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Field studies on the protozoan distribution in Damietta and Rosetta branches of the River Nile, Egypt

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ABSTRACT

This study was carried out during a period extending between February 2016 and January 2017 in both Damietta and Rosetta branches of the Nile. Water samples were collected at eight sampling sites; four at Damietta and the others at Rosetta branch so as to detect the variability of the protozoan organisms and evaluate some physico-chemical parameters. It was proved that the protozoan genera of Rosetta branch showed more diverse as compared with those of Damietta one (46 and 35 genera respectively). These organisms were belonging to three main phyla ; *Sarcodina*, *Mastigophora* and *Ciliophora* where the latter predominated the preceding two phyla at the various sampling sites in both river branches. Simultaneously, organic matter, ammonia and nitrates exhibited higher levels in Rosetta than Damietta, while phosphates, dissolved oxygen and p^H behaved in an antagonistic manner at the different seasons. The abundance of the sewage protozoan organisms was higher in Rosetta branch relative to those of Damietta which could be attributed mostly to the illegal runoff of the sewage wastes from certain villages on Rosetta branch that consequently affect oxygen and organic matter contents at these stations. These unicellular organisms were influenced and proved to be statistically significant to a certain limit with water temperature, phosphate salts, ammonia and organic matter.

Key words : Damietta, Nile, Protozoa and Rosetta,

INTRODUCTION

Protozoa are important integral components of the aquatic ecosystems and are considered as good indicators of the water quality (Antipa, 1977; Henebry and Cairns, 1980; Galal, 1989) where these organisms seem to help indirectly in purifying and enhancing water via its influence on the vitality of the beneficial bacterial populations and consequently on the biological oxidation of different waste materials. Adding to that, protozoan dynamics were studied extensively in different rivers throughout the world (Madoni, 1979; Foisner, 1980; Galal, 1993, 2000; Galal and Authman, 1994; Galal and Gaber 2002; El-Bassat, 2002; Szentivany and Tirjakova, 1994).

Protozoan diversity in a fish pond in Nigeria was followed up by Absalom *et al.* (2002) and the trophic levels and growth rates of ciliated protozoa in East Africa were investigated by Yasindi and Taylor (2006). Protozooplankton played a major role in the transferee of energy through the food chain. Zooplankton communities in rivers are not controlled solely by abiotic or biotic factors but by a combination of both as suggested by Pace *et al.* (1992) and Galal *et al.* (2008). Taylor (1982) believed that heterotrophic protists enhance nutrient cycling, stimulate bacterial growth and provide a nutritional link between bacteria and zooplankton, acting to keep energy and nutrients available and passing them up the food chain.

MATERIALS AND METHODS

The present study was carried out at various stations in both Damietta and Rosetta branches of the Nile passing through different towns (Benha, Kafr-shukr, Meet-ghamr and Talkha in the former branch beside Tamalie, Nader, Danasour and Amroose in the latter one).

These stations were chosen to follow up distribution and diversity of the protozoan organisms. Water samples were collected monthly using a transparent sampler (1.2 L) in order to pick up the different protozoan organisms and to measure some of the physical and chemical parameters at these sampling sites.

Water temperature, p^H and dissolved oxygen were measured by using Cole-Parmer's oxygen and p^H meters, while nitrates, phosphates, ammonia and organic matter were quantified by methods adopted by APHA (1999).

Protozoa were sedimented at 7^oC, examined, counted via Carl-Zeiss Jena transmitted-light inverted microscope (Galal, 1989) and they were identified according to Bick (1972) and Patterson and Hedley (1992).

RESULTS

Water samples of the different sampling stations belonging to these branches illustrated the presence of three main protozoan phyla; *Sarcodina, Mastigophora* and *Ciliophora.* The latter phylum predominates the other two during different seasons at the various examined locations. It was proved that a total of 46 protozoan genera (six flagellate, two amoeboid and a total of 38 ciliated genera were detected in Rosetta branch, while those of Damietta achieved 35 genera (four sarcodines, two flagellates and 29 ciliated genera respectively) as could be seen in table. Accordingly, it was generally illustrated that more sarcodine and low phytomastigophorean genera are present at Damietta sampling stations as compared with those of Rosetta branch (Table 1a).

