GAMAL M. EL SHABRAWY[1], G. BELMONTE[2]

[1] National Institute of Oceanography & Fisheries
Fish Research Station, El Kanater El Khyria Cairo Egypt
[2]Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali
Università degli Studi di Lecce (Italy)

ABUNDANCE AND AFFIRMATION OF *PARACARTIA LATISETOSA* (COPEPODA, CALANOIDA) IN THE INLAND LAKE QARUN (EGYPT)

RIASSUNTO

La presenza del copepode calanoide *Paracartia latisetosa* (Kriczaguin, 1873) è sempre più abbondante nel lago Qarun, 85 Km a Sud Est del Cairo, nella depressione di El Fayoum, nonostante l'aumento progressivo di salinità delle sue acque, fin da quando fu introdotto (accidentalmente) nel corso di programmi di semina di avannotti provenienti dall'area costiera marina di Alessandria.
Le dimensioni delle popolazioni di copepoditi (documentata a partire dal 1958) non pare correlata, per esame dei dati storici e per quanto è risultato nella presente indagine, alla salinità o alla temperatura, ma probabilmente dipende dal successo del reclutamento naupliare che, a sua volta, molto pare correlato con la concentrazione del fitoplancton e dall'assenza di competitori efficaci (a favore) e dalla presenza di avannotti di mugilidi (a sfavore), attivi predatori di questo stadio precoce.

INTRODUCTION

The Acartiidae copepod *Paracartia latisetosa* (Kriczaguin, 1873) has been found in many sites of the Ponto Mediterranean Province (BELMONTE, 1992; BELMONTE e POTENZA, 2001) where it prefers confined environments independently from the salinity (from 10 ‰ in the Azov Sea up to 50‰ salinity in Bitter lakes of Suez Canal).
The species is considered an anti-Lessepsian migrant (FOX, 1927). The only extra-Mediterranean records of this species came from Mauritania (ROSE, 1933) and Madagascar (DUSSART, 1989).
In confined environments *P. latisetosa* is generally abundant, being a typical representative of the family Acartiidae, which generally is the dominant component of zooplankton (YOUNGBLUTH, 1980; CASTEL e COURTIES, 1982). Lake Qarun

(about 200 Km from the marine coastline) is the more isolated site where *P. lati - setosa* has been recorded from.
Lake Qarun is a saline ecosystem remnant of an ancient historical lake (Moeris) supplied by Nile waters from its formation (about 1980 b.C.) to the Ptolemaic period (323-246 b.C.).
The lake today lies in the western desert, about 85 km southwest of Cairo (Egypt), in El-Fayoum depression, without any direct connection with the river Nile. Its abiotic features varied in the last century, consequently affecting the biotic component in it. The gradual increase of the water salinity lead to disappearance of the some fish species with low halotollerance (*Latus niloticus, Claries anguillaris, Labeo niloticus, Barbas benni,* and *Oreochromus niloticus*). The commercial fishery consequently dropped from 4,000 tons in 1920 to an average of 1,500 tons in the successive years (EL-ZARKA, 1968). To compensate for the loss of fish, the lake was periodically stocked with fish fry of coastal, brackish water origin, as mullets (*Mugil cephalus, Liza ramada,* and *Liza saliens*), and *Solea aegyptiaca.* The copepod *Paracartia latisetosa* was probably introduced to lake Qarun in consequence of this restocking process carried out with marine fish fry from the Alexandria area (Mediterranean) since 1928. In fact WIMPENNY e TITTERINGTON (1936) reported that the zooplankton of the oligohaline lake Qarun consisted mainly of brackish water species, at that time dominated by *Diaptomus salinus* (Copepoda) and *Moina salinarum* (Cladocera). NAGUIB (1958) and GRIGIS (1959), twenty years after, noticed that there was no more evidence of *D. salinus* and *M. salinarum,* while the marine neritic copepod *P. latisetosa* was detected in high numbers. BOULOS (1960) stated that the permanent zooplankton in lake Qarun was composed mainly of copepods (*P. latisetosa*) and Protozoa. DOWIDAR (1981) reported *P. latisetosa* as dominant (about 88.4% of the total zooplankton annual mean). He added that this species was highly abundant in spring, common in summer and autumn and rarely appeared in winter. On the contrary, AHMED (1994) recorded the highest standing crop of this species (2,500 specimens/m^{-3}) in winter and the lowest yield in summer (825 specimens/m^{-3}).
The aim of the present study is to confirm the presence and the seasonality of the *Paracartia latisetosa* population in the lake Qarun studying different years (1994,1995 and 1999-2000) to understand its environmental exigencies.

