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Journal of Parasitology and Vector Biology

Full Length Research Paper

Tungiasis: An Overview

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Tungiasis exists worldwide with varying degrees of incidence and prevalence. The aim of this paper was to review the existing literature concerning Tungiasis. Tungiasis has been shown to be a public health concern for resource-poor rural communities in developing countries such as Nigeria, Kenya, Cameroon, Trinidad, Tobago, and Brazil, where its prevalence has been known to reach 50%. As a literatures reviewed, poor hygienic conditions, increased poverty levels, prolonged dry season and fear of stigmatization are among the most important risk factors, severely influencing the persistence of the tungiasis. The presence of the jigger in the skin causes itching sensation, and in a severe cases causes loss of nails, formation of ulcers, inflammation, suppuration, chronic lymphedema, sepsis and could be death. Jigger infestation affects the education of children as they might be unable to walk to school, write properly, or participate in regular learning activities. Tungiasis is likely to increase and cause livelihood of communities in developing countries. Thus, new prevention and control approaches should be designed through multi-interdisciplinary team to mitigate the persistence of the disease, particularly in vulnerable communities.

Key words: Jiggers fleas, poverty, risk factors, school children.

INTRODUCTION

Tungiasis is a parasitic disease of humans and animals caused by fleas (Siphonaptera) belonging to the genus Tunga. Two species, *Tunga penetrans* and *Tunga trimamillata,* out of 10 described to date, are known to affect man or domestic animals; the other eight are exclusive to a few species of wild mammals. *T. penetrans* and *T. trimamillata* originated from Latin America, although the first species is also found in sub-Saharan Africa (between 20°N and 25°S) (Pampiglione et al., 2009). In addition, Tungiasis is endemic in equatorial and subtropical regions and rarely described in European countries, where clinicians and general pathologists could not be aware of this parasitic disease (Palicelli et al., 2016). The disease caused by this parasite causes debility in resource-poor communities of developing countries (Wilcke et al., 2002; Muehlen et al., 2006; Collins et al., 2009).

The first case of Tungiasis was described in 1526 by Gonzalo Fernández, where he discussed the skin infection and its symptoms on crew members from

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Columbus's Santa Maria after they were shipwrecked in Haiti. Through ship routes and further expeditions, the chigoe flea was spread to the rest of the world, particularly to the rest of Latin America and Africa. The spread to greater Africa occurred throughout the 17th and 19th centuries, specifically in 1872 when the infected crewmen of the ship Thomas Mitchell introduced it into Angola by illegal dumping of sand ballast, having sailed from Brazil (Jeffreys, 1952; http://en.wikipedia.org/wiki/Gonzalo_Fern%C3%A1ndez_de_Oviedo_y_Vald%C3%A9s).

Jiggers are easily transmitted among the poor living in urban slums and rural societies (Heukelbach et al., 2005; Joseph et al., 2006; Winter et al., 2009). It is endemic in developing countries in the tropics, mainly in the resource poor people of South America, the Caribbean and sub-Saharan Africa (Heukelbach et al., 2001). The disease only periodically affects travelers to endemic regions in South America and Africa; however persons living in native communities commonly suffer from serious infestation (Franck et al., 2003; Heukelbach, 2005).

In tropical regions, tungiasis caused by *T. penetrans* is a human disease directly linked to the parasitism of humans by fleas. Though, to many of the general population, the insidious attacks by fleas on people and domestic animals causes irritation, blood loss, and severe discomfort are equally important as disease threat (Bitam et al., 2010). The aim of this paper was to review the existing literature concerning tungiasis.

MATERIALS AND METHODS

An electronic internet search was carried out via PubMed and google scholars. Terminologies used to search and access the required data included tungiasis, *T. penetrans*, Jigger fleas, sand flea, pulex irritant and prevalence of tungiasis. Inclusion criteria were books and book chapters, short communication reports, case reports, conference abstracts, recognized international organizations reports, country reports and articles. The data/documents distributed by unrecognized and/or unknown publisher were not included. Finally, all relevant literatures related to tungiasis were reviewed properly for this study.

RESULTS AND DISCUSION

Ecological distribution

According to the review of Heukelbach et al. (2001), tungiasis is endemic in Latin America, the Caribbean and sub-Saharan Africa. Sporadic occurrence has been reported in parts of Asia and Oceania. In Latin America, it is found in regions spanning to Mexico to Northern Argentina and Chile. In Africa, the ecto-parasite is found in the whole sub-Saharan region: from Sierra Leone, Ivory Coast, Nigeria and Ethiopia to South Africa; it also occurs in Zanzibar and Madagascar. Tourism in endemic regions and globalization may result in new cases in developed countries and previously unaffected regions (Palicelli et al., 2016).

