Applied Ecology and Environmental Sciences, 2015, Vol. 3, No. 4, 117-126
Available online at http://pubs.sciepub.com/aees/3/4/4

DOI:10.12691/aees-3-4-4

Impact of Seasonal Water Quality and Trophic Levels on the Distribution of Various Freshwater Snails in Four Egyptian Governorates

Mohamed- Assem S. Marie[1], Fatma Afifi Aly El-Deeb[2], Wafaa S. Hasheesh[1,*], Rehab Atef Mohamed[1], Sara Sayed M. Sayed[2]

[1]Zoology Department, Faculty of Science, Cairo University
[2]Environmental Research and Medical Malacology Department, Theodor Bilharz Research Institute, Giza, Egypt
*Corresponding author: Fab201355@yahoo.com

Received November 28, 2014; Revised September 01, 2015; Accepted September 16, 2015

Abstract This study aimed to the density and distributions of some freshwater snails collected from eight freshwater streams at Egyptian governorates (Giza, Ismailia, Menoufia and Gharbia). Physical and chemical properties of water quality (i.e. water temperature, pH, dissolved oxygen, total dissolved solids and electrical conductivity), and measuring ammonia, nitrite, nitrate and phosphate was done. Density of aquatic plants was evaluated. Chlorophyll-a content was measured to determine the trophic level of water. The results revealed that *Biomphalaria alexandrina* was the most enumeration snail spices, where they have the ability to tolerate and adapt to various environmental circumstances. Results proved that the eutrophic state recorded at Giza and Gharbia whereas, hyper-eutrophic state observed at Ismailia and Menoufia. *Eichhornia crassipes; Echinochloa sp.* (Water grass) and *Lemma gibba* aquatic plants were the most dominant aquatic plants and almost they were found in all examined sites.

Keywords: *water quality, distribution, eutrophication, freshwater snails*

Cite This Article: Mohamed- Assem S. Marie, Fatma Afifi Aly El-Deeb, Wafaa S. Hasheesh, Rehab Atef Mohamed, and Sara Sayed M. Sayed, "Impact of Seasonal Water Quality and Trophic Levels on the Distribution of Various Freshwater Snails in Four Egyptian Governorates." *Applied Ecology and Environmental Sciences*, vol. 3, no. 4 (2015): 117-126. doi: 10.12691/aees-3-4-4.

1. Introduction

One of the most profound changes to earth's ecosystems is the alteration of global nutrient cycle those of phosphorus (P) and nitrogen (N) [24]. They can get into water from a number of sources, including fertilizer put on soil to enhance crop growth, some industrial pollutants, and especially in the cases of phosphates and nitrates from the degradation of sewage in wastewater [29]. Considering forecasted increases in global agricultural production and fertilizer application, as well as the persistence of anthropogenic phosphorus in agricultural soils and aquatic ecosystem [5], eutrophication will almost certainly become an increasingly severe problem in coming century [26]. Nitrate, potassium and phosphate in agricultural run-off have potentially serious ecological and public health implications resulting in a variety of problems, such as clogged pipelines, fish mortality and reduced recreational opportunities [35]. Water pollution affects the bioavailability of chemicals which may be toxic substances [15]. One of them the nutrients that composed mainly of nitrogen and phosphorus which in turn affect directly snail's populations or indirectly affect them though modifying temperature, pH, oxygen concentration and salinity [14]. Several factors are considered as affecting the ecology of snails and other intermediate hosts of diseases, hence their focal and seasonal distributions [34]. Since snails are obligatory hosts for the larval stages of schistosomes, their examination provides important information on active transmission foci. Both the parasite and the vector must be targeted in order to break the cycle of transmission so as to achieve success in controlling schistosomiasis [33]. Therefore, this work highlights the impact seasonal water quality and trophic state index (TSI) on the density and distributions of some freshwater snails in different water streams. In addition, the correlation between distribution of snails that have a medical importance and water physico-chemical parameters, aquatic plants type and trophic level of water were determined.

2. Materials and methods

2.1. Sites of Investigation

A natural survey was conducted to examine the degree of variability of nutrient availability resulting in aquatic systems especially that serve as habitats for intermediate host of schistosomiasis in Egypt. The watercourses included Nile River branches, irrigation canals and agriculture drains as follows: from Giza gonernorate (Site-1: El-Englizia drain, kafer hakim, and Site-2: Ghabor drain, Ezbeat beet el qaseed); from Ismailia governorate (Site-3: Ramdan drain, El-tal el kabir and Site-4: Tabot el-nos drain, El-tal el kabir); from Menoufia governorate (Site-5: Nile River, Rasheed branch, manshit el sadat, El-Shohdaa and Site-6: Nile River- Ezbet el Masry, Menof) and from Gharbia governorate (Site-7: El nanaia canal, Kafer-el Zayat and Site-8: Abo mashohor canal, Tanta).

2.2. Sampling of Snails

Seasonally samples of freshwater snails were collected from the eight selected sites during a period (from spring 2012 till winter 2013). Sampling was carried out along the shoreline of each site and always by the same collector. Snails were collected by passing a dip net (30 cm×40 cm) five times through the upper surface of sediment, water and vegetations on a depth of 20 cm (a column of water as parallel rectangles and its base is the rectangular net). The snails attached to the macrophytes were separated and all collected snails were kept in pre-labeled plastic containers. In the laboratory, the snails were counted and identified according to Brown [7] and Ibrahim *et al*. [23]. The density of each species was calculated as the number of specimens that present in samples of each selected site.

2.3. Physico-chemical Characterization of Water

Surface water samples were collected in 2 liters plastic containers by the simple dip method. Temperature (°C), Electrical conductivity (µmhos/cm) using a portable conductivity meter (HI 9635), pH using a portable pH meter (HI 9024), Total dissolved solids (TDS) and dissolved oxygen (D.O.) using a portable D.O. meter (HI 8543) were measured on spot at mid day, at 20 cm under the water surface. Free ammonia, nitrite, nitrate, phosphate and quantification of chlorophyll-a concentration were measured according to standards methods [2]. Trophic State Index (TSI) was calculating according to Carlson [10] depending on chlorophyll-a for predicting level of eutrphication, using the following equation: **TSI (Chl) = 30.6 + 9.81 In (Chl-a),** Where, TSI (Chl) = Trophic State Index depending on chlorophyll-a; ln = natural logarithm and (Chl-a) = concentration of chlorophyll-a (µg/L), measured at the water surface.

2.4. Aquatic Macrophytes

All types of macrophytes found in each site were collected, properly labeled and identified to species level. Subsequently, each vegetation type was monitored every season in each site for presence of coverage and relative association with snails. Coverage was determined with some modification by a simple estimation of the proportion of site covered by each species and scored 1 for ≤ + (very low coverage), 2 for ++ (low coverage), 3 for +++ (moderate coverage), 4 for ++++ (high coverage) and 5 for ≥ +++++ (very high coverage) according to Owojori *et al*. [34] and Hussein *et al* [22].

2.5. Statistical Analysis

Correlation coefficients between physico-chemical parameters with each others and between physico-chemical parameters and aquatic plants were performed and analysis of variance between distribution of snails and investigating selected sites using the statistical program SPSS version 17 (SPSS, Inc., Chicago, IL) [38] for windows.