On the other hand, from the nutritive point of view, bacterial-feeding protozoa are more abundant in Rosetta stations as compared with those of Damietta ones, while the other types (carnivores, omnivores and algaevores) were more or less similar to each other throughout the time course of this study in both branches as shown in Table (1b).

Having a glance to Table (2), it appears that the highest numerical densities of the protozoan genera were obtained during autumn at the different sampling stations belonging to these Nile branches, while those of the lowest ones were collected during winter.

The monthly numerical densities of the total protozoan organisms and the values of the physico-chemical parameters at Damietta and Rosetta branches can be seen in figures 1 and 2 according to the time series analysis. At the same time table (2) exhibited that the dissolved oxygen, phosphate salts, and p^H values were higher in Damietta branch as compared with those of Rosetta one, while organic matter, water temperatures, nitrates and ammonia belonging to Rosetta sampling stations exceed those of the other branch.

From the seasonal point of view, it was found that the highest p^H, phosphate and ammonia levels beside the lowest values of water temperature, organic matter and protozoan densities were obtained during Winter in Damietta stations. On the other hand, the relative values of Rosetta branch behaved irregularly during various seasons which could be interpreted as a result of the level of pollution mainly of organic origin. Having a glance to Figure (3), it was obvious that the seasonal numerical densities of phytomastigophorean protozoa belonging to Damietta branch were higher than those of Rosetta, while those belonging to *Sarcodina* and *Ciliophora* showed an antagonistic behaviour.

It is necessary to keep in mind that ciliates are the most representative protozoan organisms used as bio-indicators for sewage pollution. Simultaneously, it was found also in the present study that the sewage-indicating ciliophoran protozoa (*Metopus, Saprodinium, Pelodinium, Discomorphella, Epistylis, Carchesium, Platycola, Opercularia and Vaginicola* sp.) in Rosetta branch predominated those of Damietta one.

The protozoan growth rates were calculated by the application of Taylor's equation (1978). Regarding the seasonal growth rates of the total protozoa, it was proved that samples of Damietta branch have the highest values during Spring as compared with those of Rosetta.

On the other hand, the protozoan growth rates of Rosetta were higher than those of Damietta throughout the rest of the seasons (Summer, Autumn and Winter) which could be seen in Table (4). It is worthy to mention that the seasonal growth rates exhibited positive values throughout the various seasons except that of Winter. Simultaneously, it was exhibited also that the annual growth rate of the total protozoan organisms in Damietta samples (2.02 10^{-3}) is higher than that of Rosetta branch (1.84 10^{-3}) which could be referred generally to the less polluted condition of the former site.

The relationships between different combinations of certain ecological parameters and the numerical densities of total protozoa were examined through simple and multiple regression analyses which gave an indication that water temperature, phosphate and ammonia affect strongly and significantly the protozoan densities in Damietta water samples, while temperature, ammonia and organic materials influence protozoan densities in stations of Rosetta branch as could be seen in Table (3). Accordingly, it was proved that the combination of these parameters affect significantly the availability of these important unicellular organisms.

DISCUSSION

Aquatic ecosystems are more subjected to different types of pollution than terrestrial environments since water is widely used in industrial, urban and agricultural activities and consequently their effluents are deposited in rivers, streams, lakes, seas and oceans. The majority of these ecosystems can cope with the pollution level and generally severe pollution is reflected with a change in faunal and floral communities as a result of creating hypoxic and/or anoxic ecological condition.

Protozoa is the most abundant group among the other plankton groups which could be referred mainly to its higher reproductive rates. The insignificant variations in case of water temperature within each season at the different sampling stations at both Rosetta and Damietta branches of the Nile might be attributed to the moderate water current and to the slight variations in the sampling time which is parallel to the data obtained by Foissner (1980). On the other hand, the organic matter concentrations, the dissolved oxygen, nitrate and phosphate contents showed quite variations between those of various sampling stations at Rosetta and Damietta branches. This could be referred mainly to the illegal discharge of certain pollutants as fertilizers (particularly phosphates and nitrates) which drained finally in the Nile and also due to the release of organic orthophosphates and ammonia-free amino acids as excretory products by various plankton mainly protozoa. The behaviour of the previous factors are parallel to that found by Aboul-Ela *et al*. (1990). It was proved that the dynamics of the protozoan organisms in rivers are similar to those of the other fluvial ecosystems (Cairns, 1966; Madoni, 1979; Foissner, 1980) in having great changes which could be referred to flow variations as well as vigorous chemical changes of the habitat which are caused by the heterogeneity of the received wastes. According to Laybourn (1984), protozoa could be used as indicators of different levels of pollution through investigating their diversity in a community.

