

AN ABSTRACT OF THE THESIS OF

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Title: THE EFFECT OF TEMPERATURE AND SALINITY
ACCLIMATION ON THE RESPIRATION RATE OF A MARINE
POLYCHAETE, SERPULA VERMICULARIS L.

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In January 1970, collections of Serpula vermicularis L. were obtained from Bray Point, Oregon, for the purpose of determining the effect of acclimation to salinity and temperature on its rate of respiration. The worms were removed from their tubes and acclimated to one of three salinities (28.8‰, 31.1‰, or 35.9‰) and one of two temperatures (10°C or 15°C). Following a two-week acclimation period, measurements of the rates of respiration were made at 10°C, 15°C, 20°C, 25°C, and 30°C.

The results of these measurements revealed that acclimation to salinity has no effect on the rate of respiration of Serpula vermicularis. This indicates that the serpulids had undergone complete compensation to these salinities. In comparing the rates of respiration of serpulids acclimated to different temperatures, it was found that the cold

acclimated worms had higher rates of respiration than the warm acclimated worms at all experimental temperatures.

The results of acclimation to temperature might be used to compare serpulids from different geographical areas. Perhaps such experiments would enable the researcher to gain insight into the variability of temperature regimes in different geographical locations by measuring the rates of respiration of serpulids collected in these areas.

The Effect of Temperature and Salinity
Acclimation on the Respiration Rate of
a Marine Polychaete, Serpula vermicularis L.

by

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THE EFFECT OF TEMPERATURE AND SALINITY
ACCLIMATION ON THE RESPIRATION RATE OF
OF A MARINE POLYCHAETE, SERPULA VERMICULARIS L.

INTRODUCTION

The literature on polychaetous annelids is most extensive, although much of this literature is taxonomic. However, in recent years more studies have been made on the physiology of this diverse group of annelids.

Some of the recent studies have been concerned with serpulid reef-like formations which have been considered fouling. Individual serpulids have been found from the Ordovician and reef-like colonies from the Cretaceous (Behrens, 1968).

The purpose of this paper is to examine the influence of two physiological variables, acclimation to temperature and salinity on the rate of respiration of Serpula vermicularis L. It is hoped that this study will add to the knowledge of serpulids in general and to the nature of acclimation in marine poikilotherms.

Anatomical Aspects of Serpula vermicularis

The polychaetous annelids are divided into two groups - the Sedentaria and the Errantia. The Errantia includes the pelagic forms, the crawlers, the active burrowers, and some of the tube-dwelling forms. The tube-dwelling members of this group often leave

their tubes in search of food or for reproductive purposes. Their tubes are not always attached to the substratum but may be carried about with the animal. The Sedentaria contains most of the tubicolous forms. Their tubes are generally attached firmly to the substratum. The members of this group (example: Serpula vermicularis) never leave their tubes.

Serpula vermicularis belongs to a group of tubicolous polychaetes known commonly as fanworms. This name arises because their first anterior segment, the prostomium, has been modified into a crown of many bipinnate processes called radioles (Barnes, 1968). The most dorsal radiole has been further modified into a chitinous operculum which functions to seal off the opening of the tube. The tube has only one opening located at the anterior end.

The crown, radioles + operculum, of this serpulid is red to magenta with variable amounts of white markings. Often the crowns owe their magenta color entirely to astaxanthin, a red pigment (Dales, 1962). Dales (1962) believes this pigment serves to screen the worm's tissue from light.

The radioles appear to function as respiratory surfaces and as a feeding mechanism. Each radiole is composed of two rows of pinnae which lay on either side of a ciliated groove. The pinnae produce a water current and particulate matter is trapped by the cilia. The cilia then move the particulate matter posteriorly to the mouth.

Barnes (1968) suggests the worm possesses a mechanism for rejecting this particulate matter on the basis of size.

In addition to functioning as a respiratory surface and a feeding mechanism, the expanded anterior portion of the body, i. e., the crown, functions in the dispersal of gametes. This is accomplished by extending and retracting the crown in and out of the tube, thus dispersing gametes into the water. This process can easily be observed by introducing a small amount of formalin into a petri dish in which the worm has been submerged with sea water or by attempting to remove the worm from its tube. Serpulids taken in the spring from Oregon and California have been found to readily release their gametes (Ricketts, Calvin and Hedgpeth, 1968).

Two ventral calcium sacs are located on each side of the mid-ventral line in the posterior region of the peristomium, or collar (Hedley, 1956). The ventral calcium sacs are important in the formation of the worm's calcareous tube. Also important in tube formation are the calcium secreting glands. These two glands are located just posterior to the middle of the ventral shield (Hedley, 1956). The calcium secreting glands are excretory; each gland is supplied with a duct which opens to the exterior in the middle of the ventral shield.

The ventral shield has mucus secreting areas which contribute organic material to the tube. There is a close association between the calcium secreting glands and the ventral shield in most serpulids

(Hedley, 1956). In Serpula vermicularis, the actual formation of the tube is always in an anterior direction. The tube takes formation under the back-rolled peristomium (Swan, 1950). Apparently, the peristomium functions as a mold in shaping the tube.

The parapodia are greatly reduced in Serpula vermicularis; the setae, however, remain an integral part of the mechanism by which the worm moves within its tube. The setae and number of segments are not discussed in this paper; anyone interested in the taxonomic characteristics of this polychaete should consult Fauvel (1927). The serpulid employed in this experiment was identified by Dr. Donald J. Reish at the California State College at Long Beach.

Distribution and Habitat

Serpula vermicularis is cosmopolitan in distribution (Straughan, 1967). It has been sampled from Australia (Straughan, 1967), South Africa (Day, 1957), England (Dales, 1962; Southward, 1963), Antarctica (Hartman, 1966), Vancouver Island (Berkeley and Berkeley, 1932) to California (Ricketts, Calvin and Hedgpeth, 1968).

Along the Oregon Coast, Serpula vermicularis is found primarily in rock pools in the middle intertidal region. The middle intertidal region is that portion of the intertidal region which is covered by the sea twice daily. Southward (1963) has reported taking samples of S. vermicularis off the continental slope at a depth of 200-750 meters.

Hartman (1966) has reported samples of S. vermicularis taken in Antarctica from shore to 260 meters. Wherever they occur, these serpulids appear to be attached to solid substrates. Off the coast of Oregon, they have been observed to grow on the shells of the California mussle, Mytilus californianus Conrad. Other serpulids, e. g., Hydroides norvegicus Gunnerus, also appear in loose material such as shelly sand. In such cases, the sand is always rich in calcium carbonate from shells or oolite (Behrens, 1968b). S. vermicularis, unlike H. norvegicus, has not been observed along the coast of Oregon on such loose substrates. Sparse populations of S. vermicularis have been observed in splash pools in the upper intertidal region at Seal Rock State Park, Oregon. Such pools would be subjected to great fluctuations in salinity and temperature. However, the populations in these pools are always small compared with populations inhabiting pools in the middle intertidal region.

