OXYGEN CONSUMPTION IN RELATION TO SPONTANEOUS ACTIVITY AND AMBIENT OXYGEN IN FIVE MARINE TELEOSTS

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Abstract

Some metabolic adaptations of 5 species of South Indian marine teleosts, namely *Caranx carangus* (Bloch), *Chorinemus lysan* (Forskål), *Chanos chanos* (Forskål), *Synagris furcosus* (Day) and *Gerres lucidus* (Day) were studied. The fishes were acclimated to and tested at an average temperature of 30°C and 35°/$_{oo}$ salinity.

In all the species the metabolic rate (oxygen consumption) measured immediately after handling was the highest and in most cases this rate corresponded to the highest rate of spontaneous activity as well. *G. lucidus* alone displayed no activity throughout the period of observation when oxygen was high. High spontaneous (random) activity and metabolic rates were seen to be associated with more active species (carangids) among the species tested. The standard metabolic rates of *C. carangus* (68 g) and *S. furcosus* (84 g) were estimated as 155 and 134 mg/kg/hour.

Oxygen dependence of metabolism was observed in all the 5 species tested. Except in the case of *C. chanos* in all the species spontaneous activity increased while the ambient oxygen decreased from air saturation to asphyxial values. In *C. chanos* alone activity decreased with a decrease in ambient oxygen. Thus it appears that there could be two separate behavioural adaptations to a reduction in concentration of ambient oxygen. While the decrease in spontaneous activity at low oxygen environment may help conserve energy, an increase in activity can help the fish escape from an unfavourable medium.

Maximum tolerance of low oxygen was found in *G. lucidus* and *C. chanos*, which perhaps encounter low oxygenated waters more often than *C. carangus*, *C. lysan* and *S. furcosus*. The latter species are associated with high oxygenated waters of the open sea and this may possibly account for their lesser tolerance of hypoxic waters.

Introduction

Information on the metabolism of tropical marine fishes is scarce. The tropical seas abound in different species of fishes and since the environmental

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conditions are so different from those of the well-studied temperate waters, it will be of much interest to know the metabolic adaptations occurring in the tropical seas. The present study was taken up in this context. Five marine teleosts, namely *Caranx carangus* (Bloch), *Chorinemum lysan* (Forskål), *Chanos chanos* (Forskål), *Synagris furcosus* (Day) and *Gerres lucidus* (Day) are included in this study.

Some information on the oxygen consumption of the marine catfish, *Plotosus anguillaris* (Job, 1959) and of the milk fish, *Chanos chanos* (Panikkar *et al.*, 1953; Job, 1957) occurring in the brackish waters of Mandapam area, is available. None of these studies has taken activity, spontaneous or forced, as a factor into consideration, even though Job (1957; 1959) tried to keep his experimental fish in some defined, 'routine-active', condition. In a recent study on the oxygen consumption of the mullet, *Liza macrolepis*, Kutty (1969) investigated the influence of forced activity (swimming speed) on metabolism. In the present study a measure of spontaneous activity (body lengths moved in unit time) is obtained simultaneously with the measurement of oxygen consumption. In the first series of experiments influence of spontaneous activity on oxygen consumption of fishes is studied keeping ambient oxygen near air saturation and in the second series influence of ambient oxygen on oxygen consumption and spontaneous activity is investigated.

MATERIAL AND METHODS

The fishes were taken live from the shore seine catches made near Mandapam during April-June, 1968. They were kept in running sea water in rectangular glass tanks (48" x 24" x 18") or in a large indoor circular cement tank (diameter: 59", depth: 44") and were acclimated to the laboratory conditions for at least 3 days before using them in experiments. Temperature of the water in the acclimation tanks was about 30°C and salinity about 35°/$_{oo}$. Dissolved oxygen at 80-90% air saturation. The experiments were done at acclimation conditions. The fishes were fed with chopped calm meat once daily.

Apparatus

The experiments were done using a 'metabolism chamber', described earlier by Kutty (1967). Inside this metabolism chamber was kept Fry's annular respirometer (Fry and Hart, 1948; Kutty, 1969) of transparent hard plastic (outer diameter: 30 cm; inner diameter: 11 cm; height: 20 cm; capacity: 12.5 litres). The respirometer was covered on top by a plastic hard lid. The arrangement of the respirometer in the metabolism chamber differed from the one described by Kutty (1967), in that in the present set-up only a single unit (respirometer) was kept submerged in the water. Sea water flushed continuously through the metabolism chamber keeping a constant level and as in the earlier set-up water flowed into the respirometer through an inlet in respirometer lid and flowed out

of the respirometer directly out of the outer box through a sampling tube. This tube could be closed or opened, allowing the water in the respiromter to stagnate or flow out depending on the need.