3. Results

General findings: Results of total snails distribution and density are summarized in Table 1. A total of 12 snail species were collected from the eight sites of investigation during the study period are *Biomphalaria alexandrina* (696 specimens); *Physa acuta* (196 specimens); *Planorbis planorbis* (176 specimens); *Lymnaea natalensis* (166 specimens); *Bulinus truncates* (30 specimens); *Succinea cleopatra* (23 specimens); *Bellamya unicolor* (14 specimens); *Melanoides tuberculata* (13 specimens) *Biomphalaria glabrata* (11 specimens); *Helisoma duryi* (3 specimens); *Lanistes carinatus* (3 specimens) and *Cleopatra bulimoides* (2 specimens). The total number of the collected snails was 1333 specimens, from which 220, 108, 120, 68, 345, 64, 218 and 190 individuals were recorded at sites 1, 2, 3, 4, 5, 6, 7 and 8 respectively. By regarding these results, one can conclude that site 1, 5 and 7 were the richest in the number of snails (Table 1).

Table 1. Distribution and density of snails collected from the selected sites in the studied period (spring, 2012-winter, 2013).

Sites \ Snails		B. a.	B.g.	B. t.	L. n.	P. a.	H.d.	L.c.	B.u.	S. c.	P. p.	C.b.	M.t.	Total	Overall total (%)
Giza	S_1	23	0	11	64	87	0	0	0	5	29	1	0	220	16.49
	S_2	81	0	0	4	9	0	0	0	1	1	0	12	108	8.09
Ismailia	S_3	100	3	0	3	2	2	2	3	5	0	0	0	120	8.99
	S_4	47	3	11	4	0	1	0	0	1	1	0	0	68	5.09
Menoufia	S_5	230	0	0	67	20	0	0	0	10	17	0	1	345	25.86
	S_6	48	0	0	9	3	0	0	0	1	3	0	0	64	4.80
Gharbia	S_7	130	5	8	6	33	0	0	10	0	26	0	0	218	16.34
	S_8	37	0	0	9	42	0	1	1	0	99	1	0	190	14.24
Total		696	11	30	166	196	3	3	14	23	176	2	13	1333	
Overall total (%)		52.21	0.82	2.25	12.45	14.70	0.22	0.22	1.05	1.72	13.20	0.15	0.97		

B. a.: Biomphalaria alexandrina; B. g: Biomphalaria glabrata; B. t.: Bulinus truncatus; L. n.: Lymnaea natalensis; P. a.: Physa acuta; H. d.: Helisoma duryi; L. c.: Lanistes carinatus; B. u.: Bellamya unicolor; S. c.: Succinea cleopatra; P.p.: Planorbis planorbis; C. b.: Cleopatra bulimoides; M. t.: Melanoides tuberculata.

Seasonal variation in snails density: Data indicated that, the seasonal variation in density of each snail species collected from the studied sites, *B. alexandrina; P. acuta; L. natalensis* and *B. truncates* showed the highest peak in spring season. While *P. planorbis* showed the highest one in autumn season. *S. cleopatra* showed the highest peak in winter. *B. unicolor* showed two peaks in spring and summer seasons. While the rest snail species did not show discernible pattern and their collection could not represent the sample size for each season (Figure 1).

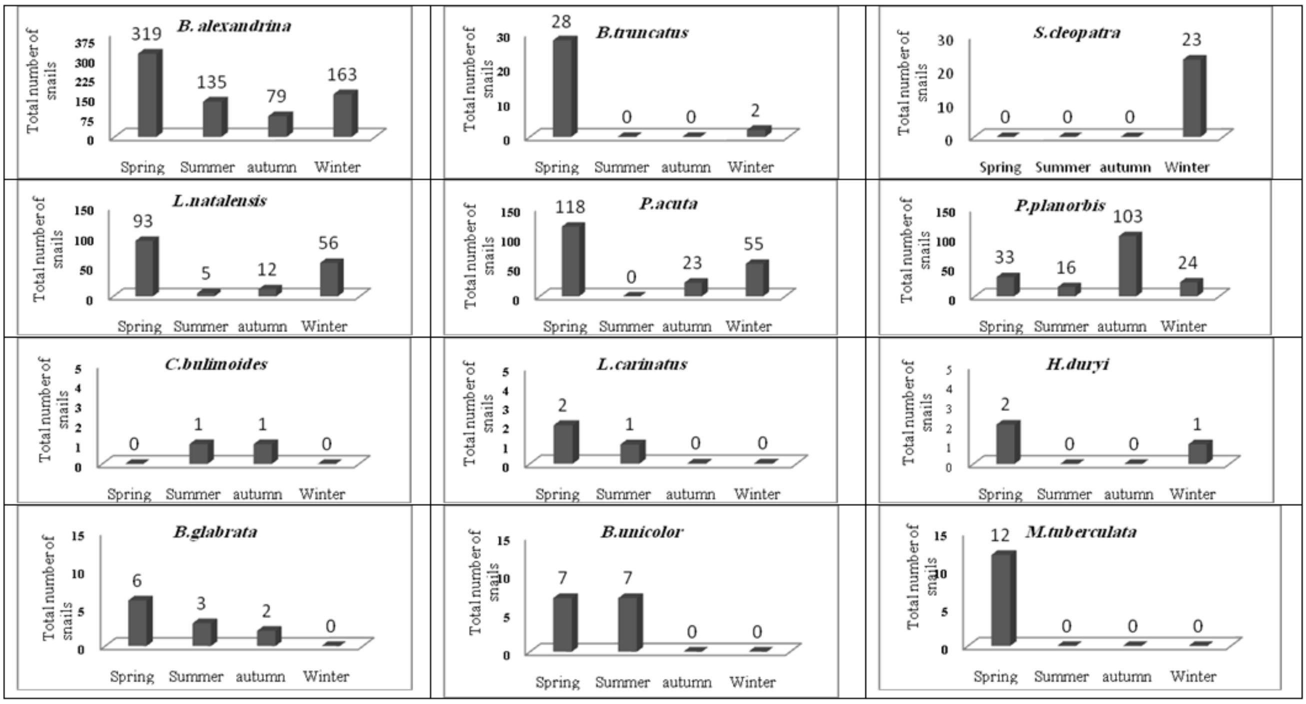

Figure 1. The seasonal variations of the snail species densities collected from the studied site

Table 2. Median and range values of the physico-chemical characteristics of water collected from eight sites during spring 2012 to winter 2013.

Sites	T (°C)	EC. (µs/ cm)	D.O. (mg/ l)	pH	TDS (mg/ l)	Ammonia (mg/ l)	Nitrite (mg/ l)	Nitrate (mg/ l)	Phosphate (mg/ l)	Chl-a (µg/ l)
S_1	23.5 (16.6-26.1)	2155 (800-2500)	1.665 (0.98-4.5)	8.03 (7.0-8.41)	1221 (1179-1660)	0.0 (0.0-0.0)	0.95 (0.06-1.5)	7.2 (1.2-9)	1 (0.2-2.6)	66.5 (21.3-89)
S_2	23.4 (17.8-28.5)	1815 (1610-2040)	2.065 (0.17-4.03)	8.03 (7.8-8.7)	1149.5 (1127-1273)	0.0 (0.0-0.0)	0.25 (0.03-0.3)	3.6 (2.9-4.5)	0.5 (0.49-0.7)	48.3 (6.3-73.7)
S_3	24.9 (16.7-28)	1900 (736-3120)	1.792 (0.27-7.56)	7.87 (6.5-8.84)	1062.5 (13.7-2180)	1.475 (0.0-7.3)	0.012 (0.0-0.04)	0.05 (0.0-0.56)	1.21 (0.7-3.4)	313 (149.6-418)
S_4	25.7 (15.4-26)	1465.5 (817-2500)	2.805 (0.66-5.00)	7.75 (6.6-9.6)	777 (13.5-1010)	0.8 (0.0-4.5)	0.005 (0.0-0.02)	0.05 (0.0-0.3)	0.41 (0.0-4.1)	48.9 (7-221)
S_5	25.9 (18.1-31.9)	720 (600-790)	0.205 (0.13-4.86)	7.82 (7.1-9.6)	499 (450-554)	3.35 (0.0-8.5)	0.023 (0.001-0.25)	2.96 (0.1-9.5)	0.0 (0.0-1.25)	112.75 (16.8-140)
S_6	25.7 (19.5-30.4)	685 (499-1700)	0.44 (0.22-0.74)	7.83 (7.6-8.19)	480 (410-1213)	3.6 (0.0-8.4)	0.012 (0.003-0.028)	0.135 (0.0-3.2)	0.275 (0.0-0.6)	102.5 (42.9-175)
S_7	23.7 (18-30.1)	530.5 (400-606)	3.82 (3.00-16.9)	8.54 (8.36-8.76)	369.5 (320-405)	0.0 (0.0-12.3)	0.051 (0.001-0.1)	0.19 (0.1-0.4)	0.32 (0.0-0.73)	17 (0.0-90)
S_8	23.2 (19.5-30.2)	789.5 (423-1925)	1.305 (1.17-4.9)	8.46 (8.40-8.75)	554.5 (291-1342)	0.0 (0.0-11.2)	0.02 (0.002-7.75)	0.155 (0.085-0.48)	0.6 (0.5-1)	34 (11-116.5)

