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Egg Development Time (EDT) in *Mesocyclops ogunnus*

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Abstract

A study was carried out on the impacts of temperature and light/dark regime on the Egg Development Time (EDT) of the cyclopoida copepod, *Mesocyclops ogunnus* in Lake Kinneret. It was found that EDT was 148, 33 and 20 hours under 15˚C, 22˚C, and 27˚C respectively. EDT was different between the two regimes of 12/12 hrs light/dark and 24 hrs light. Egg hatching and survival were higher under 24 hrs light regime. The results of temperature and light regime impacts on EDT indicate ecological implication on cyclopoida copepod population dynamics in lakes. The implication of the results to the global warming trend is also suggested.

Keywords

Development, Eggs, Kinneret, Mesocyclops, Time

1. Introduction

The impact of temperature on the life cycle stages of *Mesoocyclops oggunus* (Sin. *M. ogunnus*) in Lake Kinneret was widely documented in previous studies [1]-[6]. Nevertheless, the experimental procedure for the measurement of the Egg Development Time (EDT) was not published. The present paper is focused on the experimental implementation aimed at the study of the temperature and light/dark regime impact on EDT. To improve results' reliability, a combination of two methods was implemented: common arithmetic averages (with SD) (Standard Deviation) and timing interval sorted graphic plot of the data.

It is widely known that the biological parameter of EDT is significantly affected by temperature and essential for understanding a cyclopoida-copepod like *M. ogunnus* life cycle as well as interaction with other compartments of the ecosystem [7] [8] [9] [10] [11]. The EDT parameter also affects the predation of the

copepod because ovigerous females carrying eggs are more susceptible to predators than females without eggs [12]. The impact of light conditions on EDT was also previously documented [13] [14]. Among environmental conditions, temperature and light impact on EDT is among the top priorities in research topics of marine [11] [13] [15]-[20] and freshwater [10] [21] [22] [23] [24] [25] copepods. Increase of EDT with temperature decline in freshwater copepods and cladoceran species was documented [22]. Landry [18] studied how the EDT of *Acartia clause* females is affected by the thermal exposure history (time length and temperature level) before eggs were laid. Corcket [15] documented that, in addition to temperature, egg size also influences the EDT span. The objective of the present paper is documentation of reliable results of EDT of *M. ogunnus* as part of the eco-physiological research of this copepod in the Kinneret ecosystem. The *M. ogunnus* is the dominant species among cyclopoida copepods in Lake Kinneret which comprises 35% of the zooplankton biomass assemblages in the lake. The study is part of eco-physiological research of the zooplankton communities in Lake Kinneret and was never reported earlier.

2. Methods

2.1. Selection of Experimental Temperature

Three temperatures were selected: 15˚C which exists throughout the entire water column when the lake is totally mixed (December-April); 22˚C which mostly existed in the epilimnion of the lake during April-May and November-December; and 27˚C which is common in the epilimnion during the summer months (June-October). When the lake is stratified (December-May), the Hypolimnion is anoxic.

2.2. Experimental Procedure

Zooplankton was collected in the lake by 200 μm net mesh size. The dense material was removed into a conical shape glass funnel equipped with a bottom tap for 4.5 hours at room temperature (25˚C). Dead animals were removed through the bottom tap every 30 - 45 minutes. Due to the high tolerance of adult cyclopoida copepods to DO concentration, after 4.5 hours, the living organisms in the funnel were 90% - 95% adult copepods. The organisms were divided arbitrarily into three aliquots which were individually placed inside incubators (12/12 hours light/dark conditions) in three temperatures (15˚C, 22˚C, 27˚C) adjusted in Petri dishes. The material was immediately observed under anesthesia by CO_2 (Soda) and fecund (dark colored ovaries), or ovigerous females were isolated individually into small Petri dishes containing 15 ml filtered (45 μm Millipore filter paper) lake water and observational timing record started immediately. The dishes were observed every two hours, and lay of eggs, the subsequent hatching and the number of newborn nauplii were recorded. In case egg-laying recorded observation was missed, the time interval recorded as half of the pause was considered. No food was submitted to the females. All females recorded exposed to

the experimental temperature throughout the entire observation time started with no eggs but were close to starting the laying process or newly hatched. The sign of females' readiness for laying was dark (heavy brown) colored ovaries. The results of the total number of eggs laid and percentages of hatched and dead eggs are presented in Tables 1(a)-(c) and Figures 1(a)-(c). The incubation time at temperatures of 22˚C and 27˚C required longer night observations, and the timing accounted was half of the break. The Number of females and consequently of eggs was not similar in three experiment trials is due to different survived animals preconditioned.

