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Some Aspects on Oxygen and Total Carbon Dioxide Contents in Blood of the Yellowtail, *Seriola quinqueradiata**,**

By

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Studies on content of blood gases in fish are important for the solution of the problem of respiratory impediment in fish culture. The content of blood gases of the yellowtail, which is one of the main species of products of marine aquaculture in Japan, has never been investigated. Recently, the study on blood of fish has been prominently developed, and methods of taking blood from arterial and venous vessels have been devised under many considerations (BLACK, 1955; SCHIFFMAN, 1955; ITAZAWA, 1957; SMITH & BELL, 1964; SOIVIO, 1973; etc.). Particularly, the cannulating method of the dorsal aorta is excellent and convenient for sampling of the arterial blood from fish kept in resting state.

At the first step of the studies, in the present paper, oxygen and total carbon dioxide contents of the arterial and venous blood of the yellowtail in resting state are described. And these results are compared with those in other species, and respiratory characteristics of the yellowtail are discussed.

Material and Method

Two-year-old yellowtails, *Seriola quinqueradiata,* were used as the material and the fish were brought from Kuroi Marine Fish Farm at Toyoura-cho, Yamaguchi Prefecture. Their fork length was between 35 to 40 cm, and the body weight, 800 to 1000 g. After the transportation, they were kept in a tank (size; 2 x 1 x 0.8 m–depth) with aerated running sea water and were not fed during experimental period. The dissolved oxygen content of sea water in the tank was always at saturation level.

Arterial and venous blood were drawn from different individuals, because an individual was subjected to a single blood-collecting. For drawing of arterial blood, the fish were cannulated to the dorsal aorta, according to SMITH－BELL's method with a small modification. At the cannulating operation the fish was first anesthetized in a 1:7,000 solution

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of MS 222 (Sandoz), and then placed on its back in a wooden holder and irrigated at the gills with a 1:12,000 solution of the anesthetic during the operation. The experiment was done on the day following the operation. At sampling of blood, a man caught the fish quietly by a net and kept it just beneath the water surface, and another man was easily able to obtain the arterial blood through the cannula to the dorsal aorta. During taking blood the fish did neither move nor struggle at all.

The venous blood was directly drawn from the heart by a sylinge. In this case, the fish was captured by a scoop net as adroitly and quickly as possible. The fish was then placed on its back in a V-shaped trough contained sea water. The fish was held firmly but carefully not to interfere the breathing movements. The time taken to hold the fish from the first moment of catching fish to the finish of the blood drawing was about 30 seconds.

In cases of both the arterial and venous blood, 0.5 ml of the blood was analyzed by means of Van Slyke's manometric apparatus. Oxygen capacity of the blood was determined by using the blood equilibrated with air.

Results and Discussion

Oxygen capacity of the blood measured with six yellowtails was 13.9 ± 1.8 Vol. % on the average (Table 1). This value is at the similar level to those in old researches on

Table 1. Oxygen capacity of the blood in yellowtails

Water temperature (°C)	Oxygen capacity (Vol. %)
17	13.7
18	14.4
23	12.8
24.5	14.5
29.5	14.2
29.5	13.8
Mean ± S.D.	13.9 ± 1.8

rainbow trout (13.8 Vol. %, IRVING *et al.*, 1941), carp (12.5 Vol. %, BLACK, 1940), eel (12.2 to 14.5 Vol. %, KAWAMOTO, 1929_b) and mackerel (15.5 Vol. %, ROOT, 1931). In comparison with recent researches, however, this value was the highest among the following species; rainbow trout (11.1 Vol. %, ITAZAWA, 1959; 9 Vol. %, HOLETON & RANDALL, 1967), carp (7 Vol. %, GAREY, 1970) and tench (8 Vol. %, EDDY, 1974). In the present work, the venous blood was used for the measurement of oxygen capacity. The difference between the values in the old and recent researches is considered to may be based on difference in haemoglobin concentration of the blood. The lower values in the carp and the tench may be associated with their sluggish behaviour. It is known that haemoglobin concentration is easily changed by treatments for blood sampling such as handling and anesthesia (HOUSTON *et al.*, $1971_{a,b}$; PHAN VAN NGAN *et al.*, 1973).

