International Journal of Aquatic Science
ISSN: 2008-8019
Vol 3, No 1, 2012

Environmental conditions of a drainage channel inhabited by an invasive species Melanoides tuberculatus (Muller, 1774) in southwestern, Nigeria

Bolaji A. Dunsin[1]*, Clement A. Edokpayi[2] and Muyideen O. Lawal[2]

1) Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos, Nigeria.

2) Department of Marine Sciences, University of Lagos, Akoka Lagos, Nigeria.

Abstract:

Melanoides tuberculatus (Muller, 1774) an invasive species that serves as vector transmitting several diseases causing parasites was found inhabiting a drainage channel in University of Lagos. The prevailing environmental conditions of the drainage channel were studied between February and July 2006. Standard methods were used to collect and analyze samples. pH ranged from 6.30 to 7.70. The Air and water temperatures ranged between 29.37±2.29 ºc and 28.62±2.00 ºc respectively. Conductivity, total dissolved solid (TDS), salinity, dissolved oxygen, biochemical oxygen demand, nitrate, copper, phosphate and sulphate ranged between 37.17±13.60 μscm^{-1}, 18.50±6.75 ppm, 0.04±0.05‰, 4.28±0.34 ppm, 6.17±3.19 ppm, 1.03±0.27 ppm, 0.03±0.05 ppm, 0.20±0.36 ppm and 10.17±5.38 ppm respectively. pH significantly correlated with water temperature (r=0.891, $P < 0.05$); TDS significantly correlated with nitrate (r=0.845, $P < 0.05$) and conductivity (r=1.000, $P < 0.05$); nitrate correlated significantly with conductivity (r=0.834, $P < 0.05$) and copper correlated significantly with phosphate (r=0.987, $P < 0.05$). The observed environmental factors that favour colonization of *M. tuberculatus* in the drainage channel suggest its possible spread in several water bodies in Nigeria.

Key words: Distribution pattern, Environmental conditions, *Melanoides tuberculatus*, Nutrient elements.

Introduction

The invasion of freshwater by the molluscans has aptly been characterized as ‘desultory’ (Robert, 2000). Gastropods have successfully invaded freshwater where they serve as vectors transmitting several dangerous parasites (Russo, 1974; Jacobson, 1975; Murray, 1971; Dundee and Paine, 1977, Bogea *et al.,* 2005). *M. tuberculatus* Muller, 1774 from the Family Thiaridae commonly referred to as red–rimmed melania is one

(✉) bdunsin@yahoo.com

such vector. The species is a small aquatic herbivorous snail which is very common to sub tropical and tropical areas of northern and eastern Africa, southern Asia, Morocco, Madagascar, Saudi Arabia, Iran, Pakistan, Indian, southern China and Gelebes (Neck, 1985; Vaz *et al*., 1986; Pointier and Marquet, 1990; Howells, 1992; Pointier *et al*., 1994; Pointier, 1999; De Marco, 1999; Watanabe *et al*., 1999, Thiengo *et al*., 2001, 2004; Duggan, 2002; Fernandez *et al*., 2003; Bogea *et al*., 2005; Giovanelli *et al*., 2005; Mitchell, 2006).

The thiarid snail, *M. tuberculatus* is now been monitored worldwide because of its fast growing distribution and its economic importance. The spread of the Afro-Asian *M. tuberculatus* has been associated mainly with human activities, some of which are suggested to be by direct release (Duggan, 2002) or successive accidental release from aquaria (Vaz *et al.,* 1986; Giovanelli *et al.,* 2005). Mitchell (2006) reported that contaminated fisheries equipment is also another way by which the snail is spread from one place to another because of the presence of operculum which slows down desiccation. The dispersion of this organism has also been associated with aquatic birds (Lassen, 1975; Boag, 1986; Duggan, 2002).

Surprisingly, few studies of this species have been published in Africa where *M. tuberculatus* is a native species. However, it has been reported in Morocco from a thermal stream (Laamrani *et al*., 1997). In Kenya, Mkoji *et al*. (1992) reported the possibility of using it as a biological control agent of *Biomphalaria pfeifferi*. In Nigeria, the presence of *M. tuberculatus* has also been reported by a few authors, Ndifon and Ukoli (1989) examined the distribution and the habitat preference of the species in southwestern part of the country while Agbolade and Odaibo (2004) also reported its occurrence in Omi stream, Ago-Iwoye also in southwestern part of the country. Accordingly, this study investigates the prevailing environmental conditions of *M. tubeculatus* in a drainage channel in University of Lagos, Southwestern Nigeria.

Materials and Methods

The study site was a drainage channel located within the University of Lagos, Nigeria between latitudes 6°31'1.59"N and 6°31'06.70"N and longitudes 3°23'55.89"E and 3°23'53.93"E (Fig. 1). The water drains slowly in a unidirectional manner and does not have constant influx of water from the nearby creeklet except during heavy rains leading to partial flooding of the channel which eventually leads to stagnant water and increase in sediment deposition along the drainage. The deposition of sediment at this drainage makes it possible for several aquatic organisms to colonize the channel. The water colour was often clear but sometimes had some oil sheen as a result of domestic discharge from the surrounding buildings connected to the drainage. This channel was usually dredged yearly prior to rainy season but was not dredged during study year for the purpose of this research.