Transmission

It is identified that the animal reservoir plays vital role for spread dynamics in endemic populations. In specific, dogs, cats and rats have been described to be commonly infested, and several authors reported severe disease in pigs from various African countries (Ugbomoiko et al., 2007). When humans live in near interaction with infected animals, the risk of infestation is great and the extent of infestation is likewise great. These animals continue transmitting *T. penetrans* and contribute to unending spread in the society as long as they get in contact with human (Pilger et al., 2008).

Life cycle

Eggs are shed by the gravid female into the environment. Eggs hatch into larvae in about 3-4 days and feed on organic debris in the environment. *T. penetrans* has two larval stages before forming pupae. The pupae are in cocoons that are often covered with debris from the environment (sand, pebbles, etc). The larval and pupal stages take about 3-4 weeks to complete. Afterwards, adults hatch from pupae and seek out a warm-blooded host for blood meals. Both males and females feed intermittently on their host, but only mated females burrow into the skin (epidermis) of the host, where they cause a nodular swelling. Females do not have any specialized burrowing organs, and simply claw into the epidermis after attaching with their mouthparts. After penetrating the stratum corneum, they burrow into the stratum granulosum, with only their posterior ends exposed to the environment. The female fleas continue to feed and their abdomens extend up to about 1 cm. Females shed about 100 eggs over a two-week period, after which they die and are sloughed by the host's skin (CDC, 2016) (Figure 1).

The male flea dies after copulation. The female flea continues *in vivo* ecto development. Once the female flea expels 100-200 eggs, the cycle of transmission begins again (Heukelbach et al., 2005; Nagy et al., 2007).

Collins et al. (2009) documented that the natural history of clinical human tungiasis develops in five phases. Phase I starts with penetration of the adult flea into the skin, leading to a rigorous swelling and dilation of blood vessels in the dermis. In phase II, the flea thrusts its head into the superficial layers of the dermis, suckling on blood vessels. The posterior part of the flea relics on the skin surface, and continue having contact with the outer part. This delivers air for breathing and a way for both evacuations and eggs. During phase III, the parasite produces up to 200 white ovoid eggs, causing her body to swell up to 7 mm. The insect can now be seen as a yellow-whitish lesion under a hard hyperkeratotic skin.