Table 2 represents oxygen capacity in fishes, which was studied up to the present, with other characteristics and experimental conditions. Various values of oxygen capacity have been shown in Table 2. But it seems to exhibit a tendency in the relation between oxygen capacity and species of fish. Namely, oxygen capacity is large in active fishes, such as *Scomber, Mugil* and yellowtail, and also in fishes living in the environment easily causing oxygen lack, e.g. cyprinids, *Anguilla,* and some air-breathing fishes. Oxygen capacity is small in non-active fish and also in fishes living in the environment rarely causing oxygen lack, i.e. sluggish marine teleosts including the fishes listed following *Epinephelus* in Table 2 and primitive fishes in evolution, such as elasmobranchs and *Latimeria.*

Eight individuals were used for the determination of oxygen and carbon dioxide contents of the arterial blood. The results were represented in Table 3, with oxygen saturation calculated from the result of Table 1. The mean value of oxygen content in the arterial blood of the yellowtail was 12.4 ± 1.4 Vol.%, which was larger than that of any species of trout, carp, tench, eel and others (Table 4). And also the oxygen saturation of the arterial blood was approximately at the same level as those in active teleosts such as *Salmo* and *Scomber.* Moreover, the values in Table 3 showed no remarkable variation in spite of the wide range of temperature variation of the ambient water.

The values represented in the lower part of Table 3 are results in a few hours after recovery from the anesthesia for the cannulating operation. Even though the recovery from the operation was complete, judging from swimming movement, the undesirable sequelae of the operation are recognized to remain obviously in blood gas contents. It is considered, therefore, that the arterial blood of the yellowtail taken in one day after the operation shows the values in near-normal status. This opinion is also supported by the results of HOUSTON *et al.* (1969).

The results obtained with venous blood of the yellowtail were shown in Fig. 1, in which the contents of total carbon dioxide and oxygen together with the oxygen saturation were plotted against the temperature of the sea water. When the temperature rose, the carbon dioxide content increased straightly. The relation-ship between the temperature (X) and the carbon dioxide content (Y_{CO_2}) is represented by the following formula.

$$Y_{CO_2} = 0.34X + 7.05 \qquad (r = 0.71) \qquad \dots\dots\dots\dots\dots (1)$$

On the other hand, the oxygen content (Y_{O_2}) and the saturation (Y_{OS}) decreased straightly. Both the relationships against the temperature are represented as follows.

$$Y_{O_2} = -0.23X + 8.46 \qquad (r = 0.72) \qquad \dots\dots\dots\dots\dots (2)$$

$$Y_{OS} = -0.63X + 60.92 \qquad (r = 0.72) \qquad \dots\dots\dots\dots\dots (3)$$

The present results on the venous oxygen determination are higher than any one from the literature in which the blood was sampled by non-cannulating method (Table 4). The low oxygen content of the venous blood taken by heart puncture may be attributed to exercised or struggling condition of the fish. The relatively high oxygen content of the venous blood in the present data may be attributed to the following matters. The fish was under the condition of unexercised state, and the time requested from the first moment of capturing to sampling the blood to keep the fish was within

