A PRELIMINARY INVESTIGATION OF OXYGEN CONSUMPTION OF *MACROBRACHIUM ROSENBERGII*

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WORKING PAPER NO. 31

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ABSTRACT

A number of factors which affect oxygen consumption of Macrobrachium rosenbergii *were investigated.*

The commonly observed higher rate of oxygen consumption by smaller animals compared with larger animals on a unit weight basis was not clearly observed for the size range (39 to 119 mm) of animals tested. There were also no apparent differences in oxygen consumption rates between sexes. The two gravid females tested displayed no unusual increases in oxygen consumption as would normally be expected by sexually active individuals. An average seventeenfold increase in the rate of oxygen consumption was observed as a result of group interaction. Hence, the amount of energy expended on respiration by the experimental animals was a gross underestimate of the actual metabolic expenditure under more natural conditions where group interactions occur. A twofold increase in oxygen consumption following feed ingestion was observed.

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INTRODUCTION

Macrobrachium pond culture has continued to develop into a viable industry in Hawaii. In recent years *M. rosenbergii* has been successfully produced at a rate of 2,000 to 4,000 pounds/acre/year. However, the risk involved in these high yields has led to a major concern over the oxygen requirements of the prawn. Stephenson and Simmons (1976) reported that oxygen consumption ranges from an average of 0.21 μl/animal/hour to 400 μl/animal/hour for stage 1 and stage 8 larvae, respectfully. Juveniles were observed to be metabolic regulators at higher oxygen tensions and metabolic conformers at lower oxygen tension (Sharp, 1976). Five to eight-month-old animals ranging in size from 44.3 to 1,267.3 mg were observed to apportion a range of about 29 to 78 percent of their ingested energy for metabolism (Iwai, 1976a).

Of immediate concern to prawn farmers is the diagnostic use of low dissolved oxygen levels as predictive indicators of "adverse" changes in water quality (Leary and Iwai, 1974; Iwai, 1976b). Iwai (1976a) noted that upon exposure to "stressed conditions," such as poor water quality, the normal amount of ingested energy expended for growth would be taxed for routine metabolism, thereby "limiting" growth and overall production. The present study was conducted to determine how certain factors affect the oxygen consumption rate of *M. rosenbergii*. Among the factors examined were:

1. The effect of weight-specific respiration on oxygen consumption
2. The effect of sex on oxygen consumption
3. The effect of group interaction on oxygen consumption
4. The effect of feeding on oxygen consumption
5. The effect of reproduction on oxygen consumption by females

This study was carried out at the Hawaii Institute of Marine Biology with support from University of Hawaii Sea Grant College Program.

MATERIALS AND METHODS

Individuals of *Macrobrachium* used in the respiratory experiments were collected from an outdoor tank population at the Hawaiian Institute of Marine Biology, Kaneohe, Hawaii; a prawn pond (Pond No.1) at Pacific Aquaculture Corporation, Laie, Hawaii; and tanks kept at the Anuenue Fisheries Research Center, State Division of Fish and Game, Honolulu, Hawaii.

The experimental animals, ranging in size from 27 to 119 mm, were acclimated to laboratory conditions for 1 to 2 weeks before measurements were made. The sex of each individual was determined prior to each experiment.

Respiration measurements were conducted in a closed 2-liter cylindrical plexiglass container with a Yellow Springs Instrument polarographic oxygen probe (Figure 1). Weight-specific oxygen consumption readings were made on individual prawns starved for 24 to 48 hours.