Temperature and Salinity as Ecological Factors

Although there have been a few papers written on the physiology of some of the serpulid worms, there has been virtually nothing written on the effect of temperature and salinity on Serpula vermicularis. This is an important area of research, since it could lead to clues about the formation of serpulid reefs and the phenomenon of acclimation. Temperature tolerance experiments are also important,

since they may be used as a tool in taxonomy (Fry, 1956).

Brattström and Thorson (1941) have worked with the serpulid Microserpula inflata Dons and have taken samples of them in water temperatures of 0 to 14.5°C. Hill (1967) studied the salinity tolerances of Mercierella enigmatica Fauvel and Hydroides unicata (Philippi) and found the major variable affecting distribution of these two serpulids to be salinity.

Temperature as an intrinsic ecological factor affecting the life-cycle, abundance, and distribution of most organisms, both marine and terrestrial, has been well exemplified throughout the literature (see Bullock, 1955 for a more complete review). Orton (1920) suggests that most animals under normal conditions begin to breed either at a definite temperature or at a definite temperature change. Gunter (1957) indicates that temperature is the primary factor controlling the seasonal migration and other cyclic seasonal activities of fishes and motile invertebrates. Indeed, temperature is the controlling influence on the distribution of strict stenotherms. However, not all organisms can be classified as being stenothermal or eurythermal (Gunter, 1957). Some organisms may be eurythermal for a portion of their life cycle and stenothermal for another portion.

While there is general agreement that the marine environment presents relatively small variations in temperature when compared with the terrestrial environment, it should be noted that the intertidal

region represents a radical departure from the relatively constant temperature regime of the maritime environment in general. Indeed, organisms inhabiting this area, the area between the tides, are endangered by such physical factors as temperature and salinity changes and desiccation.

Tidepools represent a special area in the intertidal region. The littoral pools are continuous with the sea at high tide and, for all intents and purposes, are the same as the sea, being disconnected from the sea at low tide (Doty, 1957). The organisms submerged in the pool are not generally endangered by desiccation. Nevertheless, they can be exposed to temperature variations of 15°C or more in less than 30 minutes (Gersbacher and Denison, 1930).

Most littoral pools of large size do not reach such extreme temperature differences in such short periods of time. However, during periods when low tides are near midday, the temperature of even the large pools will be higher than that of the normal sea (Gersbacher and Denison, 1930). Should low tides occur during the early morning hours, the temperature reached in the tidepool can be well below the temperature of the surrounding sea (Southward, 1958). Hence, temperature has an important influence on the organisms inhabiting littoral pools as well as the intertidal region in general.

Temperature also influences organisms by producing changes in their chemical, physical, and morphological properties (Orr, 1955).

An increase in temperature decreases the viscosity of water and thereby increases the conductivity (movements of electrolytes in an electrical field) of electrolytes (Giese, 1968). The time it takes for two cleavages in the eggs of Paracentrotus (a sea urchin) increases with decreasing temperatures (Prosser and Brown, 1961). There is a tendency to increase in size in colder water in related species and, in some cases, with members of the same species (Severdrup, Johnson and Fleming, 1942). When considering temperature as a limiting factor, it is necessary to remember that a definite upper and lower limit, i. e., temperature tolerance, cannot be studied without considering other factors (Orr, 1955; Bullock, 1955). Three considerations which should be made are salinity, the duration the animal is kept at that temperature, and the period of time given the animal(s) to acclimate to that temperature.

The salinity in which the tests are made should be given in all temperature tolerance studies. Gunter (1957) suggests that marine organisms survive cold better in high salinities or hypertonic solutions. Hence, when cold death is due to the formation of ice crystals, high salt content of interstitial and intercellular fluids enhances cold resistance.

It is not known at what level(s) acclimation to temperature and salinity occurs. However, the evidence indicates that a multiple level of thermal adaptive regulation occurs in poikilotherms (Bullock, 1955).

This multiple level regulation includes the biochemical, cellular, organismic, and behavioral levels. It is not the intent of this paper to determine at what level(s) salinity and temperature acclimation occurs in Serpula vermicularis. It will be the purpose of this study to determine the relationship between acclimation to salinity and temperature to the rate of respiration of S. vermicularis.

MATERIALS AND METHODS

Collection of Experimental Serpulids

All of the experimental serpulids utilized in this study were collected in January, 1970 from Bray Point, a rocky intertidal area on the coast of Oregon. The serpulids were collected in tidepools located in the middle intertidal region, hence only moderately low tides were necessary before collections could be made.

Since the elevation of the tidepool in the intertidal region has been shown to affect the physiology and morphology of certain of the animals which inhabit them, e. g., limpets and barnacles (Humphrey and Macy, 1930), only serpulids collected from tidepools at the same elevation were used in this experiment. An attempt was made to remove the worms individually from the sides of these tidepools, about 30 centimeters below the water line. However, it was often necessary to remove the worms in clusters since they tend to aggregate in colonies. This was accomplished by the removal of a portion of the substrate which contained such colonies.

After removal from the tidepools, the worms were placed in one gallon wide-mouth jugs which contained sea water. They were then transported to the laboratory at Oregon State University, approximately 90 minutes driving time from Bray Point.

Laboratory Maintenance of Experimental Serpulids

Since the wet weights of the animals were required prior to each measurement of respiration, it was necessary to remove them from their tubes. This was accomplished by chipping away the tube from the posterior end, a most time-consuming process, but one which resulted in few injured animals (Neff, 1969). After removal, all worms were carefully checked to insure that injured animals were not used in the experiment.

Filtered sea water with a salinity of 34.0‰ was obtained from the Oregon State University Marine Science Center at Newport, Oregon. Since a portion of this study concerns itself with the effect of acclimation to various salinities, it was necessary to concentrate this original sea water sample to obtain a higher salinity (35.9‰) and to dilute to obtain lower salinities (31.1‰ and 28.8‰). Evaporation of the original sea water to 35.9‰ was accomplished by using a one liter side arm flask attached to a vacuum line. The sea water was subjected to a gentle vacuum for a period of 24 hours. This procedure was repeated a number of times and the resultant sea water was combined with the original sea water sample to obtain the desired salinity. The water was not heated since this can lead to the precipitation of certain compounds. Doubly glass distilled water was used to dilute the original sea water sample to obtain salinities of 31.1‰ and 28.8‰. Final

determination of all three acclimation salinities were made by Charles Culberson, Department of Oceanography, by silver nitrate titrations. Ten gallons of each salinity were stored in plastic jugs and placed in a coldroom (about 10°C) for the entire experimental period.

