

## RESPIRATION IN THE CLAM, *PAPHIA LATERISULCA*

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### ABSTRACT

The rate of oxygen uptake in *Paphia laterisulca* was reduced due to frequently opening and closing of the shell valves. The unit oxygen consumption was increased with decreasing body weight of the clams. With increase in temperature from 24 to 32°C, the rate of oxygen uptake increased progressively but decreased sharply from 38°C upto 40°C. The rate of oxygen uptake did not change between 30-26‰ but above and below these salinities, the respiratory rate decreased. Below normal pH of 7.6 (acidic) the rate of oxygen uptake was increased but above that pH (alkaline) the rate was decreased. The starvation of the clams for six days resulted in 50% reduction in the rate of oxygen uptake. Oxygen consumption increased during the period of exposure but after reimmersion into normal seawater the rate of oxygen uptake returned to original level. The oxygen uptake appeared to be directly related to the oxygen tension of the external medium, at very low tension of oxygen (1.5 ml/l) the rate of oxygen uptake retarded considerably. The clams showed distinct diurnal rhythmicity in the oxygen uptake: they consumed more oxygen in noon and less in midnight.

### INTRODUCTION

SEVERAL environmental factors are known to influence the respiration of bivalves. The rates of oxygen uptake under various environmental conditions are well documented by many investigators in marine and estuarine bivalves. Mussels and oysters were the main targets of the earlier studies (Collier, 1959; Schlieper, 1957; Read, 1962; Helm and Trueman, 1967; Moon and Pritchard, 1970). Recently the respiration of many other bivalves has been studied under various environmental conditions (Newell and Pye, 1970; Bayne, 1971, 1973; Vahl, 1972; Boyden, 1972 a, b; Kennedy and Mihursky, 1972).

Amongst the marine bivalves of Indian Coasts, the respiration of *Martesia fragilis* (Srinivasan, 1965), *M. striata* (Nagabhushanam, 1966), *Meretrix meretrix* (Deshmukh, 1972) and *Katelaysia opima* (Mane, 1975) has been studied so far.

The present investigation was undertaken to study the influence of various environmental factors on the rate of oxygen uptake in *Paphia laterisulca* and the variation in the respiration in relation to size, starvation and diurnal rhythm.

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## MATERIAL AND METHODS

The clams, *P. laterisulca* were collected from the Kalbadevi Estuary at Ratnagiri, west coast of India. The clams were brought to the laboratory, cleaned off to remove the mud and sand particles and were kept in large enamel trays containing seawater. The test salinities were approximated with the collection salinities over the clam beds. The clams with fully extended siphons were used in all sets of experiments. During the experimental period the temperature of the seawater in the laboratory varied from 30.0-32.5°C.

The apparatus used by Galtsoff and Whipple (1930) to determine the oxygen consumption of American oysters was used in the present study. The respiratory jars were wrapped with black papers to provide natural habitat background for the clams as they live deep into the mud four inches below. Before experimentation the clams were wiped with hydrogen peroxide and were grouped in three batches with equal size. As soon as the clams opened their shell valves, the experiment was started and the oxygen content of the seawater was determined before and after the experiment. The oxygen content of water samples was determined by the standard Winkler's method at the end of each experiment, the clams were shucked for their flesh, blotted to remove excess of water and weighed accurately. The results of each experiment are based on five determinations and expressed as oxygen uptake ml/gm/hr.

## RESULTS

*Oxygen consumption in relation to opening and closing of the shell valves*

It was noticed on careful observations that all clams did not show constancy in valve opening under laboratory conditions. Within an hour some clams remained with their shell valves open for all the time, some opened for more than half an hour while others opened for less than half an hour. It was practically difficult to record shell valve movements concurrently during the experimental period and therefore the condition of valves was noted frequently by watching the behaviour of the clams. According to the condition of the opening of shell valves of the clams, the experiment was divided into three separate phases—(a) shell valves open all the time, (b) shell valves open more than half time and (c) shell valves open less than half time. The rate of oxygen uptake determined during these three phases is expressed in Table 1. It has been observed that during the first phase the rate of oxygen uptake was 0.721 ml/gm/hr, which decreased as the clams closed their shell valves for major period (0.293 ml/gm/hr—phase c). It is evident that the closing of the shell valves reduced the rate of oxygen uptake of the clams.