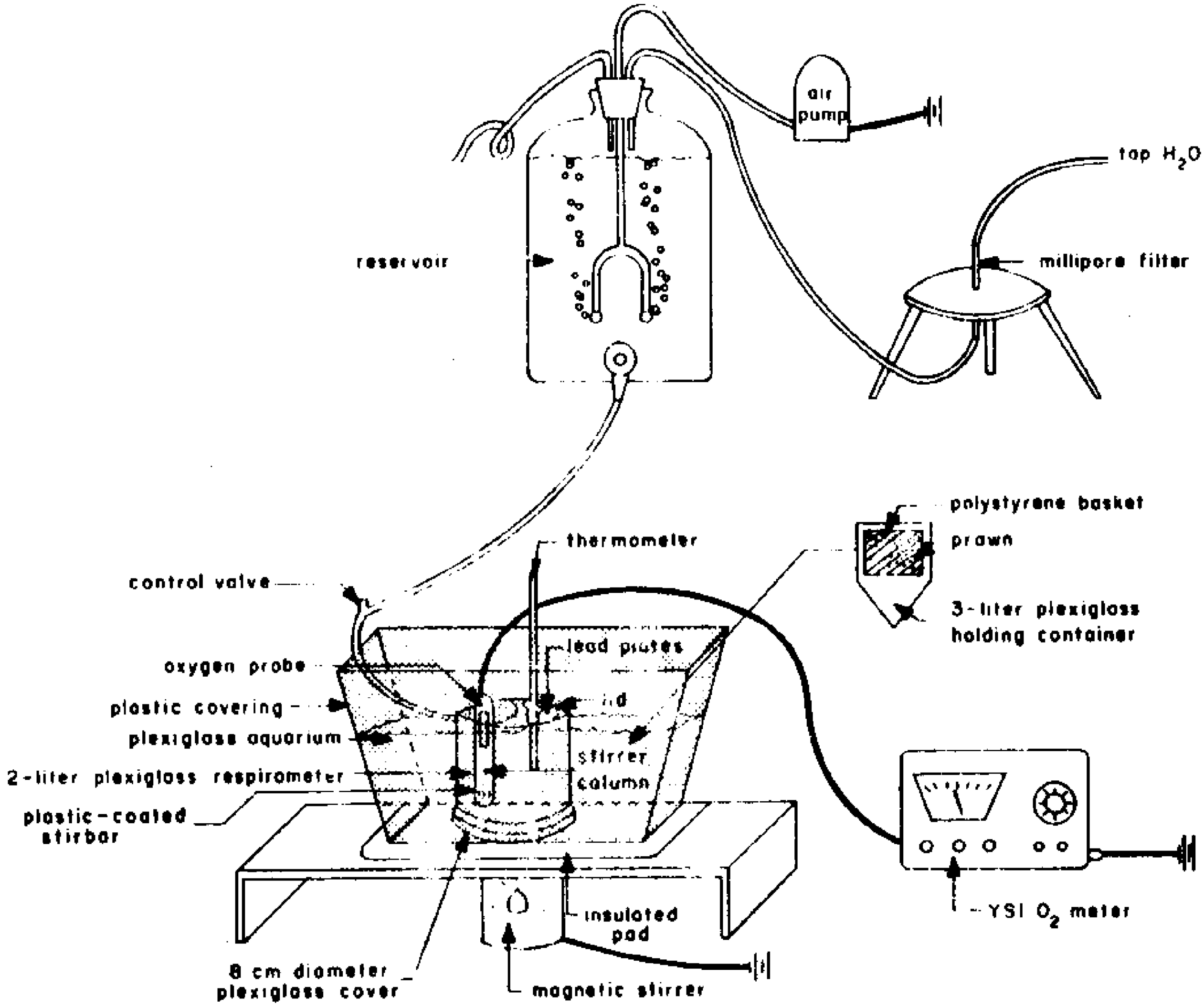

Figure 1. Experimental respiration apparatus

The animals were carefully transferred from 3-liter funnel-shaped plexiglass holding containers to the respirometer using polystyrene basket containers. Following transfer, the oxygen probe fitted with a rubber stopper was firmly secured in the stirrer column containing a plastic-coated stirbar. The magnetic stirrer provided even circulation throughout the chamber and a constant flow of water past the oxygen probe. Those animals which were unusually excited after the transfer to the respirometer were not tested.

A 15 to 30-minute acclimation period within the chamber, together with continuous flushing (~100 ml/min) of oxygen-saturated filtered tap water (0.45 μm) which was kept at room temperature, eliminated any initial increase in oxygen consumption due to handling. Prior to each run the inlet valve was turned off and lead plated (2 to 3 lbs) were placed on the lid of the chamber to keep it sealed. Oxygen uptake was then monitored at 10 to 15-minute intervals for 1 to 3 hours.