Values in parenthesis represent the range of the parameters. Temperature (T), Electrical Conductivity (EC.), Dissolved oxygen (D.O.), Total dissolved solids (TDS), Chlorophyll-a (Chl-a).

Snail distribution in relation to physico-chemical factors: Table 2 summarized the seasonal variations in the values of each physico-chemical parameter during the study period. Regarding to the effect of environment factors on the distribution of snail species, the present data (Figure 2) showed that the highest ratio of snail species (46.06 %) was collected at temperature range (18.1- 24°C), but when the temperature increased to more than 30°C this ratio was decreased to 8.33%. Also, data revealed that 67.89% of snail species were collected under electric conductivity range (501-1500 µs/cm), and this ratio decreased with increase electric conductivity. While the highest snail species ratios (54.61 %) and (35.26 %) were collected at total dissolved solids ranges (301 - 600 mg/l) and (601 - 1500 mg/l), respectively. However the important of dissolved oxygen content for aquatic snails, the highest ratio of snail species (65.12 %) were collected at dissolved oxygen range (0.6 - 8 mg/l). When this range exceeds to more than 8 mg/l the ratio of snails decreased to 0.75 %. In the present work, snail species were observed in wide range of water pH, but the highest percentage of snails (68.94 %) was found in pH range (7.6 - 8.5). This ratio was decreased to (1.35 % and 13.28 %) when pH below than 7 and/ or high than 9, respectively. The snail species ratios were inversely proportional to ranges of ammonia, nitrite, nitrate and phosphate. Where the highest snail percentage was 68.19 % at ammonia range of (0 – 2 mg/l), 71.34 % at nitrite range of (0 – 0.2

mg/l), 42.91 % at nitrate range of (0 – 0.29 mg/l) and 55.29 % at phosphate range (0 – 0.5 mg/l). The highest percentage of snail species was 39.53 % at chlorophyll-a range (50.1-100 µg/l), while the lowest percentage of snail species was 3.83 % at chlorophyll-a range (201- 500 µg/l). Correlation analysis between physicochemical parameters and medical important intermediate hosts of schistosomiasis and fascioliasis, data in Table 3 revealed that water temperature showed a negative correlation only with *L. natalensis* at site 5. Concerning to water electrical conductivity, it has a negative correlation with *B. alexandrina* at site 6 and *B. truncatus* at site 1. On the other hand, Dissolved oxygen showed a negative correlation with *B. alexandrina* at site 5 and it gives positive correlation with *B. truncatus* at site 1. Water pH showed a negative correlation only with *B. alexandrina* (P<0.05) at site 6. Total dissolved solids was negatively correlated with *B. alexandrina* at site 6 whereas it showed a positive correlation (P<0.05) with *B. truncatus* at site 4. Ammonia was positively correlated with *B. truncatus* and *L. natalensis* at site 7 with significant level (P<0.01), while *B. alexandrina* showed a positive correlation with ammonia at significant level (P<0.05) in site 4 and (P<0.01) in site 7. Generally, nitrate showed a positive correlation with *B. alexandrina* at site 8 and *L. natalensis* at site 6. Also, phosphate has a positive correlation (P<0.01) with *B. truncatus* at site 4 and with *B. alexandrina* at site 3. Finally, chlorophyll-a has a positive correlation only with *B. alexandrina* at site 8 with significant level (P<0.05).

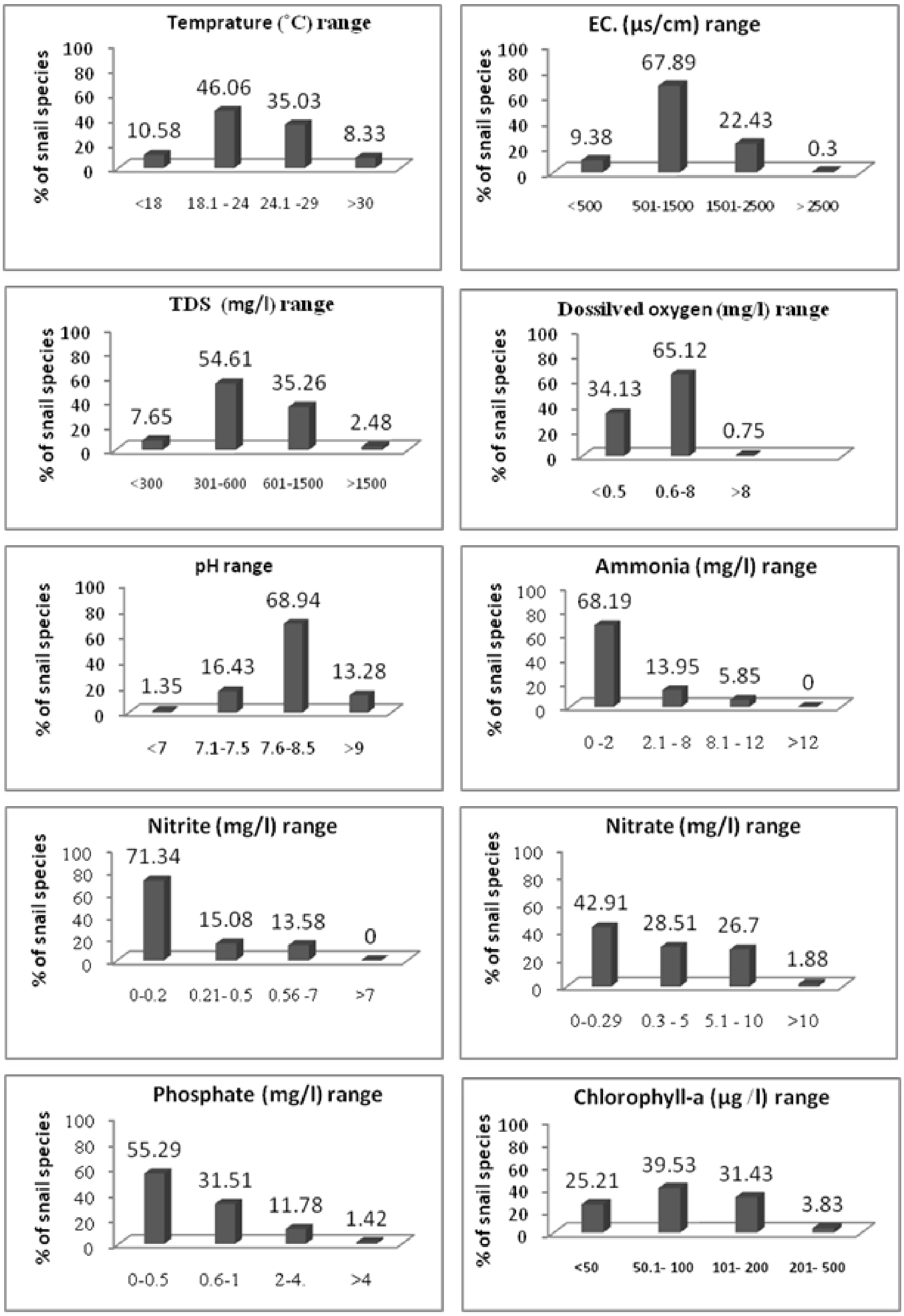

Figure 2. Percentages of snail's species collected from the investigating sites with different physico-chemical parameters ranges during the study period