MATERIALAND METHODS

Zooplankton samples were collected seasonally from 9 pelagic stations in the Lake Qarun (between longitudes 30° 29’ and 30° 49’ E, and latitude of 29° 24’ and 29° 33’N) during 1994, 1995 and 1999-2000 (Fig. 1).

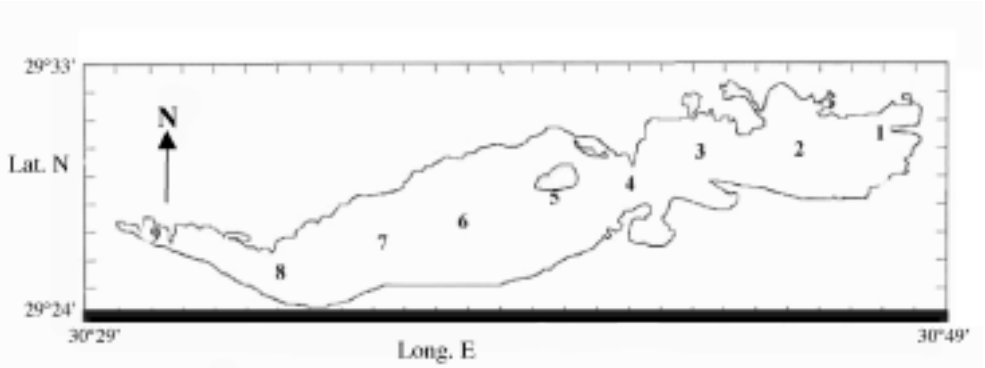

Fig. 1

Qarun is an inland closed basin, whose surface lies at 46 m under the mean sea level, with an area of about 234 km^2. The major axis extends for about 40 km from East to West and had a maximum breadth of 9.25 km in the western part, at level of El-Karn Island. The western part of the lake is relatively deeper than the eastern ones. The maximum depth reaches about 9 m on the North of El-Karn Island. More than 76 % of the lake area has a depth ranging between 2 and 5 m, while only 18 % of its area has a depth ranging from 5 to 9 m. The lake receives only agriculture drainage water, mainly through El-Bats and El-Wadi drains. About 360 millions m^3 of water come annually into the lake with an average of 430,000 t of salts, (MESHAL, 1973). The incoming of drainage water into the lake is nearly equal to the water loss by evaporation. Consequently, the water salinity increases with time, being 45.31 ‰ in 1996 (ANONIMOUS, 1997). A plankton net of 55 µm mesh size and a mouth diameter of 30 cm was used for collection. At each station the net was vertically hauled from the bottom to the surface at a uniformly slow speed, filtering from 0.15 to 0.35 m^3 of water. Zooplankton samples were preserved in 4% formaline. In the laboratory sub-samples were used for counting, under a compound microscope (100 X). Calanoid specimens were separated in nauplii, copepodids, and adults. The data were expressed as specimens/m^{-3}. GOPHEN (1973) method was used for species biomass calculation. Environmental factors (Water Temperature, Dissolved Oxygen, pH, NO_2, NO_3, PO_4, Chl-a, productivity, and total phytoplankton) were recorded at each station (Tab. 1). Canonical Correspondence Analysis (MUSP version 3 Lab. 1985-1999 Kovach Computing Services) was used to investigate the importance of environmental factors on the population structure of dominant species.

1994-95 Anon (1997); 1999-2000 Hamdy (pers. Comm.)

