Turkish Journal of Fisheries and Aquatic Sciences 8: 239-247 (2008)

Some Aspects of the Biology of two Copepods: *Apocyclops dengizicus* and *Mesocyclops isabellae* from a Pool in Garmat - Ali, Basrah, Iraq

Hanaa Hussain Mohamed[1], Salman Daood Salman[1,]*, Abdul Aziz Mahmood Abdullah[2]
[1] University of Basrah, Marine Science Center, Basrah, Iraq.
[2] University of Basrah, College of Agriculture, Basrah, Iraq.

* Corresponding Author: Tel.: +96040310252; Fax:-;
E-mail: dr_salmands@yahoo.com

Received 04 July 2007
Accepted 03 June 2008

Abstract

Some biological aspects of the copepods, *Apocyclops dengizicus* and *Mesocyclops isabellae* were studied at a pool in Garmet-Ali during the period between August 1998 and July 1999. The laboratory sex ratio was in favour of the females: 3.6:1 and 2.06:1 in the two species respectively. The females of the two species showed faster growth during the copepodites IV, V and the adult. The males reached the adult stage at a shorter time than the females. All stages of life of *A. dengizicus* appeared in August 1998 and then disappeared. In February 1999, a few copepodites and adults were present, peaked in March and disappeared during April. *M. isabellae* appeared between August 1998 - December 1998, then disappeared and reappeared in April 1999. It is suggested that predation and cannibalism may be the causes of diapause in the two species.

Key words: cyclopoid copepods, mating, sex ratio, growth, population structure, *Apocyclops dendizicus, Mesocyclops isabellae.*

Introduction

The ecosystem of temporary pools differs from other aquatic ecosystems like rivers, streams and lakes, as they are small, shallow and have no great differences in temperature between the surface and the bottom. They may be exposed to period of elimination and complete dryness in the summer when the temperature rises above 35°C or they may freeze down when exposed to low temperatures of about -5°C. These conditions affect the aquatic life, thus organisms inhabiting these water bodies must have physiological adaptations for the surrounding conditions. Moreover, they may have special breeding and growth strategies, and may have life cycles enabling them to survive and avoid unfavorable conditions (Thampson and Coldrey, 1985).

Most of previous studies in Iraq focused on seasonal fluctuation of freshwater zooplankton by treating the whole community in one locality or several localities at the same time (Salman *et al.*, 1990; Al-Zubaidi and Salman, 2001), and this resulted in a lack of knowledge regarding the seasonal fluctuations of the species composing the community. For this reason, the attention focused here on two species of copepods viz, *Apocyclops dengizicus* and *Mesocyclops isabellae*, for they are considered as a major component of the ecosystem of temporary pools in Basrah. This article is preceeded by two articles. The first was concerned with the effects of temperature on the life cycle of *A. dengizicus* (Mohamed *et al.*, 2004a) and the second investigated the effect of temperature on the stages of lifecycle and breeding of *Mesocyclops isabellae* (Mohamed *et al.*, 2004b).

Many parameters of the population dynamics of the two species are still lacking. Hence the present article is intended to shed light on some biological aspects of the two species for instance, population structure, and the relation of abundance with some ecological factors like temperature, salinity, oxygen, the growth and sex ratio. These aspects of the two species were not dealt with previously here in Basrah.

Materials and Methods

Fortnightly quantitative samples were collected early in the morning from a site at the University Campus at Garmet-Ali during the period between August 1998 and July 1999, with a plastic cylinder of a diameter of 13.7 cm, and a height of 10 cm with a capacity of 1 liter. The sampler was rinsed in water until fullness and quickly pulled back. Water samples were immediately fixed with 4% Formalin to avoid predation. One liter of water was collected at each time due to the small size of the pool and the richness of the animal in it.

Air and water temperatures were recorded by a thermometer. Salinity was measure by a salinity – temperature Bridge, type M.C.S. Dissolved oxygen was determined by a modified Winkler method (azide modification) according to Lind (1979).

In the laboratory, the samples were filtered through 0.08 mm mesh-sized bolting silk, transferred into a 30 ml Petri dish and all other species were removed together with insects larvae and plant remains, then total individual counts were performed, otherwise, in dense samples, three aliquots of 5 ml. each were taken and the average numbers per liter were calculated.

Individual counts were carried out according to the stages of development; naupliar stages I-VI were identified under a compound microscope, whereas the copepodite stages I-VI (the last of which is the adult stage) were identified under a stereodissecting microscope. Valderhaug and Kewalramani (1979) were followed for the identification of the stages of *A. dengizicus*. Specimens of Mesocyclops were sent to Dr. Maria Holynska for identification and turned out to be *M. isabellae* (Dussert and Fernando, 1988).