Fig. 1: Map of University of Lagos showing sampling location

Water samples were collected monthly between February and July 2006 at a point along the channel. Atmospheric and water temperatures were measured in-situ using dry bulb centigrade Mercury-in-glass Thermometer, 0-100°C. A transparent 250ml reagent bottle and 250ml Amber reagent bottle were used to collect water for dissolved oxygen and Bio-chemical Oxygen Demand respectively which were determined by Winkler's method (APHA, 1992). Conductivity, TDS and pH were determined with Rana Instrument (Model U-10). Surface water was collected in 1 liter plastic bottle for Phosphate, Sulphate, Copper and Nitrate analysis in the laboratory. All laboratory analyses were carried out according to USEPA, 1979; SMEWW, 1985; APHA, 1992.

One-way analysis of variance (ANOVA) and correlation coefficient matrix for water quality were carried out using SPSS 10.0 packages for windows following the procedures described by Ogbeibu (2005).

Results

The summary of the physical and chemical characteristics of the water channel is presented in Table 1 and coefficient matrix in Table 2.

Table 1: Summary of physical and chemical parameters of surface water showing Mean±Standard deviation (S.D), Minimum and Maximum values

Parameters	Mean±S.D	Minimum	Maximum
Air Temperature (ºc)	29.37±2.29	25.70	32.00
Water Temperature (ºc)	28.62±2.00	26.70	31.50
pH		6.30	7.70
Conductivity (μscm^{-1})	37.17±13.60	16.00	56.00
Total Dissolved Solid (ppm)	18.50±6.75	8.00	28.00
Salinity (‰)	0.04±0.05	0.00	0.10
DO (ppm)	4.28±0.34	4.00	4.80
BOD (ppm)	6.17±3.19	2.00	10.00
Nitrate (ppm)	1.03±0.27	0.62	1.35
Copper (ppm)	0.03 ±0.050	0.000	0.13
Phosphate (ppm)	0.20±0.36	0.02	0.94
Sulphate (ppm)	10.17±5.38	5.00	20.00

Air and water temperatures did not vary widely during the study period. The air temperature decreased while the water temperature increased for most part of the study period (Fig. 2). Conductivity and Total Dissolved Solid (TDS) follow similar pattern decreasing from February to April with a sharp increase in May recording the highest level attained during the period (Fig. 2). Salinity generally was less than 1‰ with mean salinity of 0.04‰ (Table 1). Nitrate and Phosphate concentration decreased from February to April and increased in May while Copper concentration showed an irregular fluctuation over the study period (Fig. 3). pH was slightly acidic, while Sulphate concentration decreased from February to April and a sharp increase was observed in May (Fig. 4). Dissolved Oxygen fluctuated irregularly over the study period but Biochemical Oxygen Demand (BOD_5) was high in February and June while it maintained constant levels from March to May (Fig. 4).

The Hydrogen ion concentration (pH) significantly correlated with water temperature ($r = 0.891$, $P < 0.05$). Total Dissolved Solid (TDS) was significantly correlated with nitrate ($r=0.845$, $P < 0.05$) and conductivity ($r=1.000$, $P < 0.05$). Nitrate correlated significantly with conductivity (0.834) while copper also significantly correlated with phosphate ($r= 0.987$) (Table 2)

Table 2: Correlation Co-efficient Matrix for the physical and chemical parameters of the water channel.

	A	B	C	D	E	F	G	H	I	J	K
B	.772										
C	-.332	.030									
D	.411	-0.88	-.179								
E	.612	.891*	.402	-.187							
F	-.368	-.097	.845*	.129	.154						
G	.281	.609	.602	.122	.690	.714					
H	-.738	-.558	.224	-.687	-.330	-.093	-.564				
I	-.173	-.486	-.56	.621	-.478	.409	.103	-.355			
J	-.338	.018	1.000*	-.188	.398	.834*	.563	.245	-.062		
K	-.065	-.358	.003	.636	-.331	.456	.230	-.444	.987*	-.004	
L	-.439	-.403	-.051	.317	-.574	.438	.162	-.257	.667	-.070	.604

Air Temperature= **A**, Water Temperature= **B**, TDS= **C**, Salinity= **D**, Ph= **E**, Nitrate= **F**, Sulphate= **G**, DO= **H**, Copper= **I**, Conductivity= **J**, Phosphate= **K**, BOD=**L**

*.Correlation is significant at the 0.05 level (2-tailed).

