-than-normal weights. A decrease in condition factor is considered a reflection of depletion in energy reserves because these indices are positively related to muscle and livers energy content (Lizama et al. 2002; Hasan & Seces 2003). Organosomatic indices can be described as the ratios of organs to body weight (Ronald & Bruce 1990), measured organ in relation to body mass can be directly linked to toxic effects of chemical on target organ (Giullo & Hinton 2008). It can also be used as indices of changes in nutritional and energy status (Maxwell and Dutta 2005). Gonadogenesis is typically delayed, impaired, or reversed in fish that are under nutritional stress, so it is not unexpected that parasite infections are often associated with reduced gonadogenesis or fecundity (Wiklund et al. 1996). Female common gobies (*Pomatoschistus microps*) harboring the adult stage of the trematode *Aphalloïdes coelomicola* in their body cavities exhibit reduced gonad weight as a consequence of reduced mass and energy content (but not diameter or number) of individual ova (Pampoulie et al. 1999). However, it is difficult to attribute parasite-associated changes in sexual development solely to the energetic consequences of infection, as gonadogenesis in fishes is under the control of pituitary gonadotropins as well as a multitude of hormones and growth factors (Van Der Kraak et al. 1998). Yet the fact that *Schistocephalus solidus* infections impair gonadogenesis in female threespined sticklebacks in natural populations with infected individuals having smaller ovaries (McPhail & Peacock 1983; Heins et al. 1999) that contain fewer and smaller eggs (Heins & Baker 2003) despite pituitary function being apparently unaffected in this system (Arme & Owen 1967) suggests that the energetic effects of infection per se may be important.

Pre-existing variation in the competitive ability of hosts therefore has potentially important implications for parasite infestations, but to date no studies have directly tested this. The aim of this research is to investigate the combined effects of intestinal parasitic infestation and extrinsic stresses on *Malapterurus electricus* gross energy content in the Lekki lagoon.

Materials and Methods

Total of eighty (80) fishes (*Malapterurus electricus*) within 50g to 150g and 15 to 21.5cm were collected between June and November, 2011 and dissected for intestinal parasites. All work was conducted in accordance to national and international guidelines to minimize discomfort to animals. Standard guidelines on ethical practices for fish capture and handling (AFS 2004) were adopted. The sampling period puts into consideration the seasons and spawning. Individuals' livers and gonads were weighed and sex determined. This was used in estimating the Hepatosomatic index (HSI) and Gonadosomatic Index (GSI).

Hepatosomatic Index=Weight of Liver / Body weight (Schmitt & Dethloff 2000)

Gonadosomatic Index=Weight of Gonad / Body weight (Schmitt & Dethloff 2000)

Condition factor (K): The condition factor also known as the Ponderal index or the Fulton Coefficient of condition would be computed using the formula;

$$K=\frac{100W}{L^b}$$ (Le Cren 1951)

Where b is value obtained from the growth exponent in the length (b=3), W=Total weight of fish (g), L=Standard length (cm) and K=Condition factor.

Condition factor (K) was used as a base for grouping individuals into low condition status and high condition status (Dethloff & Schmitt 2000; Friedmann et al. 2002; Amber et al. 2007). Median Condition factor is calculated using Ranking cases; order of magnitude of condition factors of individuals in the sample (50th percentile). Individuals with Condition factor less than median condition factor; 1.4 are grouped into low condition status while individuals with Condition factor greater than median condition factor; 1.4 are grouped into high condition status.

Infestation status: Individuals were also grouped based on infestation status. The livers of 20 males and 15 females making a total of 35 individuals comprising of 18 infested and 17 non-infested individuals were selected for used for total protein content, glucose levels, high and low density lipoproteins triglyceride content and total cholesterol levels. The parasite load was estimated using the formulae:

Parasite load=Number of collected parasites/Number of infected fish

Condition factor (K) + infestation status: Individuals

Table 1. Comparison of liver parameters between infected and non-infected *Malapterurus electricus*.

Parameter	Non-infected fish		Infected fish	
	K<1.4 Mean±SD	K>1.4 Mean±SD	K<1.4 Mean±SD	K>1.4 Mean±SD
PRO (g/l)	7.88±0.71a	8.04±1.79a	8.77±1.59a	8.64±2.07a
GLY (mg/dl)	6.59±7.02	20.69±17.45a	18.94±11.18b	20.48±34.55
TRI (mg/dl)	65.40±10.34a	62.05±14.29a	57.31±8.86a	59.65±9.44a
LDL (mg/dl)	82.79±15.22a	79.74±9.20a	83.30±5.97a	87.88±10.52a
HDL (mg/dl)	7.56±1.28a	4.80±1.37a	5.30±1.44a	5.46±2.49a
TC (mg/dl)	99.33±12.96a	96.96±9.44a	100.11±7.92a	105.27±10.63a

K=Condition factor; HDL=High Density Lipoproteins, PRO-Protein; GLY=Glycogen, TRI=Triglyceride, LDL=Low Density Lipoprotein; TC=Total Cholesterone, (a) Significant at 0.05 level and (b) Not significant.

with low and high condition factors (K< or >1.4) were further categorized based on infestation status. Samples were finally grouped into infested and non-infested individuals.

