

THE EFFECTS OF EXPOSURE TO AIR ON THE INTERTIDAL
ISOPOD *SPHAEROMA WALKERI*

By R. Y. GEORGE*

Zoology Research Laboratory, University of Madras, Madras-5

THE intertidal sphaeromid isopods on prolonged exposure to air face the problem of desiccation and even succumb to evaporative loss of water and consequent interference with normal respiration. Previous studies on water loss from isopods have dealt mostly with the oniscids from semi-arid habitats (Allee, 1926 ; Numanoi, 1934 ; Gunn, 1937 ; Waloff, 1941 ; Edney, 1949, '51, '52, '53, '57 & '60 ; Bursell, 1955 ; Warburg, 1965). While studying the adaptations of intertidal isopods, *Campecopea hirsuta* and *Naesa bidentata*, Wieser (1962 & 1963) has dealt with the rate of respiration and water loss on exposure to air, but omitted their relation to humidity nor did he follow the processes upto the lethal limit. The present study, besides determining the rate of oxygen consumption and water loss in relation to humidity of air, attempts to bring out the lethal effects exposure has on the intertidal isopod *Sphaeroma walkeri* Stebbing.

Material and methods : The material for the present study consisted of adult males and non-egg bearing females of the wood infesting isopod, *Sphaeroma walkeri*, occurring between the tide levels on the piles in Madras harbour.

The balance case, being made air tight, is used as the animal chamber wherein the relative humidity of air is controlled by vertically placing a shelf with necessary quantities of granular calcium chloride. It is essential to remove the adherent water in an aquatic animal before determining water loss on exposure. This was possible by finding out the weight on the principle outlined by Gnanamuthu (1961). The volume of the animal was calculated from the loss of weight the animal sustained through displacement when weighed in sea water of two different densities, applying the formula $V = \frac{W_2 - W_1}{d_1 - d_2}$. The loss of weight in water ($V \times d_1$) plus the weight in water (W_1) gives the true weight of animal in air.

Loss of weight, as a direct index of transpiration, was noted from a single isopod at regular intervals from the time it reached the true weight until death. The failure to respond when repeatedly probed by the sharp tip of a needle was taken as the fatal symptom. The surface area of non-respiratory and gill surface was measured by sketching them on a graph sheet with the aid of a camera lucida and the k-value in *S. walkeri* as per Wigglesworth's (1945) formula $S = kW^{2/3}$ was found to be 9.63. From the weight (W) of every single animal experimented surface area (S) was determined and the rate of water loss was calculated. The oxygen consumed by a group of five animals when exposed to air was determined by employing the Fenn type differential volume and pressure insensitive respirometer (Dixon, 1951) (Fig. 1).

* Present address : Department of Oceanography, Florida State University, Tallahassee, Florida 32306. U.S.A.

(a) *Relation between humidity and rate of water loss* : The rate of water loss in mg. per sq. cm. per hr. was determined every 15 minutes in the course of exposure

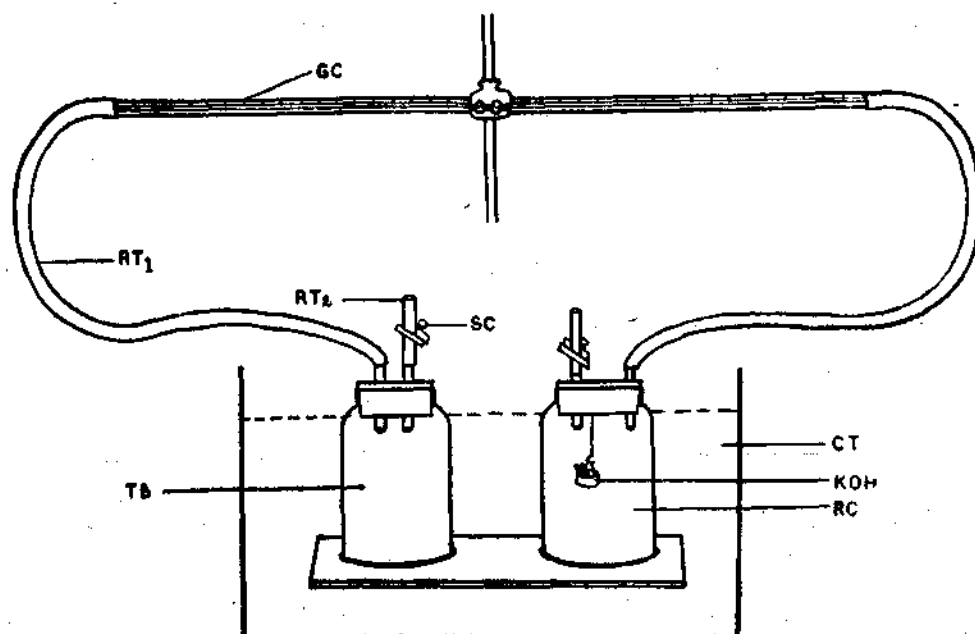


Fig. 1. Diagram showing the respirometer. CT—Constant Temperature Bath, GC—Glass Tube-calibrated, KOH—Potassium Hydroxide, RT₁ & ₂—Rubber Tubing, RC—Respiratory Chamber, SC—Screw clamp, TB—Thermobarometer.