Discussion

As reported by several authors, water chemistry of an aquatic ecosystem is dependent on the physical and geological features of its drainage basin (Victor and Al-Mahrouqi, 1996; Edokpayi *et al.,* 2004). Similar phenomenon might be responsible for the recorded physical and chemical parameters studied in the drainage channel which was small and shallow with a slow water flows. The decrease in atmospheric temperature could be as a result of delayed Harmattan associated with dust (Onyema *et al.,* 2003) since the period of study was late dry season followed by rainy season. The fluctuation pattern of temperature observed in this study agreed with the pattern reported by Onyema and Nwankwo (2006) in polluted estuarine creeks in Lagos, and this was attributed to increase in cloudy conditions and subsequent reductions in solar insulation. Iwugo *et al.* (2003) also reported the same pattern in Lagos with a mean temperature of 30ºC which agreed with our study.

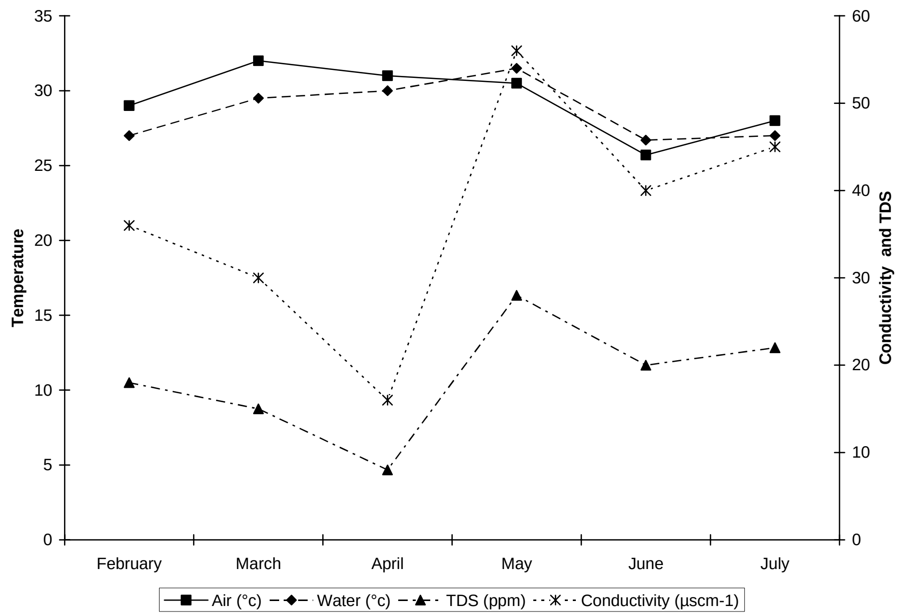

Fig. 2: Monthly fluctuation in air, water temperatures, conductivity and TDS of drainage channel

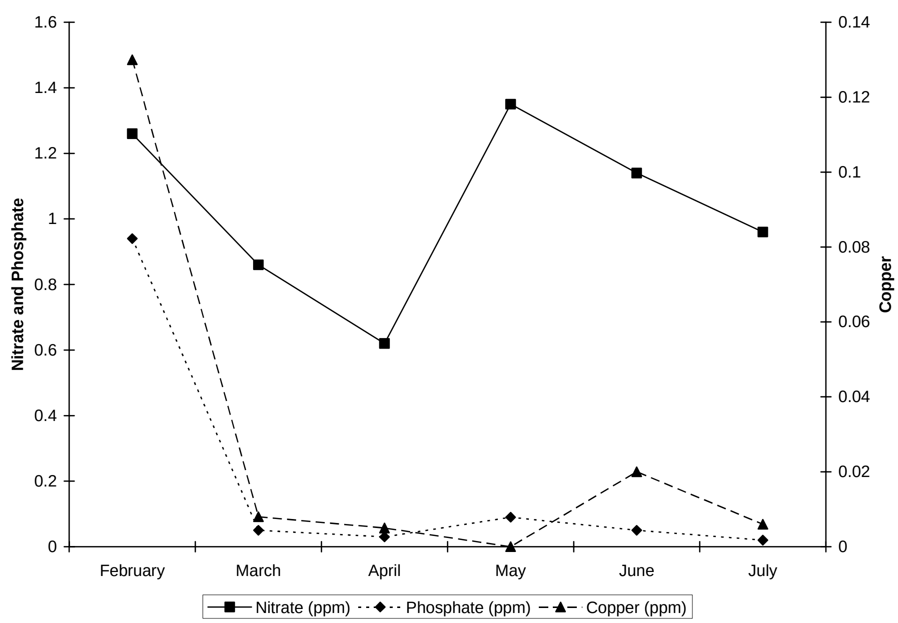

Fig. 3: Fluctuation in Nitrate, Phosphate and Copper concentration at sampled site