Biochemical analysis: The liver samples of the fish were subjected to colorimetrical analysis of total protein content (Henry 1964) using buiret reagent and total cholesterone, lipoproteins (High and Low Density) and triglycerides according to Tietz (1995) using enzymatic colorimetrical method. Glycogen was determined by the anthrone reagent method (Seifter et al. 1950).

Histopathological technique: Fish tissues were fixed in Bouins's fluid (composed of picric acid, acetic acid and formaldehyde in an aqueous solution) for six hours and transferred to 10% phosphate buffered formalin (Pearse 1968; Bancroft 1975). The dehydration of the tissues took place in ascending series of ethanol (70%, 95% and then twice in absolute ethanol at 30 minutes duration). Tissues were infiltrated with molten paraffin wax three times at room temperature and later embedded in molten paraffin wax and allowed to solidify. The blocked tissues were sectioned at 4-5 microns using microtome, floated into pre-coated slides and dried. The sections were stained using Delafield's Haematoxylin and eosin stains. The stained tissues were washed off in tap water and the over-stained ones destained in 1% acid alcohol. The tissues were mounted, using DPX mountant dried and observed under the microscope. Photomicrographs were taken with the aid Olympus DP12 microscope digital camera in the pathology laboratory of the Department of Veterinary Pathology, Faculty of Veterinary Medicine, University of Ibadan.

Diagnostic histopathology: The histopathological changes were evaluated semi-quantitatively as adapted from Poleksic & Mitrovic-Tutundzic (1994). Gut-pathological Alteration Index (GAI) for the fish was calculated using the formula:

GAI=Summation of category of alterations (X) in the fishes

$GAI = \Sigma X\ (X1+ X2 + \ldots + Xn)$

The summation of GAI was divided into five categories: 0 = normal tissue; 2 = mild to moderate damage to the tissue, 4 = moderate to severe damage to the tissue and presence of more than one ovum, 6 = severe damage to the tissue and presence of ova, greater than 8 = irreparable damage to the tissue.

Results

Comparison of liver parameters between infested and non-infested *Malapterurus electricus*: There were significant differences in the liver parameters of infested and non-infested individuals of low and high condition factor (Table 1). Infested individuals of low condition had hepatic protein; Mean±SD, 8.77±1.59g/l, P<0.01, non-infested; Mean±SD, 7.88±0.71g/l, P<0.01, while infested individuals of high condition had; Mean±SD, 8.64±2.07g/l, P<0.01, non-infested; Mean±SD, 8.04±1.79, P<0.01. Hepatic glycogen was the lowest among non-infested individuals of low condition; Mean±SD, 6.59±7.02 mg/dl, infested; Mean±SD, 18.94±11.18mg/dl,

Table 2. Hepatosomatic Index and Gonadosomatic Index of *Malapterurus electricus*.

Parameter	Non-infected fish		Infected fish	
	K < 1.4 Mean±SD	K > 1.4 Mean±SD	K < 1.4 Mean±SD	K > 1.4 Mean±SD
Weight (g)	91.20±42.25a	89.13±28.14a	73.00±27.64a	127.25±38.38a
Length (cm)	18.90±2.97a	17.75±2.12a	17.94±2.86a	20.16±1.88a
HSI	2.20±1.31b	2.02±0.57a	2.23±0.19a	1.89±0.29a
GSI	8.29±7.10	14.80±2.95a	4.76±2.91	11.47±2.20a

(a) Significant at 0.05 level and (b) not significant.

Table 3. Hepatosomatic Index and Gonadosomatic Index of *Malapterurus electricus*.

Condition Factor	Status	No	Weight (g)	*E.malopteruri* Bio-load	*P. longus* Bio-load	Summation of GAI					
						1	2	3	4	5	ΣX
Low Condition	Infected	8	73.00±27.64a	0.24	0.29	2.0	4.0	2.0	6.0	2.0	16.0
	Non-Infected	8	91.20±42.25a	Nil	Nil	0.0	0.0	2.0	0.0	2.0	4.0
High Condition	Infected	10	127.25±38.38a	0.42	0.47	0.0	2.0	0.0	2.0	4.0	8.0
	Non-Infected	9	89.13±28.14a	Nil	Nil	0.0	0.0	2.0	0.0	0.0	2.0

(a) Significant at 0.05 level and (b) not significant.

P<0.05, while individuals of high condition factor had higher hepatic glycogen level; infested, Mean±SD, 20.48±34.55mg/dl, non-infested, Mean±SD, 20.69±17.45mg/dl, P<0.01. Infested individuals of low condition had hepatic triglyceride; Mean±SD, 57.31±8.86mg/dl, P<0.01, non-infested; Mean±SD, 65.40±10.34mg/dl, P<0.01, while infested individuals of high condition had; Mean±SD, 59.65±9.44mg/dl, P<0.01, non-infested; Mean±SD, 62.05±14.29mg/dl, P<0.01. Infested individuals of low condition had hepatic low and high density lipoprotein; LDL, Mean±SD, 83.30 ±5.97mg/dl, P<0.01, HDL, Mean±SD, 5.30±1.44 mg/dl, P<0.01, non-infected; LDL, Mean±SD, 82.79±15.22mg/dl, P<0.01, HDL, Mean±SD, 7.56±1.28mg/dl, P<0.01, while infested individuals of high condition had; LDL, Mean±SD, 87.88±10.52 mg/dl, P<0.01, HDL, Mean±SD, 5.46±2.49mg/dl, P<0.01, non-infested; LDL, Mean±SD, 79.74±9.20 mg/dl, P<0.01, HDL, Mean±SD, 4.80±1.37, P<0.01. The cholesterol levels in non-infested individuals of low condition was; Mean±SD, 99.33±12.96, P<0.01, infested; Mean±SD, 100.11±7.92, P<0.01, while non-infested individuals with high condition factor had; Mean±SD, 96.96±9.44, P<0.01, infested; Mean±SD, 105.27±10.63, P<0.01.