Sex in each species was determined according to the secondary sexual characters, which appear at the late copepodite stages, IV and V. These features are: total length and width, beginning of modification of the first antenna in the male, the mating process and the transfer of the spermatophores by the male to the female.

Sex ratio was determined by counting the numbers of adult females and the total numbers of adult of each species. The χ^2 test was used to identify the occurrence or not of a significant difference between the two sexes and the deviation from the hypothetical ratio of 1:1.

Sex ratio was done for samples collected from the field and for laboratory reared animals. The latter was carried out as follows: Four egg sacs were isolated from berried females and placed in 100 ml vessel containing filtered water from the adult's habitat. Larvae were reared on a suitable food for each stage (Mohamed, 1999). The males and females were counted when they are at the copepodite stage V, the number of males and females was counted. Counting was done again after 15 days and the sex ratio was determined as before.

The growth of each stage was estimated by measuring the total length of larvae at the particular stage divided by the time taken for completion of the stage and according to the following expression (Crisp, 1984):

$$GL = L / T$$

where L = absolute or total growth in length (mm), T = time in days and GL = growth rate (mm/d).

t-test was performed to identify the presence or not of significant differences in the time of development of each of the males and females (Zar, 1984).

Results

Temperature

The highest air temperature (39.5°C) and water temperature (29°C) were recorded in July 1999 (Figure 1), whereas the lowest air temperature (12.5°C) and water temperature (12°C) were recorded in January of the same year.

Salinity

Values of salinity for most of the year were 1.7 – 2.0‰ except in winter, January, February and March 1999 when values of 7.4, 10.2 and 8.2‰ were recorded, respectively (Figure 2).

Dissolved Oxygen

The increase of values of dissolved oxygen was synchronized with the decrease of temperature and the rise in salinity. The highest value (10.9 mg/L) was recorded in January 1999, and the lowest (6.0 mg/L) was obtained in July of the same year (Figure 3).

Mating

The males in both species hold the 4th pairs of swimming legs of females by their first modified antenna, followed by fast movements of the fourth swimming legs to and from, and with aid of 5th legs male transfers spermatophores to the two female openings occurred on the ventral side of the genital segment. Females of *A. dengizicus* may carry one pair of spermatophores, whereas those of *Mesocyclops isabellae* carry up to 3 pairs of spermatophores.

Estimation of Sex Ratio in the Laboratory

The results indicated a significant preponderance

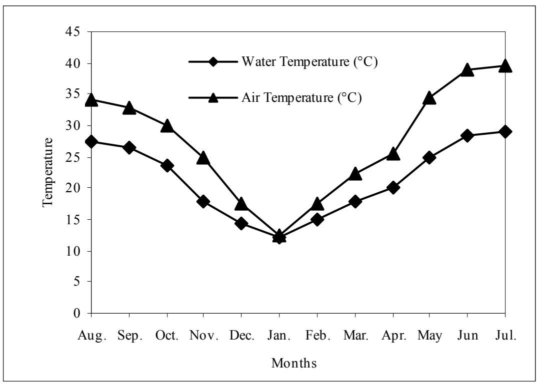

Figure 1. Monthly changes in air and water temperature at the sampling station during August 1998 – July 1999.

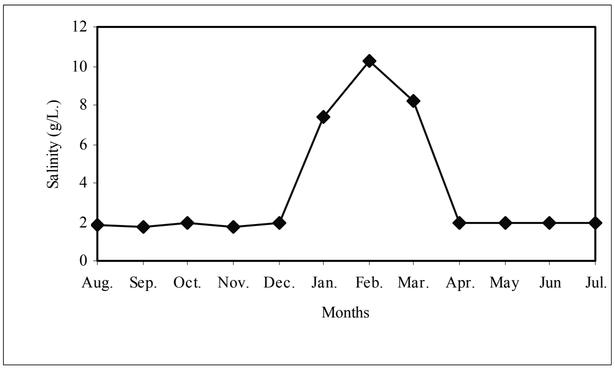

Figure 2. Monthly changes in salinity (‰) at the sampling station during August 1998 – July 1999.

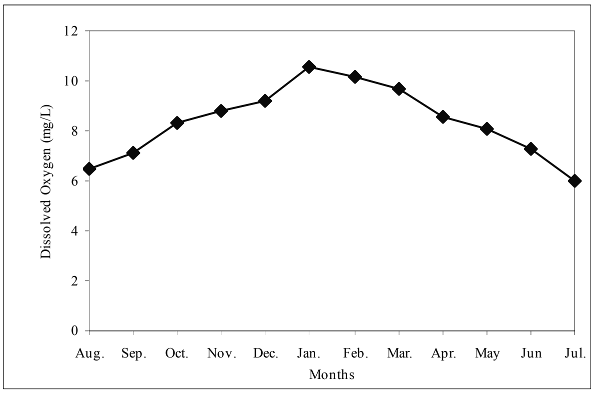

Figure 3. Monthly changes in the dissolved oxygen (mg/L) at the sampling station during August 1998 – July 1999.

of adult females over adult males ($P<0.05$) in the laboratory reared *A. dengizicus.* The percentage of females was 74–82% (Table 1). The overall female: male ratio was 3.6:1.0.

