Open Journal of Ecology, 2015, 5, 15-21
Published Online February 2015 in SciRes. http://www.scirp.org/journal/oje
http://dx.doi.org/10.4236/oje.2015.52002

Thermal Preference by *Mesocyclops ogunnus* (Onabamiro, 1957)

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Received 9 January 2015; accepted 27 January 2015; published 29 January 2015

Abstract

In this work, the thermal response of *Mesocyclops ogunnus* was experimentally studied. Temperature was the only one parameter that was tested. Other parameters, such as food quality and availability, light conditions, predation pressure, and water mass motions were not included in the study. Organisms were collected in Lake Kinneret and the experiments were carried out under diffused light, 12/12 hours light/dark conditions. In the experimental system, the organisms were exposed to different temperatures of 15˚C, 25˚C, 27˚C, and 30˚C with open pathway to migrate according to temperature preference. The preference of upper thermal range (25˚C, 27˚C, 30˚C) by copepodite and adult stages was documented.

Keywords

Mesocyclops, Ogunnus, Thermal, Preference

1. Introduction

Mesocyclops leuckarti (*Claus*) is the most common cyclopoid Copepod in Lake Kinneret (Israel) which averagely produces >30% of the lake zooplankton biomass. The name of this copepod was modified to *Mesocyclops ogunnus* (*Onabamiro*) [1]-[3]. Although many aspects of the eco-physiology of this zooplankter were widely studied by the author and others, information about thermal preference is an impact of sole parameter of temperature. The impact of temperature on the metabolism of *M. ogunnus* in Lake Kinneret and other Copepods was documented among others by Gophen [4]-[6], Gophen and Azoulay [7], and Vijverberg [8]. The impact of temperature on cyclopoids reproduction and population dynamics [8] [9], food and feeding habits [10] [11], diurnal migration [9] [12]-[14] body size [15] was documented as well. This paper describes the thermal effect on locomotive response of *M. ogunnus* in laboratory studies where using a single parameter of temperature was tested. Not any other parameters such as food quality and availability, light conditions, predation pressure, and water-

How to cite this paper: Gophen, M. (2015) Thermal Preference by *Mesocyclops ogunnus* (Onabamiro, 1957). *Open Journal of Ecology*, **5**, 15-21. http://dx.doi.org/10.4236/oje.2015.52002

mass motion, were involved in the present study. The experimented temperatures (15˚C, 25˚C, 27˚C, 30˚C) were similar to those occur in the Epilimnion of Lake Kinneret throughout a full year cycle [4]: summer stratification, fall de-stratification, winter overturn and formation of stratification in spring.

2. Material and Methods

The research was carried out using a system (**Figure 1**) comprised of two 2 liter jars placed inside two temperature controlled hot baths filled with Filtered (0.45 µ Filter Paper) Lake Kinneret water. Zooplankton animals were gently inserted into the jars by pipetting them onto the bottom of the jars while being disconnected by metal holder fixed on a flexible connecting plastic tube. Than the two jars loaded by the appropriated content were separately placed into the baths adjusted to the tested temperatures, then the holder was gently released to ensure prevention of water exchange between jars, and a free passage was open between the two jars. Collection of large animals (copepodites and adults) was done by placing lake population into sedimentation funnel during 3 - 5 hours than most of left over organisms were large body cyclopoid copepods. The temperature of 15˚C was maintained by leaving the entire system inside a cold (15˚C) room equipped by diffused light during several days. All samples of zooplankton matter were acclimated prior to initial time during 4 - 7 hours at the appropriate ambient temperature. Experiments lasted 24 hours and light conditions were neon source diffused from upper side and 12/12 hours of dark/light regime. After 24 hours each trial was blocked by sharp bending of the connecting pipe. Each jar was emptied separately into containers and the content was filtered through 10 µ mesh size net and microscopical counts were recorded.

Fresh zooplankton was daily collected in the lake by 63 µ mesh size plankton net. Single experiment was carried out daily.