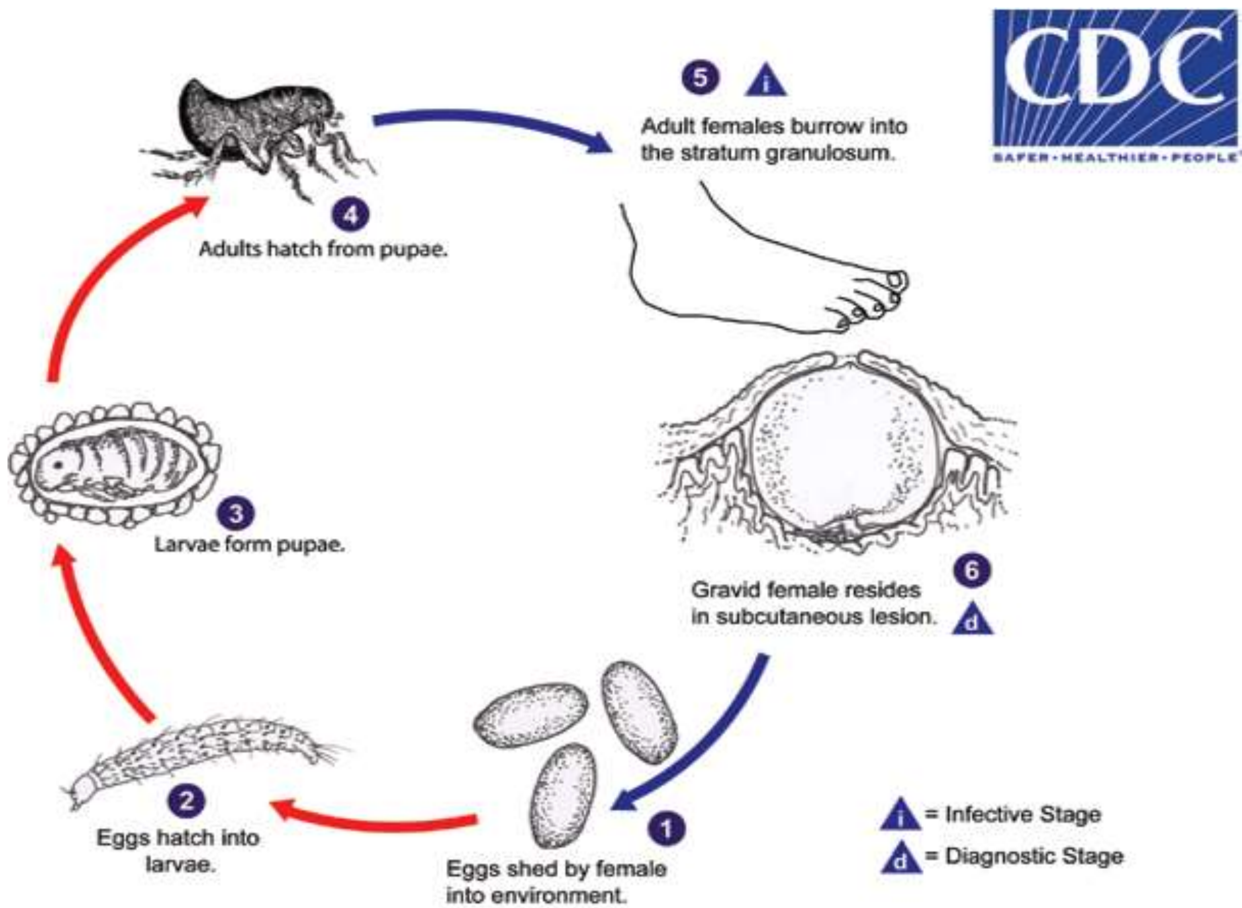

Figure 1. life cycle of jigger fleas. Source: CDC, 2016; www.cdc.gov/parasites/.

Phase IV starts after deposition of the eggs. The female flea dies and the carcass is ejected. During phase V, reorganization of the epidermis occurs, taking about four weeks, leaving slight residues that will stay for months. Meanwhile, the eggs that were left during phase III hatch in three to four days, liberating larvae that develop into pupae. After two weeks, the pupae develop adult fleas, finalizing the cycle (Heemskerk et al., 2005).

Clinical findings

The initial burrowing by the gravid females is usually painless; symptoms, including itching and irritation, usually start to develop as the females become fully-developed into the engorged state. Inflammation and ulceration may become severe, and multiple lesions in the feet can lead to difficulty in walking. Secondary bacterial infections, including tetanus and gangrene, are not uncommon with tungiasis (CDC, 2016).

The initial sign of infestation by jigger flea is a minute black lesion on the skin at the site of entrance. The zone around the entrenched flea develops very irritating swelling leading to ulcerations, lymphangitis, and formation of pus. When the female fleas die, they rest embedded inside the host, repeatedly causing swelling and consequently secondary infections. If unnoticed, it leads to gangrene, auto-amputation of fingers, damage of toes, tetanus, or death (Mark, 2004; Kiprono et al., 2012).

Diagnosis

The diagnosis of tungiasis is usually made by visual/ macroscopic examination, where the embedded gravid female abdomen can be appreciated as a white covering with a black point in its midpoint. Commonly, a limited eggs twig to the skin nearby the lesion, a finding that is pathognomonic for the infection (Bitam et al., 2010).

Differential diagnosis

The differential diagnosis of tungiasis consist of myiasis, verruca vulgaris, ingrown toe nail, acute paronychia, mycotic granuloma, malignant melanoma, and arthropod bites (Muehlen et al., 2003; Bitam et al., 2010).

EPIDEMIOLOGY OF THE DISEASE

Tungiasis is present globally in more than 88 countries with varying degrees of incidence and prevalence. Flea-borne infections are emerging or re-emerging throughout the world, and their incidence is on the rise (Bitam et al., 2010). This parasitic disease is of special community health concern in extremely prevalent regions such as Nigeria, Kenya, Cameroon, Trinidad, Tobago, and Brazil, where its prevalence, mostly in poor peoples, has been recognized to reach 50% (Heukelbach, 2005). *T. penetrans* is distributed in tropical and subtropical regions of the world, including Mexico to South America, the West Indies and Africa. The fleas normally occur in sandy climates, including beaches, stables and farms (CDC, 2016).

RISK FACTORS

Poverty

Poverty is an underlying determinant for the jiggers' epidemic (Mørkve, 2013). Several studies reported that the occurrence of jigger is high among poor groups and that individuals suffering of jiggers are less economically productive (Heukelbach et al., 2001; Heukelbach et al., 2002). It is difficult for poor people to own cemented houses, shoes or sanitary effects: many of them have to walk barefoot, reside in houses with mud walls (and mud/soil floors), and share their living space with animals that could be infected by the flea (Muehlen et al., 2006; Kiprono et al., 2012).