Experimental procedure

Fish starved for 36 hours (Beamish, 1964a), was transferred from the acclimation tank to the respirometer for experiment. Usually three measurements of metabolism were obtained within the first three hours after the fish was put in the respirometer. The first determination (run) was made by closing the respirometer for the first ¼ hour (in a few cases extended to ½ hour) allowing the fish to reduce the oxygen content. This was followed by a flushing interval of at least 15 minutes. The lid of the metabolism chamber was always kept half open and during the runs visual counts of the number of times the fish went round in the annular chamber were made during alternate 3-minute periods. From these values an estimate of spontaneous activity during the 15-minute interval forming the run obtained; simultaneously the metabolic rate was determined from the difference in dissolved oxygen values of water samples taken from the respirometer before and after the closure period.

Routine metabolic rates (Fry, 1957; Kutty, 1967) and spontaneous activity rates were similarly obtained after the fish had been in the respirometer for one or two days.

In experiments where the influence of ambient oxygen was studied, the fishes were allowed to reduce the oxygen concentration by their own respiration, while the respirometer remained closed. Metabolic rates and corresponding activity values were obtained in this case only after the fish had been in the respirometer for 24 hours. During experiments the fish continued to reduce the oxygen until the critical or the asphyxial level was reached. This level was taken as that at which the fishes were seen to lose their equilibrium.

RESULTS AND DISCUSSION

Results obtained from experiments on fishes in which the relation of spontaneous activity on oxygen consumption, was studied maintaining ambient oxygen near air saturation, are given in Table 1. The data given are separable into two: Rates of metabolism and activity obtained within the first 3 hours after 'handling' (transfer of fish from the acclimation tank to the respirometer) and values after the fish had been in respirometer for 24 hours, i.e. values which were not influenced by handling. The initial rates of oxygen consumption and activity are invariably higher than those which are uninfluenced by handling. It has been observed that metabolic rates obtained immediately after handling could be almost as high as the 'active metabolic rates' (Fry, 1947; 1967; Graham, 1949), and this may be so especially in the case of the first

TABLE 1. *Routine oxygen consumption and spontaneous activity in five species of marine teleosts. The fishes were held and tested in seawater at 30°C and 35°/$_{oo}$ S – See text for details*

1	2		3		4	5	6
Species	O$_2$ consumption immediately after 'Handling' (mg/kg/hr) Mean on right		Spontaneous activity corresponding to col. 2 (L/15 min.) Mean on right		Routine rate of O$_2$ consumption (mg/kg/hr) Mean ± SE (N)	Spontaneous activity corresponding to col. 4 (L/15 min.) Mean ± SE (N)	Weight (g) (& total length in cm) of fish tested
Caranx carangus							
Series 1	544*		644		246 ± 33(12)	244 ± 21(12)	68.0 (17.1)
Series 2	380		11				
	472	368	432	257	218 ± 17(14)	54 ± 23(14)	62.5 (17.4)
	252		327				
Chorinemus lysan	638		312				
	350	448	250	234	441 ± 56(17)	158 ± 27(17)	81.5 (23.8)
	356		129				
Chanos chanos	302	314	1	66	330 ± 26(11)	37 ± 5(11)	72.1 (21.7)
	326		131				
Synagris furcosus	583		104				
	571	498	276	199	147 ± 15(11)	27 ± 11(11)	84.0 (18.6)
	339		216				
Gerres lucidus	642		Nil			Nil	
	192	335	activity		158 ± 13(8)	activity	120.0 (18.4)
	171						

* Uusually 3 values obtained in the first three hours after 'handling'; in this case the value immediately after handling only is available.

value taken immediately after handling. But in Table 1 the values obtained in the first three hours have been grouped together. These, in the absence of actual active rates, can be taken as close to active rates and some measure of 'scope for activity' (Fry, 1947) could be obtained along with estimates of standard metabolism of the species concerned.

Mean rates of metabolism, uninfluenced by handling, (routine metabolism) and corresponding rates of spontaneous activity are also presented in Table 1.