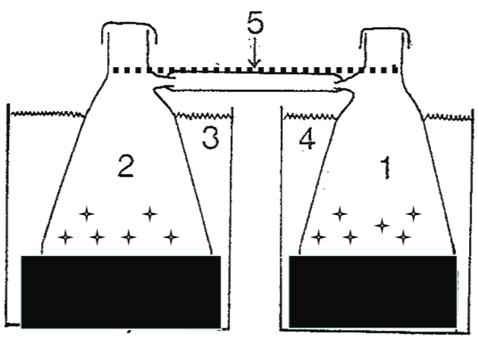
3. Results

Densities of the organisms at the end of each experiment are given in the following tables. Experimental design is given in the table titles.

Results presented in **Tables 1-7** indicate the followings:

Experiment 1: 27˚C temperature was clearly preferred by adult Females but Copepodites and Adult males were found to be at similar densities in both temperatures, 15˚C and 27˚C. Nevertheless in Experiment 2, as in Experiment 1, 27˚C preference by adult females was indicated as well as by copepodites but no preference by adult males was found. It can be indicated that a trend of 27˚C preference by cyclopoid copepods is existed. It should be taken into account that in Experiment 2 the density was very high and therefore it is possible that crowdedness, and not only temperature, might also stimulate migration.

In Experiment 4 tested temperatures were 25˚C and 30˚C. Among those two temperatures no preference was indicated. In Experiment 5 no significant migration from 30˚C to 25˚C and *vice versa* were indicated.



Legend:
1, 2 – Jars
3, 4 – Baths
5 – Connecting pipe
▪▪▪▪▪▪▪ Internal Water level
▬ Solid Base
+ + + Zooplankters

Figure 1. Experimental system chart.

Table 1. Experiment No. 1: Organisms were placed: 1) in the jar of 15˚C and 2) in the 27˚C jar. Percentage composition and total number of the cyclopoids in each jar after 24 hours of free contact between the two jars are given.

	Placed in 15˚C	Migrated to 27˚C	Total number
Copepodite iv-v	56	44	169
Adult females	20	81	386
Adult males	68	32	709
	Migrated to 15˚C	Placed in 27˚C	Total number
Copepodite iv-v	41	59	140
Adult females	7	93	380
Adult males	47	53	437

Table 2. Experiment No. 2: Equal number of organisms was placed in the jar of 15˚C and in the jar of 27˚C. Percentage composition of the cyclopoid organisms in each jar after 24 hours of free contact between the two jars are presented.

	Jar 15˚C	Jar 27˚C	Total number
Copepodite I-III	40	60	1718
Copepodite IV-V	35	65	345
Adult female	36	64	612
Adult male	52	48	296

Table 3. Experiment No. 3: Equal number of organisms was placed as follows: 1) in the jar of 15˚C and non in the jar of 27˚C; 2) into the jar of 27˚C and non into the jar of 15˚C. Percentage composition and total number of the cyclopoids and also accidentally accompanied by *Diaphanosoma* sp., *Bosmina* spp. and *Keratella* spp.) in each jar after 24 hours of free contact between the two jars are given. Zooplankton collected in the lake by fine mesh size net, 63 µ: large organisms were filtered for Trial A by 120 µ mesh size net, and the filtrate (small organisms) included in Trial B.

Trial A	Placed in 15˚C	Migrated to 27˚C	Total number
Copepodite iii-v	12	88	1426
Adult female	30	70	1674
Adult male	8	92	372
Diaphanosoma and bosmina	17	83	650
Trial B	Migrated to 15˚C	Placed in 27˚C	Total number
Small nauplius	15	85	5958
Large nauplius	6	94	2800
Copepodite i-iii	11	89	140
Keratella	17	83	485
Bosmina neonates	0	100	217

Table 4. Experiment No. 4: Tested temperatures were 25˚C and 30˚C. Experimental organisms were: Two trial (A, B) were carried out. In both trials the organisms were divided equally between the two jars of 25˚C and 30˚C. After 24 hours number of animal was counted in each jar and their percentage composition and total number are presented.