Table 1. Experimental results under (a) 15˚C, (b) (22˚C), and (c) (27˚C). Number of eggs, hatching number and % and EDT per female of: total number of laid eggs, incubation time (hrs), number and % of hatched eggs, number of dead eggs. Total number of females and mean EDT (hrs) are given.

(a)

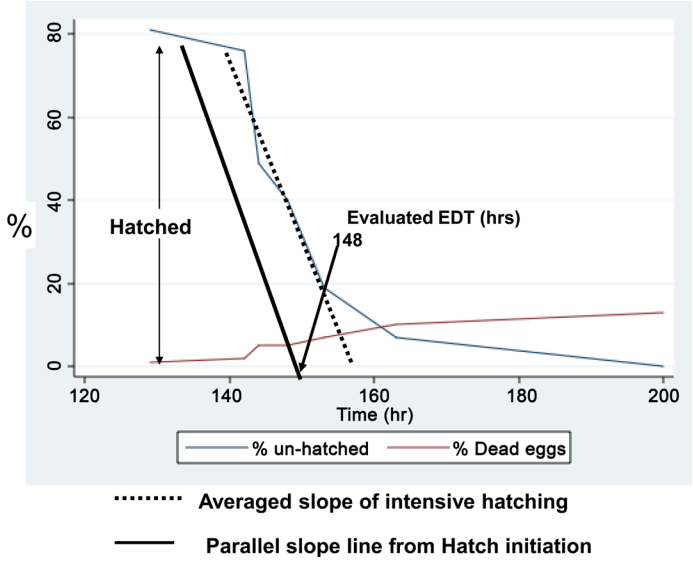
Egg/female	Hatched (% of hatched)	Incubation time (hrs)	Dead Eggs
54	51 (94)	129	3
14	13 (93)	142	1
78	70 (90)	144	8
27	25 (93)	148	2
63	54 (86)	153	9
34	27 (79)	163	7
19	12 (63)	200	7
Total: 289 (7 females)	252 (87)		37
Mean Incubation Time (hr) (SD)		148 (15)	

(b)

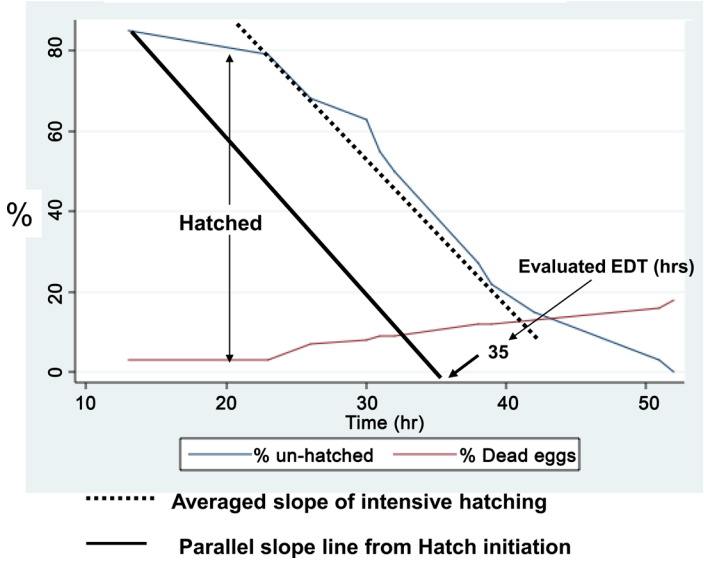
Egg/female	Hatched (% of hatched)	Incubation time (hrs)	Dead Eggs
27	22 (81)	13	5
10	9 (90)	23	1
19	14 (74)	26	5
10	6 (60)	30	4
14	12 (86)	31	2
9	9 (100)	32	0
40	36 (90)	38	4
9	9 (100)	39	0
12	10 (83))	42	2
16	14 (88)	48	2
6	2 (33)	51	4
Total: 177 (11 females)	146 (82)		31
Mean Incubation Time (hr) (SD)		33 (11)	

(c)

Egg/female	Hatched (% of hatched)	Incubation time (hrs)	Dead Eggs
5	3 (60)	9	2
9	8 (89)	15	1
63	42 (67)	16	10
35	25 (71)	20	10
24	18 (75)	24	6
28	27 (96)	26	1
14	4 (29)	27	10
Total: 178 (7 females)	127 (71)		51
Mean Incubation Time (hr) (SD)		20 (5)	