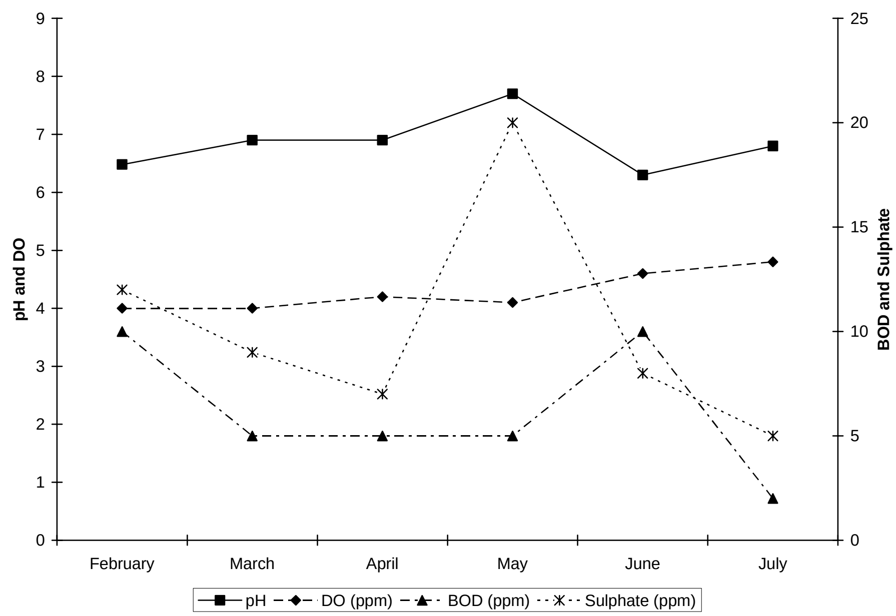

Fig. 4: Fluctuation in pH, DO, BOD and Sulphate concentration at sampled site

The range of air and water temperature observed during the study was similar to those reported for many water bodies in Southern Nigeria (Sridhar and Ademoroti, 1984; Ogbeibu and Egborge, 1995; Edokpayi and Osimen, 2001; Onyema *et al.,* 2003; Edokpayi *et al.,* 2004; Edokpayi and Ayorinde, 2005).

The pH (6.30 - 7.70) recorded at the drainage channel was observed to be weakly acidic for most of the study period except for May which was slightly alkaline but generally falls within ranges reported for rivers flowing through areas with thick vegetation (Awuchie, 1981; Osimen, 1997; Uwadiae *et al*., 2009), although the channel did not flow through thick vegetation but it received water influx from the nearby creeklet with pH (6.70-7.90) reported by Edokpayi and Ayorinde (2005) and the environment was classified as brackish. The usual pattern in which conductivity rises during dry season and falls during wet season (Ogbeibu and Victor, 1995) was not pronounced in this study. The fluctuating pattern observed agreed with the pattern observed in Ibiekuma stream studied by Edokpayi and Osimen (2002). The values of conductivity recorded during the study period were quite low when compared with those recorded in some water bodies in southern Nigeria (Edokpayi and Osimen, 2002; Edokpayi, 2005) but a similarly low conductivity result was observed by Edokpayi and Ayorinde (2005) for a brackish water swamp within the same University of Lagos and Edokpayi *et al.* (2004) for Kuramo water, Lagos. Although conductivity is the measure of the total ionic composition of water and therefore the richness of the aquatic system (Awachie, 1981), the low conductivity values observed in this study may be an indication of ionic paucity since the drainage channel construction is granite base which is composed of inert materials that do not ionize.

The variation in the values of TDS recorded during the study followed a similar pattern observed for conductivity and the values obtained were similar to that reported for Kuramo water (Edokpayi *et al.,* 2004), but far less than that reported for different network of creeks, rivers connected to Lagos Lagoon in southwestern Nigeria (Onyema and Nwankwo, 2006).

Salinity was generally low, less than 1‰ for the study period. This shows that the channel is a fresh water environment as it is a drainage channel for runoff water and domestic water from Faculty of Engineering and Mariere Hall.

The dissolved oxygen levels (0.00–0.10 mg/l) recorded along the study channel was low and around the range (3.8 – 4.2mg/l) reported by Onyema and Nwankwo (2006) for some creeks in Lagos, but lower than those reported for some other rivers in Nigeria (Edokpayi, 1988; Edokpayi and Osimen, 2002). The low oxygen level could have been as a result of the slow flowing nature of the water which could limit oxygen diffusion and small volume of water (Edokpayi, 2005). Low oxygen observed in dry season could also be associated with increase in temperature as observed during the study period.

Biochemical Oxygen Demand (BOD_5) provides a measure of the effect of pollution on a receiving water body (Mason, 1991). The BOD_5 recorded during this study (2 - 10ppm) was slightly higher compared with 0.42 to 8.0mg/l reported for some water bodies in Nigeria (Victor and Onomivbori, 1996; Edokpayi and Osimen, 2001, 2002; Ogbeibu and Oribhabor, 2002; Edokpayi and Ayorinde, 2005) but lower than 17 - 35mg/l reported in Light House Beach, Lagos (Nwankwo *et al.,* 2004) and polluted creeks in Lagos (Onyema and Nwankwo, 2006) and also far lower than 90.00-370.00 mg/l that was reported for water bodies exposed to urban run-off elsewhere (Mason, 1991).