Years	**1994 - 95**	**1999 - 2000**
Water Temperature °C min - max	17,7 - 31	15,0 - 32,7
Salinity ‰ min - max	36,5 - 42,7	39,6 - 47,3
Secchi depth cm	44,3 - 94,0	35,6 - 82,5
pH	8,14 - 8,48	7,7 - 8,8
NO_3 $ug.L^{-1}$	52,1 - 159,9	35,3 - 252,8
NO_2 $ug.L^{-1}$	2,82 - 12,65	0,8 - 46,2
NH_3 $ug.L^{-1}$	43,6 - 124,3	80 - 1080
PO_4 $ug.L^{-1}$	15,6 - 43,4	40,8 - 189,9
DO $mg.L^{-1}$	5,9 - 11,1	5,2 - 10,4
Total phytoplankton (No.of cell x 10^{-3}L)	1771	*
Chlorophyl-a ($ug.L^{-1}$)	11,6	*
Productivity $mgC.ha^{-1}$	34,2 - 218	*

* not available

Tab. 1: Abiotic and Biotic Variables from lake Qarun.

RESULTS

Paracartia latisetosa was the only calanoid and the dominant species of the mesozooplankton in the lake Qarun (Tab. 2A). Other copepods were *Canuella* sp. (a frequently recorded harpacticoid), and *Apocyclops panamensis* (one rarely occurred cyclopoid), which is here reported for the first time from lake Qarun. Copepod nauplii were the most abundant items, since they contributed up to 81.9 % of the total number of Copepoda, followed by copepodids (up to 12.3 %), and adults (up to 10.8 %).

The population density of copepods ranged an average standing crop of 32,164 specimens m^{-3} in 1994, decreased to 27,464 specimens m^{-3} in 1995, and re-increased to 48,454 specimens m^{-3} in 1999-2000. The magnitude of the copepod standing crop attained its highest density of 145,000 specimens m^{-3} at the eastern-most area (station 1) in spring 1999-2000. This was mainly due to the flourishing of the nauplii. On the other hand the lowest yield of 3,000 specimens m^{-3} was recorded at the middle of the lake (station, 6) in autumn, 1995. The population revealed a different seasonal variation during the different years. It was well represented during winter and summer in 1994, while the highest peak occurred

Tab. 2a: numerical presence of Copepoda (Ind. m^3) in lake Garun

year	1994					1998					1999-2002				
	winter	spring	summer	autumn	aver.	winter	spring	summer	autumn	aver.	winter	spring	summer	autumn	aver.
Naupli	35778	17203	28633	22422	26009	26178	27333	19667	11444	20906	25126	35333	66778	29444	39920
Calanoid copepodids	1767	2884	2866	2844	2913	1544	10778	444	889	3414	4750	444	3111	15000	6826
Cyclopoid copepodids	0	229	0	0	57	0	0	0	0	0	0	0	0	111	28
Paracyclops fimbriatus, ad.	2089	3448	2344	3089	2742	2122	8222	444	1000	2947	3625	111	2222	3222	2295
Apocyclops panamensis	0	36	0	0	10	0	0	111	0	28	0	0	0	0	0
Canuella sp.	1111	25	300	1600	794	122	333	111	111	169	0	0	778	1000	445
subtotal	40745	23822	34243	29956	32184	29966	46666	19777	13444	27463	33500	35888	71888	48777	47614

Tab. 2a: biomass of Copepoda (mg wet wt.m^3) in lake Garun

year	1994					1998					1999-2002				
	winter	spring	summer	autumn	aver.	winter	spring	summer	autumn	aver.	winter	spring	summer	autumn	aver.
Naupli	22,18	10,67	17,75	13,91	16,13	16,23	16,95	11,57	7,11	12,97	15,58	21,91	40,76	18,26	24,13
Calanoid copepodids	6,24	10,18	10,47	10,04	9,23	5,45	38,05	1,57	3,11	12,05	16,77	1,57	10,96	52,95	20,57
Cyclopoid copepodids	0	0,65	0	0	0,16	0	0	0	0	0,00	0	0	0	0,32	0,09
Paracyclops fimbriatus ad.	43,26	71,37	48,54	63,97	56,79	43,95	170,29	9,2	20,71	61,04	75,07	2,3	46,02	68,03	48,11
Apocyclops panamensis	0	0,14	0	0	0,04	0	0	0,42	0	0,11	0	0	0	0	0,00
Canuella sp.	0,33	0,08	0,9	4,52	1,46	0,47	1	0,33	0,33	0,53	0	0	2,34	3,01	1,34
subtotal	72,01	93,09	77,66	92,44	83,80	66,1	226,29	23,09	31,26	86,68	107,42	25,78	100,12	143,57	94,22