Table 3. Correlation coefficient between *Biomphalaria alexandrina, Bulinus truncatus* and *Lymnaea natalensis* snails and physico-chemical parameters at different selected sites during (spring, 2012- winter, 2013)

Parameters \ Snails	*Biomphalaria alexandrina*	*Bulinus truncatus*	*Lymnaea natalensis*
Temperature°C	NS	NS	-0.958* (S5)
Conductivity (μs/cm)	-0.972* (S6)	-.0950* (S1)	NS
Dissolved Oxygen (mg/ l)	-0.986* (S5)	0.965* (S1)	NS
pH	-0.970* (S6)	NS	NS
TDS (mg/l)	0.962* (S6)	0.969* (S4)	NS
Ammonia (mg/l)	0.965* (S4) 0.998** (S7)	1.000** (S7)	1.000** (S7)
Nitrite (mg/l)	NS	NS	NS
Nitrate (mg/l)	0.986* (S8)	NS	0.999** (S6)
Phosphate (mg/l)	1.000** (S3)	1.000** (S4)	NS
Chlorophyll -a (μg/l)	0.984*(S8)	NS	NS

(Sn)= site number, *Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level, NS= Correlation is not significant.

Trophic state index (TSI) for investigating sites: Generally, (Table 4) showed the values of (TSI) for the eight investigating selected sites depending on the mean of chlorophyll-a concentration that was measured in these sites during the studied period. According to the Carlson's Trophic state index (TSI), it was found that the eutrophic state recorded at sites (1, 2, 7 and 8) and their water qualities were fair whereas, hyper-eutrophic state observed at sites (3, 4, 5 and 6) and their water qualities were poor. Figure 3 indicated to the effect of seasonal variation on trophic state index of water with regard to percentage of snails during study period. Results showed that water is dominated by eutrophic state at site 1, where the spring and summer seasons showed hyper-eutrophic state while autumn and winter seasons showed eutrophic state. However, the highest percentage of snails (60.9 %) were collected from this site were during spring. At site 2, water trophic state fluctuated during four seasons since the spring and summer seasons showed hyper-eutropnic state, while autumn showed oligotrophic state but by the beginning of winter became mesotrophic state. Snail ratio was high in spring reaching (45.37%). Hyper-eutrophic state is continued along the year seasons at site 3, the highest ratio of snails were collected (69.17 %) during spring season, while by the summer and autumn this ratio was decreased recording (3.33 % and 0.83 %), respectively. While water has fluctuated state at site 4, where in spring eutrophic state was observed then became oligotrophic state by summer after that state convert to hyper-eutrophic in autumn then eutrophic by the beginning of the winter. The percentages of snails are almost convergent through the four seasons. Also, hyper-eutrophic state was predominantly during spring, summer and autumn seasons then became mesotrophic state by winter at site 5. The highest ratio of snails was detected (46.67 %) in winter. Similar pattern of water state found in site 6, where hyper-eutrophic state was dominated by spring, summer and autumn seasons then became eutrophic in the winter season, snail's ratio was high in spring and winter (34.39 % and 34.37 %), respectively. At site 7 the highest snail percentage was observed in spring season (73.39%) however, the water state was hyper-eutrophic. In summer water state became eutrophic. During both autumn and winter did not calculate trophic state index (TSI) because there was very little concentrations chlorophyll-a and could not detected. Finally, autumn season has the highest snail ratio reaching (71.05 %) with hyper-eutrophic state at site 8, while both spring and summer seasons have eutrophic state. Winter has oligotrophic state, it was not found snail ratio in this season.

Table 4. Classification of the eight investigating sites according to the Carlson's Trophic State Index (TSI) depending on the mean of chlorophyll-a concentration during the studied period

Carlson's Trophic state index (TSI)	Criteria	Governorates	Sites	Mean of Chl-a (μg/l)	TSI calculated/ site	Trophic state	Water quality depend on TSI/ site
Ultraoligotrophic	< 30	Giza	**1**	60.82	70.87	Eutrophic	Fair
Oligotrophic	30 - 50		**2**	44.15	67.75	Eutrophic	Fair
Mesotrophic	50 - 60	Ismailia	**3**	298.40	86.50	Hyper-eutrophic	Poor
Eutrophic	60 - 70		**4**	81.45	73.76	Hyper- eutrophic	Poor
Hyper-eutrophic	> 70	Menoufia	**5**	95.59	75.33	Hyper- eutrophic	Poor
Water quality depend on TSI values			**6**	105.59	76.32	Hyper- eutrophic	Poor
good	0-59	Gharbia	**7**	31	64.28	Eutrophic	Fair
Fair	60-69		**8**	48.87	68.75	Eutrophic	Fair
Poor	70-100						

Aquatic plants in relation to medical important snails: The frequency of occurrence and relative coverage by site of macrophytes are represented in Table 5. The survey study observed seven aquatic plant species, *Eichhornia crassipes; Lemna gibba; Ceratophyllum demrersum; Azolla pinnata; Jussia repen; Echinochloa sp.* (Water grass) and *Pistia stratiotes* (Water lettuce). Results showed that *E. crassipes; Echinochloa sp.* (Water grass) and *L. gibba* were the most dominant aquatic plants and almost they are found in all examined sites with total coverage (represented as scores) 81, 65 & 55 respectively, while *P. stratiotes* (Water lettuce) confined presence in site 2 with total coverage 15. In descending pattern the most density of aquatic plants / site was recorded as follow; 49, 42, 36 and 35 at site4, site2, site3, site 6, respectively (Table 5). Regarding to the role of aquatic plants in spread of medical important snail species, results in Table 6 recorded that *B. alexandrina* was mostly associated with *E. crassipes; L. gibba* and *Echinochloa sp.* (Water grass) in percentages of 62.5%, 62.5% & 59.3%, respectively. On the other hand, *B. truncatus* was associated with *E. crassipes* in percentages of 9.3%. Finally, *L. natalensis* was associated with *E. crassipes* and *L. gibba* in percentages of 40.6% and 34.3%, respectively.

Table 5. The frequency and relative coverage (represented as scores) of aquatic plants at eight sites during (spring, 2012- winter, 2013).