at 30°C. in five different humidities. These isopods remained stretched through the period of exposure in 96%, 86%, and 76% humidity but rolled into a ball in 66% and 55% humidity. It is apparent from Fig. 2 that the rate of water loss gradually increases from 96 to 76% humidity and thereafter the rate abruptly shoots up and thereby induces the rolling behaviour. The tendencies of these isopods to roll in varying degrees in response to touch stimuli make it possible that they do so in response to decrease of moisture pressure. Since the body water content is high (about 70% of wet weight) during the initial period, the rate of water loss in the first fifteen minutes is found to be always greater.

(b) *Period of survival and percentage loss of weight at death* : The surface/volume ratio has a profound influence on the duration of survival and also the lethal water loss as evidenced from Table 1. In all humidities the larger animals survive for a longer period with a lesser percentage loss of water. In smaller forms the area exposed is greater in proportion to weight and this explains how death occurs in smaller forms with a larger amount of water loss in a shorter period. As the humidity is lowered, the period of survival becomes shorter. The earlier death in lower humidities is attributed to the higher rate of transpiration. Further, the percentage loss of weight at death, whatever the size, increases from 96% humidity to a maximum in 76% humidity but considerably reduced in 66 and 56% humidity since the isopod rolls up and thus curtails nearly 55% of evaporating surface.

TABLE I

Period of survival and lethal water loss in relation to humidity in S. walkeri at 30°C.

Body size			a. Percentage loss of weight at death. b. Duration of survival in minutes.					
Length	Surface area mm ²	Weight mg.	Percentage Relative Humidity					
			96%	86%	76%	66%	56%	
7mm.	90.88±2	29±0.5	a.	34.98	39.71	44.83	38.13	38.57
			b.	100	95	85	67	60
9mm.	130.70±3	50±1.5	a.	32.69	34.08	36.00	31.23	39.3
			b.	125	116	110	100	85
12mm.	171.20±5	73±2.5	a.	25.48	25.61	26.81	22.80	26.21
			b.	140	137	125	110	90

(c) *Relative amount of water loss from respiratory and non-respiratory surface*: The water loss from the body surface exclusive of the gill area was studied by blocking the pleopods with a thin coating of vaseline of known weight and was compared with water lost from total body surface inclusive of gills (Table 2).

TABLE 2

Total and relative amounts of water lost from gill area and non-respiratory surface at 30°C. and 96% humidity

Time of exposure in minutes	Water loss as percentage loss of original weight per fifteen minutes			Percentage of water lost/sq. mm./15 min.	
	From total body surface (90.88 sq. mm.)	From non-respiratory surface (84.17 sq. mm.)	From respiratory surface (6.71 sq. mm.)	From non-respiratory area	From gill area
1-15	6.20	4.23	1.97	0.78	4.30
15-30	6.22	2.83	3.40	0.49	7.41
30-45	4.83	2.81	2.02	0.63	5.57
45-60	3.45	1.41	2.04	0.44	12.13
60-75	4.12	3.52	0.60	0.92	2.99
75-90	6.22	2.82	3.40	0.49	11.21
90-105*	3.94	—	—	—	—

* Denotes the point of death

Although the amount of water lost through the pleopods is much less than that from the total body surface, yet because the pleopod surface forms only 7.38% of the total body surface, the relative amount of water lost through the pleopods is about 6 to 27 times greater when calculated per unit area. Thus, the pleopods, being more permeable, suffer through greater loss of water, becoming drier much more rapidly than the rest of the body surface. The respiratory efficiency of the pleopods is thereby impaired. This necessitated to examine the influence of dehydration of gills on the oxygen consumption on exposure to air.