It is interesting to note that in most cases where the 'handled' rates were high the activity rates were also high. The highest metabolic rate for *C. carangus* (68.0 g) was 544mg/kg/hour; the corresponding activity for which was 644 body lengths (L)/15 min. But for another fish (62.5 g) of the same species the metabolic and activity rates obtained immediately after handling were 380 mg/kg/hour and 11 L/15 min. The subsequent rates were, however, the highest (472 mg/kg/hour and 432 L/15 min.) Again in *Chanos chanos* the metabolic and activity rates obtained for the period immediately after handling were 302 mg/kg/hour and 1 L/15 min. Here also the second rates obtained after handling were highest obtained for the fish. It is noteworthy that the highest ('handled') metabolic rate was displayed by *Gerres lucidus;* the fish strangely did not display any activity either for the period corresponding to this rate or for the other periods when routine rates were determined. However, as indicated in the next section, *G. lucidus* showed moderate activity when ambient oxygen was lowered close to its lethal level.

The metabolic rates uninfluenced by handling are referred to here as routine metabolic rates (Fry, 1957). The highest mean routine rate among the species tested is displayed by *C. lysan,* followed by *C. chanos, C. carangus, G. lucidus* and *S. furcosus.* As for the corresponding spontaneous activity values the highest activity was displayed by *C. carangus,* followed by *C. lysan, C. chanos, S. furcosus* and *G. lucidus.* Here again, but for the observations on *C. carangus* one is likely to conclude that the carangids, which are active swimmers, display higher spontaneous (random) activity. And it would appear, if we are to take energy spent per unit activity, that the carangids, *C. lysan* and *C. carangus,* with their well known adaptations for fast swimming, are the most effiecient and *G. lucidus* the least. This statement could be questioned from several points, but it is stated because the fishes tested were about the same size; their standard metabolic rates could be different, but perhaps not so much as to make a marked change in the generalisation. *G. lucidus,* in its behaviour, is said to stay close to the bottom and may not be an active type. It is likely that the fish is highly excitable, for its metabolic rate immediately after handling is the highest among the fishes tested and this corresponds to zero activity. Possibly the cessation of movements on encountering unfavourable conditions is part of the animal's behavioural adaptation.

Plots of oxygen consumption and activity such as those originally made by Spoor (1946) and Beamish (1964b) were made with the data obtained for
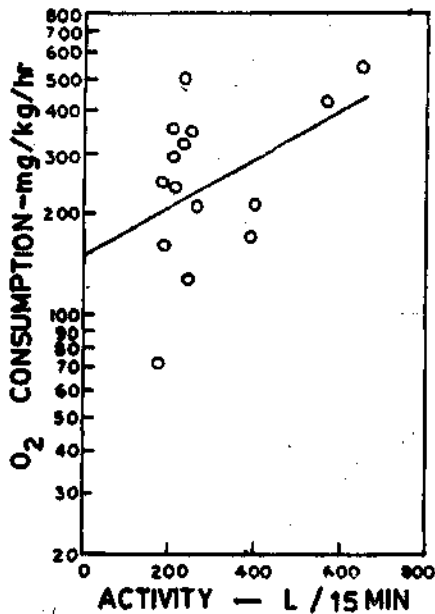

Fig. 1 A. Oxygen consumption in relation to spontaneous activity (in body lengths (L) per 15 minutes) in *Caranx carangus* (68 g, 17.1 cm.) in sea water at 30 C. Line fitted by the method of least squares.
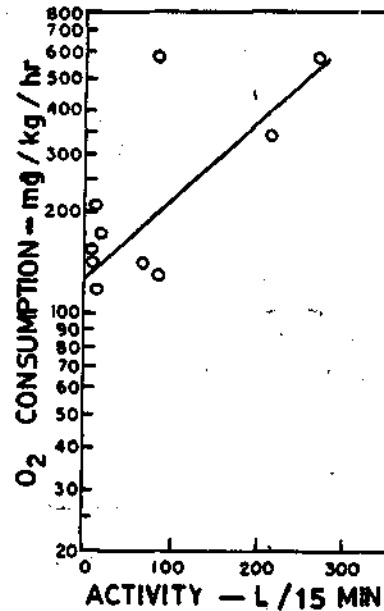
Fig. 1 B. Oxygen consumption in relation to spontaneous activity (in body lengths (L) per 15 minutes) in *Synagris furcosus* (68 g, 17.1 cm.) in ser waters at 30 C. Line fitted by the method of least squares.

C. carangus and *S. furcosus* (Figs. 1A & 1B). In these two cases extrapolated values for 'O' activity suggest standard metabolic rates of 155 and 134 mg/kg/hour respectively. In a second series of similar data with another fish (*C. carangus*) a standard metabolic rate of 195 mg/kg/hour was obtained. No such estimates could be obtained for *G. lucidus* which, as mentioned earlier, remained completely quiescent throughout the period of these tests. In two other species tested also the data could not be used for such 'spoor plots'; as it appeared from the results the fishes were excited and in such cases individual behaviour could be different and metabolism could not be related directly to activity (Brett, 1964; Smit, 1965; Kutty, 1969).