Aquatic plants		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	Total
Eichhornia crassipes	N. (Co.)	---	1(1)	4(3,4,4,4)	4(3,4,5,5)	4(1,1,3,4)	4(3,3,5,5)	3(4,4,4)	3(4,4,4)	
	Sum of (Co.)	---	1	15	17	9	16	12	11	**81**
Lemna gibba	N. (Co.)	3(1,5,4)	3(3,5,2)	1(3)	3(3,1,3)	4(3,3,2,3)	3(1,1,3)	1(2)	2(5,2)	
	Sum of (Co.)	10	10	3	7	11	5	2	7	**55**
Ceratophyllum demrersum	N. (Co.)	---	---	---	2(3,2)	1(3)	2(2)	---	---	
	Sum of (Co.)				5	3	2			**10**
Azolla pinnata	N. (Co.)	2(3,2)	1(2)	---	1(3)	---	---	---	---	
	Sum of (Co.)	5	2		3					**10**
Jussia repen	N. (Co.)	---	1(3)	3(3,2,4)	3(3,2,3)	1(2)	---	---	---	
	Sum of (Co.)		3	9	8	2				**22**
***Echinochloa sp.* (Water grass)**	N. (Co.)	3(3,4,2)	3(2,5,4)	2(5,4)	3(3,4,2)	3(2,2,2)	4(3,3,4,2)	2(2,4)	2(1,2)	
	Sum of (Co.)	9	11	9	9	6	12	6	3	**65**
***Pistia stratiotes* (Water lettuce)**	N. (Co.)	---	3(5,5,5)	---	---	---	---	---	---	
	Sum of (Co.)		15							**15**
Total density		24	42	36	49	31	35	20	21	258

N=frequency of occurrence during four seasons, Co= Coverage (represented as scores): --- (absent), 1 for ≤ + (very low coverage), 2= ++ (low coverage), 3= +++ (moderate coverage), 4= ++++ (high coverage), 5 for ≥ +++++ (very high coverage). * = Dominant macrophyte based on density.

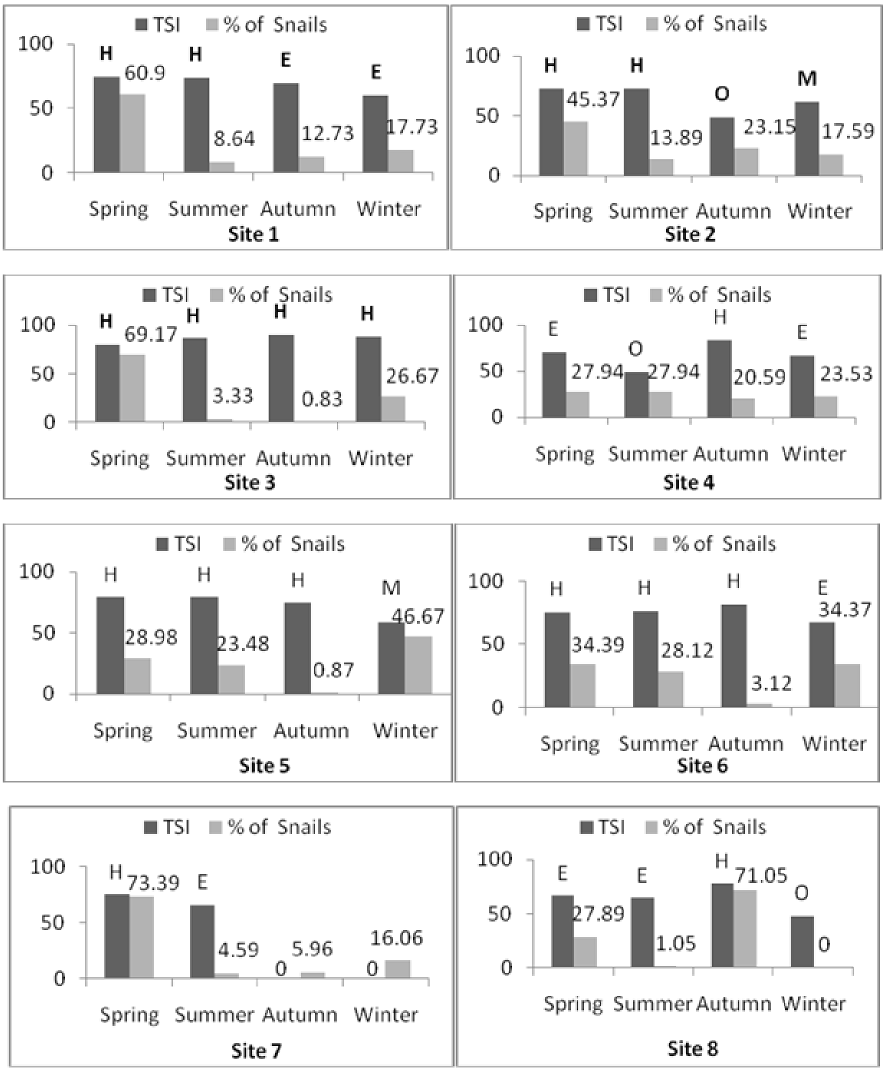

Figure 3. Effect of seasonal variation on trophic state index of water with regard to percentage of snails during study period. (H= hyper-eutrophic, E= eutrophic, M= mesotrophic, O= oligotrophic)

Table 6. The association percentage of *Biomphalaria alexandrina, Bulinus truncatus* and *Lymnaea natalensis* snails with different species of aquatic plants among examined sites during period (spring, 2012-winter, 2013)

Snails / Aquatic Plants	The association percentage of snails (%)		
	Biomphalaria alexandrina	***Bulinus truncatus***	***Lymnaea natalensis***
Eichhornia crassipes	62.5	9.3	40.6
Lemna gibba	62.5	0	34.3
Ceratophyllum demrersum	15.6	3.1	9.3
Azolla pinnata	12.5	3.1	6.2
Jussia repen	21.5	0	15.6
Echinochloa sp. (Water grass)	59.3	3.1	31.2
Pistia stratiotes (Water lettuce)	9.3	0	3.1

4. Discussion

Freshwater mollusc communities are important in terms of biodiversity and ecosystem health. Molluscs are suitable candidates to be used in biomonitoring surveys [16]. Moreover, they play a significant roles in the public and veterinary health and thus need to be explored scientifically more extensively [40]. The present study has identified a total of twelve snail species namely *B. alexandrina; B. glabrata; B. truncatus; L. natalensis; P. acuta; H. duryi; L. carinatus; B. unicolor; S. cleopatra; P. planorbis; C. bulimoides* and *M. tuberculata* in selected sites from four Egyptian governorates (Giza, Ismailia, Menoufia and Gharbia) along a survey period from spring (2012) to winter (2013). This gives an indication of stable coexistence found only in habitats, which are capable of supporting mutually exclusive and conductive niches for different species population.

Concerning to snail groups which transmit diseases to man and domestic animals, in the present work *B. alexandrina*; *B. truncatus* and *L. natalensis* showed the highest peak in spring. While Owojori *et al.* [34] reported that the distribution with peaks in March/April for *Biomphalaria pfeifferi*, while in November/December for *Bulinus globosus* and *B. truncatus;* and in June for *L. natalensis*. On the other hand, Hussein *et al.* [22] found that *L. natalensis*, and *B. alexandrina* showed peak in March/May, while *B. truncatus* showed two peaks in March and September. Another study by El-Khayat *et al.* [13] showed that *B. alexandrina* was abundant in autumn while *B. truncatus* was abundant in winter. The present field survey detected that the *B. alexandrina* was the most enumeration of snail species. This may be attributed to that, *B. alexandrina* was more tolerant than the other snail species to some of the examined parameters. This was in agreement with Mahmoud [27]; Habib [19] and El-Khayat *et al. [13]*.