*In relation to body size*

The experiments were conducted on the clams in batches of 3 mm in length and were grouped under three categories (i) smaller clams (18-26 mm), (ii) medium clams (27-44 mm) and (iii) older clams (45-53 mm). Over the whole series of experiment the temperature and salinity varied from 30.0-31.5°C and 30.0-33.0‰ respectively. The pH of the seawater was 7.6. The smaller clams per gram body weight consumed more oxygen than older ones (Table 2).

TABLE 1. *Rate of oxygen uptake under normal laboratory conditions in P. laterisulca*  
(Temperature  $30^{\circ} \pm 0.5^{\circ}\text{C}$ , Salinity 32.0‰, pH 7.6)

Condition of the shell valves' opening	Oxygen uptake ml/gm/hr with S.E.
Shell valves' open all the time	.. 0.721 $\pm$ 0.006
Shell valves' open more than half time	.. 0.572 $\pm$ 0.007
Shell valves' open less than half time	.. 0.293 $\pm$ 0.009

TABLE 2. *Oxygen uptake in relation to the body size in P. laterisulca*  
(Temperature  $30.5^{\circ} \pm 1.0^{\circ}\text{C}$ , Salinity 31.5‰)

Size groups in mm	Wet wt. of soft body parts in gms	Oxygen uptake ml/gm/hr with S.E.
18-26 (smaller clams)	0.59	1.334 $\pm$ 0.002
	0.97	1.197 $\pm$ 0.001
	1.38	0.993 $\pm$ 0.004
27-35 (medium clams)	1.89	0.974 $\pm$ 0.006
	2.56	0.856 $\pm$ 0.005
	2.99	0.797 $\pm$ 0.002
36-44	3.67	0.744 $\pm$ 0.002
	4.21	0.693 $\pm$ 0.006
	4.88	0.512 $\pm$ 0.007
45-53 (older clams)	5.33	0.475 $\pm$ 0.003
	7.42	0.417 $\pm$ 0.006
	10.82	0.298 $\pm$ 0.008

#### *Effect of temperature*

Batches of clams were exposed to five different temperatures (24, 28, 32, 38 and  $40^{\circ}\text{C}$ ) for 4-6 hours before the start of experiment. The respective temperature of the experimental media was thermostatically adjusted and kept constant. The salinity and pH were also kept constant (32‰ and 7.6 pH). The experiment was

also performed at normal room temperature (30°C). The results presented in Fig. 1 show that the rate of oxygen uptake increased with increase in temperature upto 32°C and then decreased sharply at 38° and 40°C; these temperatures are near the lethal temperature of the clams (lethal limit being 41.5°C according to our unpublished data).

#### Effect of low salinity

The batches of clams were subjected to different low salinities (33.5, 30.0, 28.0, 26.0, 23.0, 20.0, 18.0‰) for six hours before the start of experiment. The normal seawater (33‰) was diluted with distilled water to obtain low salinities. Keeping temperature (30.5°C) and pH (7.6) constant, the oxygen consumption in each salinity was determined. The results presented in Fig. 2 show that the rate of oxygen uptake

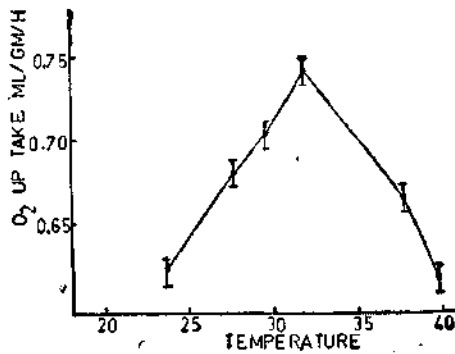


Fig. 1. Effect of temperature on the rate of oxygen uptake in *P. laterisulca*.

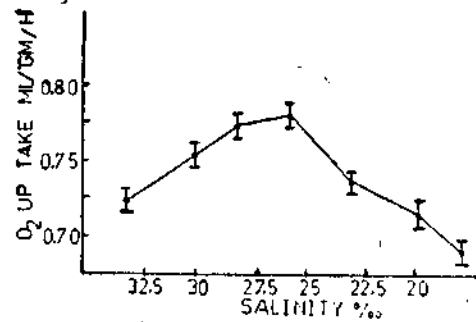


Fig. 2. Effect of low salinity on the rate of oxygen uptake in *P. laterisulca*.