Table 2. Oxygen capacity of blood in various species of fish

Scientific Name	Common Name	Body Weight (g)	Tempera-ture (°C)	Oxygen Capacity (Vol.%)
Elasmobranch				
Scyliorhinus stellaris		1.86±0.86 (kg)	17	4.7
Raja oscillata	skate		25	4.2-5.7
Dipnoi				
Lepidosiren paradoxa	south American lungfish	104-212	23	4.9-6.8 (M.5.7)
Protopterus aethiopicus	African lungfish		20	6.8
Neoceratodus forsteri	Queensland lungfish	4.2-8.8 (kg)	18	6.0-9.0 (M.7.7)
Salmonidae				
Salmo gairdnerii	rainbow trout		15	13.8
Salmo trutta			15	12.2
Salmo gairdnerii irideus		271-387	2-9	11.1
Salmo salar	Atlantic salmon(BW)	10-20 (lb)	15±1.0	12.3
Salmo salar	Atlantic salmon(FW)	10-20 (lb)	15±1.0	8.8
Salmo salar sebage	Atlantic salmon (landlocked) W.		5	9.4
Salmo salar sebago	Atlantic salmon (landlocked) S.		25	8.2
Salmo gairdnerii	rainbow trout	2-3 years	15.1	9-10
Salmo trutta	rainbow trout	212-232	15	12.3
Salmo trutta	rainbow trout		15	9.3
Salmo gairdnerii	rainbow trout			9-10
Salmo gairdnerii		300-600	6	10.42±0.44
Salmo gairdnerii		300-600	15	8.93±1.6
Salmo garidnerii		300-600	20	9.50±1.06
Salmo gairdnerii			11.5	7.04
Salmo gairdnerii			12.0	5.32
Salmo gairdnerii			20.0	7.86
Salmo gairdnerii	rainbow trout	300-600	15	7.8±0.69
Salvelinus fontinalis	brook trout		S. 15	7.47±0.424
Salvelinus fontinalis	brook trout		W. 5	8.12±0.373
Salvelinus fontinalis	brook trout		combined	7.83±0.281
Cyprinidae				
Cyprinus carpio	carp		15	12.5
Cyprinus carpio		558	14.5-15.0	10.5
Tinca tinca	tench	276.9±19.44		7.67±0.48
Carassius auratus	gold fish	(9cm)	5	10.22
Carassius auratus	gold fish	(9cm)	6	11.29
Carassius auratus	gold fish	(9cm)	26	12.29
Carassius auratus	gold fish	(9cm)	30	9.41
Anguillidae				
Anguilla anguilla	eel			6.0
Anguilla japonica	eel		17	10.2-15.6
Anguilla japonica	eel		5	14.5
Anguilla japonica	eel		17	13.7
Anguilla japonica	eel	220-297	30	12.7
Anguilla japonica	eel	220-297	11-17	10.5

Ht (%)	P_{50} (mmHg)	Source of Blood or Method of Blood Sampling	Reference
16±3	12	cann. caudal aorta & vein	PIIER *et al.*, 1967
	45		DILL *et al.*, 1932
14-19	10.5	cann. pulmonary artery & vein, dorsal aorta	JOHANSEN & LENFANT, 1967
25	10	cann. pul. art. & vein, coeliac art., vena cava	LENFANT & JOHANSEN, 1968
24-36	11	cann. left pul. art., vena cava	LENFANT *et al.*, 1967
43	18		IRVING *et al.*, 1941
35	17		IRVING *et al.*, 1941
			ITAZAWA, 1957
39.4		heart puncture	BENDITT, *et al.*, 1941
24.8		heart puncture	BENDITT, *et al.*, 1941
	8		BLACK *et al.*, 1966_b
	9		BLACK *et al.*, 1966_b
		cann. dorsal aorta	HOLETON & RANDALL, 1967
25		cann. dorsal aorta	HOLETON, 1971
21		cann. dorsal aorta	HOLETON, 1971
			EDDY & MORGAN, 1969
		cann. dorsal aorta	EDDY, 1971
		cann. dorsal aorta	EDDY, 1971
		cann. dorsal aorta	EDDY, 1971
		cann. ventral aorta	CAMERON, 1971
		cann. ventral aorta	CAMERON, 1971
		cann. ventral aorta	CAMERON, 1971
		cann. dor. aor. & vent. aor.	EDDY, 1971
22.214±1.298	12		BLACK, *et al.*, 1966_a
22.994±1.123	5		BLACK, *et al.*, 1966_a
22.653±0.833			BLACK, *et al.*, 1966_a
33.1	5	heart puncture	BLACK, 1940
		caudal vein & aorta	ITAZAWA, 1957
24.1±1.62			EDDY, 1973
34.2		cann. bulbus or ventral aorta	ANTHONY, 1961
36.0		cann. bulbus or ventral aorta	ANTHONY, 1961
37.5		cann. bulbus or ventral aorta	ANTHONY, 1961
30.9		cann. bulbus or ventral aorta	ANTHONY, 1961
			KROGH, 1919
39	4		KAWAMOTO, 1929_b
	1.5		KAWAMOTO, 1929_a
	2.0		KAWAMOTO, 1929_a
	4.0		KAWAMOTO, 1929_a
		caudal vein & aorta	ITAZAWA, 1959