Poor sanitation, poor infrastructure and animal reservoirs are central features for the high occurrence. Poor peoples are often found outside the largest cities, where there are more animals. Animals remain reservoirs of jiggers, and the extra infested animals in a community, the greater is the risk of infestation among people (Heukelbach et al., 2002). In addition to this, illiteracy, ignorance and neglect presumably are other factors favoring the high prevalence of severe pathology in children (Heukelbach et al., 2001).

Psychological suffering

A research has been done in Bungoma, Kenya concerning tungiasis by Mørkve, (2013). According to the report of this author, "those infected participants explained that they feared to be laughed at by neighbors, at the market, at school, or during jiggers' removal campaigns. However, the majority mentioned the fear of being ridiculed at the health facilities as their main concern. For instance, an elderly man claimed that; he did not want to go to the health center because he was afraid of being stigmatized".

Seasonal variation

The past decades have seen a dramatic change in the geographic and host ranges of many vector-borne pathogens, and their diseases. This process is often driven by climate change and the destruction of wild habitats (Bernard et al., 2012). Seasonal variation may influence the occurrence of Jigger fleas. A study conducted in Brazil showed that the tungiasis has a significant seasonal difference, with the prevalence of 54.4 and 16.8% in dry and rainy period, correspondingly (Heukelbach, 2005).

CONSEQUENCES OF TUNGIASIS

Uncomfortability

The appearance of the jigger in the skin causes a severe irritating sense and discomfort (Mark, 2004). When the jigger is manually extracted, minor sores are left around the feet and since the victims walk barefoot, walking becomes an agonizing exercise. Grass and small sands get into the holes left by the removed fleas and induce painful pain (Kiprono et al., 2012; http://www.AhadiKenyaTrust.org). In addition, Bernard et al. (2012) conducted a questionnaire survey concerning tungiasis. In his finding, 59.8% study participant described that jigger infested persons feel uncomfortable and might be lazy (Figure 2).

Secondary complication

Severe complications due to tungiasis are common in areas where people suffer from persistent re-infestation, and where sanitation situations are unwarranted. Microbial superinfection is frequently present, and pustules, abscesses and ulcers are commonly realized (Feldmeier et al., 2002; Heukelbach et al., 2006). The wound is associated with illness such as loss of nails, formation of ulcers, swelling, suppuration, persistent lymphedema and sepsis. Microbial super infection can lead to tissue necrosis (Joseph et al., 2006; Feldmeier et al., 2006a). Secondary infections due to jiggers might cause auto-amputation of fingers and death (Kiprono et al., 2012). Most importantly, tetanus is among secondary complication that can lead to death (Feed the Children, 2007). Reports indicated that, in 2011 about 265 persons died because of jiggers-related causes in Kenya (Karuga, 2011; Mørkve, 2013).

Low educational activity

Jigger infestation affects the education of teenagers as

Figure 2. Victims of tungiasis.
Source: Morkve (2013).

Figure 3. Several lesions on the heel of a Brazilian girl.
Source Ugbomoiko et al. (2007).

they may be incapable to walk to school, and join in regular learning activities (Kiprono et al., 2012). For instance, in Kenya reports shown that 50 000 school going children have dropped out of school due to severe infestation of tungiasis (Karuga, 2011; Mørkve, 2013; http://www.AhadiKenyaTrust.org).

Public/political rights offense

Reports indicated that, about 2,000,000 persons were estimated to be infected by Jiggers in Kenya and among these, 800,000 did not vote due to tungiasis in 2007 (available online at http://www.AhadiKenyaTrust.org).

Figure 4. Seriously ulcerated feet and deformed nails as a result of tungiasis.
Source: Morkve (2013).

People suffering from this disease are incapable to take part entirely in the democratic practice to effect politics.

Lack of self-confidence

The parasite causes pain and injury that can seriously impede activities and performance of many of life's chores, making a person dependent on others. The ulcerations and auto amputation of the digits make the victims feel embarrassed of being in public places and may usually reduce their self-confidence (Kiprono et al., 2012) (Figure 4).

Treatment

The first line of therapy is the mechanical extraction of the flea from the infected host. Removal is not always easy and may be painful for the patient. It can be accomplished using a sterile needle after cleaning the area with an antiseptic solution (Bitam et al., 2010). If the flea bursts, severe inflammation is inevitable (Heukelbach et al., 2001).