(a)



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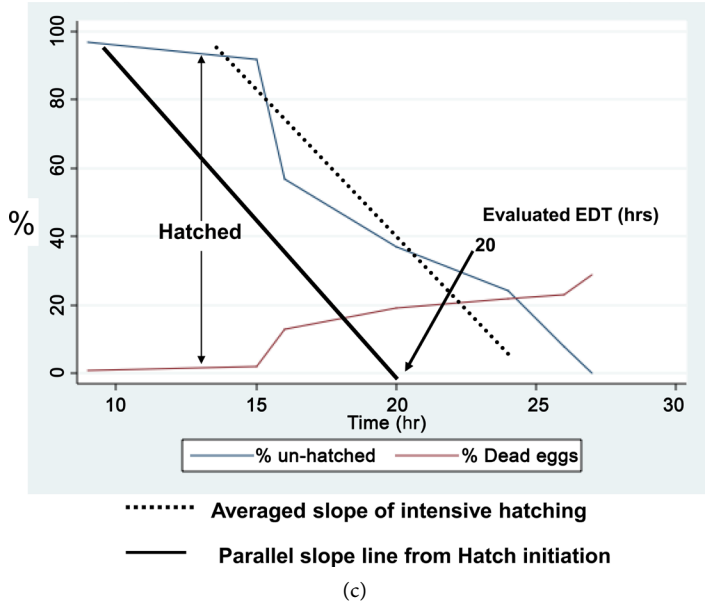

(c)

Figure 1. Time sorted course of egg development under ((a) 15˚C; (b) 22˚C; (c) 27˚C): % of dead and un-hatched; two plotted lines (Taube 1966, see text) are presented.

The second trial was similar to the first one with an additional design of light condition: 24 hours light comparatively with 12/12 hr light/dark condition under 15˚C.

7, 11, and 7 females were observed under 15˚C, 22˚C, and 27˚C, respectively. Observations were carried out every 2 hours.

3. Results

Results of incubation times (EDT) under the 3 experimental temperatures are shown in **Tables 1(a)-(c)**. In each table the total number of eggs laid per female, number of hatched eggs and dead eggs are presented, and their percentage portion indicated. The documentation of the observed data Vs (Versus) interval timing sorted is presented in **Figures 1(a)-(c)**. The three measured EDTs' (hrs) were 148, 33 and 20 under (15˚C), 2 (22˚C), and 3 (27˚C) respectively.

Results in **Table 2** indicate clearly the higher percentage of hatching and lower percentage of egg mortality under a 24 hours light regime with no significant difference in EDT between the two regimes.

4. Discussion

Results presented in **Tables 1(a)-(c)** indicate an EDT of 148, 33, and 20 hours in 15, 22, and 27, respectively. Those values were confirmed by **Figures 1(a)-(c)** evaluated through the graphic plot [26]. This graphic procedure include X axis-time (hrs) sorted of hatched and dead number of eggs (Y axis) followed by drawn line through the most active changes and parallel line started from first hatch. The touching point of the parallel draw line on the X axis is the mean EDT in hrs (see figures). Individual females which were experimentally cultivated from

Table 2. Total number of eggs laid, % hatched, % of dead eggs and incubation time (EDT) (hrs) under 12/12 light/dark and 24 hours light conditions at 15˚C.

Light Regime:	Total Number of laid Eggs	% of hatched eggs	% of Dead eggs	Incubation time (hrs) (EDT) (SD)
12/12 hr Light/Dark	180	71	29	131 (23)
24 hr Light	202	90	10	124 (26)

egg-through nauplius-copepodite-adulthood stages, the percentage of hatching under 15˚C and 22˚C was 30% and 67%, respectively, whilst in females freshly collected it was 87% and 82%, respectively. It is likely that longer exposure to natural lake conditions (food and temperatures) improved body conditions resulting in higher % of hatching. On the other hand, females' fecundity under 27˚C cultivated experimentally during the entire life cycle of the EDT was higher than that of the females described here. It can be interpreted as a negative impact of high temperature which damaged the eggs [21]. The EDT values under temperatures of 15˚C and 22˚C indicate a longer period than 24 hours. Consequently, the light/dark conditions as comparative evaluation between experimental and the natural ecosystem is legitimate. Under 27˚C, probably induction time of the dark period in summer is shorter than in winter, fall and spring periods when temperatures are lower. It is assumed that a continuation of light regime induces improvement on processes of egg development, causing less mortality and a higher % of hatching.