Table 2. continued

Scientific Name	Common Name	Body Weight (g)	Tmepear-ture (℃)	Oxygen Capacity (Vol.%)
Anguilla vulgarisa	eel		15.0-16.0	
Anguilla rostrate	eel	132±29 (FW)	13±2	8.5±1.5
Anguilla rostrata	eel	103±61 (BW)	13±2	9.2±2.4
Angulla rostrata	eel	180±85 (SW)	13±2	5.9±2.1
Other Families				
Latimeria chalumnae	coelacanth (living)	(85cm)	15	5.15
Amia carva	bowfin		15	11.8
Catostomus commerroonuii	common sucker		15	10.6
Ameiurus nebulosus	catfish		15	13.3
	pike	224-417 (M.364)	10-15	7.7-9.9 (M.8.96)
	roach	195-274 (M.229)	10-15	11.53-14.90 (M.13.35)
Electrophorus electricus	electric eel		28	19.75
Electrophorus electricus	electric eel	4-10 (kg)	28	9.6-13.9 (M.12.3)
Scomber scombrus	mackerel		20	15.77
Mugil cephalus	striped mullet	186-275	12-19	14.9
Epinephelus fario	brown spotted grouper	330-717	13-16	11.6
Stenotomus chrysops	scup		20	7.30
Prionotus carolinus	sea robin		20	7.66
Pseudopleuronectes americanus	winter flounder	200-900	5	10.1
Pseudopleuronectes americanus	winter flounder	200-900	10	8.8
Pseudopleuronectes americonus	winter flounder	200-900	15	9.0
	cod		14	6.5-7.8
Tautoga onitis	tautog		25	9.32
Opsanus tau	toad fish		20	6.21
Lophius piscatorius	goosefish		20	5.07
Spheroides maculatus	puffer		20	6.75
Symbranchus marmoratus			22	9.0-20.3(M.14.7)
Trematomus bernacchii	(antarctic fish)	50-440	-1.5	4.5-6.3 (M.5.3)
Trematomus centronotus	(antarctic fish)	116-210	-1.5	4.2-5.5 (M.5.2)
Trematomus hansoni	(antarctic fish)	90-200	-1.5	7.1-8.1 (M.7.7)
Trematomus borchgrevinki	(antarctic fish)	40-112	-1.5	6.1-7.0 (M.6.6)
Notothenia nudifrons	(antarctic fish)		0	4.6, 5.5
Notothenia gibberifrons	(antarctic fish)		0	4.5-5.7(M.5.0)
Notothenia coriiceps	(antarctic fish)		0	7.0-8.8(M.8.0)
Seriola quinqueradiata	Yellowtail	800-1000	17-29	13.9

Notes: *, estimated value; Ht, haematocrit reading; P_{50}, partial pressure of oxygen in half