Similarly in *Mesocyclops isabellae*, there was a significant predominance of adult females ($P<0.05$) (Table 1). The percentage of females were 53–77% and the overall ratio was in favour of females (2.06 : 1.0). The sex ratio at the copepodite V showed somewhat different picture, for the numbers of males of *A. dengizicus* slightly exceed those of females in 2 out of 5 cases (Table 1), whereas in *Mesocyclops isabellae*, the males outnumbered the females in 3 out of 4 cases. Although χ^2 values were high (3.3 and 1.24) for the two species respectively, yet the differences were not significant.

Data here expressed high mortality of males at the sexual maturity. The rate of mortality between the copepodite V and the adult was 25–50% in *A. dengizicus* and 29-62% in *Mesocyclops isabellae.*

Sex Ratio in the Field

In both species, the number of adult males and females collected from the field were very few. Therefore, the females collected throughout the **e**ntire sampling period were pooled together and found that the females of *A. dengizicus* formed about 46% of the population which did not differ significantly ($P>0.05$) from the ratio of 1:1, whereas in *Mesocyclops isabellae*, the females constituted about 67% and this differed significantly ($P<0.05$) from the hypothetical ratio of 1:1.

Growth

The absolute growth estimated for all stages of life of both species indicated an increase of length with age, and is more in the females (copepodite IV, V and adult) than in the males (Figure 4). The increase in length was much more pronounced at the moult between nauplius VI and copepodite I, for it was 0.145 mm in *A. dengizicus* and 0.147 mm in *Mesocyclops isabellae*. Moreover, females exhibit faster growth than males especially at the copepodite IV, V and adults, as the absolute growth were 0.14, 0.15 and 0.175 mm in *A. dengizicus* respectively, while in *Mesocyclops isabellae*, the absolute growth was 0.157, 0.245 and 0.325 mm, respectively. The increase in length of males of the former species was 0.075, 0.100 and 0.148 mm in the three stages respectively, whereas in the latter species, the increase in those stages was 0.040, 0.115 and 0.133 mm.

The effect of temperature on the growth of both species is quite obvious (Figures 5 and 6), for there was an increase in the average length of the naupliar

Table 1. Laboratory sex ratio of adult and copepodite V of *A. dengizicus and Mesocyclops isabellae.* (all χ^2 values are significantly different P<0.05)

No. of female CV	No. of Males CV	No. of adult Females	No. of adult Males	Total number	**(%)**of Females	χ^2
A. dengizicus						
20	8	18	4	22	81.8	8.9
14	15	14	5	19	73.6	4.2
21	12	20	5	25	80	9
16	11	16	4	20	80	7.2
13	16	13	4	17	76.4	4.7
	62	81	22	103	78.6	33.7
Mesocyclops isabellae						
26	34	26	10	36	72.2	7.1
21	29	20	18	38	52.6	5.41
21	25	20	9	29	68.96	6.2
27	23	27	8	35	77.1	7.56
	111	93	45	138	75	31

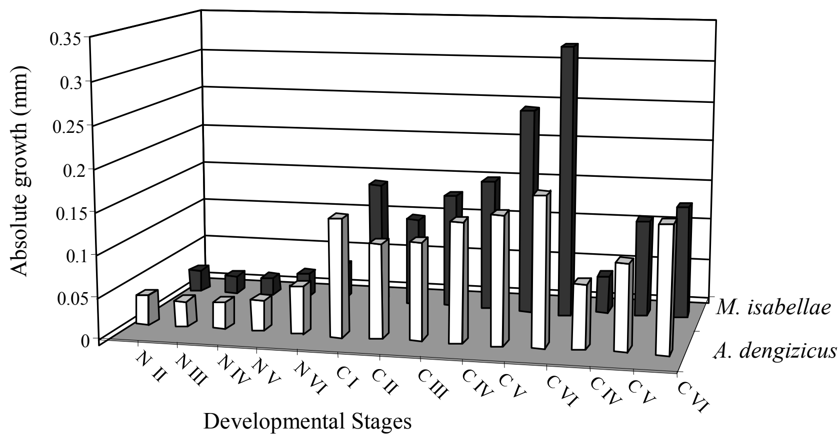

Figure 4. Absolute growth (mm) of each developmental stage of *A. dengizicus* and *Mesocyclops isabellae.*

stages with the rise in temperature reaching a peak at 30 and 35°C. However, there was a pronounce increased in mean length at the moult between nauplius VI and copepodite I, and between copepodite I and II in *A. dengizicus* (1.003 and 1.270 mm at 30°C, respectively). Whereas in *Mesocyclops isabellae*, the increase in mean length was 1.01 and 1.28 mm at the moult between copepodite II – III and III – IV at 30 and 35°C.