Prevention and control

Prevention approaches include: wearing closed shoes; keeping animals contained; wetting the floors within houses regularly; maintaining good personal hygiene (Collins et al., 2009). Daily check of the feet with immediate extraction of embedded fleas and subsequent disinfections of the lesion protect against complications (Heukelbach et al., 2001). Administering antibiotics and applying insecticide will minimize the occurrence and impact of *T. penetrans* and secondary microbial complications (Joseph et al., 2006; Pilger et al., 2008).

Conclusion

Tungiasis is existing globally with varying degrees of incidence and prevalence. The disease has been shown to be a public health concern for resource-poor rural people in developing countries in Nigeria, Kenya, Cameroon, Trinidad, Tobago, and Brazil, where its prevalence has been known to reach 50%. As a literature reviewed, poor sanitation, increased poverty levels, prolonged dry season and psychological suffering/stigmatization are among the most important risk factors, severely influencing the persistence of the tungiasis. The presence of the jigger in the skin causes itching feeling, and in severe cases causes damage of nails, formation of ulcers, inflammation, suppuration, chronic lymphedema, sepsis and could be death. Jigger infestation affects the education of teenagers as they might be incapable to walk to school, join in regular learning activities. The ulcerations of the fingers due to severe tungiasis make the sufferers feel ashamed of being in social places and it usually reduces people's self-confidence. Jiggers infestation is likely to be increasing and causing livelihood of communities in developing countries. Therefore, new appropriate prevention and control approaches should be designed to mitigate the persistence of the disease (tungiasis), particularly in vulnerable and poor communities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Spatial distribution of fresh water snail intermediate host in Yenagoa Metropolis, Bayelsa State, Nigeria

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Field investigation to establish the density of fresh water snail intermediate host in four water bodies of Yenagoa metropolis were carried out during January to March, 2016. Snails were collected in each water body using scooping and handpicking methods. The identification of snails and the determination of physico-chemical parameter of the water body followed standard procedures. Three snail species were identified. They are *Lymnaea natelensis* (91.89%), *Bulinus globosus* (2.25%), and *Oncomelania* species (5.86%). The differences in the snail abundances were not significant (F=1.8911; p>0.05). The snails' abundance by location was Etegwe (44.54%), Okutukutu (48.05%), Azikoro (6.76%), Kpansia (4.05%), and Okaka (3.60%). Differences between snail abundance and locations were significant (F=2.244; p<0.05). *B. globosus* was exclusive in Azikoro and Etegwe, while *Oncomelania* was exclusive in Azikoro and Okaka. *L. nataensis* were widely distributed in all locations. Snail species vary across microhabitat. The difference of snail abundance across microhabitat was significant (F=6.045; p<0.05). Sympatric association exists between *B. globosus* and *L. natalensis* at Etegwe. The physico-chemical parameters analyzed were temperature, pH, biochemical-oxygen demand, turbidity, and conductivity. The effect of physico-chemical parameter on the snail population across locations was not significant (F=1.9022; p>0.05). The public health implication of this study has call for timely control intervention.

Key words: Fresh water snail, intermediate host, spatial distribution, physico-chemical parameter, Yenagoa.

INTRODUCTION

Most fresh water snails (family: Planorbidae) are intermediate hosts of highly infective fluke (tremades) larvae in human and animal (Hamburger et al., 2004; Akande et al., 2011). Over 350 fresh water snail species of medical and veterinary importance have been identified (WHO, 1993). In Africa, *Biomphalaria* serves as intermediate hosts for *Schistosoma mansoni,* while *Bulinus globossus* serves as the intermediate hosts for *Schistosoma haematobium* and *Schistosoma intercalatum*, *Oncomelania* serves as the intermediate host for *Schistosoma japonicum*, while *Lymnaea natalensis* are important in the transmission of liver flukes

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causing fascioliasis in sheep and cattle (Keiser, 2005; Gabriel, 2014).

Schistosomiasis and fascioliasis are both public health diseases of human and animal in tropical and subtropical Africa, ranking second only to malaria in terms of its socio-economic impairment (McCullough, 1992). Schistosomiasis are endemic in 74 tropical countries, where over 200 million people living in rural and agricultural areas are infected and 500 to 600 million people are at risk of the infection; children aged 10 to 15 years are the most predisposed people (Kenneth, 2002). Fascioliasis is a disease of sheep and cattle. It is also an important emerging zoonotic disease of humans (Gabriel et al., 2014). More than 2.4 million people are infected and 91.1 million are living at high risk environments (WHO, 1997). Environmental modification and poor drainage system are factors that increase the density of the snail intermediate host, while lack of health education on the choice of water body for recreational purposes is a factor that predisposes people to the risk of the infection.