Ht (%)	P_{50} (mmHg)	Source of Blood or Method of Blood Sampling	Referrence
40 (adjust)		heart puncrue	STEEN, 1963
38.0±4.3		tail clipping	GUERNSEY & POLUHO-RUICH, 1975
33.0±5.0		tail clipping	GUERNSEY & POLUHO-RUICH, 1975
22.1±11.1		tail clipping	GUERNSEY & POLUHO-RUICH, 1975
(20)*	2.06		HUGHES & ITAZAWA,1972
27.1	4	heart puncture	BLACK, 1940
32.5	12	heart puncture	BLACK, 1940
32.2	1.4	heart puncture	BLACK, 1940
27.0-31.7 (M.29.1)		cann. bulbus or ventral aorta	ANTHONY, 1961
36.0-56.5 (M.46.0)		cann. bulbus or ventral aorta	ANTHONY, 1961
	12	gill vessels, heart, sinus venosus	WILLMER, 1934
25-41 (M.32)	10.7	cann. coeliac artery	JOHANSEN *et al.*, 1968
37.10	16		ROOT, 1931
		caudal artery	ITAZAWA, 1959
		caudal artery	ITAZAWA, 1959
32.60	6.4	gill	ROOT, 1931
24.00	16	gill	ROOT, 1931
		cardiac puncture	HAYDEN *et al.*, 1975
		cardiac puncture	HAYDEN *et al.*, 1975
		cardiac puncture	HAYDEN *et al.*, 1975
	15		KROGH & LEITCH, 1919
	6.0		ROOT & IRVING, 1941
19.50	14	gill	ROOT, 1931
15.45		gill	ROOT, 1931
17.50		gill	ROOT, 1931
		coeliac artery	JOHANSEN, 1966
17-26 (M.20.5)		cardinal vein or cann. caudal artery	GRIGG, 1967
17-24 (M.22.0)		cardinal vein or cann. caudal artery	GRIGG, 1967
29-33 (M.31.0)		cardinal vein or cann. caudal artery	GRIGG, 1967
26-32 (M.30.0)		cardinal vein or cann. caudal artery	GRIGG, 1967
		heart puncture	HEMMINGSEN *et al.*, 1969
		heart puncture	HEMMINGSEN *et al.*, 1969
		heart puncture	HEMMINGSEN *et al.*, 1969
		cann. dorsal aorta	the present work

saturated blood; M., mean; SW, sea water; BW, brackish water; FW, fresh water.

Table 3. Oxygen and total carbon dioxide contents, and oxygen saturation of the arterial blood in yellowtails

Water temperature (° C)	Oxygen content (Vol. %)	Total carbon dioxide content (Vol. %)	Oxygen saturation (%)
12	12.7	1.8	91.4
14	9.7	4.7	69.8
16	13.4	4.8	96.4
17	10.8	6.1	77.7
17	14.2	5.4	102.2
19	13.2	5.5	95.0
19.5	13.1	5.2	94.2
25.3	12.0	7.9	86.3
Mean ± S.D.	12.4 ± 1.4	5.2 ± 1.7	89.1 ± 10.7
* 14	17.4	7.1	
* 13	13.9	11.4	
* 12	13.5	14.1	

* These results were obtained in few hours after recovery of the operation. See text.

the circulation time of blood, though the circulation time in fish is extreamly short such as 1.0 minute in *Oplegnathus* and 2.2 minutes in rainbow trout (ITAZAWA, 1970_b).

Since the cannulation to a venous vessel has come into use of late, the relatively high value of the oxygen saturation in venous blood has been reported. For example, it was 70% in rainbow trout (HOLETON & RANDALL, 1967). The fact that the low values from 18% to 41% was obtained in the present work may be attributed to sampling methods of venous blood, although EDDY (1974) has reported the value of 40% (24% to 45%) in tench by the cannulating method.