A water bath within a 5-gallon plexiglass aquarium minimized temperature fluctuations. Water bath temperatures ranged from 23.9° to 26.0°C with an average temperature of 25.3°C. Black polyethylene plastic secured around the aquarium aided in reducing any external visual stimulus. An insulated pad was placed under the aquarium to reduce the amount of heat transfer from the magnetic stirrer to the water bath.

Each animal's body length (post orbit to telson) was recorded to the nearest 0.1 mm. Individuals were gently blotted with a paper towel and placed on a preweighed aluminum tin pan; their live weight (wet weight) was then recorded to the nearest 0.01 mg. The prawns were later oven-dried to a constant weight at 80°C. The volume of the individual prawns was measured by gently blotting them with absorbent paper towel, then placing them into a graduated cylinder containing a known volume of filtered water. The difference between the initial and final meniscus readings provided the displacement volume (in ml) of the prawns. These measurements were incorporated with earlier measurements (Iwai, 1976a) for calculating logarithmic least squares regression equations, relating body length measurements to individual dry weight, wet weight, and displacement volumes (Table 1).

Correction of the actual respirometer volume due to individual volume displacement was made in estimating oxygen consumption. For example,

$$\begin{matrix}\text{Initial} & & \text{prawn} & & \text{actual}\\ \text{respirometer} & - & \text{displacement} & = & \text{respirometer}\\ \text{volume (ml)} & & \text{volume (ml)} & & \text{volume (ml)}\end{matrix}$$

Oxygen consumption of the prawns was determined by subtracting blank readings (respirometer without the animal) taken at 10 to 15-minute intervals for 1 to 2 hours before each test run from initial oxygen consumption readings.

Preliminary experiments indicated that the reliability of the oxygen consumption readings decreased with animals less than 39 mm in length.

TABLE 1. RELATIONSHIP OF BODY LENGTH TO DRY WEIGHT, WET WEIGHT, AND VOLUME

Equation	Parameter measured	No. of observations	Regression equation
1	(x) Length (mm): (y) Dry weight (mg)	74	$Log_e O_2 = 3.32303\ Log_e W - 6.40518$
2	(x) Length (mm): (y) Wet weight (mg)	85	$Log_e O_2 = 3.3201\ Log_e W - 5.0800$
3	(x) Length (mm): (y) Volume (ml)	73	$Log_e O_2 = 3.21545\ Log_e W - 11.6735$

Hence, the weight-specific measurements were determined only for select animals ranging from 39 to 119 mm in length. The average amount of weight-specific oxygen consumption for the smaller animals was determined by placing five individuals in the respirometer at the same time. After a 10 to 15 minute acclimation period, group oxygen consumption readings were made. The group volume of these animals was estimated using the least squares regresssion equation shown in Table 1.

The effect of feeding on the rate of oxygen consumption was determined (1) by starving the experimental animals for 24 to 48 hours and then measuring their oxygen consumption rate or (2) by immediately measuring their oxygen consumption rate within 1 hour after feeding. Each individual was carefully transferred in the polystyrene baskets from the holding container to the respirometer (Figure 1). With practice, stress due to handling was reduced to a minimum. In any case, however, animals which appeared "stressed" or displayed bursts of activity following transfer to the respirometer were not measured.

A pelleted formulation of chicken broiler feed (Iwai, 1976a) was used throughout the study.

RESULTS

The amount of oxygen consumed per animal increased with increasing body size. This relationship was plotted on a double logarithmic grid (Figure 2) and may be expressed by the following equation:

$$O_2 = aW^b \qquad (1)$$

where O_2 is the amount of oxygen consumption in microliters per animal per hour, $\underline{W}$ is the body weight in milligrams, $\underline{a}$ is the intercept, and $\underline{b}$ is the slope.