In Nigeria, the population density of the snail intermediate host has been studied (Mafiana et al., 2003; Ngele, 2012; Salawu and Odaibo, 2014). The correct identification of the snail intermediate host within living environment is a basic pre requisite to mounting long term control strategy (Rudge et al., 2008; Hamburger et al., 2004; Labbo et al., 2008; Clennon et al., 2006; Opara et al., 2007; Oladejo and Ofoezie, 2006). There is paucity of this information in Bayelsa State. This study is a preliminary investigation on the spatial distribution of fresh water snails across communities in Yenagoa metropolis.

MATERIALS AND METHODS

Study area

This study was conducted in Yenagoa metropolis (4° 53′N and 5°17′E). It is the capital city of Bayelsa State and also the head quarter of Yenagoa municipal. The cross sectional survey was undertaken to study the spatial distribution of fresh water snail in five communities in Yenagoa metropolis during January to March, 2016. The communities are Okaka, Kpansia, Azikoro, Okutukutu, and Etegwe.

Samples and sampling technique

The study population comprise of five communities in Yenagoa metropolis, Bayelsa State. Samples were all water bodies. Four water bodies were identified and classified as gutter/drainage, excavation, water pool and river/stream. The water bodies from five randomly selected communities, namely, okaka, Kpansia, Azikoro, Okutukutu and Etegwe were sampled for the presence of fresh water snails.

Methods of snail collection and preservation

The snails were collected using two methods: scooping and hand picking. The procedures for collection of snails followed standard procedures (Harman and Berg, 1971). The method used for sample collection depends on the depths and sizes of the water bodies. The snails caught were preserved in plastic containers containing clay or sandy soil and transported to the laboratory for macroscopic identifications. Identification was done by a standard pictorial key in Harman and Berg (1971) cited in Salawu and Odaibo (2014).

Measurement of physico-chemical parameters

In-situ determinations of water temperature, pH, biochemical oxygen demand (BOD), turbidity, and conductivity were carried out by standard methods at the Quality Control Laboratory, Bayelsa State Water Board.

Method of data analyses

Data were cross-checked for correctness before analysis. Data checked was entered to Microsoft office excel 2007. Thereafter, it was exported into SPSS version 16.0 for statistical analysis. Percentages were used to express frequency distribution of the snails in respect to location. Analysis of variance (ANOVA) was employed to show significant difference between snails and locations, water bodies' and physico-chemical parameter. Karl Pearson's correlation matrix was used to show the influence of physico-chemical parameters on snail abundance across locations and microhabitat.

RESULTS

Spatial distribution of fresh water snail

Two hundred and twenty two fresh water snails were collected during May, 2015 to January, 2016 in five locations. The snail species in their increasing order of abundance are: *L. natelensis* (91.89%), *B. globosus* (2.25%) and *Oncomelania* species (5.86%). The differences in the snail species abundance were not significant (F=1.8911; p-value=0.124; p>0.05). The overall snails' abundance by location is Etegwe 99 (44.54%), Okutukutu 100 (48.05%), Azikoro 15 (6.76%), Kpansia 09 (4.05%), and Okaka 8 (3.60%). The snail species abundance by location are Azikoro (*B. globosus*, 26.7% and *Oncomelania*, 73.3%), Etegwe (*B. globosus*, 1.1% and *L. natelensis*, 98.9%), and Okaka (*L. natelensis*, 75% and *Oncomelania*, 25%). However, *B. globosus* was exclusive in Azikoro and Etegwe. *L. nataensis* were widely distributed in all locations. Differences between snail population and locations were significant (F=6.045; p-value=0.001; p<0.05). Sympatric association exists between *B. globosus* (20%) and *L. natalensis* (20.10%) in a water pool located at Etegwe. The difference of snail species abundance across microhabitat was significant (F=2.244; p-value=0.020; p<0.05) (Table 1).

Physico-chemical parameter of the snail across micro habitats

The population abundance of the snail vary with the

Table 1. Spatial distribution of fresh water snail across study location and microhabitat during January - March, 2016.