STEEN and KRUYSSE (1964) described that oxygen saturation of the arterial blood in eel was about 50% in resting state, but the value of the saturation increased when the demand for oxygen was raised by oxygen lack or activity, and thus the amount of oxygen transported to the tissues by the arterial blood would increase. On the other hand, STEVENS and RANDALL (1967) suggested that rainbow trout which had higher oxygen saturation of the arterial blood in resting state, would be able to transport more oxygen to the tissues by means of the decrease in oxygen saturation of the venous blood for the increased oxygen requirement.

In the case of yellowtail, the oxygen saturation of the venous blood decreased as the water temperature was raised (Fig. 1). It is obvious that basal metabolism of fish increases as water temperature rises. It is, therefore, considered that yellowtail as well as rainbow trout endures by leaving less oxygen in the venous blood to deal with an increased demand of oxygen. Thus, more oxygen will be transported to the tissues as the oxygen saturation of venous blood decreases. The mechanism to decrease the oxygen content of venous blood may be considered as follows. The carbon dioxide content of venous blood increases with the rising of water temperature (Fig. 1), therefore

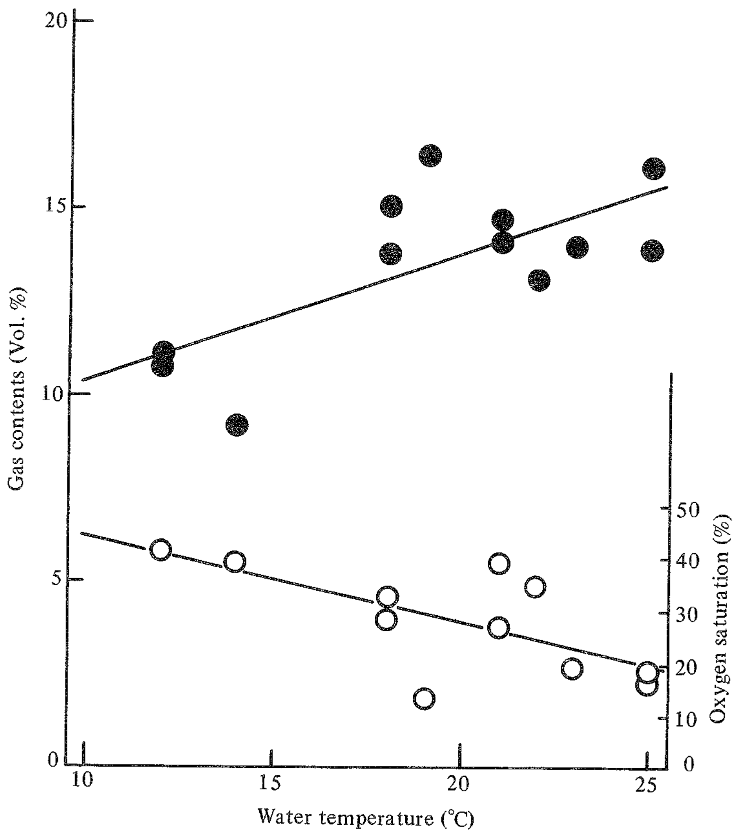

Fig. 1. Relationships between water temperature and venous blood gas contets (open circles, oxygen ; solid circles, total carbon dioxide)

the partial pressure of carbon dioxide in the venous blood will increase undoubtedly. As the water temperature is raised, therefore, the oxygen dissociation curve of the venous blood is shifted downward by BOHR effect, and hence the arterial blood conferes more oxygen on the tissues.

Recently, WATTERS and SMITH (1973) studied on change of blood gas contents in the starry flounder affected by temperature stress. The oxygen saturation of venous blood in the flounder was found to decrease from 72.1% at 11.4°C to 54.5% at 19.4°C, and the authors discussed on a respiratory function as the venous oxygen reservoir. Oxygen saturation of the venous blood in the yellowtail at the same temperature with that in the flounder was calculated according to the equation (3) obtained in Fig. 1. The results were shown in Table 5 together with those in the flounder. Decrease of oxygen saturation by the same degree of temperature shift was larger in the flounder than in the yellowtail, but the ratio of the decrease to the initial value at the lower temperature

Table 4. Respiratory characteristics of arterial and venous blood in fishes.