The high BOD_5 values that were recorded during February and June could probably be associated with increase in microbial activities which led to high oxygen consumption. Nitrate concentration observed during the study was lower than some water bodies reportedly polluted from organic source in some sections of Lagos Lagoon (Ajao, 1996; Onyema and Nwankwo, 2006) and Ikpoba River (Victor and Ogbeibu, 1991; Victor and Onomivbori, 1996). The observed low level of nitrate agreed with earlier reported values for some rivers in Nigeria (Egborge and Benka-Coker, 1986; Egborge *et al.,* 1986; Edokpayi, 1988). The low level of nitrate shows that the environment is stable, with less pollution stress from external environment (Edokpayi, 2005). This was contrary to the high nitrate-nitrogen documented by Nwankwo (1993) in some coastal waters in southwest Nigeria which was attributed to the biodegradable wastes from surrounding hotels and residential areas around the coastal waters. The observed nitrate concentration level in the present study may be due to plants releasing nitrate as leachate along the channel (Kellman and Tackaberry, 1997; Edokpayi, 2005). Sulphate decreased gradually throughout the study period except for May which showed sharp increase up to 20 ppm although was still within the range reported for some rivers in Nigeria and followed the same pattern reported by Onyema and Nwankwo (2006). Although the values obtained in this study were much lower than those they reported, which were associated with possible waste discharges.

The copper concentration within the study channel was very low compared with the concentration reported by Edokpayi and Ayorinde (2005) for brackish water swamp within University of Lagos, although slightly higher than concentration reported for Light House Beach, Lagos, Nigeria (Nwankwo *et al.,* 2004). The observed results indicate that the channel may be almost free of heavy metal pollution or having just a trace of them.

Phosphate usually occurs in small amount in aquatic ecosystem (Tait and Dipper, 1998). Low values generally less than 1ppm was recorded during the study period. The observed level was lower than those reported for some water bodies in Nigeria (Edokpayi and Osimen, 2001; Nwankwo *et al.,* 2004; Edokpayi *et al.,* 2004; Edokpayi, 2005; Edokpayi and Ayorinde, 2005) but agreed with concentrations documented for some water bodies in southwestern Nigeria (Nwankwo, 1993; Nwankwo *et al.,* 2003). The concentration observed during this period could probably be associated with surface water run-off and precipitation (Sutcliffe *et al.,* 1982).

The absence of lead in this channel throughout the study period and the observed low copper concentration mentioned earlier suggested that the environment was possibly free of external sources of heavy metals.

The correlation coefficient matrix obtained for the physical and chemical parameters was more significant among nitrate, phosphate, total dissolved solid and conductivity which showed chemical richness. Hydrogen ion concentration (pH) also significantly correlated with water temperature while copper correlated with phosphate.

M. tuberculatus has been reported to show preferences for habitat which are mainly lotic environment (Giovanelli *et al.,* 2005). Similar observations have been reported in Nigeria where preference is given to moderately shaded habitat by *M. tuberculatus* (Ndifon and Ukoli, 1989). In this study *M. tuberculatus* was found within a slow flowing or lotic and shallow drainage channel. This agreed with habitat preference of *M. tuberculatus* described by Duggan (2002). Similar observations have been reported (Dudgeon, 1989; Gutierrez *et al.,* 1997) where *M. tuberculatus* prefer mud and silt substrates. According to Duggan (2002), *M. tuberculatus* has been reported to be absent at temperatures 32.70 to 37.80ºC but have been found in abundance at 29.00 to 30.00ºC. Similar observation was recorded in the present study (26.00 to 31.00ºC) which agreed with those reported elsewhere: 18.00 to 25.00ºC in United States (Murray, 1971), 21.00 to 31.00ºc in the United Arab Emirates (Ismail and Arif, 1993) and 27.00 to 29.00 ºC from a thermal station in Morocco (Laamrani *et al.,* 1997). The trends of temperature changes observed in this study and those of earlier reports suggested that *M. tuberculatus* might have invaded several lotic and shallow water bodies in southwestern, Nigeria. The environmental conditions recorded along the drainage channel falls within the reported environmental conditions for most water bodies in Nigeria which favour colonization of *M. tuberculatus.* According to Agbolade and Odaibo, (2004) high population of *M. tuberculatus* was reported at Omi stream, Ago-Iwoye confirming the spread of *M. tuberculatus* in southwestern, Nigeria.

Acknowledgement

We wish to thank the members of staff of Postgraduate Marine Sciences Laboratory, University of Lagos for providing the needed materials and equipment for this study as well as all reviewers.

