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The distribution of the ctenophore, *Mnemiopsis leidyi* (A. Agassiz), in a vertical thermal gradient.

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INTRODUCTION

The distribution of organisms in an estuary is affected by a plethora of environmental factors. The ctenophore, Mnemiopsis leidyi, is found to exist over a wide range of these factors, temperature and salinity in particular, allowing it to occupy the estuary year round and make use of low salinity areas unavailable to most marine organisms (Miller, 1974).

Past research has centered on the horizontal distribution of M. leidyi in an estuary (Burrell 1968, Burrell and Van Engel 1976, Miller 1974, Kremer and Nixon 1976). This work was conducted in the field where several environmental factors may act together to influence ctenophore distribution. There is little information on vertical distribution. Each of the above mentioned authors made observations on the vertical distribution of M. leidyi, in all cases noting a fairly uniform distribution.

M. leidyi is a voracious predator of zooplankton. Burrell (1968) reports that the ctenophore accounted for 73% of the predation on zooplankton in the York River estuary when it occurred with the coelenterate medusae, chaetognaths and larval fish. In the Patuxent River, Bishop (1967) calculated that the ctenophore could account for 52% of the mortality of the copepod, Acartia tonsa. M. leidyi may therefore alter the structure of the estuarine food web. The larvae of commercially important fish may be excluded through competition in certain areas when M. leidyi occurs in abundance (Burrell, 1968).

The response of this animal to different environmental factors
is important to understanding the role it plays in the marine ecosystem. Knowledge of vertical distribution patterns contributes to this understanding. No data have been reported on the vertical distribution of *M. leidyi* related to vertically occurring factors such as temperature and salinity. The interaction of these factors affects the distribution of many estuarine species. There is a need for isolating temperature and/or salinity and examining the response of the ctenophore to each independently. Quantitative measurements in this area require laboratory techniques which may then be applied to conditions in the field.

Research on ctenophores in the laboratory must overcome the difficulties encountered in the collection and maintenance of these delicate animals. To examine the ecology of ctenophores requires adequate aquarium systems that allow the ctenophore to be maintained and thereby studied in the laboratory. Standard aquarium equipment required for filtration and aeration often cause injuries to the ctenophores. Furthermore, ctenophores require circulating water to supply food and disperse mucus, produced in abundance by the animal (Ward, 1972).

Greve (1970) has designed the "planktonkreisel", in which he maintained *Pleurobrachia pileus* for extended periods, a maximum of 250 days, rearing the ctenophore from egg to adulthood. The aquarium system described by Ward (1972) is suitable for "intermediate periods" of maintenance and is also tailored to the specific needs of the ctenophores.

The goal of this research was twofold; to work with and
present methods of collection and maintenance and to examine
the distribution, under laboratory conditions, of *Maemiopsis
leidyi* in a vertical thermal gradient.

**METHOD**

Specimens of *M. leidyi* were collected from the York River
at Gloucester Point, Virginia from early October, 1984 to March,
1985. Developmental stages ranged from small cydippids to adults.

Collections were made using a standard meter net (mesh
#202) with a wide-mouth 1 gal. plastic jug attached to the cod
end. The jug prevented damage to the ctenophores. The net
was set with the tide from a pier for 20-60 min. This method
was an excellent means of collecting large numbers of uninjured
catenopores; as many as 200 small (10-35mm) individuals have
been collected at once. The ctenophores were transported to
the laboratory in 10 gal. sealed buckets. In the laboratory,
the ctenophores were placed in a modified holding tank (Ward,
1972). A standard 80 liter aquarium was converted into an octagonal
tank by the insertion of glass plates in each of the four corners.
This holding tank was in line with another 80 liter aquarium
serving as the reservoir, which supplied a constant food supply
and water pumped continuously at 5-7 liters/min. A horizontal
current is established in the holding tank by passing water
pumped from the reservoir through a series of notches in two
of the glass plates in the corners of the holding tank. An undergravel filter is used to reduce suction in the tank, preventing injury to the animals. The ctenophores were maintained in water collected from the York River at the same time as the ctenophores and placed in a constant temperature room at ambient (river) temperature (4-11°C). *Artemia salina* larvae were used as food. The ctenophores were maintained under these conditions for at least 24-48 hrs. prior to the experiment.

The experimental tank, hereafter referred to as the Rice Tank (Rice, pers. comm.), consisted of a cylinder within a cylinder. The inner cylinder was 3.75 in. i.d. and the outer cylinder was 5.75 in. i.d., both were 49 in. high and made of clear plexiglass. Three drawer-like ports allow the animal to be introduced at the top, middle, or bottom. The tank was labeled at sixteen depths with 3 in. intervals, the temperature at each level was recorded. Seawater was placed in the inner cylinder, ice or hot water was placed in the outer cylinder to set up the thermal gradient. The gradient was established after the ctenophores were placed into the tank. The temperature in the tank ranged from 1°C at the bottom to 26°C at the top and varied 3-5°C throughout the experiment.

Ten individuals of 20-35 mm size range were chosen for each trial. In each case, the ctenophores were introduced to the Rice Tank at the surface. At 20 min. intervals throughout the trial, the number of ctenophores at each temperature/level was recorded. Each trial lasted 5 hrs. The first 40 min. were
designated as the acclimation period. A total of five trials with the experimental group were run. Three trials with a control group, in which there was no thermal gradient, were run.