From each salinity, 800 milliliters of sea water were extracted and divided equally into two plastic containers. These plastic containers each measured 17.5 centimeters by 12.5 centimeters by 6.2 centimeters. This left approximately five centimeters of sea water covering the worms. The serpulids were maintained in these containers for the entire experimental period. Ten worms were placed in each container and one container of each salinity was placed into a constant temperature chamber of 10°C and 15°C .

Aeration of the sea water was accomplished by changing the water in each container twice weekly. No attempt was made to introduce food into the water since it was felt that the water, although filtered, contained sufficient organic matter to maintain the worms for a period of three days before the water would be changed again. This procedure appeared to be sufficient since many of the worms were maintained in good condition for a period of time far beyond the experimental period.

Determination of Rate of Respiration

All of the experimental animals were acclimated to one of three salinities (35.9‰, 31.1‰, or 28.8‰) and to one of two temperatures (10°C or 15°C) for a period of two weeks prior to being subjected to the measurement of their rate of respiration. Wet weights of all worms were obtained immediately prior to each measurement of rate of respiration. The actual weight of each worm was obtained by subtracting the weight of the empty reaction vessel from the combined weights of the reaction vessel and the worm. All weight measurements were made on a Mettler H16 balance.

For measurements of the rates of respiration, a Gilson model GRP-14 differential respirometer was utilized in conjunction with Gilson's GME-130 reaction vessels. Before introducing the worm and reaction vessel into the water bath, five milliliters of the sea water used to acclimate each worm was introduced into the well of each reaction vessel. In addition to the sea water, 0.2 milliliters of 10% KOH was introduced into the sidearm of each vessel to absorb the CO₂ gas evolved during the respiration measurement (Umbreit, Burris and Stauffer, 1964).

Measurements of the rates of respiration were made at five degree intervals from 10°C to 30°C. Each measurement consisted of lowering the reaction vessels, each vessel containing one worm, into a water bath set at the desired temperature. One hour was allowed for

temperature equilibration between the water bath and the reaction vessels. During each experiment, approximately 10 milliliters of distilled water were maintained in the reference flask of the respirometer.

Time "zero" was considered after this one hour equilibration period. Readings were taken every two hours at the lower temperatures (10°C to 25°C) and every hour at 30°C . Immediately following each reading, the system was opened to the outside atmosphere for approximately five minutes. Total time for each measurement of rate of respiration at a particular temperature varied, but all were at least six hours in length from time zero. During this entire six hours, the vessels were being subjected to 75 oscillations per minute by the respirometer.

Immediately following each run, the worms were removed from the reaction vessels and returned to their respective acclimation containers. Twelve of the worms acclimated to 15°C (four from each of the three salinities) were run on one day while 12 worms acclimated at 10°C were run on the following day. This allowed each animal a recovery period of approximately 27 hours between each run. The total length of the experimental period, including the two week acclimation period, was slightly over one month.

RESULTS

During the initial two hours following time zero, the rates of respiration of all worms increased rapidly. The degree of this increase appeared to be dependent upon the temperature of the run. In general, the higher the experimental temperature, the greater was the initial increase in the rate of respiration. Immediately following rapid rise in the rate of respiration, the rates leveled off and remained approximately constant for the duration of the run. It was during this time interval, from two to six hours after time zero, that the rates of respiration were recorded as being indicative of that experimental temperature. Figure 1 depicts the relationship between the rate of respiration and time at 20°C for a serpulid weighing 0.189 grams.

Results of Acclimation to Salinity

In order to obtain linear regressions, the rates of respiration were converted to log form. Then the mean log rates of respiration ($\overline{\log Rr}$) for each acclimation group were calculated at each of the five experimental temperatures (Table 1). Once transformed, the method of least squares (Snedecor and Cochran, 1967) was employed to obtain the regression lines which appear as Figures 2, 3, 4, 5, and 6.

Figures 2 and 3 depict the effect of salinity acclimation for

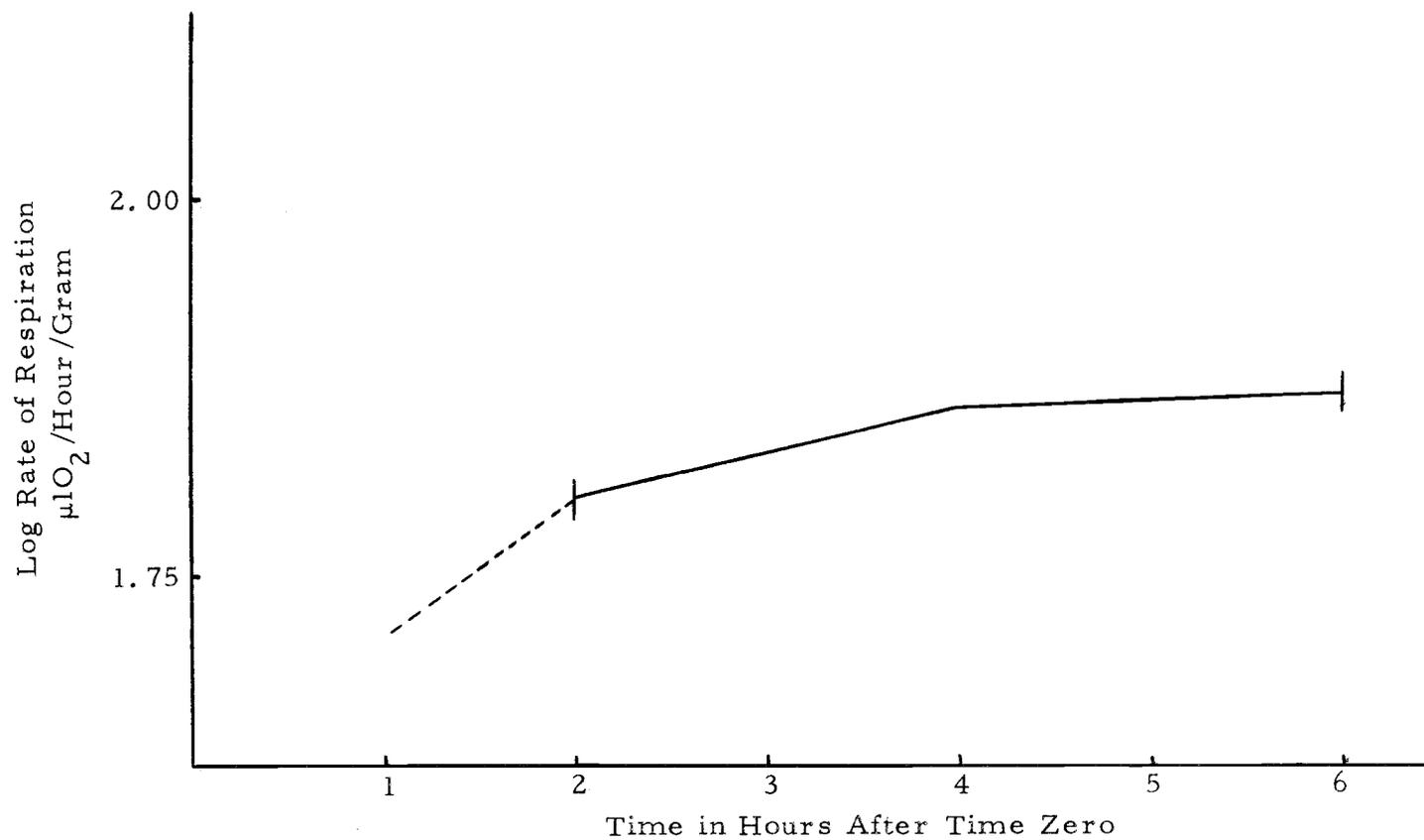


Figure 1. The relationship between the length of the experimental run (at 20°C) and the log rate of respiration of Serpula vermicularis.