Hepatosomatic index and gonadosomatic index: The difference in Hepatosomatic index (HSI) among the infested and non-infested individuals depend on their condition status (Table 2). Individuals of low condition had greater HSI. Hepatosomatic index of infested *M. electricus* with low condition factor was 2.23±0.19, P<0.01, non-infested; 2.20±0.19, P<0.01, infested fish with high condition had; 1.89±0.29, P<0.01, non-infested; 2.02±0.57, P<0.01. Gonadosomatic index (GSI) of low condition infested individuals was the lowest. GSI among the infested female individuals of low condition factor was 4.76±2.91, P<0.01 and non-infested female; 8.29±7.10 while infested fish with high condition had; 11.47±2.20, P<0.01, non-infested; 14.80±2.95, P<0.01.

Parasite load of *Electrotaenia malopteruri* and Gut-pathological Alteration Index (GAI) in low and high condition *Malapterurus electricus* in Lekki lagoon, Nigeria: The microscopic study of the intestines of the recovered helminth parasites revealed different degree of alterations; from slight to severe ulceration

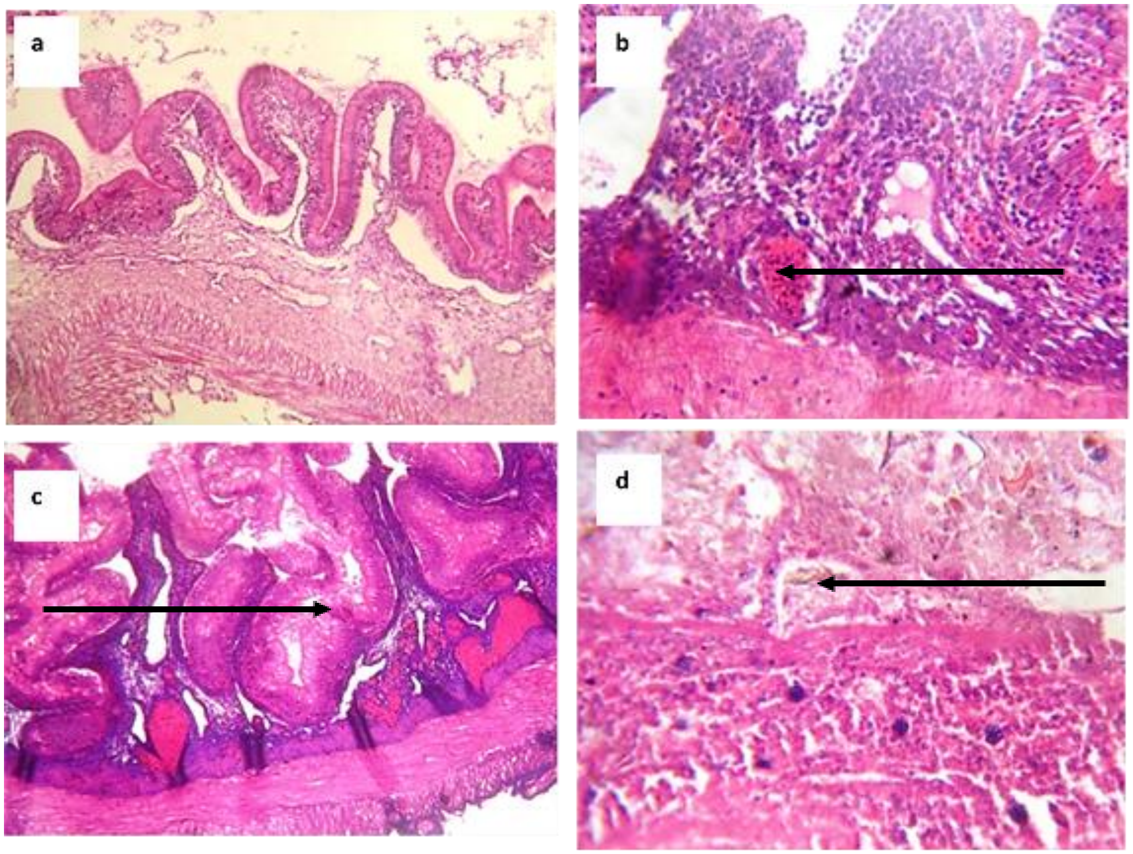

Fig.1. Sections of the intestine show (a) no significant lesion and no parasite – Score (HAI of 0), (b) slight congestion of blood vessels in the laminar propia – Score (HAI of 2), (c) moderate congestion of blood vessels in laminar propia Score (HAI of 4) and (d) villious structures completely obliterated and presence of debris in the lumen - Score (HAI of 6). X 100.

of the mucosa due to the presence of ova and adult parasites, congestion of blood vessels and presence of debris. Figure 1 shows the histopathological sections of the fish host intestine. Infested individuals of low condition factor (K<1.4) of *Malapterurus electricus* (Table 3) had a greater Gut-pathological alteration index (GAI, 16.0) compared to the high condition individuals (GAI, 8.0). They had from mild to severe ulceration of the mucosa, presence of ova, adult worms and congestion of the blood vessels. These alterations were insignificant among non-infested individuals. Individuals of low condition factor had parasite load; *Electrotaenia malopteruri* (0.24) and *Procamallanus longus* (0.29), while high condition individuals had; *E. malopteruri* (0.42) and *P. longus* (0.47).