The mean growth of the adult females was less than that of the males, 0.48 mm in *A. dengizicus* and 0.52 mm in *Mesocyclops isabellae*, whereas in the males, it was 0.84 and 0.80 mm in the two species respectively, and at all temperatures. Therefore, males reach maturity faster than females.

Minimum daily growth rate was 0.06 mm (Table 2) in *A. dengizicus* at 20°C and 0.04 mm in *Mesocyclops isabellae* at 15°C, while maximum daily growth was at 35°C (0.14-0.19 mm in the two species, respectively).

Population Structure

Figures 7 and 8 show the frequency distribution of the different developmental stages (6 nauplius, 5 copepodite and the adult stage) of the two species from August 1998 to July 1999.

In August 1998, all the developmental stages of *A. dengizicus* were present in the field (Figure 7) but in a few numbers; 40% of individuals were in the naupliar phase, 5% adult females and 2% adult males, the rest was copepodites. There was then a complete disappearance of individuals until February 1999, when a few late copepodites and adult were present. In March, there was a pronounce rise in the population and individuals in every developmental stages were recorded. The naupliar phase represented 76% of the population. In April, there was a sharp decline in the population, followed by a disappearance of the population from the entire water column.

Individuals of *Mesocyclops isabellae* were

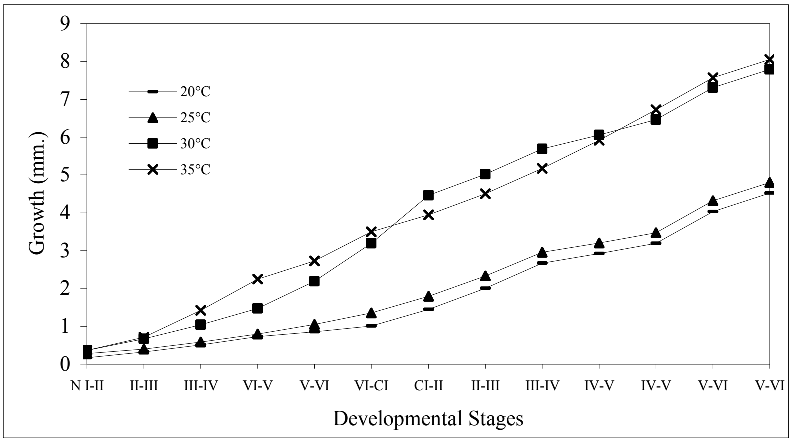

Figure 5. Growth in length (mm) of the different developmental stages of *A. dengizicus* at 20–35°C

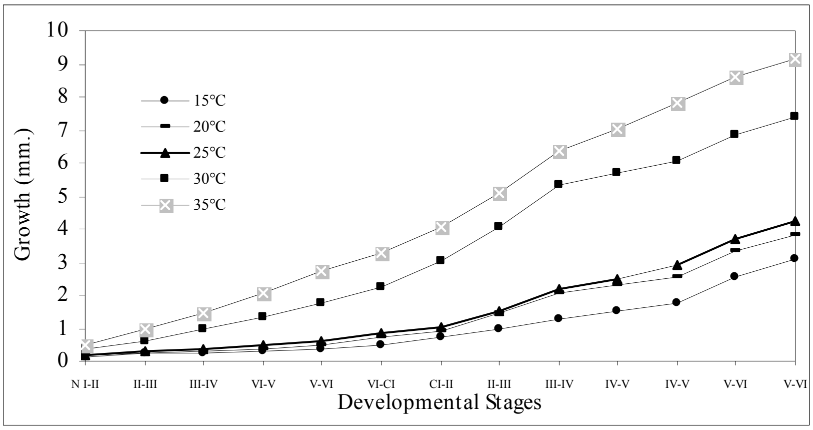

Figure 6. Growth in length (mm) of the different developmental stages of *Mesocyclops isabellae* at 15–35°C.