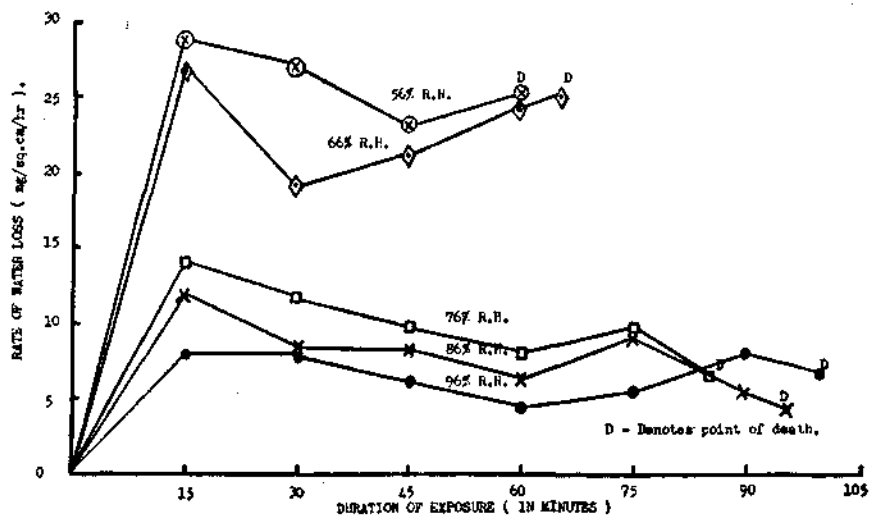


FIG. 2. Average rates of water loss at different humidities

(d) *Rate of oxygen consumption in relation to water loss on exposure to air:* In Fig. 3 the average rate of oxygen consumption is indicated with simultaneous water loss during the course of exposure to air at 30°C & 96% humidity.

Whereas the normal respiratory rate in water averages 2.5034 cc./gm./hr. at 30°C., it falls to 1.0664 cc./gm./hr. within five minutes on exposure to air. The reduction in oxygen uptake is obviously due to the slackness of diffusion through the strata of moisture around the gills. In 20 minutes the body water loss amounts to 9.73% of body weight and the rate of oxygen consumption falls from 1.0664 to 0.2836 cc./gm./hr. which is about one-fourth of the rate during the first five minutes. After 80 minutes of further exposure, when 33.34% of body weight has been lost, the respiratory rate falls to 0.054 cc./gm./hr. and the animal dies. It is evident that the oxygen uptake is not adequate to meet the respiratory needs which should be about the order of 2.5 cc./gm./hr. Asphyxial conditions induced muscular activity which would have depleted the oxygen reserve in the blood steadily and thereby the collapse is accelerated.

DISCUSSION

Although the general water relations of air-breathing isopods had been extensively studied by Edney (1957) and Bursell (1955), the lethal effects of water loss in isopods of intertidal habitat have received little attention. Miller (1938) studied

the survival time of the amphibious and land isopods in air of 75% humidity and found that *Ligidium* survived for 522 minutes, *Metaponorthus* 638 minutes, *Por-*

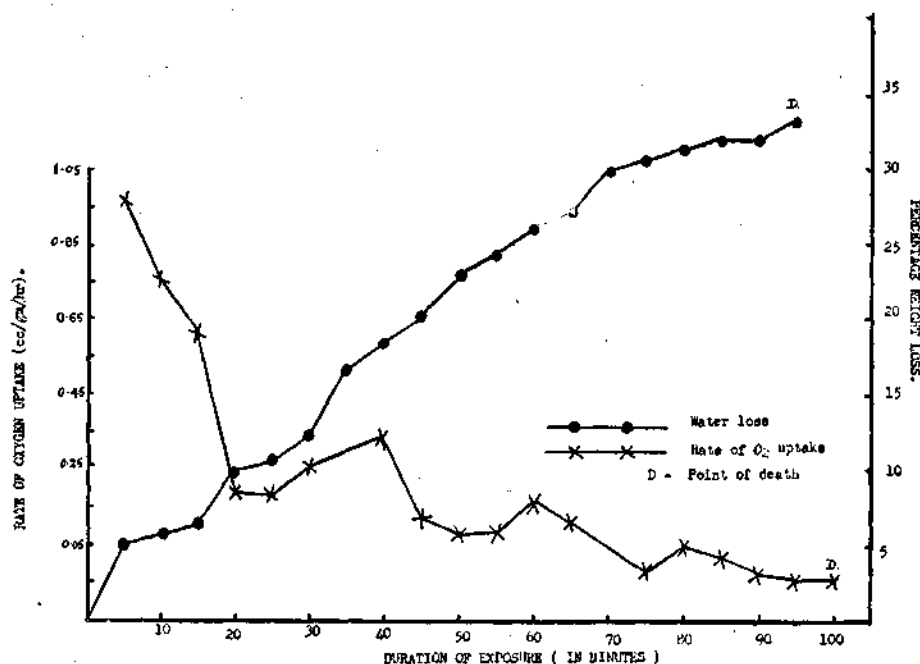


FIG. 3. Rate of oxygen consumption in relation to duration of exposure and water loss.