Discussion

Food is the major source of all the nutrients a host needs. Nutrients are chemical substances needed for growth, repair damaged tissues and supply energy for metabolic processes. Helminths infest almost all the regions of the alimentary tract of fish. Any damage to the alimentary canal will alter the physiological activities of fish. For cestode and nematode parasites the most favourable and selected site is the alimentary canal, and the reason is to meet their primary need of food from the host. The energetic cost of parasitic infection is evident by the variety of nutrients parasites directly consume from their host. Fish infested with parasites that impose a significant energetic cost may therefore be forced to increase their foraging effort or alter their foraging strategies to compensate (Metcalfe 1986). The most detailed studies of behavioral changes induced by energetically demanding parasites have examined fish harboring the large plerocercoid larvae of the closely related pseudophyllidean cestodes

Schistocephalus solidus and *Ligula intestinalis,* which infect sticklebacks and cyprinids respectively (Barber & Svensson 2003).

Glucose is an important source of energy for cestodes, inhibiting the gut (Mishra et al. 1991). Cestodes (*Electrotaenia malopteruri*) found in infected individuals for instance, actively absorb amino acids, glucose (Williamson 2003), fatty acids (Smith 1994) and whole proteins (Whitfield 1993) from the host's alimentary canal. Also, parasites can be sensitive to the presence of contaminants and rate of host infection can either increase (Hecker & Karbe 2005) or decrease (Munkittrick & Dixon 1988) depending on the type of environmental deterioration in question (Lafferty 1997). Alteration in net energy due to multi-stress can lead to change in physiological trend within the population (Bayne et al. 1983). Hepatic glycogen was the lowest among the non-infested individuals of low condition factor. Infested individuals harbor *Electrotaenia malopteruri* (a cestode) and *Procamallanus longus* (a nematode). Most parasites need a viable host to survive. Pre-existing variations in the competitive ability of hosts has potentially important implication for parasite infections as well as their individual parasite load (Metcalfe, 1986). Individuals of low condition factor had parasite load; *Electrotaenia malopteruri* (0.24) and *Procamallanus longus* (0.29), while high condition individuals had; *E. malopteruri* (0.42) and *P. longus* (0.47). Low parasite load among the low condition individuals is an indicator of host nutritional stress and loss of host vitality. These individuals might gradually be losing their host viability to harbor parasites. Some intestinal parasites utilize alternative energy source other than glucose (Chappell 1993). The cestodes utilize different degrees of protein for producing energy. Brand (1952) reported that parasites are able to adapt themselves to parasitic mode of life, only due to protein usually constitutes between 20% and 40% of dry weight. The higher content of lipid is found in older proglottids (Sonune 2012)

Alteration in condition factor and Hepatosomatic Index (HSI) are well established tertiary stress responses at the whole organism level associated with altered energy distribution (Barton 2002; Miller et al. 2007). Field studies often examining large numbers of fish have identified a number of typical differences between parasitized and non-parasitized fishes (Saliu et al. 2014; Akinsanya et al. 2015b). Like this present study, parasitized fish typically exhibit lower somatic body condition and/or hepatic energy reserves (Arme & Owen 1967; Pennycuick 1971; Tierney et al. 1996; Bagamian et al. 2004), as well as impaired gonadogenesis in females (Heins & Baker 2008) and reduced secondary traits in males (Tierney et al. 1996; Rushbrook & Barber 2006).

Metal contamination in the water medium, sediment, fish and parasites has been reported in Lekki lagoon (Kuton et al. 2015; Akinsanya et al. 2015). Natural populations of fish can develop elevated tolerances to certain environmental contaminants, but exposure must be at tolerable concentrations (Saliu et al. 2017) in order for this phenomenon to be triggered. Organisms exposed to contaminants can experience depleted energy stores presumably due to the metabolic costs associated with detoxification (Adams 1999) and/or repair of damaged cells and tissues (Campbell et al. 2003). Male individuals of high condition had reduced parasite load and heavier weights (60-130g) than their counterparts with low condition. Toxicants have high potential of reducing immunological response. These pollutants have shown to cause reduction in reproductive potential, bioenergetics and impaired growth in fish host (Dicks 2009).In addition, the tolerance is lost when exposure to the contaminants is persistent (Benson & Birge 1985). Hilmy et al. (1987) observed increases in liver total protein levels in catfish (*Clarias lazera*) and bolti (*Tilapia zilli*) exposed to zinc. Increase in lipid, soluble protein, cholesterol and glucose in the liver could also be related to the abundance of available food to the fish (Coop et al. 1997). In this study, there were changes in hepatic energy reserve (measured as HSI) among individuals within the population due to variation in utilization. There was a lower glycogen level in individuals of low condition factor compared with individuals of high condition. This was much lower among the infested individuals compared to non-infested. The energetic costs of mounting a successful immune response towards invading parasites outweighed the energetic drain for maintenance among these individuals (Paperna 1996; Marcogliese et al. 2006).