An expansion of equation (1) for *M. rosenbergii* is expressed as:

$$O_2 = 0.0625W^{1.2713}$$

or in

$$\log_e O_2 = 1.2713 \log_e W - 2.7724$$

Weight specific respiration values ($\mu l\ O_2$/mg/hour) of males and females are presented in Table 2. Group weight-specific respiration determinations are shown in Table 3 and Figure 3. Group interaction resulted in a substantial increase in oxygen consumption on a weight-specific basis when compared with individual animals. For example, a comparison of females No. 1 and No. 2 (Table 2) with group No. 4 (Table 3) indicated an average seventeenfold increase in oxygen consumption for animals of similar size.

The results of oxygen consumption determinations of fed and unfed males and females are presented in Table 4. An average twofold increase

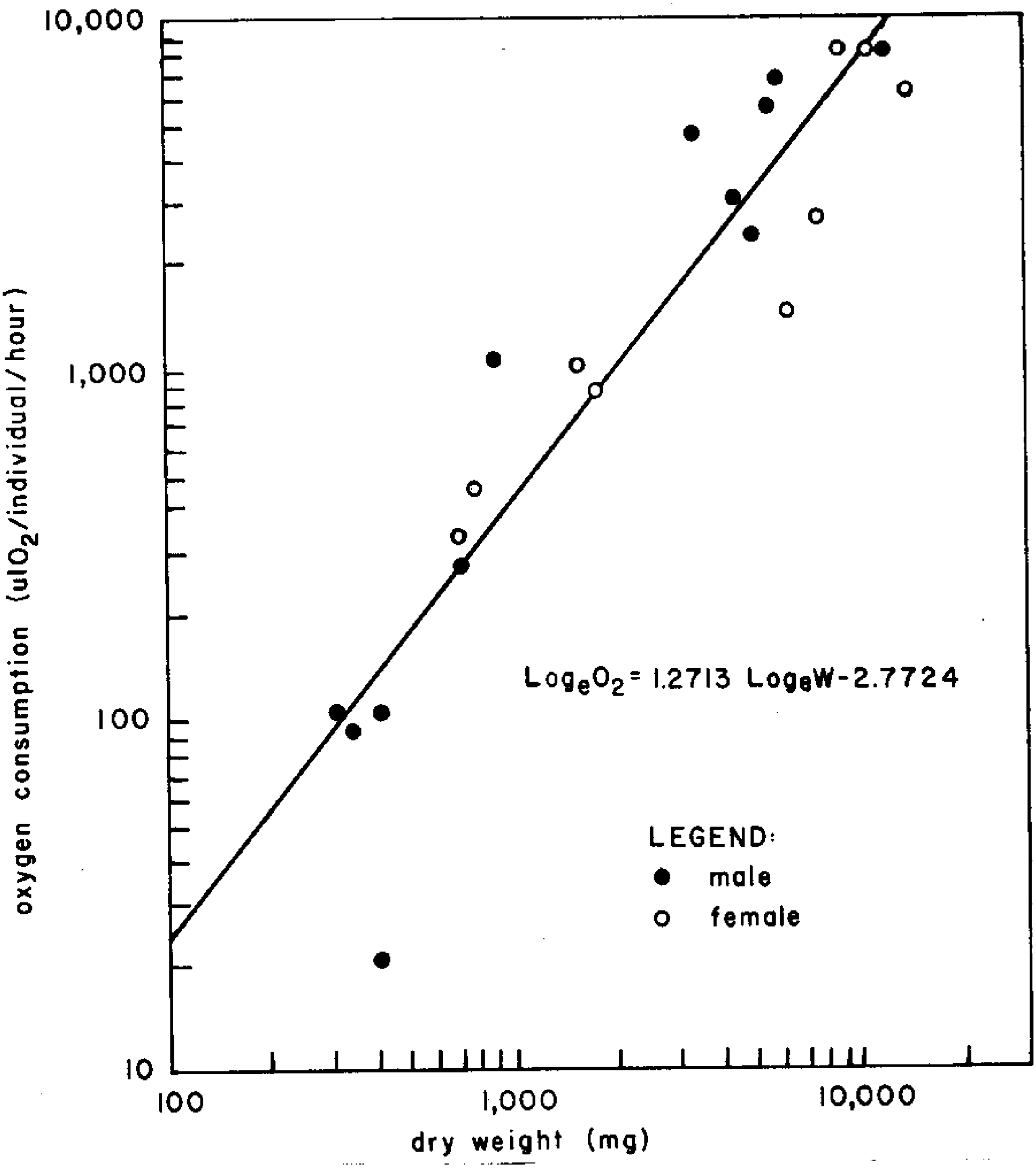

Figure 2. Relationship of oxygen consumption and dry weight of *M. rosenbergii*

TABLE 2. WEIGHT-SPECIFIC RESPIRATION VALUES OF MALES AND FEMALES ON A CALCULATED DRY AND WET WEIGHT BASIS BY CLOSED RESPIROMETRY