in spring, in 1995 and 1999-2000, (Fig 2). Nauplii exhibit more or less similar trends, while copepodids revealed a different trend. The biomass of these organisms was directly proportional to its numbers except in 1995, when the relatively low standing crop with a relatively high biomass occurred. This was mainly dued to the increased percentage of adults in spring.

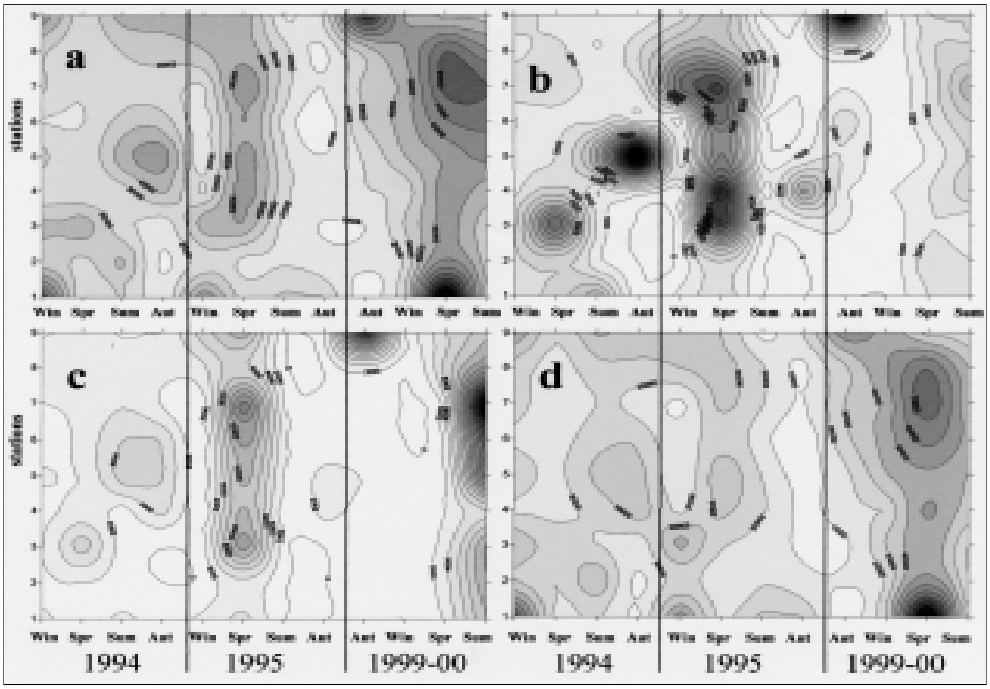

Fig. 2 - Space Distribution and seasonality of the abundance of copepods in lake Qarun.
a) Total copepods; b) *Paracartia latisetosa*, adults; c) total copepodids; d) total nauplii.

P. latisetosa dominated adult copepods, being from 78.1 to 93.7 % of their total numbers. The maximum population density (lake aver. 8,222 specimens m^{-3}) occurred in spring 1995, while the species was faintly represented or even absent from the majority of stations during summer 1995 and winter 1999-2000.Regarding spatial distribution, two major peaks of 19,500 and 18,000 specimens/m^3 were recorded at stations 5 and 9 during autumn 1994 and 1999-2000, respectively. *Paracartia latisetosa* was well represented at the middle and western parts of the Lake.
The biomasses of this species was highly correlated with numbers (Table 2B). Long term changes in standing crop of *Paracartia latisetosa* shows a gradual increase from 1118 specimens m^{-3} in 1974 - 77 until reach maximum (2947 specimens m^{-3}) in 1995 then re-decreased to 2295 specimens m^{-3} in 1999 -2000.