Influence of ambient oxygen on spontaneous activity and oxygen consumption

Results obtained from experiments on *C. carangus*, *C. lysan*, *C. chanos*, *S. furcosus* and *G. lucidus* are presented in Fig 2 A-E. Oxygen consumption in all cases decreases with decrease in ambient oxygen, which acts as a limiting

factor of metabolism (Fry, 1947). Except in the case of *C. chanos* (Fig. 2 C), always spontaneous activity increased with decrease in ambient oxygen. As
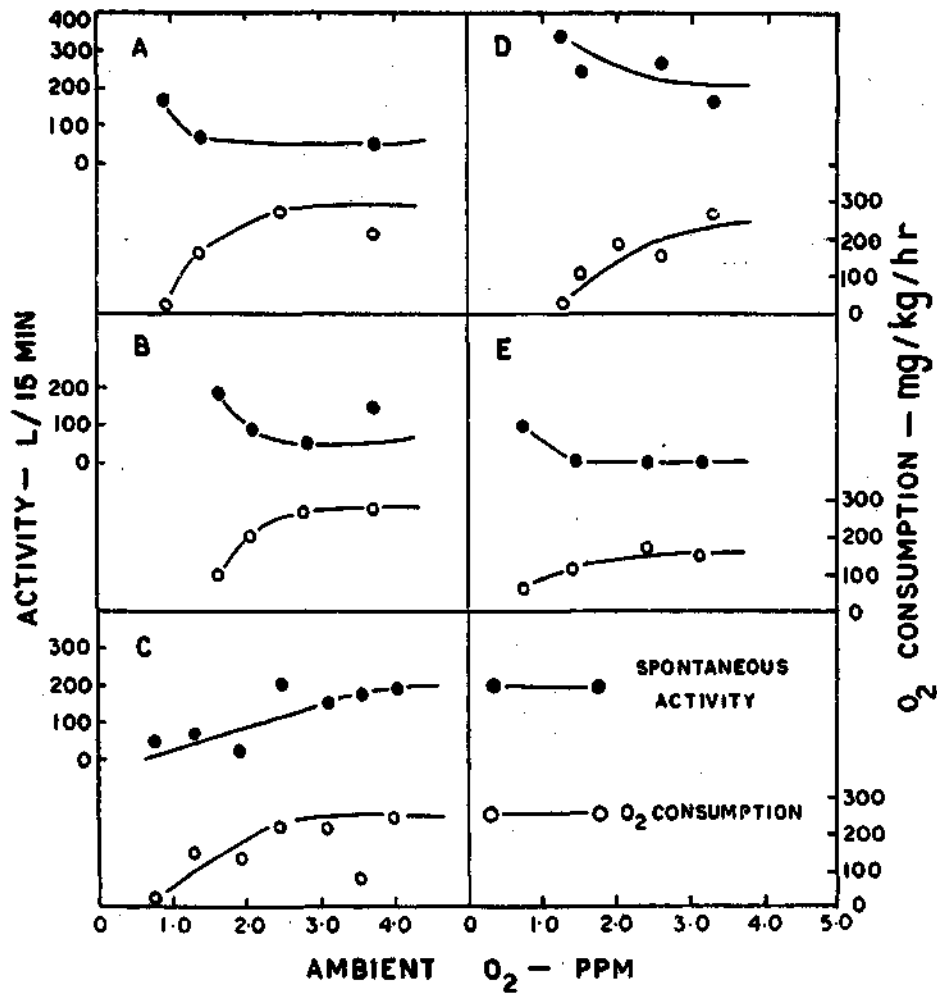

Fig. 2.   Oxygen consumption and corresponding spontaneous activity in relation to ambient oxygen in five species of marine teleosts A. *Caranx carangus* — 62.5 g (17.4 cm) B. *Chorinemus lysan* — 81.5 g (3.8cm) C. *Chanos chanos* 72-1 g (21.7 cm) D. *Synagris furcosus* — 84.0 g (18.6 cm) E. *Gerres lucidus* — 120 g (18.4 cm) at 30 C.

shown by Beamish (1964b) and Kutty (1968) metabolism at lower ambient oxygen is less than that at high, when correspondingly activity has actually increased. At this level possibly there is involvement of anaerobic metabolism as suggested by Beamish (1964b) and shown by Kutty (1968) in other fishes.

In all the species tested there is apparently accumulation of a metabolic deficit at low ambient oxygen, for in all cases the fishes became asphyxiated at an oxygen concentration close to the lowest at which the metabolic rates were estimated. In the absence of R. Q. values, as those obtained for goldfish and rainbow trout (Kutty, 1968), or other relevant information it is not possible to assess the involvement of anaerobic metabolism in the case of fishes tested presently.