Results in **Table 2** indicate a shorter incubation time by 10% under continuous darkness. It is, therefore, assumed that darkness induces a shorter EDT and thereby a higher hatching rate with possibly greater clutches at night. Moreover, darkness improvement as shorter EDT might reduce vulnerability to potential predators. It is also likely that hatching enhancement in darkness reduces visual (invertebrates and particulate feeders fishes) and filter feeder fishes accompanied by a higher survival of newborn nauplii. It was documented (Gophen 1978a) that the densities of ovigerous females (carrying eggs) is lowest at dawn. The experimental design of EDT measurement of individual observation on a fertilized female is, therefore, suggested to be appropriate and relevant. The disadvantage of this method is the limited number of observed specimens, and the advantage is the direct observation of the living individual, ensuring fecundity, egg production, laying and hatching. Nevertheless, the objective of the observations is the study of thermal effect on the EDT as one significant parameter among other metabolic rates.

Global Warming Implications

Enormous documentations confirmed quite an old statement: "All metabolic rates of zooplankton are dependent on temperature" [7].

The study of thermal influence on metabolic rates is practically the measurements of the change of those rates under temperature elevation or decline. These

changes differ significantly between poikilothermic and homeothermic, large and small, and terrestrial and aquatic animals [27]. Those differences are critical for the dynamics of the process of energy transfer from the environment into the organism body (heating) or "backwards" (cooling). In the case of such microscopical zooplankters as *M. ogunnus*, the rate of energy transfer is of immediate and direct effect. It is widely known that thermal equilibration time dynamic increases with body size or biomass [28]. *M. ogunnus* is a small aquatic poikilothermic organism which, therefore, maintains an immediate body temperature equilibration with environmental changes of the initial temperature. Exposure time to modified heat levels, food quality and dark/light conditions were found to have a significant impact on egg size, rate of development and biochemical composition [29]. Global warming or climate change is presently at the top of the international agenda [30]. Global warming is accounted as the mother of most environmental scares and may be linked to many other sorts of calamities [30]. Nevertheless, natural life evolution developed adaptive capacity in aquatic organisms like *M. ogunnus* in Lake Kinneret to adjust metabolic rates within the thermal amplitude ranges of 15˚C - 27˚C as presented in this paper or even slightly extended (12˚C - 30˚C). As predicted, in continuation of the global warming process, higher temperatures (>33˚C, *Thermocyclops* sp.; [21]) might demolish the cyclopoid population in Lake Kinneret as a result of eggs partly damaged or entirely disintegrated and/or other stressed metabolic rates. It is not impossible that a continuation of the global warming trend in a large lake such as Kinneret might be damageable to the physiological traits of planktonic organisms. The global warming trend of the ecological condition is predicted to stress directly or indirectly freshwater ecosystems [27]. Lake ecosystems might experience changes in diel, seasonal and annual thermal and hydrological patterns [31] as a result of long-term thermal elevation. Such a stressor within freshwater lake ecosystems will be followed by biological modifications of metabolic rates, or life cycle dynamics caused by inappropriate balances between the food web compartments [31]. Results shown in **Table 2** indicate a shorter EDT and prominent increase of metabolic rates in relation to the thermal elevation, which confirms the prediction of energy flow enhancement within the food-web which can be ascribed to the impact of the global warming process.

5. Conclusive Summary

Experimental study of the impact of temperature has indicated 148, 33 and 20 hours under 15˚C, 22˚C, and 27˚C, respectively. Experimental light/dark regime has indicated improvement of egg hatching and survival. Previous documentations of metabolic rates of *M. ogunnus* confirmed a complementary thermal impact: 58% increase of EDT under 22˚C in comparison with 15˚C and lower (33%) shortening at 27˚C as compared with 22˚C whilst efficiency of food consumption by. *M. ogunnus* declined (−47%) between 15˚C and 22˚C and elevated (+63%) between 22˚C and 27˚C (**Table 3**). It is concluded that the thermal ele-

Table 3. Percentage changes of EDT duration and metabolic rates (mgC/mgC(body)/day); [6] in adult females of *M. ogunnus*: P = Production as egg production and body length increment; R = Respiration, Oxygen demand converted to Carbon; C = Food consumption; E = Efficiency as (P + R)/C in %. A = the % change between 15˚C and 22˚C; B = The % change between 22˚C and 27˚C.