Canonical Corresponding Analysis is helpful in characterizing patterns of variation in the copepod assemblages relative to environmental variable. Axis I (Fig. 3) explained 83.8% of the variance in species scores and well correlated with NO_3, PO_4, pH, Chl-a, Temperature and Salinity. The eigenvalues with axis I is 0.045. *P. latisetosa* adults and copepodid stages had the highest score on axis I, while nauplii revealed the lowest score. Axis II explained 14.7 % of the variation in species score. It was well correlated with Transparency, NO_2, Productivity, total Phytoplankton. Nauplii located near to the origin of the ordination diagram, indicating a weak correlation with either of the environmental variables. *P. latisetosa* "adults" revealed a strong positive correlation with NO_3, pH and a weak one with Salinity, "temperature" and Dissolved Oxygen, while their presence resulted inversely proportional with Total Phosphorus, NO_2, Productivity and Total Phytoplankton.

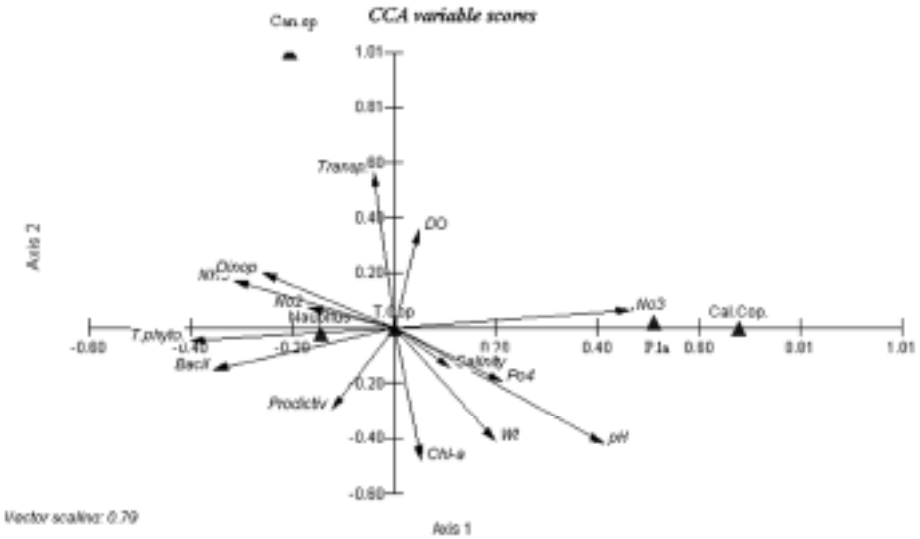

Fig. 3 - CCA ordination plot of axis I and axis II relating variations in the distribution of Copepods communities to environmental variables. The joint plot of species triangular and the environmental arrows is a biplot that approximats the weighted average of each species with respect to each of the environmental variables.
T Cop: Total copepoda P la: Paracartia latisetosa Cal Cop: Calaniod copepoda
Can. sp: Canuella sp

DISCUSSION

The presence of *P. latisetosa* in the Lake Qarun could be considered as progressively ameliorated in the last 50 years. The species, recorded for the first time in the lake Qarun by NAGUIB (1958) and GRIGIS (1959), arrived to be the dominant

species of the mesozooplankton. In fact, its adults occurred with a population density of an average of 1,118 specimens m^{-3} in 1974-77 (ABDEL-MALEK e ISHAK, 1980), and it gradually increased from 1,660 specimens m^{-3} in 1989 (AHMED, 1994), until more than 2,000 specimens m^{-3} in the years considered in the present study (1995-2000). *P. latisetosa* probably arrived in Lake Qarun as resting eggs. In fact this stage, present in the life cycle of this species (BELMONTE, 1992), is considered as one of the most responsible of the geographic distribution of Acartiidae (BELMONTE e POTENZA, 2001) giving to the species the possibility to cross geographic barriers.