Table 2. Average daily growth (mm) of *A. dengizicus* and *Mesocyclops isabellae* at different temperatures

Species	15°C	20°C	25°C	30°C	35°C
A. dengizicus	-	0.06	0.08	0.11	0.14
M. isabellae	0.04	0.05	0.07	0.15	0.19

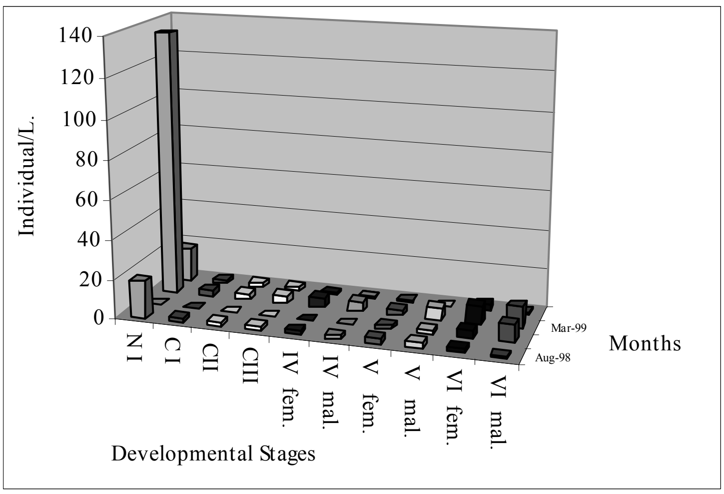

Figure 7. Population structure of *A. dengizicus* at the sampling site during August 1998 to July 1999.
N: nauplius , C: copepodite.

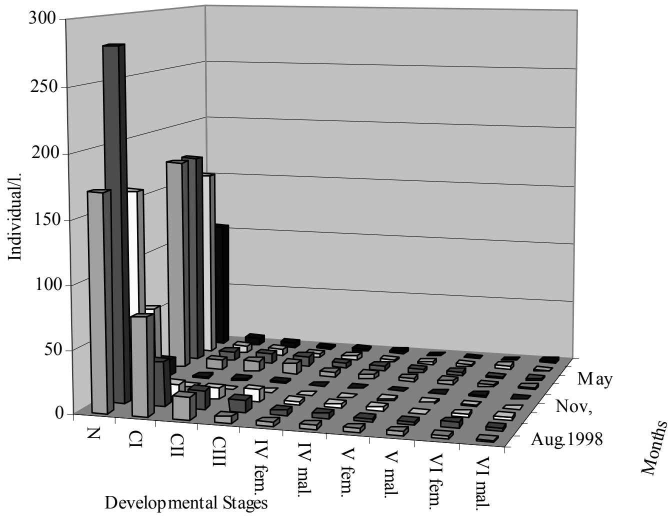

Figure 8. Population structure of *Mesocyclops isabellae* at the sampling site during August 1998 to July 1999. N: nauplius, C: copepodite.

present in the pool from August 1998 till December of the same year (Figure 8), disappeared later and appeared again in April 1999 and remained so until the cease of sampling in July 1999. Nauplii were very much more than the copepodites indicating a high mortality rate. The peak of nauplii was in September 1998 (82% of the population), whereas the lowest density of nauplii was recorded in December of the same year.

In December 1999, only the first three copepodite stages were present and one adult female was found. In April 1999 till the end of sampling, naupliar numbers were 87 – 88% of the population

Discussion

Environmental factors play an important role in the activity of the organisms. They affect its existence, distribution, density and growth. The factors may have great influence on the organisms inhabiting shallow lakes, and pools for the maneuver would be very limited. Temperature and dissolved oxygen are very essential in these habitats much more than other environmental factors (Jonsson, 1985; Rosenberg *et al.,* 1995). Temperature is considered as the most important governing factor, for it directly affects the metabolic activities and growth and indirectly affects the amount of food and dissolved oxygen concentration (Downing and Rigler, 1984; Pains *et al.,* 1995).

In the present study, the highest values of oxygen concentrations were recorded in winter and the lowest records were in summer and this reflects the natural reverse relationship between temperature and oxygen concentration (Perkins, 1974). The pool is considered as oligohaline at most of the times, but high values of salinity were recorded in January and February and this may be attributed to the fact that it is surrounded by arid land which rises the salinity of the pool through landwashing and subsequent evaporation during rainfalls in winter.

The peak of density of *A. dengizicus* occurred when the temperature was lower than 20°C, whereas peaks of density of *Mesocyclops isabellae* coincided with high temperatures in September 1998 and June 1999. This indicates that the former species preferred lower temperatures and the latter preferred relatively higher temperatures. The contrary is true for salinity and oxygen concentrations.

The presence of stage I nauplii together with the adults in the samples indicated reproductive activities at that time. Laboratory observations showed that reproduction is sexual in both species and that reproductive activities in *A. dengizicus* is ceased at temperature of 15°C, while in *Mesocyclops isabellae* reproduction continued during winter and stopped at 10°C. Therefore, the preference of the two species to a relatively high temperatures reflects their adaptation to live in such subtropical environment, and this is apparent when comparing them with species from temperate and cold areas like *Megacyclops viridis* and *Macrocyclops albidus* which reproduce at 20–25ºC (Abdullahi, 1990). On the other hand, when temperature drops beyond the limit of tolerance of the two species, they penetrate into the sediments and exhibit diapause. This phenomenon was quite obvious in *Mesocyclops isabellae.* Therefore understanding the biology of reproduction in Cyclopoida is very important in understanding the population dynamics of the species.