Table 1. A summary of the mean log rates of respiration ($\overline{\log Rr}$) at each experimental temperature for each acclimation salinity and temperature. A, B, and C represent acclimation salinities of 35.9‰, 31.1‰, and 28.8‰, respectively.

	A _{10°C}	B _{10°C}	C _{10°C}	A _{15°C}	B _{15°C}	C _{15°C}
$\overline{\log Rr}_{10°C}$	1.66	1.68	1.73	1.57	1.60	1.55
$\overline{\log Rr}_{15°C}$	1.88	1.88	1.78	1.73	1.69	1.77
$\overline{\log Rr}_{20°C}$	2.04	1.95	1.93	1.83	1.91	1.88
$\overline{\log Rr}_{25°C}$	2.16	2.14	2.09	2.03	2.05	2.01
$\overline{\log Rr}_{30°C}$	2.52	2.40	2.29	2.23	2.13	2.11
$\frac{\sum \overline{\log Rr}}{5}$	2.05	2.01	1.96	1.88	1.88	1.86

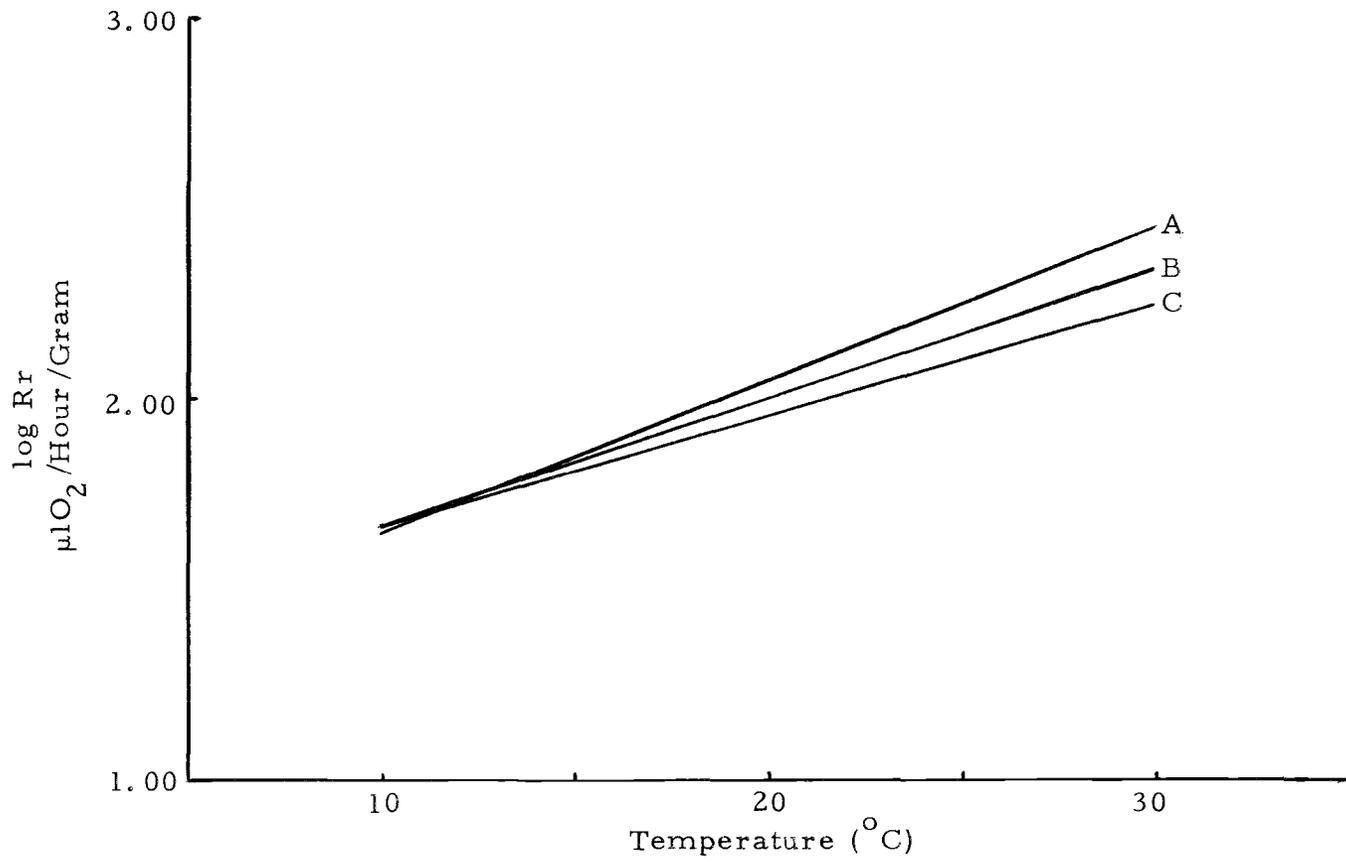


Figure 2. The effect of salinity acclimation on animals acclimated to 10°C. A = 35.9‰, B = 31.1‰, C = 28.8‰.