References

- ✓ Agbolade, O.M. and Odaibo, A.B. (2004) Dockovdia cookarum infestion and the prosobranch gastropod *Lanistes libycus* host in Omi stream, Ago-Iwoye, South-western, Nigeria. *African Journal of Biotechnology,* 3(3): 202-205.
- ✓ Ajao, E.A. (1996) Review of the state of pollution of the Lagos Lagoon. NIOMR Tech. Paper No. 106. 20 pp.
- ✓ Ajao, E.A. and Fagade S.O. (1990) The ecology of *Neritina glabrata* in Lagos Lagoon, Nigeria. *Archiv fur Hydrobiologie* 119: 339-350.
- ✓ American Public Health Association (APHA) (1992) *Standard Methods for the Examination of Water and Wastewater* 18th edn. Washington D. C, American Public Health Association, 1268 pp.
- ✓ Awachie, J.B.E. (1981) Running Water Ecology in Africa, 339-366 pp. In: M.A. Lock and D.D. Williams (eds) *Perspectives in Running Water Ecology.* Plenum Press, New York and London.
- ✓ Boag, D. A. (1986) Dispersal in pond snails: potential role of waterfowl. *Canadian Journal of Zoology* 64: 904–909.
- ✓ Bogea, T., Cordetro, F.M. and Gouveja, J.S. (2005) *Melanoides tuberculatus* (Gastropda: Thairidae) As Intermediate Host of Heterophyidae (Trematoda: Digenea) In Rio Janeiro Metropolitan Area, Brazil. *Rev. Inst. Med. Trop. S. Paulo* 47(2): 87-90.
- ✓ Brown, C.A. (1998) Distribution and population dynamics of an estuarine population of *Aloidis trigona* Hinds (Bivalvia) *Acta Hydrobiologie* 40(4): 227-237.
- ✓ Brown, C.A. and Oyenekan, J.A. (1998) Temporal variability in the structure of benthic macrofauna

communities of Lagos Lagoon and Harbour, Nigeria. *Polish Archiv. Fur Hydrobiologie* 45(1): 45-54.

- De Marco, P. J. (1999) Invasion by the introduced aquatic snail *Melanoides tuberculata* (Müller, 1774) (Gastropoda: Prosobranchia: Thiaridae) of the Rio Doce Park, Mina Gerais, Brazil. *Studies on Neotropical Fauna and Environment* 34: 186–189.
- Dudgeon, D. (1989) Ecological strategies of Hong Kong Thiaridae (Gastropoda: Prosobranchia) *Malacological Review* 22: 39–53.
- Duggan, I.C. (2002) First record of a wild population of the tropical snail *Melanoides tuberculata* in New Zealand natural waters. *New Zealand Journal of Marine and Freshwater Research* 36: 825-829.
- Dundee, D.S. and Paine, A. (1977) Ecology of The Snail *Melanoides tuberculata* (Müller), Intermediate Host Of The Human Liver Fluke (*Opisthorchis Sinensis*) In New Orleans, Louisiana. *The Nautilus* 91(1):17-20.
- Edokpayi, C.A. (1988) Transport of particulate suspended matter in a perturbed stream in southern Nigeria. *Trop. Freshwater. Biol.,* 1: 16–29.
- Edokpayi, C.A. (2005) Variation of chemical constituents of a brackish water prawn habitat in southern Nigeria. *Journal of Life and Physical Sciences, acta SATECH 2*(1): 11-18.
- Edokpayi, C.A. and Ayorinde, A.O. (2005) Physical, Chemical and Macrobenthc Invertebrate Fauna Characteristics of Swampy Water Bodies within University of Lagos, Nigeria. *West African Journal of Applied Ecology* 8: 129-139.
- Edokpayi, C.A. and Osimen, C.E. (2001) Hydrobiological studies on Ibiekuma River at Ekpoma, southern Nigeria, after impoundment: the fauna characteristics. *African Journal of Science and Technology* 2(1): 72-81.
- Edokpayi, C.A. and Osimen, C.E. (2002) The impact of impoundment on the physical and chemical hydrology of Ibiekuma stream in southern Nigeria. *Tropical Ecology* 43(2): 287-296.
- Edokpayi, C.A., Lawal, M.O., Okwok, N.A. and Ogunwenmo, C.A. (2004) Physico-chemical and macrobenthic faunal characteristics of Kuramo Water, Lagos, southern Nigeria. *African Journal of Aquatic Science* 29(2): 235-241.
- Egborge, A.B.M. and Benka-Coker, J. (1986) Water Quality Index. Application in Warri River, Nigeria. *Environ. Poll. (Ser. B.)* 12: 27-40.
- Egborge, A.B.M., Okoro, J.I., Alawani, O.A. and Uraih, N. (1986) Thermal and chemical pollution of Benin River and its tributary, the Jamieson River. *Nigerian Journal of Applied Science* 4(2):121-149.
- Fernandez, M.A., Thiengo, S.C. and Simone, L.R.L. (2003) Distribution of the introduced freshwater snail *Melanoides tuberculatus* (Mollusca; Thiaridae) in Brazil. *The Nautilus* 117: 78-82.
- Giovanelli, A., Coelho da Silva, C.L. P. A., Leal, G. B. E. and Baptista, D. F. (2005) Habitat preference of freshwater snails in relation to environmental factors and the presence of the competitor snail *Melanoides tuberculatus* (Müller, 1774) *Mem. Inst. Oswaldo Cruz, Rio de Janeiro* 100(2): 169-176.
- Gutiérrez, A., Perera, G., Young, M. and Fernandez, J. A. (1997) Relationships of the prosobranch snails *Pomacea paludosa*, *Taberia granifera* and *Melanoides tuberculata* with the abiotic environment and freshwater snail diversity in the central region of Cuba. *Malacological Review* 30: 39–44.
- Howells, R. G. (1992) *Annotated list of introduced non-native fishes, mollusks, crustaceans and aquatic plants in Texas waters.* Texas Parks and Wildlife Department, Management Data Series 78, Austin, Texas. 19 pp.
- Ismail, N. S. and Arif, A. M. S. (1993) Population dynamics of *Melanoides tuberculata* (Thiaridae) snails in a desert spring, United Arab Emirates and interaction with larval trematodes. *Hydrobiologia* 257: 57–64.
- Iwugo, K.O., D' Arcy, B. and Andoh, (2003) Aspects of Land-Based Pollution of an African Coastal Megacity of Lagos. Diffuse Polltion Conference, Dublin 14-122.
- Jacobson, M.K. (1975) The Freshwater Prosobranch, *Tarebia granifera*, In Oriente, Cuba. *The Nautilus* 89(4):106.
- Kellman, M. and Tackaberry, R. (1997) *Tropical Environments-the functioning and management of*