Scientific Name	Common Name	Body Weight (g)	Tempe-rature (℃)	Arterial Blood Ht (%)	Po_2 (mmHg)	O_2 (Vol.%)	O_2 Sat. (%)
Raja oscillata						5.6	
Scyliorhinus stellaris	dog fish	1860±860		16±3	81.31	4.5±1.0	90
Scyliorhinus acanthias		3860±1100		19±3		3.85±0.75	
Scyliorhinus stellaris	dog fish		16		92±24	10±2	
Scyliorhinus canicula	dog fish	857±46	16	7±1.1	90.9±8.7	4.0±0.2	
Scyliorhinus canicula	dog fish	788±27	12	17.2±1.0	114.4±1.0	4.7±0.4	
Scyliorhinus canicula	dog fish	716±37	17	20.5±1.6	97.6±2.8	4.7±0.6	
Dasyatis salrna(normal)	sting ray	491±47	20–26	14.6	90.		92.5
Dasyatis salrna (ligated)	sting ray	562±113			91.		93.3
Salmo gairdneri			11.5				
Salmo gairdneri			12.0				
Salmo gairdneri			20.0				
	rainbow trout		15.1		122.		95–100
Salmo gairdneri	rainbow trout	300–600	15		84.7+3.65	8.2±0.64	100
Salmo gairdneri	rainbow trout	300–600	15		91.6		95
Salmo gairdnerii irideus	rainbow trout	235–510	2.3–13.0			10.7±1.4	
Cyprinus carpio	carp	2000–6000	10.1			5.16±1.3	75
Tinca tinca	tench	276.9±19.4					
Cyprinus carpio	carp	235–785	13.3–25.0			8.0±1.5	
Cyprinus carpio	carp					8.5	
	eel						
	eel						
Anguilla japonica	eel	220–630	11.3–17.0			6.7±1.0	
Platichthys stellatus	starry flounder	1175–1475	11.4±1.1	13.7	75.5±17.9		88.6±4.6
Platichthys stellatus	starry flounder	1175–1475	11.7±1.1(Hb 3.98)		41.3±14.9		75.2±9.6
Platichthys stellatus	starry flounder	1175–1475	19.4±1.5		62.3±13.9		85.6±5.7
Seriola quinqueradiata	Yellowtail	800–1000	17–29			12.4±1.4	89.1±10.7

	Venous Blood				
Source of Blood or Method of Blood Sampling	Po_2 (mmHg)	O_2 (Vol. %)	O_2 Sat. (%)	Source of Blood or Method of Blood Sampling	Reference
		1.9			DILL *et al.*, 1932
cann. caudal aorta	11±9	1.5±1.0	31	cann. caudal vein	PIIPER, 1967
cann. caudal artery		1.26±0.59		cann. ducts of Cuvier	ROBIN *et al.*, 1966
cann. peripheral aorta	4.1±0.7	1.1±0.3		cann. ventral aorta	BAUMGARTEN, 1968
iliac-artery	21.3±3.4	2.1±0.2		afferent br. artery	BUTHER *et al.*, 1975
illiac-artery	34.5±3.4	2.7±0.4		afferent br. artery	BUCHER *et al.*, 1975
illiac-artery	32.9±3.2	2.7±0.6		afferent br. artery	BUCHER *el al.*, 1975
dorsal aorta				afferent br. artery	CAMERON *et al.*, 1971
dorsal aorta	14.2		28	afferent br. artery	CAMERON *et al.*, 1971
	28.3	3.82	54.3	cann. ventral aorta	CAMERON *et al.*, 1971
	37.5	3.25	60.5		CAMERON *et al.*, 1971
	46.5	4.83	61.5		CAMERON *et al.*, 1971
cann. dorsal aorta	30–35		67–73	cann. caudal vein	WATTERS *et al.*, 1973
cann. dorsal aorta					EDDY, 1976
	17.3		61	cann. ventral aorta	EDDY, 1976
caudal aorta		1.3±0.6		bulbus art. & vent. aor.	ITAZAWA, 1970
cann. dorsal aorta		2.54±1.46		cann. ventral aorta	GAREY, 1970
caudal aorta		1.1±0.3		bulbus art. & caud. vein	ITAZAWA, 1970
		1.9			KOYAMA, 1960
		6.6 (Hb:4.9±0.5)		iliac-art. & inters. vein	WOOD *et al.*, 1973
		9.8 (Hb:7.3±0.5)			WOOD *et al.*, 1973
caudal aorta		2.7±0.7		bulbus arteriosus	ITAZAWA, 1970
cann. caudal artery	42.9±7.3		72.1±5.2	cann. caudal vein	WATTERS *et al.*, 1973
cann. caudal artery	23.9±6.8		52.6±10.8	cann. caudal vein	WATTERS *et al.*, 1973
cann. caudal artery	29.8±8.4		54.5±10.0	cann. caudal vein	WATTERS *et al.*, 1973
cann. dorsal aorta		1.9–5.8	13.7–41.7	heart puncture	the present work