In contrast to some freshwater Calanoida, remating is rare in Cyclopoida (Watras and Haney, 1980; Watras, 1983). The present laboratory experiments indicated that a single mating might be sufficient for fertilizing 6 broods in *A. dengizicus* and 11 broods in *Mesocyclops isabellae*. However, Whithouse and Lewis (1973) reported 9 more broods in *M. leuckarti* from a single mating than in *A.*

dengizicus. The present results reported more than a pair of spermatophores carried by females of *Mesocyclops isabellae* whereas a single pair was recorded in females of *A. dengizicus*. In this context, Giesbrecht (1882) found 70 spermatophores in female *Pseudocalanus* and Hirschfeld (1974) counted up to 350 sperms per spermatophore in male *Pseudocalanus* arranged spirally and it is thought that they are sufficient to fertilize the eggs of a female throughout her entire life. Moreover, many cyclopoid copepods are only present for short periods during which clutch production and population growth must take place, while many calanoid copepods are present throughout the year (Maier, 1995). Actually, many studies showed that there were other factors that may affect this strategy. The short life span of males of the present species together with their high mortality in comparison with the females, may indicate a single copulation of female throughout her entire life. Moreover, the process of copulation puts the animal at a high risk of predation (Ward, 1986; Wing, 1988; Sih *et al*., 1990; Ronkainen and Ylonen, 1994). Therefore, some species exhibit adaptive means in shortening the time of copulation. This is supported here by the fact that copulation in the present two species is lasted for seconds or a few minutes. This is in accordance with the results of Maier (1993) on *M. leuckarti* at Lake Gronne in south Germany, who recorded a few minutes as a time of copulation. He also found that the mating might have lasted for half an hour in *Cyclops vicinus*. This difference in the time of mating between different species may be in relation with predation, as members of *M. leuckarti* inhabit the upper water layers where predation pressure by fish is high, whereas *C. vicinus* is living in deeper darker water layers. More further, this is probably in avoidance of predation of males by the females in Cyclopoida (Maier, 1995). This was actually noticed in the present study for many times. Moreover, males of *Mesocyclops isabellae* disappeared shortly after transfer of spermatophores.

The present field data showed that in the two species, the number of immature males is approaching that of immature females (copepodite V). A similar result was obtained by Marshall (1949) and Fontain (1955) in *Calanus finmarchicus* and McLaren (1965) in *Pseudocalanus minutus*. However, the present laboratory results indicated that the number of mature females in both species was more than that of the males (3.6 : 1 in *A. dengizicus* and 2.06 : 1 in *Mesocyclops isabellae*). This reflects the fact that differential natural mortality has greatly influenced the sex ratio and ultimately the population structure. It was noticed here that males have a life span of about half that of the females and this is in agreement with the results of other workers (Ravera, 1955; Elgmork, 1959; Smyly, 1970; Gophen, 1979; Maier, 1989b; Maier, 1992). Predation of males by females is of a great importance in determining sex ratio in *Mesocyclops isabellae*. Females preying on males were frequently noticed here especially when females were larger than males, which is common in Cyclopoida as observed in *M. leuckarti* (Maier, 1995).

It is apparent from the present data that diapause has a clear influence on sex ratio of *A. dengizicus,* such an effect has not been confirmed in *Mesocyclops isabellae*. For instance, in the former species and after the diapause (middle of August 1998 to early February) copepodites IV developed into adult males faster than adult females and resulted in an increase in number of males throughout that period. However, the number of females increased later so as in the period before diapause (August 1998). Whereas in the latter species, emergence from the sediment occurred in early summer (mean temperature 20°C), which ultimately means that the time of development into adult was shorter than that of the former species at its emergence out of sediments during winter (from December to February 1998-1999; mean temperature 15°C). Moreover, because of the diapause, it was not possible to follow up the changes in the sex ratio in *Mesocyclops isabellae*. The rise in numbers of males after the diapause was also recorded in *Thermocyclops crassus*, but a faster decline in number of females was noted during the rest of the year (Maier, 1989a).

Generally in both *A. dengizicus* and *Mesocyclops isabellae*, the number of nauplii was pronouncedly higher than the copepodites and adults, and the same was also noticed in the populations of *M. leuckarti* in Lake Kinneret (Gophen, 1978), *Macrocyclops albidus* and *Acanthocyclops robustus* in Azibo reservoir in Portugal (Vasconcelos, 1990). Georg (1973) and Infant (1982) found higher numbers of copepodites *Cyclops vicinus* in many pools in Venezuela and this is due to a prolonged period of development of the copepodites in comparison with that of the nauplii. Moreover, Abdul- Hussein (1985) found that the density of nauplii and copepodites in Ardigh reservoir, U.K., was very much higher than that of the adults. He attributed that to the higher rates of mortality of the adults as they become older or to the predation by fish imposed on this group becomes of their larger sizes.