It was found that both Nile branches are characterized by an intensive agricultural activity with particular reference to Rosetta one and consequently the presence of high levels of different pollutants (mainly of organic nature). The varying densities of various protozoa at different sampling stations might be referred to: a) The illegal runoff of agricultural and sewage wastes from neighbouring villages that consequently affect the oxygen demand in these stations particularly in Rosetta stations. b) The topography of Rosetta city and its surrounding urban places on the western bank of the Nile is located on an elevated land which orientated with moderate slope towards the eastern edge of the town near the Nile. This situation caused severe problems with the sanitary drainage, as the town lacks a good sanitary drainage system, where the sewage congregates beneath the ground forming continuous streams which cause immense contamination in both underground and river water (personal communication with Geology Dept.) and accordingly it was recognizable that Rosetta branch had more pollution level than Damietta one. It was proved that water with a low organic matter have a low species diversity (a low number of species) and a low proportion of the bacterial feeding protozoa as mentioned by Szentivany and Tirjakova (1994).

According to Laybourn (1984) it was proved that when water temperature and food supply decrease, the growth rate quickly slows down whereas the reproductive rate responds more slowly. Although many protozoan organisms have the ability to exercise some control and compensation over their metabolic rates, the temperature regimes experienced in the habitat occupied by an organism have a great influence on almost all the physiological activities. As the majority of protozoa are aquatic they live in a medium which undergoes gradual variations in temperature throughout the annual seasonal cycle. Simultaneously, the response of protozoa to both temperature and food supply were proved to be variable and hence growth and reproduction rates could not be expected perfectly.

It was not easy to detect a significant relationship between the protozoan densities and some of physico-chemical factors in most of the examined sampling stations. However, the combined impact of various physical and chemical parameters against the numerical densities of total protozoa proved that water temperature, phosphates, ammonia and organic matter, in the present study, affect significantly to varying levels on both abundance and distribution of the protozoan organisms which is parallel to the findings of Laybourn (1976), Rogerson (1981), Andronikova (1996) and Marneffe *et al.* (1996). Water temperature was proved to be the most influencing factor on protozoan densities at the examined sampling stations at both Rosetta ($P = 0.007$) and Damietta ($P < 0.001$) branches of the Nile.

Protozoa perform different ecological roles in various ecosystems particularly the aquatic one. These organisms provide a source of energy to carnivorous micro-, meio- and macrofauna and enhance the decomposition processes. Regarding the energy transfer between trophic levels, their feeding rates especially among bacterial-feeding protozoa and their relative high assimilation and production efficiencies make them a very important component of the ecosystems in which live particularly the most dominant ones among the other microfaunal communities.

Conclusions:

1- Sewage pollution was higher in Rosetta which is concomitant with the high organic matter levels and low dissolved Oxygen levels. Simultaneously, nitrate salts are higher in Rosetta branch which could be mostly referred to the widely use of nitrate fertilizers, while phosphates were dominated in Damietta stations (personal communication with representatives of some agricultural authorities). Also, the presence of high levels of ammonia is an indication to the exaggerated sewage pollution in Rosetta branch passing throughout El-Menofeyia province beside the metabolic products of nitrogenous compounds oxidation in both branches of the Nile.
2- The presence of higher numerical densities of protozoa in Rosetta could be interpreted as a result of an elevation of the nutritive material with particular reference to the organic nutritive matter.
3- The higher numerical densities of bacterial feeder protozoa in Rosetta branch is concomitant with the abnormal high pollution levels.

Table (1a) Different protozoan genera at Damietta and Rosetta branches of the Nile.