Parasites induce stress on the host as well as contaminants. There are several possible qualitative outcomes when parasite interact with other stressors (pollution, or/and water temperature). The effects that multiple stressors exhibit on hosts can be additive or non-additive (Sures et al. 1997; Folt et al. 1999; Marcogliese 2005; Lafferty 2008). The most obvious concept is that some stressors may make hosts more susceptible to parasitism (Marcogliese 2005; Lafferty 2008; Saliu et al. 2014). This appears to be due to an increase in susceptibility because toxic conditions compromise a fish's immune system (Paperna 1996; Lafferty 2008). When the dynamic equilibrium between host and parasite is lost, some changes can occur, such as mechanical damage (fusion of gill lamellae, tissue replacement, and ulceration of the mucosa), physiological damage (cell proliferation, immunomodulation, altered growth, detrimental behavioral responses,) and/or reproductive damage (Buchman & Lindstrøm 2002; Knudsen et al. 2009; Al-Jahdali & Hassanine 2010). These changes can cause other pathological effects. Infested individuals of low condition factor (K<1.4) of *Malapterurus electricus* had a greater Gut-pathological Alteration Index (HAI, 16.0) compared to the high condition individuals (HAI, 8.0). These individuals had from mild to severe ulceration of the mucosa, presence of ova and adult worms and congestion of the blood vessels. The infested individuals of high condition factors had the highest body weight, gonadosomatic index, triglycerides, cholesterone and low density lipids (LDL). These individuals had reduced Gut-pathological Alteration Index. This indicates that these individuals are not under nutritional stress, but the stress could rather be toxicological. In this study, there was high lipid, and protein among infested individuals. However, in a similar study by Lohner et al. (2001), who reported lipid levels in fish from both Stingy Run sampling efforts were significantly lower than those in fish from the Ohio River indicating possible nutritional stress.

In conclusion, this study shows that parasitic infestations have been shown to decrease energy stores in fish as reported by Bakker & Mundwiler (1999), but is only evident among multi-stressed individuals in the population. This is dependent on the relative abundance, prevalence and intensity of the parasitic infestation (Marcogliese 2005; Lafferty 2008; Saliu et al. 2014), extrinsic stressors (Sures et al. 1997) and the impact on host gross energy content (Metcalfe 1986; Adams 1999; Dicks 2009). However, assessment of the energy status in fish should be considered within ichthyological, ichthyopathological, and ecological investigations in comparison to condition factor and HSI to provide sufficient information about energetic demands posed by a multi-stress environment. The development of an understanding of the physiological mechanisms by which parasites impact host biology is highly essential.

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References
Adams, S.M. 1999. Ecological role of lipids in the health and success of fish populations, In: Arts, M.T. & Wainman, B.C. (eds), *Lipids in Freshwater Ecosystems*. Springer-Verlag, New York. pp. 132-160.

Akinsanya, B.; Ukwa, U.D.; Kuton, M.P. & Saliu, J.K. 2015a. Parasite load, condition factor, and heavy metal accumulation as multiple stressors on fish with public health significance in Lekki Lagoon, Lagos, Nigeria. Journal of Public and Allied Health Sciences

(1): 21-33.

Aknsanya, B.; Kuton, M.P.; Oyebola, L.; Saliu, J.K. & Ukwa, U.D. 2015b. Condition factor and Gastro-intestinal Parasites of fish as indicators of stress in Lekki lagoon, Lagos, Nigeria. Egyptian Academic Journal of Biological Science (E-Medical Entomology and Parasitology 7: 1-13.

Al-Jahdali, M.O. & El-S Hassanine, R.M. 2010. Ovarian abnormality in a pathological case caused by *Myxidium* sp. (Myxozoa, Myxosporea) in one spot snapper fish *Lutjanus monostigma* (Teleostei, Lutjanidae) from the Red Sea. Acta Parasitologica 55: 1-7.

Amber, K.P.; Michael L.J.; Dale, C.H. & James, R.B. 2007. Monitoring energetic status of lake Michigan Chinook Salmon using water content as a predictor of whole fish lipid content. Journal of Great Lake Resource 33: 253-263.

Arme, C. & Owen, R.W. 1967. Infections of 3-Spined stickleback *Gasterosteus aculeatus* L. with plerocercoid larvae of *Schistocephalus solidus* (Miller, 1776) with special reference to pathological effects. Parasitology 57: 301-304.

Andu, A.K. & Kangur, P. 1996. The Condition, length and age distribution of pikeperch Hydrobiologica 338: 179-183.

Azmat, R.; Talat, R. & Ahmed, K. 2007. The length–weight relationship. Condition factor and impact of fluoride concentration in *Johnius belangerii* of Arabian Sea. Research Journal of Environmental Toxicology 1(3): 138-143.

Bagamian, K.H.; Hein, D.C. & Baker, J.A. 2004. Body condition and reproductive capacity of three-spined stickleback infected with the cestode *Schistocephalus solidus.* Journal of fish Biology 51: 654-658.

Barber, I. & Svensson, P.A. 2003. Effects of experimental *Schistocephalus solidus* infections on growth, morphology and sexual development of female three-spined sticklebacks, *Gasterosteus aculeatus*. Parasitology 126: 359-367.