			Oxygen Consumption			
Sex	Individual	Length (mm)	Dry weight (mg)	$\mu l O_2$/mg dry weight/hr	Wet weight (mg)	$\mu l O_2$/mg wet weight/hr
Female	1	39.0	320.2	0.3410	1192.0	0.0916
	2	39.0	320.2	0.3016	1192.0	0.0810
	3	42.0	409.6	0.0512	1524.5	0.0137
	4	42.0	409.6	0.2460	1524.5	0.0661
	5	50.0	731.1	0.3791	2719.8	0.1019
	6	53.0	887.3	1.2022	3300.3	0.3232
	7	80.0	3485.7	1.3327	12948.9	0.3587
	8	86.0	4432.6	0.7078	16463.1	0.1905
	9	89.0	4967.6	0.4962	18448.2	0.1336
	10*	92.0	5546.2	1.0354	20594.7	0.2788
	11*	94.0	5957.0	1.1585	22119.0	0.3120
	12	114.0	11308.9	0.7249	41967.5	0.1953
Male	13	49.5	707.1	0.4969	2630.5	0.1335
	14	51.0	780.9	0.5970	2904.6	0.1605
	15	63.0	1575.9	0.6799	5858.3	0.1829
	16	66.0	1839.4	0.4795	6836.8	0.1290
	17	96.0	6388.7	0.2347	23720.4	0.0632
	18	101.0	7562.8	0.3576	28075.7	0.0963
	19	106.0	8880.1	0.9557	32961.1	0.2574
	20	112.0	10663.0	0.7773	39572.4	0.2094
	21	119.0	13042.8	0.4910	48395.7	0.1323

*Gravid females

Note: dry weight = equation No. 1 (see Table 1); wet weight = equation No. 2 (see Table 1);

TABLE 3. GROUP WEIGHT-SPECIFIC RESPIRATION VALUES AS MEASURED BY CLOSED RESPIROMETRY

Group	N	Length (mm) ($\bar{x}$)	Oxygen Consumption			
			Dry weight (mg) ($\bar{x}$)	$\mu l O_2$/mg dry wt/hr	Wet weight (mg) ($\bar{x}$)	$\mu l O_2$/mg wet wt/hr
1	5	31.4 (30.0-41.0)	161.1	6.2048	600.1	1.6657
2	5	33.8 (27.0-36.0)	223.6	4.8085	832.6	1.2913
3	5	35.8 (36.0-52.0)	254.3	4.2941	946.9	1.1532
4	5	39.6 (29.0-45.0)	376.9	5.4826	1402.8	1.4730

Note: Figures in brackets represent the size range of individuals used. $\bar{x}$ = mean; N = number of individuals; dry weight = equation No. 1 (see Table 1); wet weight = equation No. 2 (see Table 1).