Rosetta branch at El-Menofeyia Province (46 genera)	Damietta branch at Kalubeyia and Dakhleyia Provinces (35 genera)
Sarcodina ***Amoeba sp.*** and ***Actinophora spp.*** **Mastigophora** ***Euglena, Phacus, Volvox, Gonium, Chlamydomonas*** and ***Ceratium spp.*** **Ciliophora** ***Paramecium, Cinetochilum, Cyclidium, Colpidium, Urocentrum, Stentor, Metopus, Colpoda, Spirostomum, Plagiopyla, Chilodonella, Lacrymaria, Strombilidium, Strombidium, Urotricha, Litonotus, Amphileptus, Dileptus, Spathidium, Euplotes, Frontonia, Oxytricha, Urostyla, Uroleptus,*** Opercularia, ***Vorticella spp,Trichodina, Carchesium, Coleps, Loxodes, Epistylis, Halteria, Saprodinium, Ophridium, Discomorphella, Glaucoma spp.***, ***Vaginicola*** and ***Platycola***.	**Sarcodina** ***Arcella***, ***Centropyxis***, ***Difflugia, and Actinosphaerium spp.*** **Mastigophora** ***Euglena and Phacus spp.*** **Ciliophora** ***Vorticella, Acanthocystis Codonella, Stentor, Podophyra, Scyphidia, Coleps, Strobilidium, Dileptus, Askenasia, Tokophrya, Acineta, Stylonychia, Aspidisca, Metopus, Cothurina, stokesia, Carchesium, Epistylis,Vaginicola, Trichodina, Cyphoderia, Euplotes, Opercularia, Discomorphella, Paradileptus, Strombidium, Colpidium*** and ***Cyclidium*** spp.

Table (1b) Different protozoan genera at Damietta and Rosetta branches of the Nile according to their feeding type. Extracted from Bick (1972).

Bacterivores (22)		Carnivores (15)		Mixed feeding (10) (Bacteria, algae & flagellates)
Actinophora sp.	*Metopus sp*	*Coleps hirtus*	*Spathidium sp.*	*Urotricha sp.*
Colpoda spp.	*Plagiopyla sp.*	*Lacrymaria sp.*	*Litonotus spp.*	*Chilodonella spp.*
Trimyema sp.	*Paramecium spp.*	*Hemiophrys spp.*	*Amphileptus sp.*	*Colpidium spp.*
Cinetochilum sp.	*Cyclidium spp.*	*Acineria sp.*	*Didinium sp.*	*Paramecium bursaria (symbiont)*
Ophrydium spp.	*Vorticella spp.*	*Trachelius sp.*	*Dileptus sp.*	*Stentor spp.*
Carchesium sp.	*Epistylis sp.*	*Frontonia sp.*	*Podophrya sp.*	*Strmbidium sp*
Opercularia spp.	*Vaginicola sp.*	*Euplotes sp.*	*Stylonychia sp.*	*Spirostomum sp.(mixotrophic)*
Platycola sp.	*Halteria sp.*	*Gastrostyla sp.*		*Urostyla sp.*
Aspidisca spp.	*Urocentrum sp.*			*Oxytricha spp.*
Glaucoma sp.	*Saprodinium sp*.*			*Tachysoma spp.*
*Discomorphella sp.**	*Pelodinium sp.**			

***Feed on Sulphur bacteria**

Table (2). Averge values of certain physico-chemical parameters at Damietta and Rosetta branches of the River Nile.

Season		Temp. °C	P^H	DO (mg/l)	PO_4 (mg/l)	NO_3 (mg/l)	NH_3 (mg/l)	OM (mg/l)	Protozoa (10^3/L)
Win.	Dam.	17.2	7.9	7.7	96.5	30.4	0.17	17.3	21.0
	Ros.	18.3	7.7	4.3	41.8	53.4	0.38	36.8	41.2
Spr.	Dam.	21.0	7.8	8.5	65.3	32.3	0.09	18.0	34.1
	Ros.	19.8	7.5	5.1	44.2	51.4	0.19	43.1	58.7
Sum.	Dam.	29.3	7.6	6.6	73.9	40.6	0.04	19	39.5
	Ros.	26.7	7.4	3.2	53.9	57.6	0.27	34.7	74.8
Aut.	Dam.	25.3	7.5	6.6	60.1	31.7	0.08	19.9	43.4
	Ros.	25.6	7.5	3.9	45.3	60.4	0.29	38.7	79.8

Table (3). Summary of the significant relationship between numerical densities of total protozoa and some of the physico-chemical parameters in Damietta and Rosetta branches of the Nile.