Under natural condition, snails are exposed to several environmental factors which produce a collective effect on the snails. In the present study, it was found that the highest ratio of snail species (46.06 %) was collected at temperature range (18.1- 24°C), but when the temperature increased to more than 30°C this ratio was decreased to 8.33%. This is partially in coincidence with El-Emam and Roushdy [12] who demonstrated that the optimum temperature for these mollusca lies between 22 °C to 26°C. While Mahmoud [27] showed that snails can tolerate low temperature rather than high temperature which can lethally affect them. Another study by El-Khayat *et al. [14]* revealed that snails can tolerate a wide range of temperature 19 – 34°C. Correlations between temperature and medical important snails, the present results revealed that temperature was negatively correlated with *L. natalensis* at Menoufia (site 5) where the water temperature was ranged (18.1- 31.9°C). This indicate that snail species is highly sensitive to elevation in temperature that may causes thermal stress on snail and also reduces the dissolved oxygen content of water body [21]. Also, Caňete *et al.*, [9] observed that temperature plays an important role in *Lymnaea* sp. abundance. This is in accordance with Azzam [4] who reported that the highest distribution of *L. natalensis* appeared during spring at a temperature range from 23 to 25°C.

Regarding the electrical conductivity (EC), generally, the present study revealed that 67.89% of snail species were collected under electrical conductivity range (501-1500 µs/cm). This finding is in agreement with the pervious study of Berrie [6] who promulgated that snails are not found in waters with low conductivity. This may be attributed to the ability of snails to tolerate a wide range of water hardness and these results were supported by Abdel Malek [1] who stated that water with low hardness showed a reduction in the individual number and snail's shells become relatively thin. However, the present data showed a negative correlation between electrical conductivity (EC) and both of *B. alexandrina* snails at Menoufia (site 6) and *B. truncatus* snails at Giza (site 1), this means that these snail species have limit range of water conductivity which permit them to live whatever in the flowing or stagnant water. This is in harmony with Njoku-Tony [30] who claimed that conductivity is a limiting factor to snail growth and abundance as snail population. The mean of (EC) for *B. alexandrina* and *B. truncatus* were 415 and 418 µs/cm, respectively as shown reported by Saad *et al.* [37]. Moreover, El-Khayat *et al. [14]* found that the lowest value of water conductivity was at sites harboring with snails only as it ranged (200- 500 µs/cm). While EC generally higher at sites in which snails associated with aquatic plants as its value ranged (337-1700 µs/cm), they reflected that to the plants role of increasing snail's tolerance of high conductivity.

Field study showed that, the maximal snail species ratios (54.61 %) were collected at total dissolved solids (TDS) ranges of (301-600 mg/l). However, the correlation analysis revealed that *B. alexandrina* snails at Menoufia (site 6) with (TDS range 410-1213 mg/l), and *B. truncatus* snails at Ismailia (site 4) with (TDS range 13.5-1010 mg/l) were positively correlated to (TDS). These results give an indication that schisosomiasis snail vectors could survive under high concentrations of salts and this finding is in harmony with that observation by Hairson *et al.* [20] who reported that snails are not found in waters with low concentrations of salts. Also, Ofoezie [32] postulated that certain snails found in habitat with higher salinity more suitable. On the contrary, Saad *et al.* [37] found that the highest numbers of *B. truncatus* snails were found under low dissolved salts (100-300 ppm), while *B. alexandrina* snails were obtained from a range of (601-1000 ppm).

From the current work, it was found that the highest ratio of snail species (65.12 %) were collected at dissolved oxygen range (0.6 - 8 mg/l). This result was almost within the range mentioned by Njoku-Tony [30] who found that the desired concentration of dissolved oxygen for snails ranged between 2.2 – 8.5 mg/l. *B. alexandrina* snails that collected from Menoufia (site 5) were negatively correlated with dissolved oxygen (DO), while *B. truncatus* snails that collected from Giza (site 1) were positively correlated. This result may be attributed to those *B. alexandrina* snails could live under low dissolved oxygen content than *B. truncatus* snails. The total number of *B. alexandrina* snails was (230 specimens) from Menoufia (site 5) where the (DO) ranged (0.13- 4.86 mg/l). This result is in coincidence with Yirenya-Tawiah *et al.* [46] who reported that the mean dissolved oxygen of 4.6 mg/l which is favorable for the snail host. On the other hand, 11 specimens of *B. truncatus* snails were collected from Giza (site 1) were collected during spring season at 4.5 mg/l of dissolved oxygen and did not appeared in the other seasons with low (DO) level. These results were in accordance to Ofoezie [32] who observed a significant positive influence of dissolved oxygen on the density of pulmonate snails *Bulinus* spp. and *L. natalensis*.

In the present work, snail species were observed in wide range of water pH, but the highest percentage of snails (68.94 %) was found in pH range (7.6 - 8.5). This ratio was decreased to (1.35 % and 13.28 %) when pH below than 7 and/or higher than 9, respectively. Makela and Oikari [28] declared that an acid pH level was shown to be unfavorable to the occurrence of molluscs (*Physella cubensis, Melanoides tuberculata, Biomphalaria straminea* and *Pisidium sp*.) which prefer slightly alkaline environments. Also, Ashmawy *et al.* [3] stated that pulmonata snails *Lymnaea* sp., *Bulinus* sp. and *B. alexandrina* were collected from large as well as small canals in Beheria governorate and from narrow ditches, where pH ranged from 7.2 to 7.6. The present pH range found to be nearly similar to the reported by Ntonifor and Ajayi [31] who stated that pH range for all the sites that harbored snails was (7.2 – 10.9). However, the correlation analysis showed that *B. alexandrina* snails were negatively correlated with pH levels at Menoufia (site 6). This result is in agreement with Kazibwe *et al.* [25] who observed that *Biomphalaria sudanica* abundance was negatively correlated with pH levels. The pervious investigations showed that *B. alexandrina* and *B. truncatus* snails were abundant in habitats characterized by pH range of 6- 6.5 [27] and pH range of 6.9-7.2 [14].

Concerning the fertilizers residues that measured in water samples collected from the studied sites, the current results revealed that the maximal percentage of snails was 68.19 % at ammonia range of (0 - 2 mg/l), 71.34 % at nitrite range of (0 - 0.2 mg/l), 42.91 % at nitrate range of (0 - 0.29 mg/l) and 55.29 % at phosphate range (0 - 0.5 mg/l). Furthermore, the correlation analysis proved that ammonia was positively correlated with *B. truncatus* and *L. natalensis* at Gharbia (site 7), while *B. alexandrina* showed a positive correlation with ammonia at Ismailia (site 4) and Gharbia (site 7). Moreover, nitrate showed a positive correlation with *B. alexandrina* at Gharbia (site 8) and *L. natalensis* at Menoufia (site 6). These results pointed to that snails withstand at the different levels of fertilizers residues during the study periods, this resistance of snails may occurred by helping the presence of aquatic plants that play an important role to consumption of these fertilizers residues in their habitat. These observations agree with Rumi and Hamann [36] who found *Biompalaria orbignyi* was positively correlated to nitrite, nitrate and ammonium. Thomas *et al.* [42] declared that *Biomphalaria glabrata* seems able to withstand higher levels of ambient ammonia than many other aquatic organisms. Also, phosphate was positively correlated with *B. truncatus* at Ismailia (site 4) with phosphate range (0 - 4.1 mg/l) and with *B. alexandrina* at Ismailia (site 3) with phosphate range (0.7- 3.4 mg/l). These findings is agree with the range mentioned by Gohar and El- Gindy [18] who reported that *B. truncatus* was found to occur at a phosphate concentration variable between (0 - 4 ppm), while *B. alexandrina* was present in laccolites where the concentration varied between (0 - 10 ppm). In addition, Tantawy [41] found that the habitats of both *B. alexandrina* and *B. truncatus* snails showed wide range for concentrations of ions (fertilizers restudies). Also, the analysis of water samples indicated that the concentration of various ions seldom reaches sublethal doses, where physical and biological factors being suggested to play a great role.