Bayne, B.L. & Newell, R.C. 1983. Physiological energetics of marine molluscs. In: Sa1euddin, A.S.M. & Mi1bur M.K. (eds), *the Mollusca*. Vol. 4, Physiology. Part. 7. Academic Press, New York. pp. 407-515.

Begon, M.; Harper, J.L & Townsend, R.C. 1990. Ecology: Individuals, Populations and Communities, second edition. Blackwell Scientific Publishing, Boston. 945 p.

Benson, W.H. & Birge, W.J. 1985. Heavy metal tolerance and metalothionein induction in fathead minnows; Results from Field and Laboratory investigations. Environmental Toxicology and Chemistry 4: 209-217.

Brand, T.V. 1952. Chemical physiology of endoparasitic animals. Academic Press, NewYork. 339 p.

Buchmann, K. & Lindenstrøm, T. 2002. Interactions between monogenean parasites and their fish from Ibero-Atlantic waters. Journal of Fish Diseases 28: 125-132.

Bush, A.O.; Ferna´ndez, J.C.; Esch, G.W. & Seed, R. 2001. Parasitism: The Diversity and Ecology of Animal Parasites. Cambridge University Press, Cambridge.

Campbell, P.; Hontela A.; Rasmussen J.B.; Giguere A.; Gravel, A.; Kraemer, L.; Kovesces, J.; Lacroix A.; Levesque, H. & Sherwood, G. 2003. Differentiating between direct (physiological) and food-chain mediated (bioenergetics) effects on fish in metal-impacted lakes. Human and Ecological Risk Assessment 9-84.

Williamson, A.L. 2003. Free amino acid or smallpeptides absorbed across the gut lumen. Haemolysis (e.g undefined membrane proteins in *A.caninum* and *H.cantortus.* Trends in Parasitology 19: 9-15.

Chrousos, G.P. 1998. Stressors, stress and neuroendocrine integration of the adaptive response: the 1997 Hans Selye memorial lecture. Annals of the New York Academy of Sciences 851: 311-335.

Dick, E.J. 2009. Modelling the reproductive potential of Rockfishes (*Sebastes* spp.) PhD Thesis. Department of Ocean Science. University of California, USA. 256 p.

Doyon, S.F.; Downing, J.A. & Magnin, E. 1988. Variation in the condition of Northern pike, *Esox Lucius*. Canadian Journal of Fish Aquatic Culture Science 45: 479-483.

Friedmann, A.S.; Costain, E.K.; MacLatchy, D.L.; Stansley, W. & Washuta, E.J. 2002. Effects of mercury on general and reproductive health of largemouth bass (*Micropterus salmoides*) from three lakes in New Jersey. Ecotoxicology Environmental Safety 52: 117-122.

Folt, C.L.; Chen, C.Y.; Moore, M.V. & Burnaford, J. 1999. Synergism and antagonism among multiple stressors. Limnology and Oceanography 44: 864-877.

Giulio, R.T. & Hinton D.E. 2008. *The Toxicology of Fishes*. First edition. CRC Press, Taylor and Francis Group, Boca Raton. 1071 p.

Hasan, H.A. & Secer, S. 2003. Width length–weight relationship of the blue crab (*Callinectes sapidus*) population living in Beymelek Lagoon Lake Turkish Journal Veterinary and Animal Science 27: 443-442.

Henry, R.J. 1964. Colorimetric determination of total protein. In: *Clinical chemistry*. Harper and Row Publishing press, New York. 181 p.

Hecker, M. & Karbe, L. 2005. Parasitism in fish-an endocrine modulator of ecological relevance? Aquatic Toxicology 72: 195-207.

Heins, D.C. & Baker, J.A. 2008. Reduction of egg size in natural populations of three spine stickleback infected with a cestode macroparasites. Journal of Parasitology 89: 1-6.

Heins, D.C.; Singer, S.S. & Baker, J.A. 1999. Virulence of the cestode *Schistocephalus solidus* and reproduction in infected threespine stickleback, *Gasterosteus aculeatus*. Canadian Journal of Zoology 77: 1967-1974.

Hilmy, A.M.; Domiaty, N.A.; Daabees, A.Y. & Abdel Latife, H.A. 1987. Some physiological and biochemical indices of zinc toxicity in two freshwater fishes, *Clarias lazera* and *Tilapia zilli*. Comprehensive Biochemical Physiology 87: 297-301.

Knudsen, R.; Amundsen, P.A.; Jobling, M. & Klemetsen, A. 2009. Differences in pyloric caeca morphology between Arctic char *Salvelinus alpines* ecotypes: adaptation to trophic specialization or parasite-induced phenotypic modifications? Journal of Fish Biology 73: 275-287.

Kuton, M.P.; Akinsanya, B.; Ukwa, U.D. & Saliu J.K. 2015. Relevance of Intestinal Parasites of *Parachanna obscura* and *Sarotherodon melanotheron* on Host Metal Accumulation in Lekki lagoon, Lagos, Nigeria.Unilag Journal of Medicine, Science and Technology 2: 116-125.

Lafferty, K.D. 1997. Environmental parasitology: what can parasites tell us about human impacts on the environment? Parasitology Today 13: 251-255.

Lafferty, K.D. 2008. Ecosystem consequences of fish parasites. Journal of Fish Biology 73: 2083-2093.