	A	B
EDT	−58	−33
P	+115	+55
R	+76	+74
C	+361	+18
E	−47	+63

EDT = shorter; Metabolic Rates: + = Elevation; − =decline.

vation (global warming) might be reflected as an ecosystem productivity enhancement in cold periods (Winter) more than in summer time. Nevertheless, a smaller thermal increase in summer can enhance egg damage and reduction of zooplankton biomass increment. For future research on the potential influences of global warming on freshwater aquatic ecosystem, the experimental studies of EDT and metabolic rate changes under temperatures above 27˚C and below 15˚C are recommended. Data documented in closely related studies indicated results compatibility, among others, [7] [8] [10] [11] [13] [18] [21] [22] [23].

References

[1] Gophen, M. (1976) The Ecological Conditions That Influence the Reproduction and Development of *Mesocyclops leuckarti* (Claus) and Its Role in the Food Chain in Lake Kinneret. Ph.D. Thesis, Hebrew University of Jerusalem, Jerusalem, 187 p.

[2] Gophen, M. (1978a) Errors in the Estimation of Recruitment of Early Stages of *Mesocyclops leuckarti* (Claus) Caused by the Diurnal Periodicity of Egg Production. *Hydrobiologia*, **57**, 59-64. https://doi.org/10.1007/BF00018628

[3] Gophen, M. (1978b) The Productivity of *Mesocyclops leuckarti* (Claus) in Lake Kinneret (Israel). *Hydrobiologia*, **60**, 17-22. https://doi.org/10.1007/BF00018683

[4] Gophen, M. (1978c) Zooplankton. In: Serruya, C., Ed., *Lake Kinneret, Monographiae Biologicae* 32, Dr. W. Junk Publishers, The Hague, 297-311. https://doi.org/10.1007/978-94-009-9954-1_11

[5] Gophen, M. (2015) Thermal Preference by *Mesocyclops ogunnus* (Onabamiro 1957). *Open Journal of Ecology*, **5**, 15-21. https://doi.org/10.4236/oje.2015.52002

[6] Gophen, M. and Azoulay, B. (2002) The Trophic Status of Zooplankton Communities in Lake Kinneret (Israel). *Verhandlungen des Internationalen Verein Limnologie*, **28**, 836-839.

[7] Heinle, D.R. (1969) Temperature and Zooplankton/Chesapeake Science. *Proceedings of the 2nd Thermal Workshop of the US International Biological Program*, **10**, 186-209. http://www.jstor.orgf./stab/1350456

[8] McLaren A.D. (1966) Predicting Development Rate of Copepod Eggs. *The Biological Bulletin*, **131**, 457-469. https://doi.org/10.2307/1539985

[9] Corket, C.J. and McLaren. A.I. (1970) Relationships between Development Rate of

Eggs and Older Stages of Copepods. *Journal of the Marine Biological Association of the United Kingdom*, **50**, 161-168. https://doi.org/10.1017/S0025315400000680

[10] Maier, G. (1989) The Effect of Temperature on the Development Times of Eggs, Naupliar, and Copepodite Stages of Five Species of Cyclopoid Copepods. *Hydrobiologia*, **184**, 145-160. https://doi.org/10.1007/BF00014304

[11] Sullivan, L.J. and Kimmer, W.J. (2013) Egg Development Times of *Eurythemora affinis*, and *Pseudodiaptomus forbesi*, (Coprpoda, Calanoida) from the Upper San Francisco Estuary with Notes on Methods. *Journal of Plankton Research*, **35**, 1331-1338.

[12] Vuorinen, I., Rajasilta, M. and Salo, J. (1983) Selective Predation and Habitat Shift in Copepod Species: Support for the Predation Hypothesis. *Oecologia*, **59**, 62-64. https://doi.org/10.1007/BF00388073

[13] Landry, M.R. (1975) Dark Inhibition of Egg Hatching of the Marine Copepod *Acartia clausi* Giesbr. *Journal of Experimental Marine Biology and Ecology*, **20**, 43-47. https://doi.org/10.1016/0022-0981(75)90100-8

[14] Uye, S. (1976) Effects of Various Environmental Factors on Egg Development of Several Species of *Acartia* in Southern California. *Marine Biology*, **38**, 253-262. https://doi.org/10.1007/BF00388938

[15] Corcket, C.J. (1972) Development Rate of Copepod Eggs of the genus *Calanus*. *Journal of Experimental Marine Biology and Ecology*, **10**, 171-175. https://doi.org/10.1016/0022-0981(72)90070-6