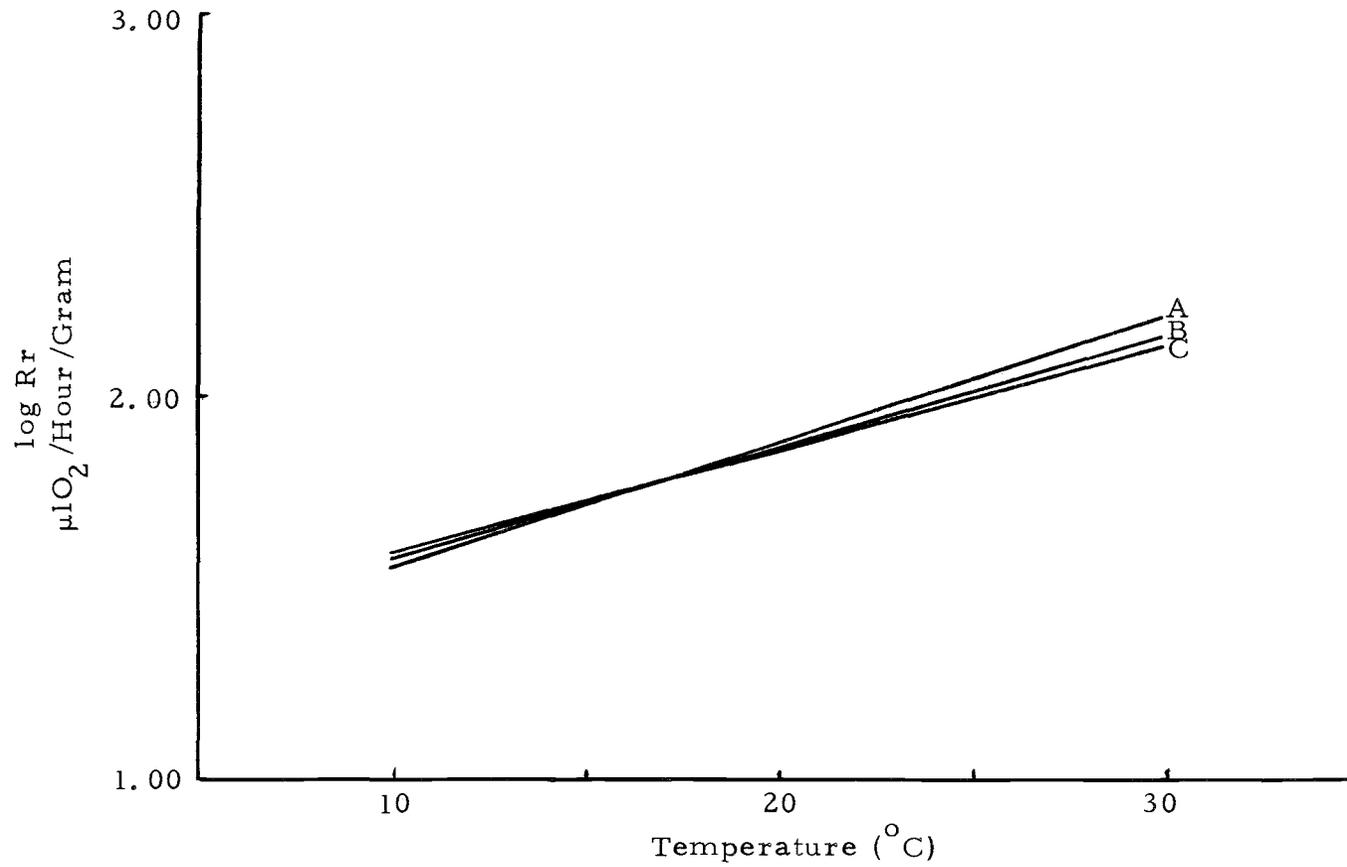


Figure 3. The effect of salinity acclimation on animals acclimated to 15°C. A = 35.9‰, B = 31.1‰, C = 28.8‰.

serpulids acclimated to 10°C and 15°C , respectively. Student's t-test was employed to compare the mean log rates of respiration for the three acclimation salinities at 30°C . There were no significant differences at the 5% or 10% levels for either of the acclimation temperatures.

In addition to Student's t-test, an analysis of variance of a two way classification (Snedecor and Cochran, 1967) was used to determine if acclimation to the three salinities had any affect on the slopes of the regression lines. There was no difference at the 5% or 10% significance levels. This indicates that acclimation to salinity had no affect on the slopes of the regression lines.

Results of Acclimation to Temperature

Figures 4, 5, and 6 depict the effect of acclimation to temperature on the rates of respiration for animals acclimated to 35.9‰, 31.1‰, and 28.8‰, respectively. In order to determine if temperature acclimation affected the absolute rates of respiration, a Student's t-test comparing the mean log rates of respiration for each acclimation salinity at 30°C was employed. Unlike acclimation to salinity, acclimation to temperature did affect the absolute rates of respiration of the serpulids. At the 10% significance level, the serpulids acclimated to 10°C showed higher rates of respiration than serpulids acclimated to 15°C .