tropical ecosystems. Routledge, London and New York, 379.

- Laamrani, H., Khallayoune, K., Delay, B., Pointier, J. P. (1997) Factors affecting the distribution and abundance of two prosobranch snails in a thermal spring. *Journal of Freshwater Ecology* 12: 75–79.
- Lassen, H. H. (1975) The diversity of freshwater snails in view of the equilibrium theory of island biogeography. *Oecologia* 19: 1–8.
- Mason, C.F. (1991) *Biology of Freshwater Pollution,* 2nd edn. Longman Scientific & Technical, Essex, England. 351pp.
- Mitchell, A.J. (2006) The effect of chemical treatments on *Melanoides tuberculatus,* a snail that vectors an important fish trematode. *Aquaculture America*. 190.
- Mkoji, G.M., Mungai, B.N., Koech, D.K., Hofkin, B.V., Loker, E.S., Kihara, J.H., Kageni, F.M. (1992) Does the snail *Melanoides tuberculata* have a role in biological control of *Biomphalaria pfeifferi* and other medically important African pulmonates? *Ann Trop Med Parasitol* 86: 201-204.
- Murray, H. D. (1971) The Introduction and spread of Thiarids in the United States. *The Biologist* 53:133–135.
- Ndifon, G. T. and Ukoli, F. M. A. (1989) Ecology of freshwater snails in south-western Nigeria. I. Distribution and habitat preferences. *Hydrobiologia* 171: 231–253.
- Neck, R.W. (1985) *Melanoides Tuberculata* In Extreme Southern Texas. *Texas Conchologist* 21(4):150-152.
- Nwankwo, D.I. (1993) Cyanobacteria bloom species n coastal waters of south western Nigeria. *Arch Hydrobiol/ Suppl.* 90(4): 533-542.
- Nwankwo, D.I. and Onyema, I.C., Adesalu, T.A. (2003) "A survey of harmful algae in coastal waters of south-western Nigeria". *Journal of Nigerian Environmental Society.* 1(2): 241-246.
- Nwankwo, D.I., Onyema, I.C., Labiran, C.O., Otuorumo, A.O., Onadipe, E.I., Ebulu, M.O. and Emubaiye, N. (2004) Notes on the Observations of Brown Water Discolouration off the Light House Beach, Lagos, Nigeria. *Discov. Innov.* 16(3/4): 111-116.
- Nybakken, J.W. (1997) *Marine Biology-An Ecological Approach.* Addison-Wesley Educational Publishers, Inc. New York. 418pp.
- Ogbeibu, A.E. (2005) Biostatistics-A practical Approach to Research and Data Handling. Mindex Press, Ugbowu, Benin City. 264pp.
- Ogbeibu, A.E. and Egborge, A.B.M. (1995) Hydrological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in Southern Nigeria. 2. Physical and Chemical hydrology. *Tropical Freshwater Biol*. 4: 83-100.
- Ogbeibu, A.E. and Oribhabor, B.J. (2002) Ecological impact of river impoundment using benthic macro-invertebrates as indicators. *Water Research* 36: 2427-2436.
- Ogbeibu, A.E. and Victor, R. (1995) Hydrological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in outhern Nigeria. 2: Physical and Chemical hydrology. *Tropical Freshwater Biol.* 4: 83-100.
- Onyema, I.C. and Nwankwo, D.I. (2006) The Epipelic Assemblage of a Polluted Estuarine Creek in Lagos, Nigeria. *Poll. Res.* 25(3): 459-468.
- Onyema, I.C., Otudeko, O.G. and Nwankwo, D.I. (2003) The distribution and composition of plankton around a sewage disposal site at Iddo, Nigeria. *Journal of Scientific Research Development* 7: 11-24.
- Pointier, J. P. (1999) Invading freshwater gastropods: some conflicting aspects for public health. *Malacologia* 41: 403–411.
- Pointier, J. P. and Marquet, G. (1990) Taxonomy and distribution of freshwater molluscs of French Polynesia. *Japanese Journal of Malacology* 49: 215–231.
- Pointier, J. P., Incani, R. N., Balzan, C., Chrosciechowski, P. and Prypchan, S. (1994) Invasion of the rivers of the littoral central region of Venezuela by *Thiara granifera* and *Melanoides tuberculata* (Mollusca: Prosobranchia: Thiaridae) and the absence of *Biomphalaria glabrata*, snail host of *Scistosoma mansoni*. *The Nautilus 107*: 124–128.
- Robert T. D. (Jn.), 2000. *Ecology of freshwater Molluscs.* Cambridge University Press, United Kingdom. 499 pp.