It can be concluded here that reproduction in *A. dengizicus* and *Mesocyclops isabellae* is continuous throughout their presence in the water column of the pools as long as the temperature does not drop below 15 and 10°C in the two species respectively. The proportion of adult females was higher than that of adult males in both species. Hence a single mating may be sufficient to fertilize the egg batches produced by the female throughout her entire life. This strategy was developed to overcome the pressure imposed on the population through predation by fish or other animals and by cannibalism.

Acknowledgement

We are grateful to Dr. M. Holynska of the Museum and Institution of Zoology, Warsaw, Poland for the identification of *Mesocyclops isabellae*. H. H.

M. would like to thank Prof. K. Elgmork of Univ. of Oslo, Norway and Dr. B. Santer of Institute for Limnology, FRG for help in sending many of their publications. S.D.S. is deeply indebted to Dr. A.Y. Al-Handal of Dept. Marine Ecology, Gothenburg Sweden, for sending some useful literatures.

References

Abdul-Hussein, M.M. 1985. Zooplankton and Phytoplankton interaction in an Eutrophic Reservior. PhD. thesis, Colchester: University of Essex, 280 pp.

Abdullahi, B.A. 1990. The effect of temperature on reproduction in three species of cyclopoid copepods. Hydrobiologia, 196: 101-109.

Al-Zubaidi, A.J.M. and Salman, S.D. 2001. Distribution and abundance of zooplankton in the Shatt Al-Arab estuary, Northwest Arabian Gulf. Marina Mesopotamica, 16(2): 187–199.

Crisp, D. J. 1984. Energy flow measurements. Methods for the study of Marine Benthos. In: N. Holm, and A.D. McIntyre, (Eds.). IBP Hand Book No. 16. Blackwell, Oxford: 284-372.

Downing, J.A. and Rigler, F.H. 1984. A manual on methods for the assessment of secondary productivity in fresh waters. IBP Hand Book 17. Scientific publication Blackwell, Oxford: 1-18.

Elgmork, K. 1959. Seasonal occurrence of *Cyclops strenuus strenuus* in relation to environment in small water bodies in Southern Norway. Folia Limnol. Scand., 11: 196.

Fontain, M. 1955. The planktonic copepods (Calanoida, Cyclopoida, Monstrilloida) of Ungava Bay, with special reference to the biology of *Pseudocalanus minutus* and *Calanus finmarchicus*. J. fish. Res. Bd. Can., 12: 858-898.

Georg, D.G. 1973 . Diapause in *Cyclops vicinus*. Oikos, 24: 136-142.

Giesbrecht, W. 1882. Die frieilebenden copepoden der Kieler Foehrd. Bericht Komiision zur wissenschaftlichen Untersuchung des deutschen Meere, Kiel, 4: 85-168.

Gophen, M. 1978. Errors in the estimation of recruitment of early stages of *Mesocyclops leuckarti* (Claus) caused by the diurnal periodicity of egg-production. Hydrobiologia, 57(1): 59-64.

Gophen, M. 1979. Sex ratio in *Mesocyclops leuckarti* (Claus) populations in Lake Kinneret (Israel). Hydrobiologia, 66(1): 41-43.

Hirschfeld, H. 1974. Some observations on the breeding of *Pseudocalanus* in the laboratory and comparisons with other calanoid species. BSc. Hons. Thesis, Nova Scotia: Dalhouies Univ, 255 pp.

Infant, A. 1982. Annual variations in abundance of zooplankton in Lake Valencia (Venezuela). Arch. Hydrobiol., 93: 194-208.

Jonsson, E. 1985. Population dynamic and production of Chironomidae (Diptera) at 2m depth in Lake Esrm Denmark. Arch. Hydrobiol. Suppl., 20: 239-278.

Lind, D.T. 1979. Handbook of Common Methods in Limnology. C.V. Mosby. Co., Louis, 199 pp.

Maier, G. 1989a. The seasonal cycle of *Thermocyclops crassus* (Fischer, 1853) (Copepoda: Cyclopoida) in shallow, eutrophic Lake. Hydrobiologia, 178: 43-58.

Maier, G. 1989b. The effect of temperature on the development times of eggs, naupliar and copepodite stages of five species of cyclopoid copepods. Hydrobiologia, 184: 79-88.

Maier, G. 1992. The reproductive biology of *Cyclops vicinus*. J. Plankton Res., 4: 127-135.

Maier, G. 1993. An example of nich partitioning in three coexisting freshwater cyclopoid copepods. J. Plankton Res., 15: 1097-1102.