cellio 1441 minutes and *Armadillidium* 2157 minutes. He has not, however, examined how far transpiration affects the respiratory efficiency of the gills. Numanoi (1934) held the view that death is caused in *Ligia exotica* when the body water is reduced by 13% of the original body weight at humidities varying from 2 to 76% R.H. On the contrary, Allee's observations (1926) on *Oniscus* and *Cylisticus* show that the lethal water loss varies, depending on humidity and temperature. It is now evident from the present study that the lethal water loss can be between 25.48 and 44.83% of body weight, depending on body size, humidity and rolling behaviour.

Since the faster transpiratory rate hastens death in lower humidities, the rate of water loss in different isopods merits attention. The transpiratory rate expressed in mg./sq.cm./hr. in *Sphaeroma* is 10.7 on an average, at 30°C. in dry air, whereas in *Armadillidium* it is 2.7, *Porcellio* 3.0, *Oniscus* 4.2, *Phyloscia* 4.5 and in *Ligia* 7.0 (Edney, 1954). This comparison of rates of water loss in identical conditions reveals the permeability or the water-proofing efficiency of the integument and this capacity is the least in the aquatic form *Sphaeroma*. On the basis of the respective rates of water loss these isopods can be placed in a series from *Sphaeroma* (intertidal isopod, showing the highest rate) through *Ligia* (amphibious) to land isopods, from lesser to higher degree of terrestriality as in the order *Phyloscia*, *Oniscus*, *Porcellio*, *Cylisticus* and *Armadillidium* (which shows the highest rate) (Edney, 1951). A triple correlation is therefore arrived at between the permeability of the integument, rate of water loss and the habitat. In air-breathing

isopods such as *Oniscus* the water proofing capacity is attributed to the endo-cuticular layer impregnated by a lipid (Bursell, 1955). Gorvett (1946) and Lafon (1948) have found that the imperviousness of the cuticle of isopod like *Porcellio* is due to calcification.

Edney (1951) has demonstrated that in *Armadillidium* and *Porcellio* the gill area loses water 10 to 20 times faster per unit area than the rest of the body surface and in *Ligia* 5 times more. Whereas the pleopod surface in *Sphaeroma* loses even 27 times greater amount of water per unit area compared to body surface.

Wieser (1962) has measured the rate of oxygen consumption of the intertidal isopod *Campeopea hirsuta* on exposure to air and found that the respiratory rate is higher when the animal is placed on moist filter paper and lesser when left on the dry glass bottom of the respiratory flask. However, he has not followed the progressive decrease in the oxygen consumption of the isopod with increased exposure till it reaches the asphyxial level as performed in the present study. The results obtained prove that the water evaporated from the pleopods deprives of the film of moisture necessary for gaseous diffusion and thus hampers the respiratory efficiency of the gills. The gill surface in wood lice is kept moist by special devices like the capillary water-conducting system (Verhoeff, 1920). Waloff (1941) has shown that desiccated *Oniscus* has the power to absorb moisture from the surrounding atmosphere and thereby the gill surface is kept functional (Spencer and Edney, 1954). The secretion of the uropodial glands in *Porcellio* serves to keep the pleopod surface always moist (Gorvett, 1950). The plate-like pleopods with simple folds on the endopodites of the fourth and fifth pairs in *Sphaeroma* do not possess accessory respiratory structures such as the tracheal system, developed in different degrees in *Ligia*, *Alloniscus*, *Philoscia*, *Porcellio*, *Metaponorthus* and *Armadillidium* (Modlinger, 1931, Unwin, 1931). In the absence of the above devices the gill surface of *Sphaeroma* loses its moistness on prolonged exposure and consequently the supply of oxygen to the tissues becomes gradually inadequate and death follows because of respiratory failure.

SUMMARY

1. The rate of water loss (mg./sq.cm./hr.), lethal water loss and period of survival in five different humidities for three different sizes of *S. walkeri* were determined at 30°C. Total water loss at death varies, depending on body size, humidity and also rolling behaviour.
2. It was found that the pleopod is the most vulnerable site of water loss since it loses even 27 times faster compared to non-respiratory surface.
3. The rate of respiration on exposure to air and the progressive decrease in oxygen consumption with increased exposure till the asphyxial level were followed. It was concluded that the removal of moistness in the pleopods due to transpiration interfered with respiration and caused death.
4. The significance of evaporative loss of water is explained and discussed in the light of the previous work on isopods.

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