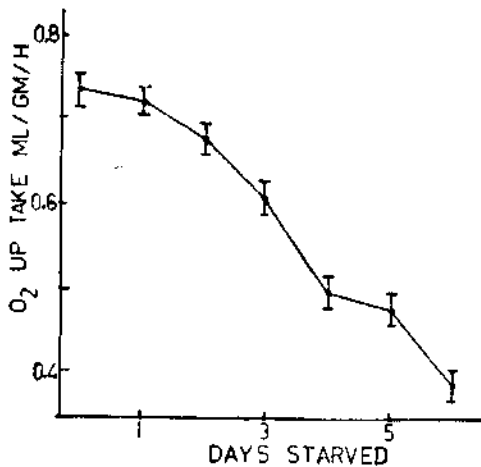


Fig. 3. Effect of starvation on the rate of oxygen uptake in *P. laterisulca*.

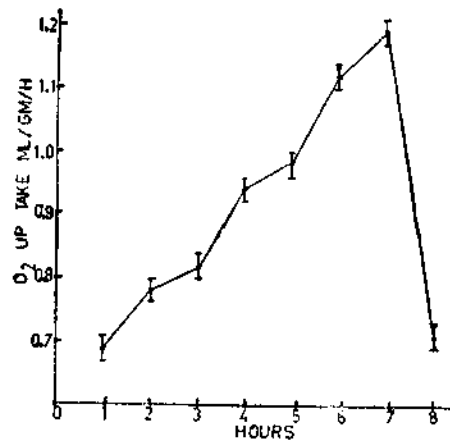


Fig. 4. Oxygen uptake after a period of low tide in *P. laterisulca*.

was slightly decreased from 30 to 26‰, whereas above 30‰ and below 26‰ the respiratory rate was decreased.

#### *Effect of pH*

The rate of oxygen uptake was determined at four different pH. To obtain the required pH of the medium, dilute HCl or NaOH was added to normal seawater having pH 7.6. The results in Table 3 show that the rate of oxygen uptake was increased in low pH and decreased in high pH compared to the rate at 7.6 pH.

#### *Effect of starvation*

Few clams were removed from the aquaria and were kept for starvation in the seawater filtered through Whatmann filter paper. From the second day onwards the clams were kept in double filtered seawater which was changed twice a day. In the initial stage of starvation the clams extended their siphons to maximum extent and pumped seawater vigorously to get food. On each day the oxygen uptake of the clams was determined for a period of six days. The results plotted in Fig. 3 show that the rate of oxygen uptake gradually decreased as the starvation period increased and approximately 50% decrease in the rate took place on the sixth day of starvation.

TABLE 3. *Influence of pH on oxygen uptake in P. laterisulca*  
(Temperature  $31.0^{\circ} \pm 0.5^{\circ}\text{C}$ , Salinity 32.5‰)

pH of the experimental medium	Average oxygen uptake ml/gm/hr with S.E.
6.4	0.924 $\pm$ 0.008
6.8	0.873 $\pm$ 0.004
7.6	0.731 $\pm$ 0.002
8.2	0.530 $\pm$ 0.003

#### *In relation to exposure to air*

The clams in laboratory (room temperature  $32.5^{\circ}\text{C}$ ) were exposed to atmospheric air for seven hours by keeping them in the tray filled with wet sand so as to provide the low tide effect on a sunny and windy day, and were returned back to normal seawater for an hour more. The normal rate of oxygen consumption was determined prior to exposure. The respiratory rate of the exposed clams was determined at every hour for 7 hours and then for an hour more after immersion in seawater. The results plotted in Fig. 4 show that the clams which consumed oxygen at the rate of 0.69 ml/gm/hr, upon seven hours of exposure consumed oxygen at the rate of 1.19 ml/gm/hr. But after returning to the normal seawater after seven hours of exposure, the rate of oxygen uptake attained the normal level of 0.71 ml/gm/hr.

*In relation to oxygen tension*

The clams were exposed to the water of different oxygen concentrations, and the respiratory rates were determined. It is seen from Fig. 5 the rate of oxygen uptake was slightly decreased down to a concentration of 3.0 ml/l but at very low level of oxygen content of 1.5 ml/l the rate of oxygen uptake was considerably decreased.

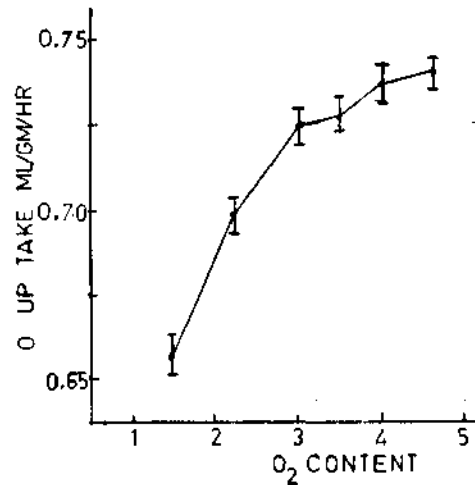


Fig. 5. Oxygen uptake in relation to oxygen tension in *P. laterisulca*.