The distribution of ctenophores in the control and experimental groups were analyzed using the Chi Square goodness-of-fit test. The average depth interval of the ctenophores at each time interval for all control and all experimental trials were compared.

RESULTS

The holding tank used in this study is well suited for the maintenance of _M. leidyi_. The ctenophores were originally maintained in Instant Ocean artificial seawater (Aquarium Systems, Inc., Eastlake, Ohio) at a specific gravity of 1.010 g/cm³. The water was filtered and distilled prior to mixing, and carefully adjusted to match the natural conditions of the river. A drip cord was used to acclimate the ctenophores to the new environment. Despite these precautions, I have been unable to successfully maintain the ctenophores in Instant Ocean for more than 5-7 days. This is contrary to Ward's findings in which he was able to successfully maintain ctenophores for 2-4 weeks in this artificial seawater. The reason for this discrepancy is unclear. When maintained in water collected from the York River, _M. leidyi_ survived for 4-6 weeks.
A. salina larvae were an adequate food source, being easily cultured and hatched and readily consumed by M. laevis. During periods of starvation, the ctenophore survived for as long as 14 days, the largest individuals enduring the longest, decreasing in size until they disintegrated.

The results of the experiments conducted in the Rice Tank are presented in figures 1-4. Each depth interval for the experimental group has a corresponding temperature associated with it. The thermal gradient was not consistent between trials, the specific temperature at each depth varying as much as 5°C. The temperature profile shown in figure 2 is therefore an average of the five trials.

A significant difference between the distribution of M. laevis in the control group and the experimental group was found using the Chi Square test (alpha=.05, X²=68.15, with 15° freedcm). The distribution of ctenophores in the control group exhibited aggregations at levels 1 (top) and 16 (bottom), although it was fairly uniform showing a greater concentration in the upper half of the tank. The greatest concentration of ctenophores in the experimental group occurred at 12-14°C. Figures 2 and 4 illustrate these observations.

**DISCUSSION**

The presence of a thermal gradient did influence the distri-
bution of *M. leidyi* in the Rice Tank. The aggregations that occurred at 12-14°C may be due to the fact that this is at or near the temperature in which they were maintained. Three of the five experimental groups were maintained at 11°C, the other two at 4°C. A slight aggregation also occurred at 3-4°C (figure 3).

In the estuary, temperature does not appear to limit the horizontal distribution of *M. leidyi*, although in colder water it is apparently restricted to higher salinities (Burrell and Van Engel, 1975). Furthermore, population biomass is apparently not closely regulated by temperature. Miller (1974) found spring peaks in biomass at 19.5°C and 23°C and fall peaks at 22.5°C and 16°C.

Notes have been made on the vertical distribution of the ctenophore in an estuary. Miller (1974) compared the depth distributions of three size groups of *M. leidyi* over a 24 hr. period. All groups had a marked preference for the surface at day, although the small individuals showed a greater affinity for the bottom than mid-depth. At night the distribution was nearly uniform, with a greater percentage of small individuals at the bottom. Both Burrell (1968) and Kremer and Nixon (1976) describe a fairly uniform vertical distribution of *M. leidyi*. Burrell found smaller individuals tended to aggregate near bottom currents, which may be a mechanism serving to retain them in the estuary.

*M. leidyi* exists at nearly all temperatures to which it
is exposed in the estuary (Miller 1974, Burrell and Van Engel 1975). This was the case in this study; the ctenophore was found at all temperatures, from 10 to 28°C, in the Rice Tank. The effect of temperature on ctenophore distribution in this study may have been the result of *M. leidyi* seeking out the temperature in which it was maintained, as discussed above. However, this distribution may be a result of individual responses to temperature among the ctenophores. Differences in temperature response among individuals, particularly of different size groups, would serve to reduce feeding competition.

In the field, there has been no attempt to correlate the distribution of *M. leidyi* with the thermal profile of the area in which they were collected. Further examination of the effects of temperature and temperature and salinity together is needed. A study similar to this except using a horizontal thermal gradient would better isolate the response to temperature, with the effect of depth being removed.

In summary, although a population of ctenophores shows little response to temperature, individual differences may exist. Individual temperature preferences in conjunction with salinity factors may influence the distribution of *M. leidyi* in the estuary. In the Rice Tank, a significant difference in the distributions of ctenophores in a thermal gradient and an isothermal condition existed, therefore temperature apparently does exert an influence on distribution. More research in this area is needed to adequately relate these observations to conditions in the field.
Figure 1. Distribution of *M. leidyi* in the Rice Tank (see text). The average of three 5 h trials in an isothermal tank (4°C) is shown. Ctenophores collected from the York River, January-March, 1983 (as in Figs. 2-6).
Figure 2. Distribution of *M. leidyi* in Rice Tank. The average of five 5 h trials in a thermal gradient is shown. Each level has an average temperature (°C) associated with it.
Figure 3. Number of *M. leidyi* at each level in Rice Tank. Represents three 5 h trials. Temperature = 4°C.
Figure 4. Number of *V. leidyi* at each temperature in Rice Tank. Represents five 5 h trials.
LITERATURE CITED