In Lake Quarun *P. latisetosa* probably feeds on different food sources during its development. Nauplii are probably the only stage which feeds on phytoplankton, while juveniles and adults probably are omnivorous or detritivorous (their abundance is not correlated with Chl-a and Phytoplankton abundance). *P. latisetosa* has been acclimatized with the changing environment of Lake Qarun after transplantation from the Mediterranean. NO_3 concentration proved to be the major factor controlling the permanence and/or the population dynamics of the species in Lake Qarun temperature is weakly correlated with *P. latisetosa* while the continuos increase of salinity 47.3 ‰ may responsible for re-decrease in standing crop. Contrarily, ABDEL RAHMAN (1993) mentioned that *Acartia centrura* is a warm water form, occurred in a considerable numbers from May to July (temperature 23.2 - 28.5 °C) in Suez Bay (Gulf of Suez). ABOU-ZEID (1990) recorded the maximum of *Acartia centrura* in Lake Timsah (Suez Canal) coincide with high temperature (28 °C) and salinity (42.2 ‰). RANTA e VUORINEN (1990) and VIITASALO *et al.* (1990), found that the long-term changes of many copepod species coincided with the changes in temperature and salinity. The response of a species to temperature and salinity may change during the development. The number of *Acartia bifilosa* nauplii present in the sample was negatively correlated with Temperature, while the number of copepodids was positively correlated, (VIITASATO *et al.*, 1994). This data agree with the present study where nauplii abundance is not Temperature-dependent, while the adults show the opposite.

Data from CCAanalysis revealed a negative correlation between *Paracartia latisetosa* (copepodids) and total phytoplankton. TURNER *et al.*, (1984) and DAM et al. (1994) mentioned that many copepods are omnivorous feeders. LANDRY (1978) stated that the cycles of abundance of *Acartia clausii* is not affected by algal food availability. In lake Qarun nauplii show a small positive correlation with total phytoplankton, while copepodids and adults do not show this correlation. Probably nauplii use small phytoplankton species as food, while the adults and copepodids could be omnivorous or detritivorous. This could justify the lack of one stage, even in presence of huge amounts of the other stage of the species (e.g., massive abundance of adults without nauplii) which could produce those. But probably the reason of this

absence is partially dued also to selective predation from mullet fry. Transplantation of the mullet fry to Lake Qarun has been going on since 1928. A total of about two million fry were annually introduced during the period 1928 - 1964 (EL-ZARKA e KAMEL, 1965). These numbers were highly increased, reaching 55 million during 1971 - 1978. In fact, nauplii constituted a major part of the food items of mullet fry in winter and spring. With time probably the mullet died is directed on benthic preys, and *Canuella* sp (Harpacticioda) was the only well represented copepod species in the gut of all different adult mullet species in lake Qarun (EL-SHABRAWY e FISHAR, 1999).

REFERENCES

ABDEL-MALEK S.A., ISHAK M. M, 1980 - *Some ecological aspects of Lake Qarun, Fayoum,* Egypt. Part II: production of plankton and benthic organisms. Hydrobiologia 75: 201-208.

ABDEL-RAHMAN S. N., 1993 - *Ecological studies on the distribution of zooplankton communities in the north part of Suez Gulf (Suez Bay).* M.Sc. Thesis, Fac. Sci. Suez Canal Univ.: 316pp.

ABOU-ZEID G. M., 1990 - *Distribution of zooplankton in Lake Timsah with special reference to copepoda.* M. Sc. Thesis, Fac. Sci. Suez Canal Univ.: 96pp.

AHMED N. K., 1994 - *Ecological studies on zooplankton in Lake Qarun,* ElFayoum Egypt. M Sc.Thesis . Fac.Sci. Cairo Univ.: 178pp.

ANONYMOUS, 1997 - *Investigation of Lake Qarun ecosystem. Final Report submited to USAID and NIOF,* Cairo, Egypt: 287pp.

BELMONTE G., 1992 - *Diapause egg production in Acartia (Paracartia) latisetosa (Crustacea, Copepoda, Calanoida).* Boll. Zool. 59: 363-366.

BELMONTE G., POTENZA D., 2001 - *Biogeography of the family Acartiide (Calanioda) in the Ponto-Mediterranean Province.* Hydrobiologia.

BOULOS R., 1960 - *Okologische unterschungen in Lake Qarun.* Thesis.