- ✓ Russo, T. N. (1974) Discovery Of The Gastropod Snail *Melanoides* (Thiara) t*uberculata* (Miiller) In Florida. *Florida Scientist* 36(2-4):212-213.
- ✓ SMEWW (1985) Standard Methods for the Examination of Water and Wastewater. 16th Edition: Method 507, pp 525-532.
- ✓ Sridhar, M.K.C. and Ademoroti, C.M.A. (1984) "Effluent Discharge Stardards Needed in Nigeria", African and Asia Water and Sewage *Journal of United Kingdom*. 3(4): 32-36.
- ✓ Sutcliffe, D.W., Carrick, T.R., Heron, J., Rigg, E., Talling, J.F., Woof, C. and Lund, J.W.C. (1982) Long-term and seasonal changes in the chemical composition of precipitation and surface water of lakes and tarns in the English Lake District. *Freshwater Biology.* 12: 451-506.
- ✓ Tait, R.V. and Dipper F.A. (1998) *Element of Marine Ecology.* Butterworths Publishers, Oxford. 462pp.
- ✓ Thiengo, S.C., Fernandez, M.A., Boaventura, M.F.F. (2001) Freshwater snails and *Schistosomiasis mansoni* in the State of Rio de Janeiro, Brazil. I. Metropolitan Mesoregion. *Mem. Inst. Oswaldo Cruz* 96(suppl.): 177-184.
- ✓ Thiengo, S.C., Maltos, A.C., Boaventura, M.F., Loureiro, M.S., Santos, S.B., Fernandez, M.A. (2004) Freshwater Snails and *Schistosomiasis mansoni* in the State of Rio de Janeiro, Brazil: V-Norte Fluminense Mesoregion. *Mem Inst Oswaldo Cruz,* 99: 99-103.
- ✓ USEPA (1979) United States Environmental Protection Agency *Methods for Chemical Analysis of Water and Wastes.* 1974 editorial revision. Method 405.1.
- ✓ Uwadiae R.E, Edokpayi C.A, Adegbite O, Abimbola O. (2009) Impact of sediment characteristics on the Macrobenthic invertebrates community of a perturbed tropical lagoon. *Ecol. Environ. Conserv.*15(3): 441 -448.
- ✓ Vaz, J.F., Teles, H.M.S., Correa, M.A. and Leite, S.P.S. (1986) Ocorrência no Brasil de *Thiara (Melanoides) tuberculata* (Müller, 1774) (Gastropoda, Prosobranchia), primeiro hospedeiro intermediário de *Clonorchis sinensis*. *Rev. Saúde públ. (S. Paulo),* 20: 318-322.
- ✓ Victor, R. and Al-Mahrouqi A.I.S. (1996) Physical, Chemical and Fuanal characteristics of a perennial stream in arid northern Oman. *Journal of Arid Environments* 34: 465-476.
- ✓ Victor, R. and Ogbeibu, A.E. (1991) Macroinvertebrate communities in the erosional biotope of an urban stream in Nigeria. *Tropical Zoology* 4: 1-12.
- ✓ Victor, R. and Onomivbori, O. (1996) The effects of urban perturbations on the benthic macroinvertebrates of a southern Nigeria stream. pp 223-238 In: Schiemer, F. and Biland, K.T. (eds) *Perspectives in Tropical Limnology.* SPB Academic Publishing, Amsterdam.
- ✓ Watanabe, E.T., Paz, R.J., Dijck, M.P.M. and Abílio, F.J.P. (1999) First record of *Melanoides tuberculata* (Müller, 1774) (Gastropoda: Prosobranchia: Thiaridae) in the state of Paraíba (Brazil) and its ecological implications. *Rev. Nord. Biol.* 10: 72-84.