Table 5. Influences of temperature on oxygen saturation of the venous blood (OS) and on utilization of oxygen at the tissues, in the yellowtail and the flounder

Water temperature (°C)	The yellowtail			The flounder*		
	Oxygen saturation (%)		Utilization of oxygen (%)	Oxygen saturation (%)		Utilization of oxygen (%)
	Venous blood (OS)	Arterial blood		Venous blood (OS)	Arterial blood	
11.4	42.3	89.1	53.0	72.1	88.6	18.6
19.4	31.7	89.1	64.2	54.5	85.6	36.3
Decrease ratio** (%)	25.1			24.4		

*cited from WATTERS & SMITH (1973), **calculated by $\frac{(OS)_{11.4℃}-(OS)_{19.4℃}}{(OS)_{11.4℃}} \times 100$

was almost the same. In the yellowtail, a pelagic fish, the "venous oxygen reservoir" (WATTERS & SMITH, 1973) seems to function as effectively as in benthonic fishes such as the flounder.

Decrease in oxygen saturation of the venous blood owing to rising of the temperature results from the large supply of oxygen to the tissues. In order to know the degree of transfer of oxygen to the tissues, utilization ratios of oxygen ($\frac{A-V}{V} \times 100$) at the tissues were calculated from the value of oxygen saturation of the arterial (A) and the venous (V) blood at each temperature, after ITAZAWA (1970a). From the results represented in Table 5, it is clear that the utilization increases with rising of the temperature. When the oxygen demand at the tissues increases, the fish is considered to make a physiological adjustment either by increase of cardiac output or by increase of oxygen supply by means of increased conferment of oxygen from an unit volume of the arterial blood. As mentioned above, oxygen saturation of the venous blood in the yellowtail decreased and the difference between those of the arterial and the venous blood increased by rising of the temperature. In this case, therefore, the increase of cardiac output in the yellowtail may be not great.

Summary

1) Oxygen capacity of blood and contents of oxygen and total carbon dioxide in the arterial and venous blood were measured in the yellowtail, *Seriola quinqueradiata*, in resting state at various temperature. In comparison with the results, the data in many fishes reported hitherto were listed in Tables 2 and 4.

2) Variation of oxygen content by temperature change was larger in the venous blood than in the arterial one. The relation-ship between oxygen content of the venous blood (Y) and temperature (X) was given by a formula,

$Y = -0.23X + 8.46$ ($r = 0.72$).

3) For the increase of basal metabolism owing to rising of water temperature, it is considered in the yellowtail that much more oxygen will be transferred to the tissues by the increase of the difference between the oxygen content of the arterial blood and that of the venous blood rather than by the increase of cardiac output.

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