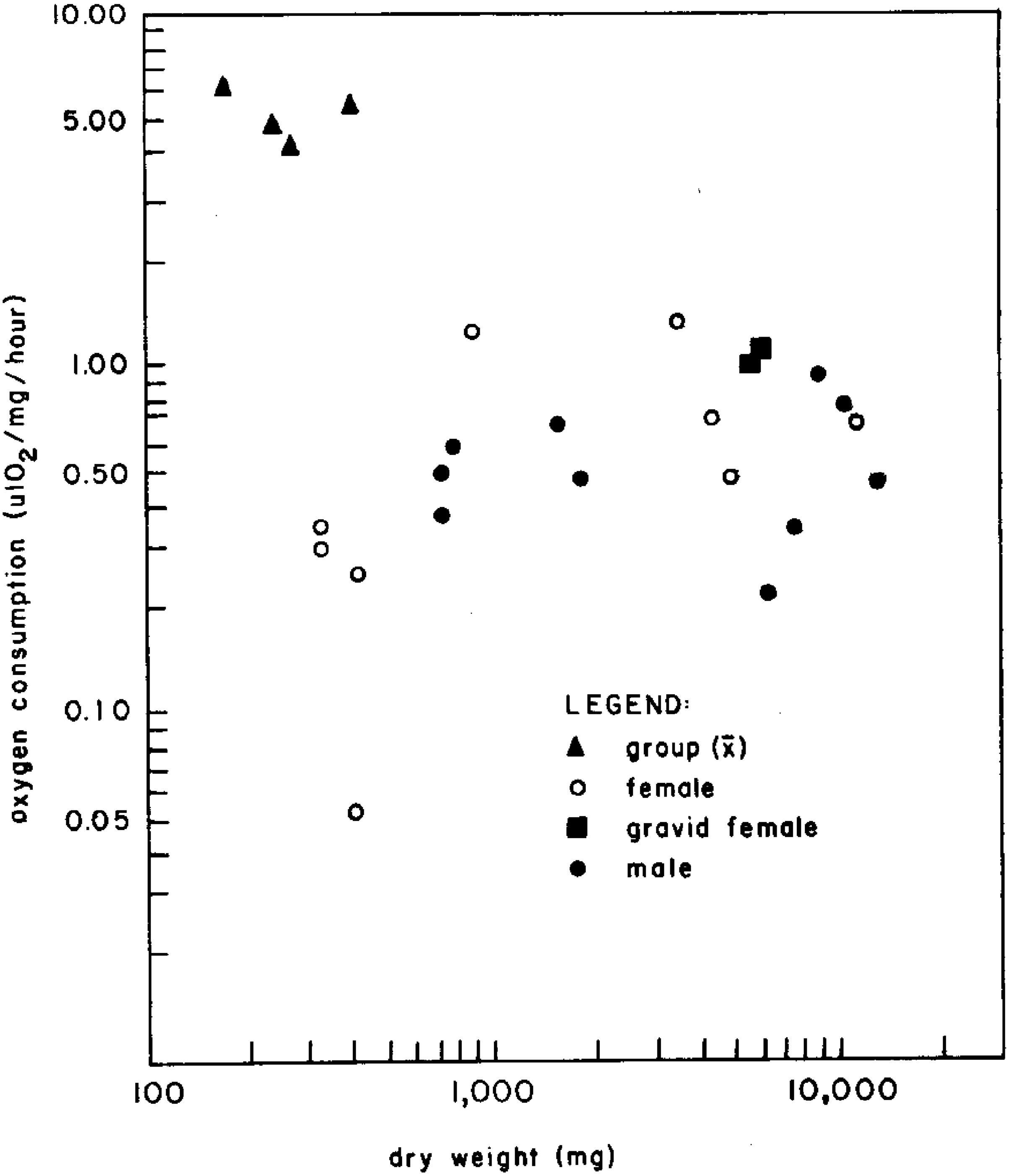

Figure 3. Weight-specific respiration of males and females measured by closed respirometry (from calculated dry weight measurements)

TABLE 4. WEIGHT-SPECIFIC RESPIRATION OF FED AND UNFED MALE AND FEMALE *M. rosenbergii* AS MEASURED BY CLOSED RESPIROMETRY

Sex	N	Length (mm)	Dry Weight (mg)	Wet Weight (mg)	Oxygen Consumption $\mu l O_2$/mg/hr				% Increase DW-basis
					Fed		Unfed		
					DW	WW	DW	WW	
Male	1	51.0	640.0	2622.1	0.7284	0.1777	0.7612	0.1858	4.5
	2	66.0	1733.7	6629.2	0.5087	0.1330	0.6516	0.1704	28.1
Female	3	39.0	284.7	1091.8	0.3835	0.1000	0.8556	0.2231	123.1
	4	39.0	307.7	1068.0	0.3139	0.0904	0.5323	0.1533	69.6
	5	42.0	366.7	1634.9	0.0572	0.0128	0.1584	0.0355	176.9
	6	42.0	396.6	1443.9	0.2541	0.0698	0.5506	0.1512	116.7
	7	50.0	700.2	2632.4	0.3958	0.1053	0.5578	0.1483	40.9
	8	53.0	900.0	3230.9	1.1853	0.3301	0.6160	0.1715	-48.0