Trial A	25˚C	30˚C	Total number
Copepodite i	50	50	80
Copepodite ii	47	53	150
Copepodite iii	52	48	230
Copepodite iv	46	54	240
Copepodite v	62	38	130
Adult female	38	62	240
Adult male	37	63	270
Trial B	25˚C	30˚C	Total number
Copepodite i	45	55	93
Copepodite ii	53	47	165
Copepodite iii	52	48	81
Copepodite iv	56	44	48
Copepodite v	50	50	32
Adult female	25	75	24
Adult male	35	65	51

Table 5. Experiment No. 5: Two Temperatures were tested: 25˚C and 30˚C. Trial A: Organisms were placed in 25˚C and no animal in 30 jar; and Trial B where organisms were placed in 30˚C and no animals in the 25 jar. Percentage composition in all jars after 24 hours and total number of organisms are given.

Trial A	Placed in 25˚C	Migrated to 30˚C	Total number
Copepodite i	80	20	30
Copepodite ii	90	10	43
Copepodite iii	70	30	60
Copepodite iv	85	15	39
Copepodite v	nd	nd	Nd
Adult female	nd	nd	Nd
Adult male	77	23	66
Trial B	Migrated to 25˚C	Placed in 30˚C	Total number
Copepodite i	44	56	27
Copepodite ii	10	90	33
Copepodite iii	15	85	39
Copepodite iv	0	100	21
Copepodite v	0	100	18
Adult female	0	100	12
Adult male	50	50	18

Table 6. Experiment No. 6: Two Temperatures were tested: 15˚C and 30˚C. Trial A: Organisms were placed in 15˚C and Trial B where organisms were placed in 30˚C. In two trials the second jars did not contained animal at initial time. Percentage composition in all jars after free migration during 24 hours and total number of organisms are given.

Trial A	Placed in 15˚C	Migrated to 30˚C	Total number
Copepodite i-iii	78	22	177
Copepodite v	64	36	110
Adult female	40	60	182
Adult male	78	22	148
Trial B	**Migrated to 15˚C**	**Placed in 30˚C**	**Total number**
Copepodite i-iii	13	87	99
Copepodite v	19	81	97
Adult female	10	90	102
Adult male	18	82	91

Table 7. Experiment No. 7: Two zooplankton densities were tested: Trial A-3000 organisms and Trial B-1300 organisms. All organisms were place in one of the two jars and their densities were counted after free optional migration during 24 hours. Percentage composition of the organisms in all jars are given. Temperature of the entire system was 27˚C.

	3000 organisms		1300 organisms	
	Placed organisms	No organisms	Placed organisms	No organisms
Copepodite i-iii	97	3	99	1
Copepodite iv-v	91	9	95	5
Adult female	90	10	94	6
Adult male	96	4	100	0

In Experiment 6 the tested temperatures were 15˚C and 30˚C. Significant 30˚C preference by adult females in two trials and by other stages as well in Trial B were concluded. Those experiments indicated high temperature preferences, mostly by adult stages.

Experiment, No. 7 indicates no clear effect of high densities at 27˚C.

4. Discussion

M. ogunnus is certainly classified as an absolute poikilotherm or ectotherm organism. The internal physiological source of heat has a negligible importance in controlling body temperature which is absolutely controlled by the environment. Zooplankton organisms rely completely on ambient heat sources. It is likely that where environmental temperature varies very widely such as in stratified lakes like Kinneret the low thermal range limit their physiological activities and enhanced by increase of thermal conditions.

In previous studies a correlation was found between temperature and life span, development time, number of eggs produced, period length of eggs laying, percentage of hatched eggs, number of clutches, the total length of life span and metabolic efficiencies of females of *M. ogunnus* [4] [16] (**Table 8**).