Parameters	A	DF	F	P
Damietta				
T. Protoz. Vs Temp.	-0.65	1,11	11.5	0.007
Vs Phos.	50.1	1,11	4.9	0.05
Vs NH_3	19.0	1,11	6.25	0.031
Vs Temp, posp & NH_3	16.4	3,11	4.8	0.033
Vs all examined factors	174	7,11	5.8	0.054
Rosetta				
T.Protoz. Vs Temp.	22.2	1,11	58.5	<0.001
Vs NH_3	25.4	1,11	18.03	0.002
Vs OM	-40.8	1,11	8.99	0.013
Vs Temp, NH_3 & OM	-35.1	3,11	20.1	<0.001
Vs all examined factors	60.0	7,11	7.65	0.034

Table (4). Seasonal and annual growth rates (/day) of the total protozoa in Damietta and Rosetta branches of the Nile.

Season	Damietta branch	Rosetta branch
Spring	5.44 10^{-3}	3.89 10^{-3}
Summer	1.67 10^{-3}	2.78 10^{-3}
Autumn	1.22 10^{-3}	0.017
Winter	- 0.111	- 0.024
Annual growth rate	2.02 10^{-3}	1.84 10^{-3}

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Figure (1) Total protozoa and physico-chemical parameters in sampling stations of Damietta branch of the Nile.

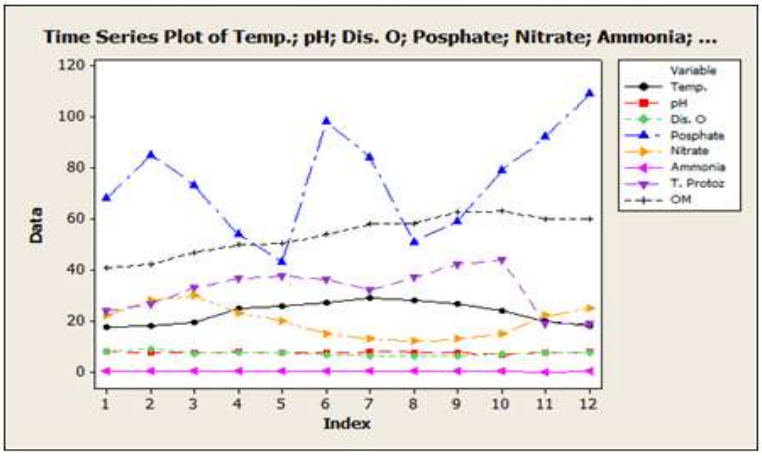


Figure (2) Total protozoa and physico-chemical parameters in sampling stations of Rosetta branch of the Nile.