The present results showed that the highest percentage of snail species was 39.53 % at chlorophyll-a (Chl-a) range (50.1-100 µg/l), while the lowest percentage was 3.83 % at chlorophyll-a range (201- 500 µg/l). Besides, correlation analysis showed that chlorophyll-a has a positive correlation only with *B. alexandrina* at Gharbia (site 8), where chlorophyll- a ranged (11-116.5 µg/l). Yipp [45] who demonstrated that the common Hong Kong gastropods *Biomphalaria straminea, Austropeplea ollula* and *Physella ollula* are species with the greatest affinity for eutrophic habitats where the water hardness is ranged from intermediate to very hard, and they tolerate high trophic enrichment. Calculation of the trophic level of water samples was according to the Carlson's trophic state index (TSI) during study period. Generally, results proved that the eutrophic state recorded at Giza (sites 1and 2) and Gharbia (sites 7 and 8) whereas, hyper-eutrophic state observed at Ismailia (sites 3 and 4) and Menoufia (sites 5 and 6). Also, results revealed that trophic state may be differ by seasonal variation and concentration of chlorophyll-a at each season. This variation may be due to the concentrations and types of fertilizers residues that runoff in the examined sites with agriculture activity, and then intake by algae and phytoplankton. The present results, it could be concluded that the important role of Chlorophyll-a content which is often used as an estimate of algal biomass, these results were in coincidence with the pervious studied by Wetzel [44]; Brown and Simpson [8]; Stanley *et al.* [39] and Virginia WRRC [43]. On the other hand, chlorophyll-a could be considered as one of the significant parameters that may affect the distribution of snails.

Field survey revealed that *Eichhornia crassipes; Echinochloa sp.* (Water grass) and *Lemma gibba* were the most dominant aquatic plants and almost they were found in all examined sites, while *Pistia stratiotes* (Water lettuce) confined presence at Giza (site 2). Belonging to the density of aquatic plants in each investigated sites, results showed that the most density of collected plants was recorded at Giza (site 2), Ismailia (sites 3 and 4) and Menoufia (site 6). These results may be attributed to high concentrations of nutrients (nitrate and phosphate ions) that recorded at these sites during the study period. Hence, they considered the simplest form in the structure of the nutrients which can consumed by aquatic plant easily and rapidly. Regarding to the association of the medical important snails and aquatic plants, the present study found that *B. alexandrina* was associated with *E. crassipes* and Water grass. While *B. truncatus* was associated with *E. crassipes*, *L. natalensis* was associated with *E. crassipes* and *L. gibba.* This result is in accordance with El-Khayat *et al. [14]* who found that *B. alexandrina, B. truncatus* and *L. natalensis* snails were accumulated with *E. crassipes* with the highest association percentage. This reflect the important of such plant in life of snail vectors of schistosomiasis and fascioliasis. On the contrary, Hussein *et al*. [22] found that *E. crassipes* and *L. gibba* were positively correlated with *B. truncatus* and *B. alexandrina*, respectively. So, it could be concluded that, aquatic plants help snails to withstand the unfavorable conditions. This is in harmony with findings that considered that, the aquatic vegetation (such as some *Eichhornia* sp. and *Lemna* sp.) consequently, providing shelter and food resource [11]. Also, the present results are in line with the results of Flefel [17] who promulgated that *E. crassipes* and *L. gibba* were the most abundance aquatic plants found in all centers of Kafr El-Sheik governorate, and both of *B. alexandrina* and *B. truncatus* were mostly associated with *E. crassipes.*

Reviewing the above mentioned results of the field study, it could be concluded the important role of the studying of the environmental factors that may affect the distribution and population of snails, where snails exploits each factor to acclimate and resists to continue their life against any pollutants might be found in their habitat.

References

[1] Abdel Malek, E. (1958): Factors conditioning the habitat of bilharziasis intermediate hosts of the family planorbidae, Bull. Wld. Hlth. Org., 18: 785-818.

[2] APHA, (American Public Health Association) (2005): Standard methods for the examination of water and wastewater, 21st ed. AWWA, WPAE, N.Y. Washington.

[3] Ashmawy, K.; Abu-El-Wafa, S. A.; El-Bahi, M. M. and Diab, M. R. (1994): Incidence and ecology of freshwater snails in Beheira province. Assiut. J. Vet. Med., 30(59):101-113.

[4] Azzam, A.M.A. (2008): Environmental factors related to prevalence of the snail intermediate hosts of *Fasciola* in some Egyptian governorates. M.Sc. Thesis Institute of Environmental studies and researches, Ain-Shams Univ., Cairo, Egypt.

[5] Bennett, E. M.; Carpenter, S. R. and Caraco, N. F. (2001): Human impact on erodible phosphorus and eutrophication: a global perspective. Biosci., 51: 227-234.

[6] Berrie, A.D. (1970): Snail problems in Africa schistosomiasis. Advances in parasitol., 8:43-96.

[7] Brown, D.S. (1994): Freshwater snails of Africa and their medical important. Taylor and Francis, London. 2nd edition.

[8] Brown, T. and Simpson, J. (2001): Determining the Trophic State of Your Lake, Watershed Protection Techniques, Urban Lake Management, 3 (4): 771-781.

[9] Cañete, R.; Yong, M.; Sánchez, J.; Wong, L. and Gutiérrez, A. (2004): Population dynamics of intermediate snail hosts of *Fasciola hepatica* and some environmental factors in San Juan Martinez Municipiality, Cuba. Mem. Inst. Oswaldo Cruz, Rio de Janerio, 99 (30): 257-262.

[10] Carlson, R. E. (1977): A trophic state index for lakes, Limnol. Oceanog., 22 (2):361-369.

[11] De souza, M.A.A. and De melo, A.L. (2012): Ecological aspects of *Biomphalaria* in endemic areas for Schistosomiasis in Brazil, schistsomiasis, Prof. Mohamed Bagher Rokni (Ed.), ISBN: 978-953-307-852-6, In. Tech., Available from http://www.Intechopen.com/book/schistosomiasis/ecologicalaspects-of-*Biomphalaria*-in -endemic-areas-for-schistosomiasis-in-Brazil.

[12] El-Emam, M. and Roushdy, M.Z. (1981): Ecological studies on the snail intermediate hosts of schistosomiasis in certain areas in Egypt. J. Bill., 8:75-86.

[13] El-Khayat, H.M.; Ismail, N.M.; Mahmoud, K.M.; Ragb, F.M.; El-Said, K.M.; Mostafa, B.B.; El-Deeb, F.A. and Tantawy, A.A. (2011): Evaluation of some chemical parameters as potential determinants of freshwater snails with special reference to medically important snails in Egypt. World Academy of Science, Engin. and Technol., 59: 1313-1326.

[14] El- Khayat, H.M.M.; Mostafa, B.B.; Mahmoud, K.M.A.; El- Said, K.M. and Ismail, N.M.M. (2009): The association between freshwater snails, macrophytes and water quality in different water courses in Egypt. New Egy. J. Med., 40(5): 381-392.

[15] El-Nahas, H.A. and El-Deeb, F.A. (2002): Molluscicidal and physiological activities of certain pesticides against *Biomphalaria alexandrina* snails. Arab. Uni. J. Agric. Sci. Ain-Shams Univ., Cairo, 10 (1): 417-427.