CASTEL J., COURTIES C., 1982 - *Composition and differential distribution of zoo - plankton in Arcachon Bay. J. Plankton. Res.,* 4: 417-433.

DAM H. G., PETERSON W. T., BELLANTONI D. C., 1994 - *Seasonal feeding and fecun - dity of the Calanoid Copepod Acartia tonsa in long Island sound: Is omnivory important to egg production.* Hydrobiologia 292/293: 191-199.

DOWIDAR N. M., 1981 - *Zooplankton biomass of lake Qarun (Upper Egypt).* Rapp. Comm. Int. Mer. Medit. 27 (7).

DUSSART B., 1989 - *Crustaces Copepodes Calanoides des eaux interieures africai - nes.* Crustaceana, Suppl. 15: 205pp.

EL-SHABRAWY G. M., FISHAR R. M., 1999 - *Zooplankton consumption and feeding habits of mullet fry in lake Qarun Egypt. Symposium proceeding (the role of Science in development of Egypt society and environment),* 23-24 Oct.: 175-186.

EL-ZARKA S., 1968 - *Rehabilitation of the Fisheries of an inland saline lake in the United Arab Repub.* Stud. Rev. Ge. Fish. Counc. Medit, 35: 21-43.

EL-ZARKA S., KAMEL F., 1965 - *Mullet fry transplantation and its contribution to the fisheries of the inland brackish lake in Egypt,* U.A.R. Proc. Gen. Fish. Counc. Medit., 8: 209-226.

FOX M. H., 1927 - *Cambridge Expedition to the Suez Canal, 1924.* I. General part.- Trabs. Zool. Soc. London 22: 1-64.

GIRGIS R. B., 1959 - *Okologisch unterschungen in Lake Qarun (Agypten).* Dissertation, Universitat. Kiel.

GOPHEN H., 1973 - *Zooplankton in Lake Kinnert. T. Berman* (ed.) Israel Scient. Res. Conf. : 61-68.

LANDRY M. R., 1978 - *Population dynamic and production of a planktonic marine copepod, Acartia clausi, in a small temperature Lagoon on San Juan Island,* Washington. Int. Revue. Ges. Hydrobiol. 63 (1): 77-119.

MESHAL A .N., 1973 - *Water and salt budget of Lake Qarun,* Fayoum, Egypt. Ph.D. Thesis, Fac.Sci., Alexandria Univ.: 109pp.

NAGUIB M., 1958 - *Studies on the ecology of Lake Qarun* (Fayoum, Egypt). Part I. Kiel. Meeresforach, 14(2): 187-222.

RANTA E., VUORINEN I., 1990 - *Changes of species abundance relations in marine mesozooplankton at Seili,* Northern Baltic Sea, in1967-1975. Aqua. Fennica 20: 171-180

ROSE M., 1933 - *Fauna de France.26. Copepodes pelagiques. P. lechevalier,* Paris: 374pp.

TURNER J. T., 1984 - *The feeding ecology of some zooplankters that are important prey items of the larval fish.* NOAA. Tech. Rept. NMF 57: 28pp.

VIITASALO M., VUORINEN I., RANTA E., 1990 - *Changes in Crustacean mesozoo - plankton and some environmental parameters in the Archipelago Sea (North Baltic) in 1976-1984,* Ophelia 31: 207-217.

VIITASALO M., KATAJISTO T., VUORINEN I., 1994 - *Seasonal dynamic of Acartia bifi - losa and Eurytemora affinis (Copepoda: Calanioda) in relation to a biotic fac - tors in the northern Baltic Sea,* Hydrobiologia 292-293: 415-422.

WIMPENNY R., TITTERINGTON E. T., 1936 - *The tow net-plankton of Lake Qarun,* Egypt. Dec., 1930 to Dec., 1931.Fish. Res. Direct., Notes & Mem. Cairo: 57pp.

YOUNGBLUTH M. J., 1980 - *Daily, seasonal, and annual fluctuations among zoo - plankton population in an unpolluted tropical embayment.* Estuar. Coas. Mar. Sci. 10: 265-287.