[16] Devreker, D., Souissi, S., Winkler, G., *et al*. (2009) Effect of Salinity, Temperature and Individual Variability on the Reproduction of *Eurytemora affinis* (Copepoda: Calanoida) from the Sein Estuary: A Laboratory Study. *Journal of Experimental Marine Biology and Ecology*, **368**, 113-123. https://doi.org/10.1016/j.jembe.2008.10.015

[17] Guerrero, F., Blanco, J.M. and Rodriguez, V. (1994) Temperature-Dependent Development in Marine Copepod: A Comparative Analysis of Models. *Journal of Plankton Research*, **16**, 95-103. https://doi.org/10.1093/plankt/16.1.95

[18] Landry, M.R. (1975) Seasonal Temperature Effect and Predicting Development Rates of Marine Copepod Eggs. *Limnology and Oceanography*, **20**, 434-440. https://doi.org/10.4319/lo.1975.20.3.0434

[19] McLaren, I.A., Corckett, C.J. and Zillious, E.J. (1969) Temperature Adaptations of Copepod Eggs from the Arctic to the Tropics. *The Biological Bulletin*, **137**, 486-493. https://doi.org/10.2307/1540170

[20] Tester, P.A. (1985) Effect of Parental Acclimation Temperature and Egg Incubation Temperature on Egg Hatching Time in *Acartia tonsa* (Copepoda, Calanoida). *Marine Biology*, **89**, 45-53. https://doi.org/10.1007/BF00392876

[21] Burgis, M.J. (1970) The Effect of Temperature on the Development Time of Eggs of *Thermocyclops* sp. a Tropical Cyclopoid Copepod from Lake Georg Uganda. *Limnology and Oceanography*, **15**, 742-747. https://doi.org/10.4319/lo.1970.15.5.0742

[22] Bottrell, H.H. (1975) The Relationship between Temperature and Duration of Egg Development in Some Epiphytic Cladocera and Copepoda from the River Thames, Reading, with a Discussion of Temperature Function. *Oecologia*, **18**, 63-84. https://doi.org/10.1007/BF00350636

[23] Hart, R.C. and McLaren, I.J. (1978) Temperature Acclimation and Other Influences on Embryonic Duration in the Copepod Pseudocalanus sp. *Marine Biology*, **45**, 23-30.

[24] Herzig, A. (1983) The Ecological Significance of the Relationship between Temperature and Duration of Embryonic Development in Planktonic Freshwater Copepod. *Hydrobiologia*, **100**, 65-91. https://doi.org/10.1007/BF00027423

[25] Vijverberg, J. (1980) Effect of Temperature in Laboratory Studies on Development and Growth of Cladocera and Coprpoda from Tjeukemeer, the Neytherlands. *Freshwater Biology*, **10**, 317-340.

[26] Taube, I. (1966) The Temperature Dependence of the Development of the Embrio in *Mesocyclops leuckarti* (Claus) and *Cyclops scutifer* Sars. MSc Thesis, English Translation by Talling, I.B., Limnological Institute, Uppsala, 35 p.

[27] Sweeny, B.W., Jackson, J.K., Newbold, J.D. and Funk, D.H. (1992) Climate Change and the Life Histories and Biogeography of Aquatic Insects in Eastern North America. In: Firth, P. and Fisher, S.G., Eds., *Global Climate Change and Freshwater Ecosystems*, Springer-Verlag, New York, 143-176. https://doi.org/10.1007/978-1-4612-2814-1

[28] Peters, R.H. (1993) Chapter: Temperature and Metabolic Rate. In: Peters, R.H., Ed., *The Ecological Implications of Body Size*, Cambridge University Press, Cambridge, 54-78.

[29] Bonnet, D. and Carlotti, F. (2001) Development and Egg Production in *Centropages typicus* (Copepoda: Calanoida) Fed Different Food Types: A Laboratory Study. *Marine Ecology Progress Series*, **224**, 133-148. https://doi.org/10.3354/meps224133

[30] Parsons, M.L. (1995) Global Warming the Truth behind the Myth. Chapter: Singer, S. F. Forward, Insight Books, Plenum Press, New York and London, 7-8.

[31] Schindler, D.W., *et al.* (1990) Effect of Climate Warming on Lakes of the Central Boreal Forest. *Science*, **250**, 967-970. https://doi.org/10.1126/science.250.4983.967