Location	Microhabitat	Species No. (%)			Total
		B. globosus	***L. natalensis***	***Oncomelania* spp.**	
	Excavation	-	6 (66.7)	-	6 (66.7)
	Gutter/Drains	-	-	-	-
Kpansia	Water pool	-	3 (33.3)	-	3 (33.3)
	River/Stream	-	-	-	-
	Total	-	9 (100)	-	9 (4.05)
	Excavation	-	-	2 (18.2)	2 (13.3)
	Gutter/Drains	1 (25)	-	-	1 (6.7)
Azikoro	Water pool	3 (75)	-	-	3 (20)
	River/Stream	-	-	9 (81.8)	9 (60)
	Total	4 (26.7)	-	11 (73.3)	15 (6.76)
	Excavation	-	2 (2)	-	2 (2)
	Gutter/Drains	-	46 (46)	-	46 (46)
Okutukutu	Water pool	-	52(52)	-	52 (52)
	River/Stream	-	-	-	-
	Total	-	100 (100)	-	100 (45.04)
	Excavation	-	2 (2.2)	-	2 (2.2)
	Gutter/Drains	-	46 (51.7)	-	46 (51.1)
Etegwe	Water pool	1 (100)	41 (46.1)	-	42 (46.7)
	River/Stream	-	-	-	-
	Total	1 (1.1)	89 (98.9)	-	90 (40.54)
	Excavation	-	2 (33.3)	-	2 (25)
	Gutter/Drains	-	4 (66.7)	-	4 (50)
Okaka	Water pool	-	-	2 (100)	2 (25)
	River/Stream	-	-	-	-
	Total	-	6 (75)	2 (25)	8 (3.60)
Total		5 (2.25)	204 (91.89)	13 (5.86)	222

**The number in the parentheses is the percentages of the snail species counted in each location and microhabitat.

physico-chemical parameters (F=1.902208; p-value= 0.126554, p>0.05) (Tables 2 and 3). However, the parameters seem to influence the species richness in each habitat (Table 4). The mean temperature ranges from 27 to 28°C. Temperature was positively correlated with the abundance of *L. natalensis* (r=0.054). The pH of the water bodies was within the range of 7.5 to 7.8. Positive correlation was recorded with the snail abundance; *L. natalensis* (r=0.214) and *B. globosus* (r=0.053), while negative correlation exists with *Oncomelania* spp. (r = -0.266). The overall mean value of biological oxygen demand across the location was 25.1 mg/L. This value varies between water bodies: excavation (16.7 mg/L), water pool (30.4 mg/L), and 28.2 mg/L in gutter. BOD was positively correlated with the abundance of *L. natalensis* and *B. globosus* (r =0.346, r = 0.168), respectively;

The overall mean conductivity value of the micro habitat was 280 μS/cm with gutter having the highest conductivity value (450 μS/cm), while water pool had the least value (180 μS/cm). Conductivity showed positive correlations with *L. natalensis* and *B. globosus* (r=0.147, r= 0.214), respectively. Turbidity also showed positive correlation with *L. natalensis* and *B. globosus* (r=0.083, r= 0.021), respectively. However, *Oncomelania* spp. had negative correlation with all the physico-chemical parameters.

DISCUSSION

The presence of the three fresh water snails, *B. globosus,*

Table 2. Physico-chemical parameter of the snail across location and microhabitat.

Microhabitat	Snail species (Mean±SD)			Physico chemical parameter				
	L.natalensis	*B. globosus*	*Oncomelania*	T^{O}	pH	TUB	BOD	COND
Excavation	12±0.5	0±0.0	2.2±0.2	28±0.0	7.8±0.0	40.8±3.2	17.5±1.2	210±0.0
Gutter/Drainage	55.4±0.3	0.8±0.2	0±0.0	26.8±0.2	7.5±0.02	34.2±5.7	28.6±0.3	430±0.0
Water pool	96.2±0.2	4.2±0.2	2.2±0.2	27.2±0.2	7.6±0.0	28.2±25.7	30.7±0.2	150±0.0
River/Stream	0±0.0	0±0.0	8.5±0.2	25.6±0.3	8.12±0.25	36.2±5.7	30.9±1.56	437±27
Total	40.9±1520.3	1.25±3.25	3.3±11.58	26.9±0.94	7.76±0.11	34.9±30.03	26.9±32.7	314±15099.6

*****The value of the physico-chemical parameters is the mean of the consecutive data collection.

Table 3. Analysis of variance (ANOVA) on the relationship between physico-chemical parameters and snail abundance across locations.