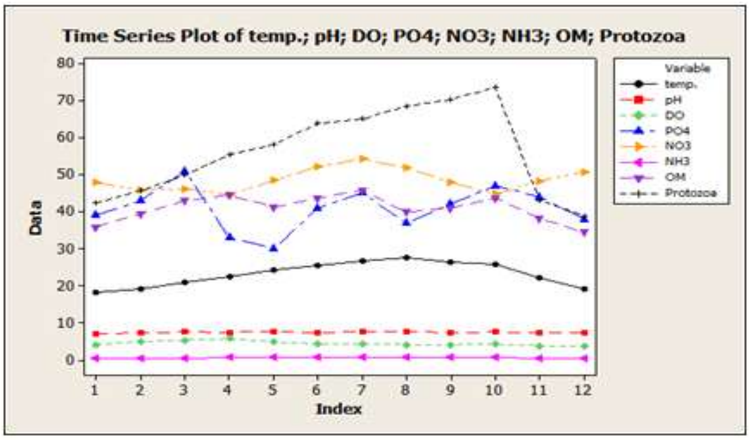
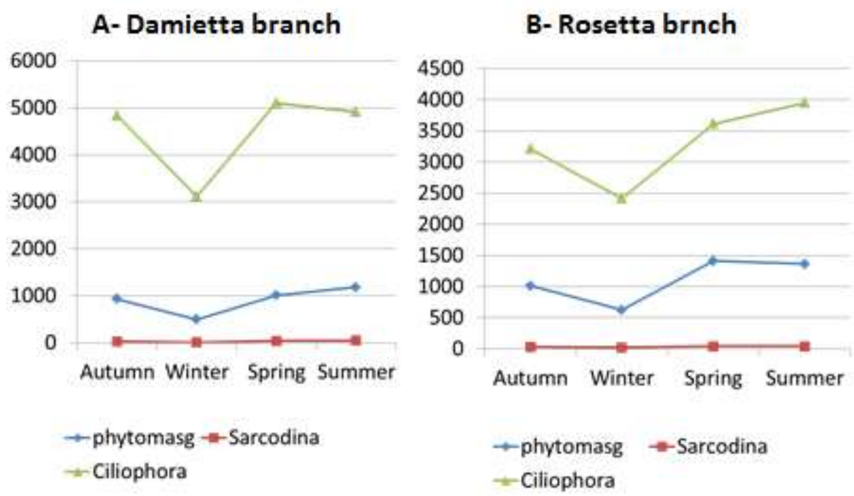


Figure (3) Seasonal abundance of different phylla of protozoa in Damietta and Rosetta branches of the Nile.



REFERENCES

Antipa, G.A. (1977). Use of commensal protozoa as biological indicator of water quality and pollution. Trans. Amer. Micros. Soc., 96: 482 – 489.

Aboul Ela, T.A.; Fayed, S.E. and Ghazy, M.M. (1990). Zooplankton as parameter of pollution of the Nile water in Egypt. Proc. Zool. Soc. A.R.Egypt, 21: 203-217.

Absalom, K.V.; Musa, S.O.; Akpa, L.E. and Oyindshola, A. (2002). Protozoan diversity in a reproductive fishpond of a tropical plateau. J. Aquat. Sci., 17 (2): 109-112.

Andronikova, I.N. (1996). Zooplankton characteristics in monitoring of lake Ladoga. Hydrobiologia, 322: 173-179.

APHA (American Public Health Association) (1999). Standard methods for the examination of water and wastewater. Green berg, A.E; Clesceri,L.S. and Eatan, A.D. (editors) APHA, WFF and AWWA, Washington D.C.

Bick, H. (1972). Ciliated Protozoa : An illustrated guide to the species used as biological indicator in freshwater biology. W.H.O. Geneva, Switzerland.

Cairns, J. (1966). The Protozoa of the Potomac River from point of rocks to whites ferry. Notul. Nat., 387: 1- 11.

El-Bassat, R. (2002). Ecological studies on zoplankton communities with particular refernce to free-living Protozoa at Damietta Branch. Ph.D. Thesis, Ain-Shams Univ.

Foissner, W. (1980). Colpodide Ciliaten aus alpinen Boden Zool. Jb. Syst., 107: 391-432.

Galal, M. (1989). Ecological studies on the ciliate and bacterial populations of slow sand filters. Ph. D. Thesis, Univ. of London.

Galal, M. (1993). A study of protozoan diversity, in the River Nil;e at Benha, Kalubeyia, Egypt with particular reference to ciliates. J.Egypt. Ger. Soc. Zool., 20 (D): 27 – 42.

Galal, M. (2000). population densities, growth and filtering rates of certain bacteria feeding hymenostome ciliates at three different water bodies. Egyp.J.Aquat.Biol. & Fish., 4(3):251–270.

Galal, M. and Authman, M.N (1994).The population densities and the growth rates of the most common Holotrichs and Spirotrichs in the River Nile at Benha, Kalubeyia, Egypt. J. Egypt.Ger.Soc. Zool.13 D: 207 – 218.

Galal, M. and Gaber, N. (2002). Population densities of protozooplankton and their response to certain factors in the River Nile in El-Menofeyia province, Egypt. J. Egypt. Ger. Soc. Zool., 38 (D): 1 – 14.