*In relation to diurnal rhythm*

The experiments were performed in the morning, noon, evening and night to see the rate of oxygen uptake of these clams. The results are presented in Table 4. A distinct diurnal rhythmicity in the oxygen uptake of the clams was observed; the clams consumed maximum oxygen in noon and minimum in midnight.

TABLE 4. Diurnal rhythm of oxygen uptake in *P. laterisulca* (Temperature 25.5° - 30.0°C, Salinity 32.5‰)

Date and Time	Oxygen uptake ml/gm/hr with S.E.
16.12.1973	
7 a.m.	0.611 ± 0.002
1 p.m.	0.791 ± 0.004
7 p.m.	0.723 ± 0.005
17.12.1973	
1 a.m.	0.497 ± 0.006

## DISCUSSION

Variations in the values of rate of oxygen uptake between individuals may be related to the shell valve opening and closing, and it is not certain that the bivalve in a shell opened condition must respire continuously (van Dam, 1935). In *P. laterisulca* the frequent shell valve closing activity caused reduction in the rate of oxygen uptake. Similar results were obtained by Hiscock (1953) in *Hyridella australis*, Nagabhushanam (1966) in *Martesia striata* and Mane (1975) in *Katelysia opima*.

If the total oxygen uptake is plotted against body weight, the large animals have a higher metabolic rate. This type of relationship has been shown to exist for poikilotherms and homeotherms. The respiratory rates of smaller animals were high than older when measured at per gram body weight in *P. laterisulca*. Identical results were obtained in *M. striata* (Nagabhushanam, 1966), in *Mya arenaria*, *Macoma balthica* and *Mulinia lateralis* (Kennedy and Mihursky, 1972) and in *K. opima* (Mane, 1975).

Read (1962) observed increase in the oxygen uptake of *Branchidontes demissus plicatulus* with increase in temperature upto 32°C, the highest temperature tested. Increase in oxygen uptake of *Mytilus edulis* with increase in temperature from 3° to 20°C was also observed by him. In *Martesia striata* a little increase in oxygen uptake with the rise in temperature from 24°-33°C was recorded by Nagabhushanam (1966). Deshmukh (1972) in *M. meretrix* reported a steady increase in the oxygen uptake with rise in temperature from 21°-35°C. Poikilothermic animals perform their metabolic activities within a certain range of temperature at which the animals carry their normal activities and beyond this limit the activities decrease as the lethal temperature approaches. In *P. laterisulca*, increase in the oxygen uptake was observed with the rise in temperature from 24°-32°C and then sharply decreased as the temperature reached 40°C.

It is generally agreed that the salinity of the seawater affects the oxygen uptake in marine animals. The isolated gills of the mussels from high salinity when transferred to low (i.e. from 30 to 15‰) the consumption for low salinity adapted was less than that of the same area with low salinity, and the tissues of a sessile animal adapted to low salinity have a higher rate of oxygen uptake when compared to those adapted to high salinity; further acclimation to low salinity results in higher rates (Schlieper, 1955). At several instances it was noted that the decrease in salinity of the external medium caused increase in metabolism of animals and many hypotheses have been put forth to explain this increased metabolism (Schlieper, 1929, 1935; Winkren, 1953; Gross, 1957). In the present study the oxygen uptake of *P. laterisulca* increased upto 26‰, beyond this salinity it decreased and the minimum activity was found in 33‰. Deshmukh (1972) in *M. meretrix* observed an increase in oxygen uptake beyond 70‰ seawater.

Powers (1930) found that fishes are affected directly by increase or decrease in the pH of the medium. This change in the respiratory metabolism is supposed to be due to the influence of pH of outside medium on the alkaline reserves of the blood. In *M. striata* a slight change in the oxygen uptake with the change in the pH of the external medium was observed by Nagabhushanam (1966). *P. laterisulca* showed the maximum rate of oxygen uptake in pH 6.4 and the minimum in pH 8.2. In

*K. opima*, Mane (1975) found maximum rate of oxygen uptake at pH 6.8 and minimum at pH 8.4.