Maier, G. 1995. Mating frequency and interspecific matings in some freshwater cyclopoid copepods. Oecologia, 101: 245-250.

Marshall, S.M. 1949. On the biology of the small copepods in Loch Striven. J. Mar. Biol. Asso., 28: 45-122.

McLaren, I.A. 1965. Some relationships between temperature and egg size, body size, development rate and fecundity of the copepod *Pseudocalanus*. Limnol. Oceanog., 10: 528–538.

Mohamed, H.H. 1999. The reproductive biology of *Apocyclops dengizicus* and *Mesocyclops* sp. (Copepoda: Cyclopoida) from a temporary pool in Basrah, Iraq. MSc. thesis, Basrah Iraq: Basrah Univ., 90 pp

Mohamed, H.H., Salman, S.D. and Abdullah, A.M.A. 2004a. The effect of temperature on the life cycle of *Apocyclops dengizicus* Lepshkin, (Copepoda: Cyclopoida). Marina Mesopotamica, 19(1): 6-18.

Mohamed, H.H., Salman, S.D. and Abdullah, A.M.A. 2004b. The effect of temperature on the life stages and reproduction of *Mesocyclops leuckarti* (Copepoda : Cyclopoida) in Garmet –Ali Region , Basrah. The Iraqi Journal of Aquaculture, 1(1): 1-11.

Pains, L.I., Goddeerin, B. and Verheyen, R.F. 1995. The Hemoglobin concentration of *Chironomus cf plumosus* L. (Diptera: Chironomidae) larvae in Lake Sevan. Sovi. J. Ecol., 14 : 54-60.

Perkins, E.J. 1974. The biology of Estuaries and coastal waters. Academic Press, London. New York, 678 pp.

Ravera, O. 1955. Seasonal variations of the reproductive rate in pelagic copepods of Lake Maggiore. Verh. Int. Ver. Limnol., 12: 236-252.

Ronkainen, H. and Ylonen, H. 1994. Behaviour of cyclic bank voles under risk of mustelid predation: do females avoid copulation. Oecologia, 97: 337-381.

Rosenberg, D.M., Wiens, A.P., Bliv, B. and Armstreng, L. 1995. Experimental acidification of a poor fen in north western Ontario effects of emergence of *Chironomidae* (Diptera). Can. J. fish. Aqua. Sci., 52: 2299-2237.

Salman, S.D., Marina, B.A. and Ali, M.H.A. 1990. The zooplankton of Khor Abdullah, Northwest Arabian Gulf. Marina Mesopotamica, 5 (1): 11-26.

Sih, A., Kurpa, J. and Travers, S. 1990. An experimental study on the effects of predation risk and feeding regime on the mating behaviour of the water strider. Am. Nat., 135: 284-290.

Smyly, W.J. 1970. Observations on rate of development, longevity and fecundity of *Acanthocyclops viridis* (Jurine) (Copepoda, Cyclopoida) in relation to type of prey. Crustaceana, 18: 21-36.

Thampson, G. and Coldrey, J. 1985. The pond. Toppan printing company, 256 pp.

Valderhaug, V.A. and Kewalramani, H.G. 1979. Larval development of *Apocyclops dengizicus* Lepeshkin (Copepoda : Cyclopoida). Crustaceana, 36(1): 1-9.

Van de Velde, I. 1984. Revision of the African species of the genus *Mesocyclops* Sars, 1914 (Copepoda: Cyclopoida). Hydrobiologia, 109: 3-66.

Vasconcelos, V. 1990. Seasonal fluctuation in the zooplankton community of Azibo Reservior (Portugal). Hydrobiologia, 196: 198-204.

Ward, P.I. 1986. A comparative field study of the breeding behavior of a stream and a pond population of *Gammarus pulex* (Amphipoda). Oikos, 46: 29-36.

Watras, C.J. 1983. Reproductive cycles in diaptomid copepods effect of temperature, photocycle, and species on reproductive potential. Can. J. Fish. Aquat. Sci., 40: 1607–1613.

Watras, C.J. and Haney, J.F. 1980. Oscillations in the reproductive condition of *Diaptomus leptopus* (Copepoda: Calanioda) and their relation to rates of egg – clutch production. Oecologia, 45: 94-103.

Whitehouse, J.W. and Lewis, B.G. 1973. The effect of diet and density on development, size and egg production in *Cyclops abyssorum* Sars, 1863 (Copepoda: Cyclopoida). Crustaceana, 25: 225–236.

Wing, S.R. 1988. Cost of mating for female insects: risk of predation in *Photinus collustrans* (Coleoptera: Lampyridae). Am. Nat., 131: 139-142.

Zar, J.H. 1984. Biostatistical Analysis. Englewoods Cliffs. N.J., Prentice Hall, New Jersey, 718 pp.