Galal, M.; Khallaf, E. and El-Sehemy, M. (2008). Protozoan diversity at Bahr-Shebeen and Al-Atf canals in El-Menofeyia Province. Mansoura J. Biol., 35 (2): 91-108.

Henebry, M.S. and cairns, J. (1980). Monitoring of stream pollution using protozoan communities on artificial substrates. Trans. Am. Micro. Soc., 99: 151 – 160.

Laybourn-Parry, J. (1976). Energy budgets for *Stentor coeruleus* Ehrenberg. Oecologia (berlin), 22: 431-437.

Laybourn-Parry, J. (1984). A functional biology of free-living Protozoa. Croom Helm Ltd., London and Sydney.

Madoni, P. (1979). The Ciliated Protozoa in Torrente Parma, Torrente Silvestri & Fiume Po, Biol. Water Assessment Methods (Ed. by Ghetti) Comission of the European Communities: 295 - 312.

Marneffe,Y; Descy, J.P. and Thome, J.P. (1996). The zooplankton of the lower river Meuse, Belgiumi seasonal changes and import of industrial and municipal discharges. Hydrobiologia, 319: 1-13.

Pace, M.L.; Findlay, S.E.G. and Lints, D.(1992). Zooplankton in advective environments: The Hudson River community and a comparative analysis. Can. J. Fish. Aquat. Sci., 49: 1059-1069.

Patterson, D.J. and Hedely, S. (1992). Free-Living freshwater Protozoa. A colour guide. Wolfe publishing Ltd. England.
Rogerson, A. (1981).The ecological energetics of *Amoeba proteus* (Leidy) as influenced by temperature and food concentration. Can. J. Zool., 56: 543– 548.
Szentivany, M. and Tirjakova, E. (1994). The structure and dynamics of the community of Ciliophora in the benthos of the Karlova Ves (Bratislava) branch of the Danube.Acta.
Taylor, W.D. (1978). Growth responses of ciliate Protozoa to the abundance of their bacterial prey. Microbial Ecol., 4: 207 – 214.
Taylor, G.T. (1982). The role of pelagic heterotrophic Protozoa in nutrient cycling-a review. Ann. De Institute Oceanographique, Paris, 58: 227-242.
Yasindi, A.W. and Taylor, W. (2006). The trophic position of planktonic ciliate populations on the food webs of some East African lakes. Afr. J. Aquat. Sci., 31 (1): 53-62.

دراسات حقلية على توزيع الأوليات فى فرعى دمياط ورشيد بنهر النيل بمصر

منصور جلال
قسم علم الحيوان - كلية العلوم – جامعة المنوفية

اجريت هذه الدراسة فى الفترة من فبراير 2016 وحتى يناير 2017 للوقوف على طبيعة التغيرات النوعية والعددية للكائنات الأولية وتأثرها بالعوامل البيئية فيزيقية كانت أو كيميائية بفرعى دمياط و رشيد بنهر النيل. ولقد وجد أن تلك الكائنات تكون أكثر تنوعاً وكثافة عددية فى معظم المحطات المختلفة بفرع رشيد مع الأخذ فى الاعتبار أن هذا الفرع اكثر ازدهاراً فى النشاط الزراعى وكذلك فى معدل التلوث خاصة الـتلوث بمياه الصرف الصحى . ولقد ثبت أن قيم بعض العوامل البيئية تكون اكثر ارتفاعاً فى فرع دمياط ، بينما يكون البعض الآخر أعلى فى فرع رشيد ويمكن إرجاع ذلك إلى طبيعة وكمية بعض العناصر التى تتخذ كغذاء لكثير من هذه الكائنات والتى تتمثل فى صورة مواد عضوية ونيتروجينية وفوسفاتية. ولقد اتضح أهمية درجة الحرارة و بعض المغذيات فى ازدهار تلك الكائنات ولقد تأكد ذلك احصائياً من التأثير المعنوى الملموس لكل من درجة حرارة الماء والفوسفات والمواد العضوية على تنوع وكثافة الاعداد لتلك الكائنات وحيدة الخلية.