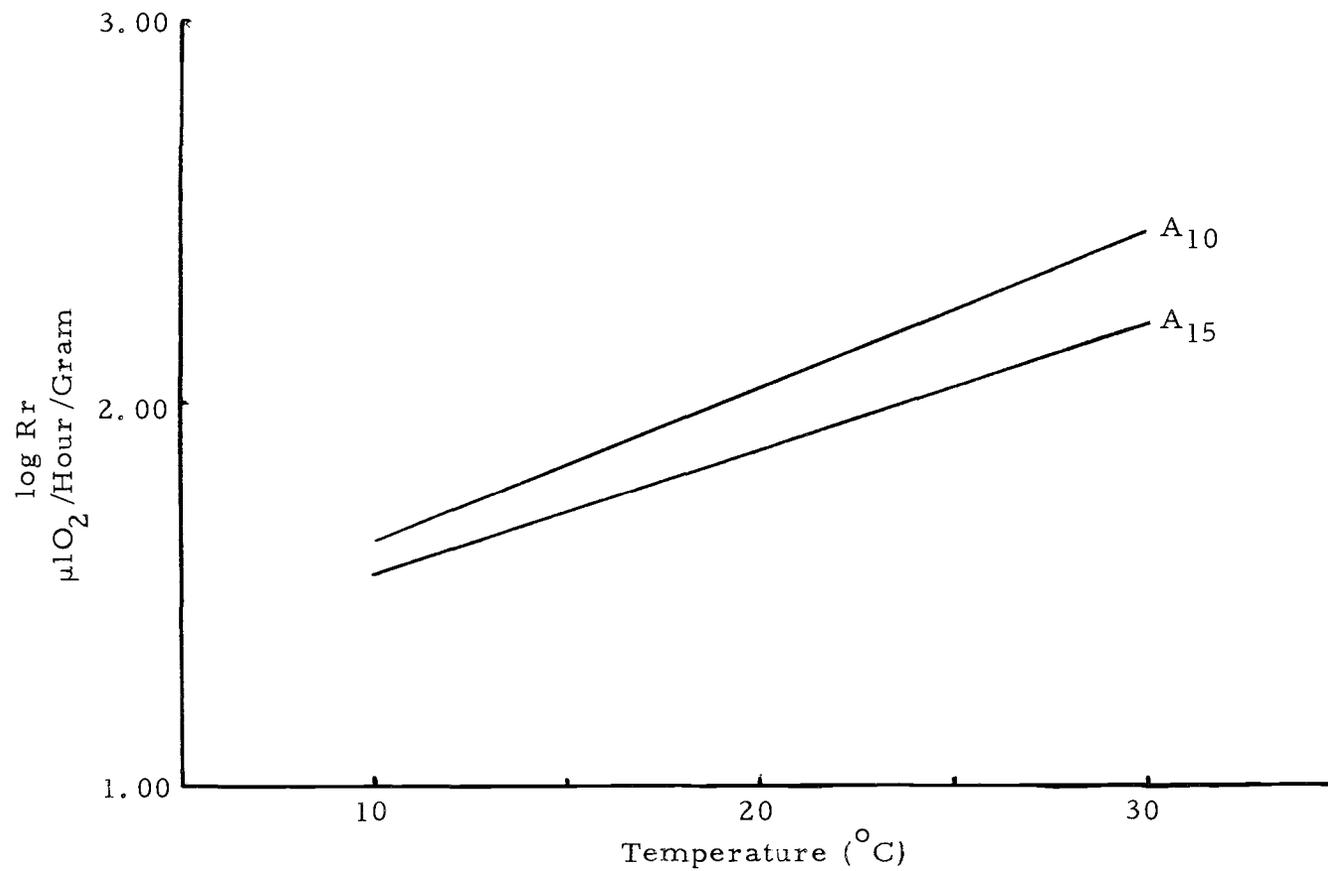


Figure 4. The effect of temperature acclimation on animals acclimated to the same salinity (35.9‰).

A₁₀ = acclimated to 10°C.

A₁₅ = acclimated to 15°C.

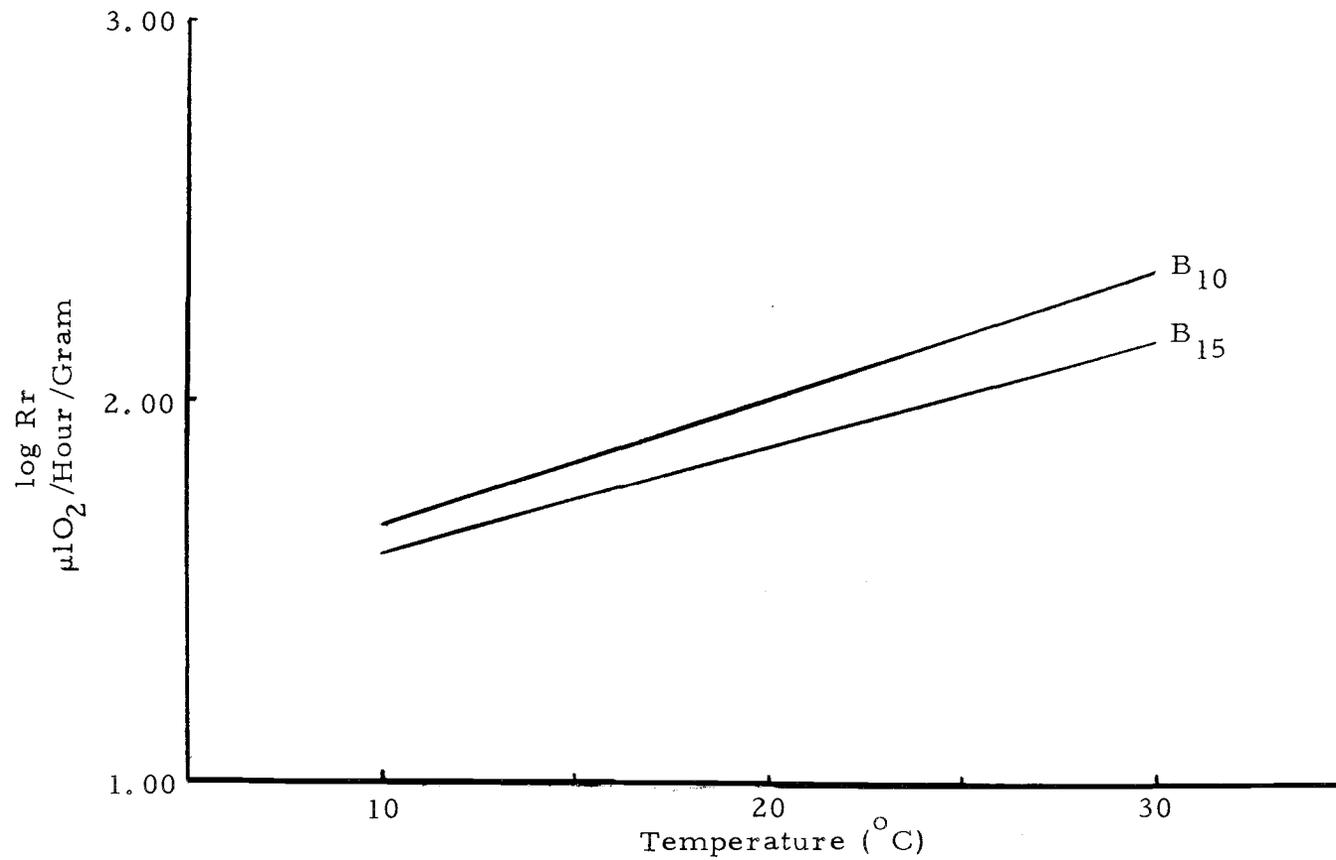


Figure 5. The effect of temperature acclimation on animals acclimated to the same salinity (31.1‰).

B₁₀ = acclimated to 10 $^{\circ}$ C.

B₁₅ = acclimated to 15 $^{\circ}$ C.