Data presented in **Table 8** indicates prominently the ecological advantage of high temperatures for the enhancement of population density. Nevertheless consideration of metabolic advantage resulted in the opposite. In fact, when temperature is a sole effect it is a contradiction: population development versus metabolic quality (efficiencies): A combined shorter life time, higher production and lower metabolic efficiencies in high temperature whilst longer longevity, lower production but higher metabolic efficiencies induced at the lower thermal range. If we consider lower pressure of fish predation, lower rate of algal primary production under the low thermal range and *vice versa*, the following can be concluded: the zooplankton responses to the high and low ranges of thermal conditions represent optimization of ecological adaptation. The question emerged from the present study is only related to zooplankton preference of thermal range. Conclusive answer is probably that under wider range of 15˚C - 27˚C - 30˚C the warmer is the better whilst the full range of the upper level, 25˚C - 27˚C - 30˚C. Crowding, or density had no impact on migration between jars (**Table 7**).

A conclusive summary of thermal preferences is given in **Table 9**.

Moreover, similar behavior of *M. ogunnus* was documented in Lake Kinneret during thermal stratification [12]-[14]. Analysis of diurnal migrations of *M. ogunnus* indicated changeable response of *M. ogunnus* to light conditions, fish predation pressures alternating diurnally. It is obviously understood that poikilothermic animals, loose heat to a cooler environment and gain heat from a warmer one. The question what is the metabolic benefit of heat loose or gain for small zooplankter is the focus of the present study. It is not impossible that the heat budget of a zooplankter is just a by-product beside other metabolic or environmental responses. If this is the case in the complex interaction between a zooplankter and temperature a non linear interrelation between the cyclopoid and temperature is relevant. If a copepod loose or gain heat its body temperature will change and its metabolic rates will follow. With regard to *M. ogunnus* it was documented that the highest metabolic efficiency is due to the lower ambient thermal range but reproduction rate is lower and significantly increase with temperature elevation [4] [5] [8]. Results of the present study define the preference of high temperatures by all life cycle stages and adults. When high range of 25 - 30 was tested no clear preference as indicated. Nonetheless when higher temperatures of 15, 27, and 30 were tested, 27 and 30 were preferred. Crowding did not affected thermal migration. It is well known that small organism cool and heat faster than large animal exposed to the similar thermal gradient. If it is true to the difference between Fish weighted 200 g and a Crustacean body weight of 20 g which is 10 times lower it might also relevant to the difference between cyclopoid copepodite (3 μg/ind)

Table 8. Span (days) of life cycle stages and egg production of females of *M. ogunnus* in three temperatures, 15˚C, 22˚C, and 27˚C (modified from [4]).

Parameters	15˚C	22˚C	27˚C
Total number of eggs	23	100	93
Hatching (%)	30	67	86
Number of clutches	2	4	4
Laying period	17	18	10
Egg incubation time	6.2	1.4	0.8
Nauplius	28	16	9
Copepodite	39	15	10
Adult	149	62	42
Total life span	222.2	94.4	61.8

Table 9. Seven experiments summary of thermal preference in *M. ogunnus*.

Experiment No. (see text)	Thermal range (˚C)	Result
1	15 - 27	Adult female prefer 27˚C
2	15 - 27	Slight preference to 27˚C (except adult males)
3	15 - 27	Clear preference to 27˚C
4	25 - 30	No preference
5	25 - 30	No preference neither to 25˚C nor 30˚C
6	15 - 30	Clear preference to 30˚C

and adult female (30 μg/ind), which is also 10 times higher. It is likely that such a predicted similarity was not confirmed in this study. This principle under different body size of cyclopoids, the larger cool and heat faster then the smaller. Nevertheless the period of 24 hours these fluxes are equilibrated and the final results of migration are not affected by body size. Even if thermal flux equilibration is increasing with body size and initial "ambient" temperature, 24 hours is sufficient time for it.

5. Summary

Heat preference by the cyclopoid copepod *Mesocyclops ogunnus* was experimentally studied. Only one single parameter was tested—temperature. The tested temperatures (15˚C, 25˚C, 27˚C, 30˚C) were those which are common in the Epilimnion of Lake Kinneret throughout the full year cycle: summer stratification, fall destratification, winter overturn, and spring formation of stratification. It was found that between 15˚C and 27˚C, the latter is preferred whilst between 15˚C and 30˚C, the 30˚C is preferred. No preference was indicated between 25˚C and 30˚C and no significant impact of animal density as well.

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