[16] Fishar, M.R. and Ali, M.H.H. (2006): Accumulation of trace metals in some benthic invertebrate and fish species relevant to their concentration in water and sediment of lake Qarun, Egypt. Egypt. J. Aqua. Res., 31 (1): 289-301.

[17] Flefel, H.E.K. (2014): Environmental studies on transmission of schistosomiasis in some rice farm and fish aquacultures in Kafr El- Sheikh Governorate. M.Sc. Thesis, Fac. Agri., Al-Azhar Univ., Egypt.

[18] Gohar, H.A.F. and El- Gindy, H.I. (1960): The ecology of Egyptian snail vectors of bilharziasis and fasciliasis. II. Chemical factors. J. Proceedings of the Egyptian Acad. Sci., 15: 79-86.

[19] Habib, M.R.A. (2010): Studies on the effect of geographical distribution of *Biomphalaria alexandrina* snails on their susceptibility to *Schistosoma mansoni* infection in some localities in Egypt. M.Sc. Thesis, Fac. Sci., Menoufia. Univ., Egypt.

[20] Hairson, N.G.; Hubenick, B.; Watson, J. M. and Oliver, L. J. (1958): An evaluation of techniques used in establishing snail population. Bull. Wld. Hlth. Org., 19: 661-672.

[21] Hofkin, B.V.; Mkoji, G.M.; Koech, D.K. and Loker, E.S. (1991): Control of schistosome-transmitting snails in Kenya by the North American crayfish *Procambarus clarkii*. Am. J. Trop. Med. Hyg., 45: 339-344.

[22] Hussein, M. A.; Obuid-Allah, A. H.; Mahmoud, A. A. and Fangary, H. M. (2011): Population dynamics of freshwater snails (Mollusca: Gastropoda) at Qena Governorate, Upper Egypt. Egypt. Acad. J. Biol. Sci., 3(1): 11-22.

[23] Ibrahim, A.M.; Bishai, H.M. and Khalil, M.T. (1999): Freshwater molluscs of Egypt. Egyptian Environmental Affairs Agency, National Biodiversity Unit, (10): 145 pp.

[24] Johnson, P.T.J.; Townsend, A.R.; Cleveland, C.C.; Glibert, P.M.; Howarth, R.W.; Mckenzie, V.J.; rejmankova, E. And Ward, M.H. (2010): Linking environmental nutrient enrichment and disease emergence in humans and wildlife. Ecol. Appl., 20(1):16-29.

[25] Kazibwe, F.; Makanga, B.; Rubaire-Akiiki, C.; Ouma, J.; Kariuki, C.; Kabatereine, N. B.; Booth, M.; Vennervald, B. J.; Sturrock, R. F. and Stothard, J. R. (2006): Ecology of *Biomphalaria* (Gastropoda: Planorbidae) in Lake Albert, Western Uganda: snail distribution, infection with schistosomes and temporal associations with environmental dynamics. Hydrobiol., 568: 433-444.

[26] Lafferty, K. D. and Holt, R. D. (2003): How should environmental stress affect the population dynamics of disease? Ecology Letters, 6: 654-664.

[27] Mahmoud, K. A. (1994): The feeding ecology of the snail intermediate hosts of schistosomiasis in Egypt M.Sc. Thesis, Sci. Fac., Cairo Univ., Egypt.

[28] Makela, T.P. and Oikari, A.O.J. (1992): The effects of low water pH on the ionic balance in the freshwater mussel *Anodonta anatina* L. Animal Zool. Fennici., 29: 169-175.

[29] Manahan, S.E. (2007): Environmental science and technology a sustainable approach to green science technology. 2nd edition, Taylor and Francis.

[30] Njoku- Tony, R.F. (2011): Effect of some physicochemical parameters on abundance of intermediate snails of animal trematodes in Imo state, Nigeria. Res., 3 (4): 5-12.

[31] Ntonifor, H.N. and Ajayi, J.A. (2007): Studies on the ecology and distribution of some medically important freshwater snail species in Bauchi state, Nigeria. Int. J. Biol. Chem. Sci., 1(2): 121-127.

[32] Ofoezie, I.E. (1999): Distribution of freshwater snails in the man-made Oyan Reservior, Ogun State, Nigeria. Hydrobiol., 416: 181-191.

[33] Opisa, S.; Odiere, M.R.; Jura, W.G.; Karanja, D.MS. and Mwinzi, P.NM. (2011): Malacological survey and geographical distribution of vector snails for schistosomiasis within informal settlements of Kisumu City, western Kenya. Parasites & Vectors, 4: 226-234.

[34] Owojori, O.J.; Asaolu, S.O. and Ofoezie, I.E. (2006): Ecology of freshwater snails in Opa reservoir and research farm ponds at Obafemi Awolowo University Ile- Ife, Nigeria. J. App. Sci., 6(15): 3004-3015.

[35] Ribaudo, M. and Johansson, R. (2006): Water quality: Impacts of agriculture. In Agricultural resources and environmental indicators: 2006 edition. USDA Economic Research Service. Washington, DC.

[36] Rumi, A. and Hamann, M.I. (1990): Potential schistosome vector snails and associated trematodes in rice fields of corrients province, Argentia. Preliminary results. Mem. Inst. Oswaldo Cruz, Rio de Janeiro, 85(3):321-328.

[37] Saad, A.E.A.; Mostafa, B.B.; El-Magd, S.S.A. and Azzam, A.M.A. (2012): Impact of some environmental factors on distribution of certain vector snails in five Egyptian Governorates. Egypt. J. Aquat. Biol. & Fish., 16 (1):33-40.

[38] SPSS (2013): Statistical Package for the Social Science, Version 17.0.

[39] Stanley, C.D.; Clarke, R.A.; McNeal, B.L. and MacLeod B.W. (2003): Relationship of Chlorophyll a Concentration to Seasonal Water Quality in Lake Manatee, Florida. Publication of the Soil and Water Science Department, Florida Cooperative Extension Service, IFAS, University of Florida. EDIS Website http: //edis.ifas.ufl.edu.7pp.

[40] Supian, Z. and Ikhwanuddin, A.M. (2002): Population dynamics of freshwater molluscs (Gastropod: Melanoides tuberculata) in Crocker Range Park, Sabah. ASEAN Review of Biodiversity and Environmental Conservation (ARBEC).

[41] Tantawy, A.A. (1985): Studies on some chemical fertilizers with special reference to effects on schistosima. M.Sc. Thesis. Agri. Fac., Ain Shams Univ. Cairo, Egypt.

[42] Thomas, J.D.; Powles, M. and Lodge, R. (1976): The chemical ecology of *Biompalaria glabrata*: The effects of ammonia on the growth rate of juvenile snails. Reference Biol. Bull., 151: 386-397.

[43] Virginia WRRC [Water Resources Research Center] (2006): A literature review for use in nutrient criteria development for freshwater stream and rivers in Virginia. Virginia Polytechnic Institute and State Univ., Blacksburg, Virginia.

[44] Wetzel, R.G. (2001): Limnology Lakes and Rivers ecosystems. San Diego Academic press, 1006 pp.

[45] Yipp, M.W. (1983): The ecology of *Biomphalaria straminea* (Dunker,1848) (gastropoda: pulmonata) introduced into Hong Kong. Ph.D, Thesis, Hong Kong Univ., 26 p.

[46] Yirenya- Tawiah, D.R.; Abdul Rashid, A.; Futagbi, G.; Aboagye, I. and Dade, M. (2011): Prevalence of snail vectors of schistosomiasis in the Kpong Head Pond, Ghana. West Afr. J. Appl. Ecol., 18: 39-45.