Le Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch *Perca fluviatilis*. Journal of Animal Ecology 20: 201-219.

Lizama, M., Delos, A.P. & Ambrosio, P. 2002. Condition factor in nine species of fish of the characidae family in the upper Parana River flood plain Brazil. Brazil Journal of Biology 62: 1519-1526.

Lohner, T.W.; Reash R.J.; Willet V.E. & Rose L.A. 2001. Assessment of tolerant sunfish populations (*Lepomis* sp.) inhabiting selenium-laden coal ash effluents.1.Hematological and population level assessment. Ecotoxicology and Environmental Safety 50: 203-216.

Marcogliese, D.J. 2005. Parasites of the super organism: are they indicators of ecosystem health? International Journal of Parasitology 35: 705-716.

Marcogliese, D.J.; Gendron, A.D.; Plante, C.; Fournier, M. & Cyr, D. 2006. Parasites of spottail shiners (*Notropis hudsonius*) in the St. Lawrence River: effects of municipal effluents and habitat. Canadian Journal of Zoology 84: 1461-1481.

Maxwell, L.B. & Dutta, H.M. 2005. Diacinon induced endocrine disruption in sole gill sun fish *Lepomis macrochirus*. Ecotoxicology and Environmental Safety 60: 21-27.

McPhail, J.D. & Peacock, S.D. 1983. Some effects of the cestode (*Schistocephalus solidus*) on reproduction in the threespined stickleback (*Gasterosteus aculeatus*): Evolutionary aspects of a host-parasite interaction. Canadian Journal of Zoology 61: 901-908.

Metcalfe, N.B. 1986. Intra specific variation in competitive ability and food intake in salmonids—consequences for energy budgets and growth rates. Journal of Fish Biology 28: 525-531.

Mishra, V.P.; King, R.H.M.; Harding, A.E.; Muddle J.R. & Thomas, P.K. 1991. Peripheral neuropathy in the Chediak-Higashi syndrome. Acta Neuropathy 81: 354-358.

Munkittrick, K.R. & Dixon P.G. 1988. Growth, fecundity, and energy stores of white sucker

(*Catostomus commersoni*) from lakes containing elevated levels of copper and zinc. Canadian Journal of Fisheries and Aquatic Sciences 45: 1355-1365.

Paperna, T. 1996. Parasites, infections and disease of fishes in Africa and update CIFA Technical Paper. 220 p.

Pampoulie, C.; Morand, S.; Lambert, A.; Rosecchi, E.; Bouchereau, J.L. & Crivelli, A.J. 1999. Influence of the trematode *Aphalloıdes coelomicola* Dollfus, Chabaud and Golvan, 1957 on the fecundity and survival of *Pomatoschistus microps* (Kroyer, 1838) (Teleostei: Gobiidae). Parasitology 119:61-67.

Pearse, A.G.E. 1968. *Histochemistry*. Theoretical and applied. 2nd Edition, Little Brown and Company, Boston, MSS.

Pennycuick, L. 1971. Quantitative effects of 3 species of parasiteson a population of three spined sticklebacks, *Gasterosteus aculeatus*. Journal of Zoology 165: 143-162.

Ronald, W.G. & Bruce, A.B. 1990. Organosomic indices and an autopsy based assessment as indicators of health condition of fish. American Fisheries Society 8: 93-108.

Rushbrook, B.J. & Barber, I. 2006. Nesting, courtship and kidney hypertrophy in *Schistocephalus*-infected male three spined stickleback from an upland lake. Journal of fish Biology 69: 870-882.

Tierney, J.F; Huntingford, F.A. & Crompton D.W.T. 1996. Body composition and reproductive status in stickleback exposed to a single wave of *Schistocephalus solidus* infection. Journal of fish Biology 49: 483-493.

Saliu, J.K.; Akinsanya, B.; Ukwa, U.D.; Odozie, J. & Ganiu, Y. 2014. Host condition, parasite interaction and metal accumulation in *Tilapia guineensis* from Iddo area of Lagos Lagoon, Nigeria. Iranian Journal of Ichthyology 1: 286-295.

Saliu, J.K.; Oluberu, S.A.; Akpoke, I.I. & Ukwa, U.D. 2017. Cortisol stress response and histopathological alteration index in *Clarias gariepinus* exposed to sub-lethal concentrations of Qua Iboe crude oil and Rig wash. African Journal of Aquatic Science 42: 55-64.

Schmitt, C.I. & Dethloff, G.M. 2000. Biomonitoring of environmental status and trends (BEST) program: Selected methods for monitoring chemical contaminants and their effects in aquatic ecosystem. U.S. Geological Survey, Biological Resources Division, Columbia, (MO): Information and Technological Report. 81 p.

Seifter, S.; Dayton, S.; Novic, B. & Muntmyler, E. 1950. Estimation of glycogen with the anthrone reagent, Archive of Biochemistry 25: 291-295.

Smith, J.D. 1994. *Introduction to animal parasitology*. 3rd edition. Cambridge University Press, Cambridge. 572 p.

Sonune, M.B. 2012. Biochemical studies of gastrointestinal cestode parasites in *Ovis Bharal* (L.) from Vidharbha region. Bioscience Discovery 3: 321-322.