When the stress due to low oxygen increases, a reduction in activity, as displayed by *C. chanos* (Fig. 2 C), may be of survival value, for the fish could then save energy for more basic functions than activity and sustain life for a longer period until perhaps the unfavourable conditions change. A similar response was obtained in *Tilapia mossambica* also (Peer Mohamed and Kutty, MS). Increase in random activity at low oxygen concentrations, as diplayed by 4 out of the 5 species tested in this study, can also be of much help to the animal in that this behaviour can aid the fish in escaping out of the unsafe environment. These two types of behaviour may have specific significance ecologically and may be of interest when viewed from the angle of behavioural evolution in fishes.

The asphyxial oxygen levels of the species studied are given in Table 2. Maximum tolerance of low oxygen, as judged from the asphyxial levels, is displayed

TABLE 2. *Asphyxial level of oxygen of five Marine Teleosts. The fishes were held and tested in seawater at 30°C and 35°/$_{oo}$ S*

Species	Asphyxial level of oxygen (ppm.) — mean on right		Weight (g) in cm)	(and total length of fish tested
Caranx carangus	0.87	0.86	62.5	(17.4)
	0.85			
Chorinemus lysan	1.50			
	1.02	1.18	81.5	(23.8)
	1.02			
Chanos chanos	0.62		72.1	(21.7)
Synagris furcosus	1.22	1.22	84.0	(18.6)
	1.22			
Gerres lucidus	0.63		120.0	(18.4)

by *C. chanos* and *G. lucidus,* but in either of these cases only a single observation is available. As mentioned earlier *G. lucidus* has the habit of staying close to the bottom and it is likely that, when compared to some other species studied, this fish encounters low oxygenated waters more often. *C. chanos* occurs during some part of its life history in shallow muddy waters of the estuaries, which

are again poorly oxygenated when compared to the open-sea habitat of the carangids and *S. furcosus*. The latter as it appears, are used to more oxygenated waters and in their turn show minimum tolerance to hypoxic waters among the fishes tested. Job (1971) shows that the swarming area of larvae and fry of *Chanos* near Pamban (Chinnapalam tidal creek) ambient oxygen reaches very low levels, whereas the oxygen concentration at the mouth of the creek was always closer to air saturation. Thus the limited data available do indicate an ecological basis for the oxygen tolerance of the different species of fishes included in this study.

ACKNOWLEDGEMENTS

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SEASONAL ABUNDANCE OF LARVAE AND POST-LARVAE OF THE COMMERCIALLY IMPORTANT PENAEID PRAWNS IN THE INSHORE WATERS OF COCHIN

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˙ABSTRACT

Seasonal distribution of the larvae and post-larvae of five species of the commercially important penaeid prawns of the Cochin area during the years 1966-67, 1967-68 and 1968-69 showed that the larvae and post-larvae of *Metapenaeus dobsoni* formed a major component (80%) of the total larval population in the inshore waters. The larvae and post-larvae of *Parapenaeopsis stylifera* were next in the order of abundance. The annual fluctuations in the occurrence of the larvae and post-larvae of *Metapenaeus monoceros, M. affinis* and *Penaeus indicus* were very wide. The percentage reduction in the total number, from larvae to post-larvae, which was attributed as mortality rate, varied from year to year in different species. Most of these species breed throughout the year with two peaks, one during October-December which is common to all the species and the other which is less pronounced extends from May to August. The larvae of most of the species are able to withstand a wide range in salinity. The larvae of *P. stylifera* are generally absent in the inshore waters during the monsoon months. A greater abundance of the larvae in the inshore waters during the year seems to indicate a good prawn fishery in the subsequent season.

INTRODUCTION

The capture fishery for prawns is characterised by wide seasonal and annual fluctuations in the yield, caused by the changes in the biotic and abiotic factors affecting the population. Among the biotic factors, the relative abundance of larvae which determines the intensity of recruitment into the exploitable stock is by far the most important. Insufficient knowledge on the correct identification of the larval stages of these prawns has greatly hampered detailed investigations on their survival and recruitment. While studying the plankton from the Cochin Backwaters, George (1958) made a brief reference to the occurrence of penaeid larvae along with the other planktonic decapods. Later on, George (1962) determined the breeding seasons of *Metapenaeus dobsoni, M. monoceros* and *Penaeus indicus* based on the seasonal abundance of post-larvae of these species in the backwater regions of Cochin. Mohamed *et al.* (1968) described the first post-larval stage of five penaeid prawns and