Note: N = number of observations; DW = dry weight; and WW = wet weight.

in oxygen consumption on a unit weight basis was observed in fed animals. Individual increases in oxygen consumption after feeding ranged from 4.50 to 176.92 percent.

The oxygen consumption rate of two gravid females are presented in Table 2.

DISCUSSION

Oxygen consumption

Oxygen consumption is reported to be proportional to the exponential 2/3 power of the body weight (Wolvekamp and Waterman, 1960). A "b" slope value between 0.67 and 1.0 is generally observed. Although a significant correlation ($r = 0.9310$) was obtained relating body dry weight to oxygen consumption, there was no apparent reason for the higher "b" value of 1.2713 for *M. rosenbergii*. However, Wolvekamp and Waterman (1960) noted that differences in body shape, the presence of more than one type of respiratory surface, or the fraction of living protoplasm to metabolically inert elements may cause deviations of the "b" value. Nonetheless, the higher "b" value observed does suggest that oxygen consumption is proportionally affected more by body surface area and less by body weight.

Weight-specific respiration

The generally observed higher rate of oxygen consumption by the smaller animals compared with the larger animals on a unit weight basis (Weymouth et al., 1944; Zeuthen, 1947; Ellenby, 1951) was not clearly observed in the present experiment (Figure 3). This discrepancy was probably due to the inability to reliably test individually a larger sample of smaller animals with the present respirometer.

Effect of sex on oxygen consumption

There were no apparent differences in the rate of oxygen consumption between sexes. Weymouth et al. (1944) similarly reported no significant differences in the rate of oxygen consumption between sexes of the caridean shrimp, *Pugettia producta*. Thomas (1954) also noted no apparent difference in oxygen uptake between sexes of a decapod crustacean, *Homarus vulgaris*.

Group effects on oxygen consumption

The substantial seventeenfold increase in oxygen consumption values between individually tested and grouped animals of similar size reflects the importance of group interaction in pond growout systems. For example, stress factors such as poor water quality, lack of food, over-crowding, etc., may drastically affect communal respiration through intensified group interaction. As individual respiration increases, less of the ingested energy will be available for growth (Iwai, 1976a). Thus, every effort should be made to minimize these "stressed conditions" to achieve optimal prawn production.

Feeding effects on oxygen consumption

The observed individual increase in oxygen consumption is probably attributed to specific dynamic action. However, in one instance there was a decrease in oxygen consumption after feeding (observation 8, Table 4). This anomaly was probably the result of the prawn's increased physical activity level during the unfed respirometry run. Marshall et al. (1935), working with the zooplankter *Calanus finmarchicus*, reported no difference in oxygen consumption between fed and unfed animals. Kutty (1967), however, observed a marked reduction in the oxygen consumption rate of the starved marine shrimps *Penaeus indicus* and *Penaeus semisulatus*.

Effect of reproduction on oxygen consumption by females

Two of the gravid females tested (Table 2) displayed no unusual increases in oxygen consumption as would normally be expected of sexually active individuals.

CONCLUSIONS

1. The relationship between oxygen consumption and dry weight of *Macrobrachium rosenbergii* can be expressed by the regression equation:

   $$\mathrm{Log}_e O_2 = 1.2713 \log_e W - 2.7724.$$

   However, the commonly observed higher rate of oxygen consumption by smaller animals compared with larger animals on a unit weight basis was not clearly observed.

2. There was no apparent difference in the oxygen consumption rate between males and females.

3. The two gravid females tested displayed no unusual increase in oxygen consumption.

4. A seventeenfold increase in oxygen consumption was observed between individually tested and grouped animals of similar size.

5. A twofold increase in oxygen consumption following feed ingestion was observed.

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