In *Pachygrapsus crassipes* (Roberts, 1957) observed a decrease in the rate of oxygen uptake during the initial stage of starvation which then reached a steady level. Berg *et al.* (1958) reported 3/5th reduction in the initial rate of oxygen uptake by the limpet, *Ancylus* after 96 hours of starvation. In *Paratelphusa*, Rajabai (1961) found 36% of reduction in the respiratory rate on the 14th day of starvation. Identical results were obtained by Berg *et al.* (1962) in *Pisidium* and Bayne and Thomson (1970) in *M. edulis*. In *P. laterisulca* due to starvation for 6 days nearly 50% decrease in the rate of oxygen uptake took place. In *K. opima* similar type of reduction occurred by the end of 7th day of starvation (Mane, 1975).

The periodic exposure to air of a bivalve is of interest because the body is oxygenated only by the continuous circulation of water. Schlieper (1957) and Helm and Trueman (1967) found increase in respiration and heart rate as a result of anoxic stress in *M. edulis* and *M. californianus*, respectively. Such type of increase in oxygen uptake in bivalves during the period of exposure has been recorded by many workers (van Dam, 1935; Nagabhushanam, 1966; Rao and Kutty, 1968; Moon and Pritchard, 1970; Mane, 1975). In *P. laterisulca* the rate of oxygen consumption increased during first six hours and later on after immersion received a normal rate.

Collip (1921) reported that the utilization of oxygen in the bivalves is little affected by oxygen tension at very low oxygen concentrations. In *Teredo navalis*, Roch (1931) showed normal activities between 9.75 ml/l to 0.98 ml/l of oxygen content. van Dam (1934) observed that the scallops were capable of maintaining a normal oxygen uptake down to concentration of about 1.0 ml/l to 0.5 ml/l. But in *P. laterisulca*, it has been observed that the rate of oxygen consumption was slightly decreased upto 3.0 ml/l of oxygen content but decreased considerably with further reduction in oxygen content and oxygen consumption did not remain constant at any level of oxygen tension tested in the experiments.

A distinct diurnal rhythm in the oxygen uptake of oysters was observed by Webb and Brown (1959). The oysters consumed more oxygen in the late morning and early noon than at midnight. Certain environmental factors such as low and high tide, temperature, light, darkness, salinity, etc. initiate the rhythms at first which then become persistent (Prosser and Brown, 1961). In *P. laterisulca* it has been observed that the maximum oxygen uptake was at noon whereas minimum at midnight. Similar reports were made by Mane (1975) in *K. opima*.

#### REFERENCES

- BAYNE, B. L. 1971. Ventilation, the heart beat and oxygen uptake by *Mytilus edulis* L. in declining oxygen tension. *Comp. Biochem. Physiol.*, 40A : 1065-1085.
- 1973. The responses of three species of bivalve molluscs to declining oxygen tension at reduced salinity. *Ibid.*, 45A : 793-806.
- BERG, K., J. LUMBAY AND K. W. OCKELMANN 1958. Seasonal and external variations of the oxygen consumption of the limpet *Ancylus fluviatilis*. *Jour. Exp. Biol.*, 35(1) : 43-73.
- P. JONASSON AND K. W. OCKELMANN 1962. The respiration of animals from the profound zone lake. *Hydrobiol.*, 19 : 1-39.