Soutter, A.M.; Walkey, M. & Arme, C. 1980. Amino acids in the plerocercoid of *Ligula intestinalis* (Cestoda, Pseudophyllidea) and its fish host, *Rutilus rutilus*. Z. fur Parasitkde 63: 151-158.

Sures, B.; Taraschewski, H. & Rydlo, M. 1997. Intestinal fish parasites as heavy metal bioindicators: A comparison between *Acanthocephalus lucii* (Palaeacanthocephala) and the Zebra Mussel, *Dreissena polymorpha*. Bulletin of Environmental Contamination Toxicology 59: 14-21.

Tietz, N.W. 1995. Clinical Guide to Laboratory Test, 3rd Edition. W.B Saunders, Philadelpia, PA. 482 p.

Van Der Kraak, G.; Chang, J.P. & Janz, D.M. 1998. Reproduction. In: Evans, D.H. (ed), *Physiology of Fishes*. 2nd edition. CRC Press, Boca Raton. pp. 465-490.

Westerberg, M.; Staffan F. & Magnhagen, C. 2004. Influence of predation risk on individual competitive ability and growth in Eurasian perch, *Perca fluviatilis*. Animal Behaviour 67: 273–279.

Whitfield, P.J. 1993. Physiology and nutrition. In: Cox, F.E.G. (ed), *Modern Parasitology*. 2nd edition. Blackwell Scientific Publications, Oxford, UK, pp. 24-52.

Wiklund, T.; Lounasheimo, L.; Lom, J. & Bylund, G. 1996. Gonadal impairment in roach Rutilus rutilus from Finnish coastal areas of the northern Baltic sea. Diseases of Aquatic Organisms 26: 163-171.

Zeidberg, L.D. & Robison, B.H. 2007. Invasive range expansion by the Humboldt squid, *Dosidicus gigas* in the Eastern North Pacific. Proceedings of the National Academy of Sciences 104: 12948-12950.

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مقاله پژوهشی

تأثیر توام ابتلا به انگل روده‌ای و استرس‌های داخلی بر انرژی میزبان در سیستم میزبان-انگل ماهی الکتریکی (ماهیان استخوانی عالی: گربه ماهیان الکتریکی) در تالاب لکی نیجریه

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چکیده: این مقاله تاثیر توام ابتلا به انگل روده‌ای و استرس‌های داخلی بر انرژی میزبان در سیستم میزبان-انگل ماهی الکتریکی توصیف می‌نماید. تعداد ۸۰ ماهی از تالاب لکی نیجریه تهیه و فاکتور وضعیت، نمایه‌های اندامی-بدنی و گلیکوژن کبدی آنها برآورد/اندازه‌گیری شد. وضعیت ابتلا به انگل و میانگین وضعیت ماهی الکتریکی برای گروه بندی افراد مورد استفاده قرار گرفت. تغییرات بافتی روده نیز مشاهده و به عنوان نمایه تغییرات پاتولوژیکی گوارشی مورد استفاده قرار گرفت. ماهیان مورد مطالعه به کرم پهن نواری *Electrotaenia malopteruri* و کرم لوله‌ای *Procamallanus longus* مبتلا بودند. ماهیان غیر مبتلا به انگل و دارای فاکتور وضعیت پایین دارای پایین‌ترین مقدار گلیکوژن کبدی ۶/۵۹±۷/۰۲ میلی‌گرم بر دسی لیتر و افراد مبتلا و دارای فاکتور وضعیت پایین دارای دارای ۱۸/۹۴±۱۱/۱۸ میلی‌گرم بر دسی لیتر گلیکوژن کبدی بودند در حالی‌که ماهیان با فاکتور وضعیت بالا دارای بالاترین مقدار گلیکوژن کبدی یعنی ۲۰/۴۸±۳۴/۵۵ میلی‌گرم بر دسی لیتر در افراد مبتلا و ۲۰/۶۹±۱۷/۴۵ میلی‌گرم بر دسی لیتر در ماهیان غیر مبتلا به انگل. ماهیان الکتریکی دارای فاکتور وضعیت پایین دارای بار انگلی ۰/۲۴ برای انگل *E. malopteruri* و ۰/۲۹ برای انگل *P. longus* بودند. ماهیان الکتریکی دارای فاکتور وضعیت بالا دارای بار انگلی ۰/۴۲ برای انگل *E. malopteruri* و ۰/۴۷ برای انگل *P. longus* بودند. ماهیان مبتلا به انگل و دارای فاکتور وضعیت بالا دارای بالاترین میانگین وزن بدن، نمایه گنادی-بدنی، تری‌گلیسیدهای کبدی، کلسترون و لیپیدهای با چگالی کم بودند. ماهیان مبتلا به انگل و دارای فاکتور وضعیت پایین در مقایسه با افراد دارای فاکتور وضعیت بالا، شاخص تغییرات پاتولوژیکی گوارشی بالاتر (GAI, ۱۶/۰) داشتند. این ماهیان دارای زخم کم تا شدید در بافت پوششی روده و احتقان رگ‌های خونی بودند. به‌نظر می‌رسد که ابتلا به انگل روده‌ای و استرس‌های داخلی تاثیر معنی‌داری بر میزان انرژی میزبان دارند.

کلمات‌کلیدی: استرس‌های فیزیولوژیکی، فاکتور وضعیت، نمایه تغییرات پاتولوژیکی گوارشی، نمایه اندامی-بدنی.