Source of variation	ANOVA					
	SS	df	MS	F	P-value	F crit
Physico-chem	717.7667	4	179.4417	1.902208	0.126554	2.578739
Columns	1269.1	2	634.55	6.726678	0.00278	3.204317
Interaction	1736.733	8	217.0917	2.301325	0.036808	2.152133
Within	4245	45	94.33333	-	-	-
Total	7968.6	59	-	-	-	-

Table 4. Correlation matrix on the influence of physico-chemical parameters on snail density.

Correlation	T	pH	TUB	BOD	COND	L.n	B.g	OC
T	1							
pH	-0.734[a]	1						
TUB	0.2945[a]	0.4600[a]	1					
BOD	-0.9914[b]	0.4283[a]	-0.4169[a]	1				
COND	-0.7356[a]	0.3236[a]	0.1681[a]	0.6741[a]	1			
L.n	0.1449[a]	-0.7830[a]	-0.8927[a]	-0.9653	-0.4222[a]	1		
B.g	0.05858[a]	-0.5546[a]	-0.9210[a]	0.0711[a]	-0.5369[a]	0.9434[a]	1	
O.c	-0.722[a]	0.9615[b]	0.2103[a]	0.6420[a]	0.6140[a]	0.1368[a]	0.5675[a]	1

The numbers are correlation values; positive values mean positive correlation; Negative values mean negative correlation; a-correlation is significant; b-correlation is not significant. T: Temperature; pH: hydrogen ion concentration; BOD: biochemical-oxygen demand; TUB: turbidity; COND: conductivity; B,g: *Bulinus globosus*; L.n: *Lymnaea natalensis*; O.c: *Oncomelania*.

L. natalensis and *Oncomelania* spp. is novel in attempting to establish the distribution of schistosome snail species in a metropolitan city of Bayelsa State. The spatial distribution of *B. globosus* and *L. natalensis* in the study location agrees with Grimes (2015), Ngele (2012), and Gabriel et al. (2014). This also highlights the risk of fascioliasis and urinary schistosomiasis in near future in Yenagoa metropolis. However, this is the first report of *Oncomelania* in South Southern Nigeria. The sympatry of the two fresh water snails: *B. globosus* and *L. natalensis* in a water pool at Etegwe have also been reported elsewhere (Madsen, 1992; Giovanelli et al., 2005). Although, the snails were sympatric, negative association existing between *B. globosus* and *L. natalensis*is; *Oncomelania* spp. and *L. natalensis* agrees with Giovanelli et al. (2005). Eventually, in all the study locations, no snail was recovered from river. According to Jones (1993), snail intermediate hosts do not tolerate strong currents and their breeding sites are usually places where water velocity is below 40 cm/s). In this study, sampling of snails corresponds with the time the rivers were flooded with early rain water.

Environmental factors over time have affected the distribution patterns, the life cycles and population dynamics of fresh water snails (Rollinson et al., 2001). The observed relationship between snail abundance and temperatures, pH, BOD, turbidity and conductivity in this study is consistent with the report elsewhere (Opisa et al., 2011; Salawu and Odaibo, 2014; Olofintoye and Odaibo, 1996; Owojori et al., 2006). The optimum temperature for the hatching of *B. globosus* eggs is between 25 and 28°C (Madsen, 1985). The mean temperature of 27 to 28°C recorded at the different microhabitats in this study is within the limit of snail survival. The positive correlations between temperature and *L. natalensis* and *B. globosus* has been reported by Salawu and Odaibo (2014). The mean pH value of 7.5 to 7.8 recorded in this present study is slightly lower than the pH range of 0.8 to 8.5 value recorded by Salawu and Odaibo (2014). However, the pH value showed positive effect on the two snails' species (*L. natalensis* and *B. globosus)* in all the locations.

The BOD defines as the amount of oxygen required to degrade a biological process. The BOD value of 16.7 to 30.4 showed positive correlation with the snail population. The conductivity and turbidity values observed in this study were higher than those reported in Tubonimi et al. (2010). The implication is that the variation in temperature, pH, BOD, turbidity and conductivity of the water impact on the population variables of the snail species. This is a bio-indicator showing that transmission foci are likely when the snail population is not control. However, the negative correlations between *Onchomelania* spp. with temperature, pH, BOD, turbidity and conductivity lack explanations at the mean time.

Conclusion

This study has established the presence of three snail intermediate host for fascioliasis and schistosomiasis around human environment in Yenagoa metropolis. The result has demonstrated that the snails' abundance was affected by physico-chemical parameters of the water bodies. It is recommended that individual should take cognizance of the possibility of a snail borne infections in the locality and redirect their water recreational activities. Government should also make functional drainages so as to reduce further establishment of the snails around human environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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