- BOYDEN, C. R. 1972a. The behaviour, survival and respiration of the cockles *Cerastoderma edule* and *C. glaucum* in air. *J. Mar. Biol. Ass. U.K.*, 52 : 661-680.
- 1972b. Aerial respiration of the cockle, *Cerastoderma edule* in relation to temperature. *Comp. Biochem. Physiol.*, 43A : 697-712.
- COLLIER, A. 1959. Some observations on the respiration of the American oyster, *Crassostrea virginica*. *Inst. mar. Sci.*, 6 : 92-108.
- COLLIP, J. B. 1921. A further study of the respiratory processes in *Mya arenaria* and other marine molluscs. *J. Biol. Chem.*, 49 : 297-311.
- DESHMUKH, R. S. 1972. Some aspects of the biology of *Meretrix meretrix*. Ph.D. thesis—Marathwada University, Aurangabad, Maharashtra : 185-217.
- GALTSOFF, P. S. AND D. V. WHIPPLE 1930. Oxygen consumption of normal and green oysters. *Bull. U.S. Bur. Fish.*, 46 : 489-508.
- GROSS, W. J. 1957. An analysis of response to osmotic stress in selected decapod Crustacea. *Biol. Bull.*, 112 : 43-62.
- HELM, M. M. AND E. R. TRUEMAN 1967. The effect of exposure on the heart rate of the mussel, *Mytilus californianus*. *Comp. Biochem. Physiol.*, 21 : 121-127.
- HISCOCK, I. D. 1953. Osmoregulation in Australian freshwater mussels. II. Respiration and its relation to osmoregulation in *Hyridella australis*. *Aust. J. Mar. Freshw. Res.*, 4 (2) : 330-342.
- KENNEDY, V. S. AND J. A. MIHURSKY 1972. Effects of temperature on the respiratory metabolism of three Chesapeake Bay bivalves. *Chesapeake Science*, 13 (1) : 1-22.
- MANE, U. H. 1975. Oxygen consumption of the clam, *Katylsia opima* in relation to environmental conditions. *Broteria*, 64 (1-2) : 33-58.
- MOON, T. W. AND A. W. PRITCHARD 1970. Metabolic adaptations in vertically separated populations of *Mytilus californianus*. *J. expt. mar. Biol. Ecol.*, 5 : 35-46.
- NAGABHUSHANAM, R. 1966. On the oxygen consumption of the wood boring mollusc, *Martesia striata* under various conditions. *Proc. 2nd All India Cong. Zool.* (1962), 2 : 154-159.
- NEWELL, R. C. AND V. I. PYE 1970. Seasonal changes in the effect of temperature on the oxygen consumption of the winkle *Littorina littorea* (L.) and the mussel *Mytilus edulis*. *Comp. Biochem. Physiol.*, 34 : 367-387.
- POWERS, E. B. 1930. The relation between pH and respiration in aquatic animals. *Amer. Nat.*, 64 : 242.
- PROSSER, C. L. AND F. A. BROWN 1961. In : *Comparative Animal Physiology. Chapters 7 and 9* Saunders, Philadelphia.
- RAJABAI, K. G. 1961. Studies on the oxygen consumption in tropical poikilotherms. VI. Effect of starvation on the oxygen consumption of freshwater field crab *Paratelphusa* sp. *Proc. Ind. Acad. Sci. B.*, 54 : 276-280.
- RAO, S. R. AND M. N. KUTTY 1968. Resistance to desiccation and oxygen debt in wedge clams. *Proc. Symp. Mollusca, MBI, Cochln*, Part II (3) : 595-606.
- READ, K. R. H. 1962. Respiration of the bivalve molluscs *Mytilus edulis* and *Branchidontes demissus plicatulus* as a function of size and temperature. *Comp. Biochem. Physiol.*, 7 : 89-101.

- ROBERTS, J. L. 1957. Thermal acclimation of metabolism in the crab *Pachygrapsus crassipes*. I. The influence of body size, starvation and moulting. *Physiol. Zool.*, 30 : 232-242.
- ROCH, F. 1931. Observations on the ecology and physiology of *Teredo naxalis*. *Mar. Pil. Inv. New England Comm. Second Prog. Rep.*, 249 : 1935-1936.
- SCHLIEFER, C. 1929. Über die Einwirkung nieder Salzkonzentrationen auf marine Organismen. *Zeitschr. Vergl. Physiol.*, 9 : 478-514.
- 1935. Neuere Ergebnisse und Probleme aus Gebiet der osmoregulation Wasserlebender Tiere. *Biol. Rev.*, 10 : 334-360.
- \*----- 1955. Über die physiologischen Wirkungen des Brackwassers. *Kieler Meeresforsch.*, 11 : 22-23.
- 1957. Comparative study of *Asterias rubens* and *Mytilus edulis* from the North Sea (30 per 1000 S) and the western Baltic Sea (15 per 1000 S). *Anne's Biol.*, 33 : 117-127.
- SRINIVASAN, V. V. 1965. Respiratory metabolism in *Martesia fragilis* in relation to body size and nitrogen. *Proc. Ind. Acad. Sci.*, 62 : 273.
- VAHL, O. 1972. Porosity of the gill, oxygen consumption and pumping rate in *Cardium edule* (L.) (Bivalvia). *Ophelia*, 10 : 109-118.
- VAN DAM, L. 1935. Oxygen utilisation in *Mya arenaria*. *J. Expt. Biol.*, 72 : 86-94.
- WEBB, H. M. AND F. A. BROWN, JR. 1959. Biological rhythms. *Physiol. Rev.*, 39 : 127-161.
- \*WINKGREN, BO-JUNGAR 1953. Osmotic regulation in some aquatic animals with special reference to the influence of temperature. *Acta Zool. Fennica.*, 71 : 1-102.

\* Not referred to the original.