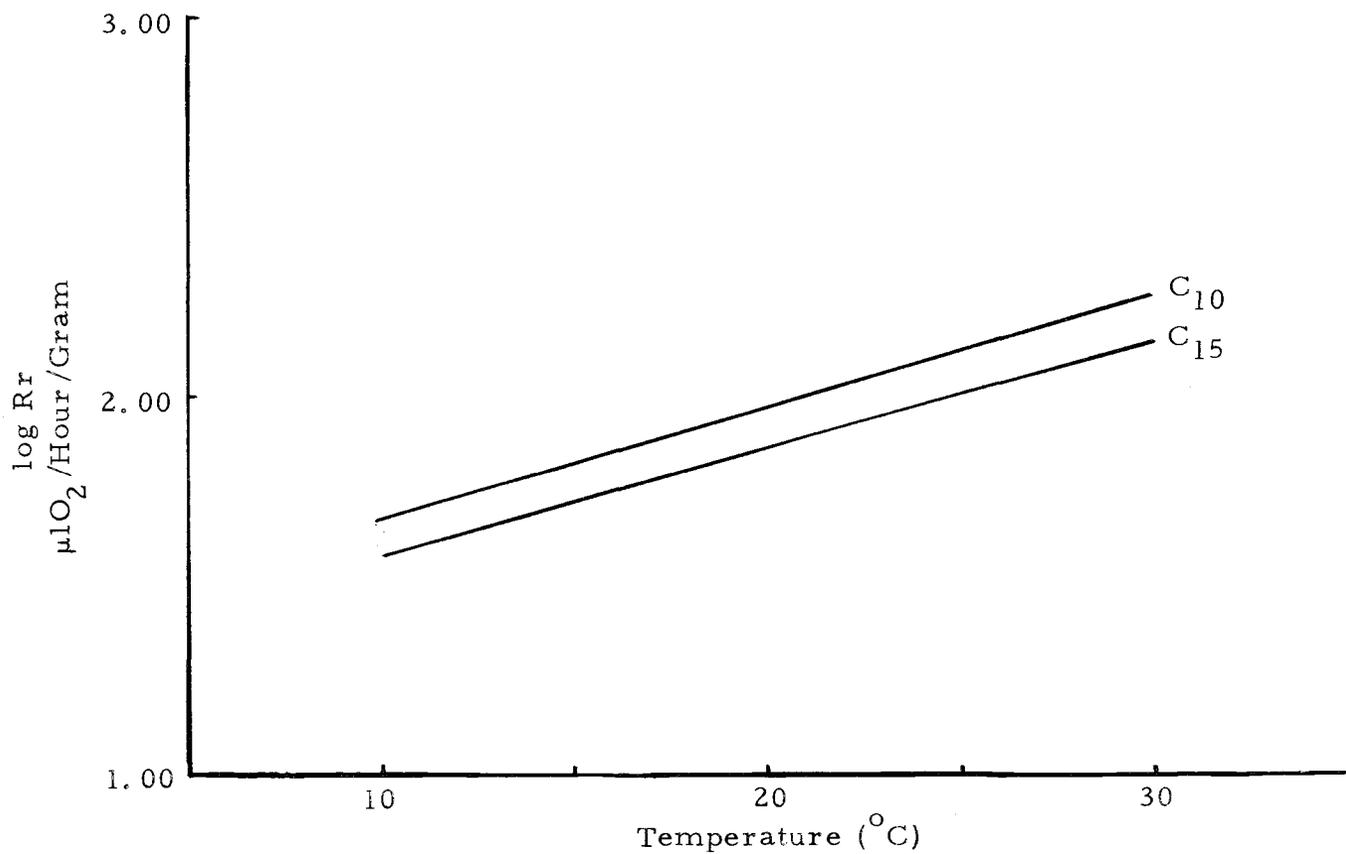


Figure 6. The effect of temperature acclimation on animals acclimated to the same salinity (28.8‰).
 C₁₀ = acclimated to 10°C.
 C₁₅ = acclimated to 15°C.

In addition to Student's t-test, an analysis of variance of a two way classification was employed to determine if acclimation to temperature affected the slopes of the regression lines. Like acclimation to salinity, acclimation to temperature had no effect on the slopes of the lines.

DISCUSSION

Physiological variations are important factors in determining the success of animals. In order to study a physiological variation such as acclimation, it is often necessary to study the extremes in nature rather than the means, since it is often the extremes which determine the long-term success of animals (Prosser and Brown, 1961). In order to study sensitivity of the variation, it is also necessary to use moderate differences. To this end, it was decided to use three acclimation salinities and two acclimation temperatures.

The Effect of Acclimation to Salinity

The serpulids utilized in this experiment probably do not experience these extreme acclimation salinities in the tidepool from which they were collected. However, serpulids observed in other localities, e. g., the small upper intertidal pools at Seal Rock State Park, could be expected to be exposed to these salinities for brief periods. The intermediate acclimation salinity of 31.1‰ would be well within the normal salinity regime experienced by most serpulids located in the mid- to upper intertidal region, which is subjected to dilution by rain or freshwater run-off.

Serpula vermicularis appeared to survive equally well in all three acclimation salinities. In addition, there did not appear to be any difference in rates of respiration between worms acclimated to

different salinities (see Figures 2 and 3). This absence of any differences in rates of respiration suggests that compensation to the new salinities was complete.

Compensation to the acclimation salinities could occur in a number of ways. Since most polychaetes are osmoconformers to some extent, osmosis could be one mechanism involved with this compensation. By the process of osmosis, the worm would maintain body fluids approximately isotonic to the external medium without the utilization of energy. If osmosis was the only mechanism used to maintain osmotic balance the worm would swell in hypotonic solutions and shrink in hypertonic solutions. Such expansion and shrinkage was not observed in this experiment.

Serpulids are equipped with excretory organs called nephridia, which probably function to a limited extent in ionic regulation (Barnes, 1968). Such ionic regulation is a second mechanism which could be involved with salinity compensation. Ionic regulation of this nature generally involves active transport and active transport requires energy. If Serpula vermicularis is able to regulate osmotic concentration, i. e., osmoregulators, then there must occur a shift in energy from some other bodily function, since there did not appear to be a difference in the rates of respiration between animals acclimated to different salinities. Such differences could be expected if active uptake or removal of ions occurred with no shift in energy.

In any event, both mechanisms, osmosis and active transport, could occur simultaneously in acclimation to salinity. Perhaps active transport in Serpula vermicularis is so slight that it fails to manifest itself as a change in respiratory rate. Likewise, the acclimation salinities could have been too moderate to detect any shrinkage or swelling in the worm's body.

The Effect of Acclimation to Temperature

At the time of collections, the experimental serpulids were experiencing tidepool temperatures around 11.5°C . For this reason, it was decided to use acclimation temperatures of 10°C and 15°C , i. e., temperatures slightly below and above the temperature of the tidepool at the time of collection. Should lowtide occur during the early morning hours, the temperature of the water could be expected to dip down to 10°C . Likewise, low tides occurring during midday could be expected to result in temperatures of 15°C . Hence, it seemed reasonable to assume that serpulids normally experience these acclimation temperatures in nature.

When Serpula vermicularis is acclimated to temperatures of 10°C and 15°C , it appears to survive equally well. Unlike acclimation to salinity, acclimation to temperature appears to affect the rates of respiration of these worms. Keeping in mind that the regression lines have the same slope, i. e., the Q_{10} 's are the same for all worms,

it will be noted that the curves produced by the cold acclimated worms are displaced to the left of the curves produced by the warm acclimated animals (see Figures 4, 5, and 6). In other words, the cold acclimated serpulids had higher rates of respiration than warm acclimated serpulids.

Such a response to acclimation to temperature is called translation and is frequently observed in poikilotherms (Prosser, 1958). This translation in the position of the rate-temperature curve implies a change in activity of some enzyme system (Precht, 1958). For example, Precht (1958) has observed that peroxidase activity in yeast increases with increasing acclimation temperatures.

It appears certain that these serpulids do undergo perceptible acclimation to temperature. Should temperature acclimation occur in Serpula vermicularis as Precht (1958) suggests, the cold acclimated serpulids would have a higher enzyme concentration than the warm acclimated animals. A higher enzyme concentration would account for the higher rate of respiration observed, in these cold acclimated animals, due to increased rate of reaction.

In order to determine the exact level(s) of acclimation to temperature, it would be necessary to measure the rate functions at a number of levels. Measurements of special organ functions, cellular activity, and enzyme activity could lead to clues about the level(s) involved with temperature acclimation.

In any event, translational acclimation suggests that these serpulids are able to keep vital functions approximately at a constant level independent of the environmental temperature. That is, the Q_{10} 's remain approximately constant. Perhaps this type of temperature acclimation is one factor which allows cosmopolitan distribution of Serpula vermicularis.

CONCLUSIONS

The results of acclimation to salinities of 28.8‰, 31.1‰, and 35.9‰ indicate that acclimation to salinity does not appreciably affect the Q_{10} 's of Serpula vermicularis. In addition, no significant differences in the absolute rates of respiration between worms acclimated to different salinities could be detected. Two possible mechanisms could be involved with acclimation to salinity, osmosis and active transport.

The results of acclimation to temperatures of 10°C and 15°C indicate that acclimation to temperature does not appreciably affect the Q_{10} 's of Serpula vermicularis. However, acclimation to temperature does influence the absolute rates of respiration of the experimental serpulids. The category of response to acclimation to temperature exhibited by the S. vermicularis is called translation. Translation occurs when the cold acclimated animals exhibit a higher respiration rate than warm acclimated animals. This response to acclimation to temperature could be due to a change in the enzyme system of the worm.

BIBLIOGRAPHY

- Barnes, Robert D. 1968. Invertebrate zoology. 2d ed. Philadelphia, Saunders. 743 p.
- Behrens, E. William. 1968a. Cyclic and current structures in a serpulid reef. *Contributions in Marine Science* 13:21-27.
- _____ 1968b. Assistant Professor, University of Texas Marine Science Institute, at Port Aransas, Texas. Personal communication. Port Aransas, Texas. August 19.
- Berkeley, E. and C. Berkeley. 1932. On a collection of littoral Polychaeta from the west coast of Vancouver Island. *Contributions to Canadian Biology* 7:309-318.
- Brattström, H. and C. Thorson. 1941. Notes on the distribution of the polychaete Microserpula inflata Dons through the North Atlantic. *Vidensk. Medd København* 105:30-31. (Cited in: Hartman, Olga. Marine worms. In: *Treatise on marine ecology and paleoecology*, ed. by Joel W. Hedgpeth. Vol. 1. Washington, D. C. p. 1123. (Geological Society of America. Memoir 67))
- Bullock, Theodore Holmes. 1955. Compensation for temperature in the metabolism and activity of poikilotherms. *Biological Reviews of the Cambridge Philosophical Society* 30:211-242.
- Dales, R. Phillips. 1962. The nature of the pigments in the crowns of sabellid and serpulid polychaetes. *Journal of the Marine Biological Association of the United Kingdom* 42:250-274.
- Day, J. H. 1955. The Polychaeta of South Africa. *Zoological Journal of the Linnean Society of London* 42:407-452.
- Doty, Maxwell S. 1957. Rocky intertidal surfaces. In: *Treatise on marine ecology and paleoecology*, ed. by Joel W. Hedgpeth. Vol. 1. Washington, D. C. p. 535-585. (Geological Society of America. Memoir 67)
- Fauvel, Pierre. 1927. Polychètes sédentaires. *Fauna de France* 16:1-494.
- Fry, F. E. J. 1956. The lethal temperature as a tool in taxonomy. *Annales of Biology* 33:205-218.

- Gersbacher, W. M. and Marggie Denison. 1930. Experiments with animals in tide pools. Publication of the Puget Sound Biological Station 7:209-215.
- Giese, Arthur C. 1968. Cell physiology. 3d ed. Philadelphia, Saunders. 671 p.
- Gunter, Gordon. 1957. Temperature. In: Treatise on marine ecology and paleoecology, ed. by Joel W. Hedgpeth. Vol. 1. Washington, D. C. p. 159-184. (Geological Society of America. Memoir 67)
- Hartman, Olga. 1966. Polychaeta, Myzostomidae, and Sedentaria of Antarctica. Antarctic Research Series 7:1-158.
- Hedley, R. H. 1956. Studies of serpulid tube formation. II. Quarterly Journal of Microscopical Science 97:421-427.
- Hill, M. B. 1967. The life cycles and salinity tolerance of the serpulids Mercierella enigmatica Fauvel and Hydroides unicata (Philippi) at Lagos, Nigeria. The Journal of Animal Ecology 36:303-321.
- Humphrey, R. R. and R. W. Macy. 1930. Observations on some of the probable factors controlling the size of certain tide pool snails. Publication of the Puget Sound Biological Station 7:205-208.
- Neff, Jerry M. 1969. Mineral regeneration by serpulid polychaete worms. Biological Bulletin 136(1):76-90.
- Orr, Paul R. 1955. Heat death. Physiological Zoology 28:290-294.
- Orton, J. H. 1920. Sea temperature, breeding, and distribution in marine animals. Journal of the Marine Biological Association of the United Kingdom 12:339-366.
- Precht, H. 1958. Concepts of the temperature adaptation of unchanging reaction systems of cold-blooded animals. In: Physiological adaptation, ed. by C. Ladd Prosser. Washington, D. C., Society of General Physiologists. p. 50-78.
- Prosser, C. Ladd. 1958. The nature of physiological adaptation. In: Physiological adaptation, ed. by C. Ladd Prosser. Washington, D. C., Society of General Physiologists. p. 167-180.

- Prosser, C. Ladd and Frank A. Brown, Jr. 1961. Comparative animal physiology. 2d ed. Philadelphia, Saunders. 688 p.
- Ricketts, Edward F., Jack Calvin and Joel W. Hedgpeth. 1968. Between Pacific tides. Rev. ed. Stanford, Stanford University. 614 p.
- Severdup, A. U., Martin W. Johnson and Richard H. Fleming. 1942. The oceans, their physics, chemistry, and general biology. Inglewood, Prentice-Hall. 856 p.
- Southward, A. J. 1958. Note on the temperature tolerance of some intertidal animals in relation to environmental temperatures and geographical distribution. *Journal of the Marine Biological Association of the United Kingdom* 43:573-587.
- Southward, Eve C. 1963. Some new and little-known serpulid polychaetes from the continental slope. *Journal of the Marine Biological Association of the United Kingdom* 43:573-587.
- Snedecor, George W. and William Cochran. 1967. Statistical methods. 6th ed. Ames, Iowa State University. 593 p.
- Straughan, Dale. 1967. Marine Serpulidae (Annelida: Polychaeta) of Eastern Queensland and New South Wales. *Australian Journal of Zoology* 15(1):201-261.
- Swan, Emery F. 1950. The calcareous tube secreting glands of the serpulid polychaetes. *Journal of Morphology* 86:285-314.
- Umbreit, W. W., R. H. Burris and J. F. Stauffer. 1964. Manometric techniques. 4th ed. Minneapolis, Burgess. 305 p.