and yolk, and it was suggested that they might have survived to sibling birth, albeit at a smaller size. In the present case this seems less likely because the shared yolk sac was empty, -- its contents had already been used up, although the siblings were still perhaps 4 or 5 months from being born. Nothing is known about the birth of spiny dogfish, whether a female bears all her young at one time, or sequentially, when each is completely developed. In the first case, it seems that the twins would have too little yolk resource left to survive through the period until the siblings were ready for birth. In the second case the twins might have been born alive, although smaller in size than normal and possible not fully matured in their development.

A COMPARISON OF CARDIOVASCULAR VARIABLES IN RESTING EEL POUT AND SEA RAVEN

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A few species of teleost fish possess "white" hearts, as opposed to the normal red colour of the ventricle in all other fish and vertebrates. The reason for the white appearance of the ventricular myocardium in fish such as the eel pout (Macrozoarces americanus) is a lack of intracellular myoglobin (Driedzic et al, this volume). Myoglobin is believed to facilitate O_2 transfer from blood in the ventricular lumen to the myocardium, as well as being a potential intracellular O_2 store (a high proportion if not all the myocardial O_2 supply is provided by venous blood in the lumen since many fish lack coronary vessels). Because of this unusual occurrence, recent work has focused on the metabolic and physiological performance of the white heart in the eel pout. One would expect physiological adaptations in fish with a myoglobin-less myocardium. For instance they may have higher venous blood oxygen tensions, or the heart may have a reduced power output, or the myocardium itself may be more tolerant to hypoxia compared to fish hearts containing myoglobin. The latter possibility has, however, been ruled out since the eel pout heart tolerates anoxia poorly (Turner and Driedzic, Can. J. Zool., 58:886-889, 1980). The two other possibilities have not been examined.

The present work reports preliminary data on blood flow and blood pressure measurements in the ventral aorta (VA) (i.e. immediately after the heart) in the resting eel pout. The oxygen tension (P_{O_2}) of ventral aortic blood (P_{VO_2}) was also measured and was used as an index of the ventricular lumen blood P_{O_2}. Comparisons were made with similar measurements from the sea raven (Hemitripterus americanus) which possesses a myoglobin-rich myocardium.

METHODOLOGY

The sea ravens (n = 5; wt. = 0.9 to 2.0 kg) were obtained locally. The eel pout (n = 6; wt. = 0.8 to 1.0 kg) were transported from St. Andrews, N.B., Canada and held at MDIBL. Ventral aortic blood pressures (P_{VA}) and VA blood flow (cardiac output, $\dot{Q}$) measurements were not made on the same fish. An indwelling, nonocclusive polyethylene cannula (i.d. = 0.58 mm, o.d. = 0.96 mm) was used to measure P_{VA} and to sample VA blood. A cuff-type electromagnetic flow probe (Biotronix) was fitted snugly around the VA for blood flow measurements. The protocol used to implant these cannulae is similar to that described by Farrell (J. Exp. Biol., in press, 1980). The fish were held in a darkened plexiglass box that approximated the fish size and received a flow-through supply of aerated sea water at 17°C, and they were allowed to recover from surgery overnight. Blood pressure and flow records were taken continuously during the day time and occasionally during the evening. The traces were only sampled at times when the fish appeared to be resting, i.e., no apparent swimming. Blood flow signals were detected with a Biotronix BL 610 electromagnetic flow meter. Blood pressure signals were detected with a Harvard pressure transducer. The blood flow and pressure signals were recorded on a Narco physiograph chart recorder after suitable amplification. Blood samples (0.3 ml) were taken from resting fish, usually at three different times for P_{VO_2} and Ht measurements. The blood was replaced by an equivalent Cortland saline infusion. P_{V02} was measured with a Radiometer PH 71 plus associated 0_2 electrode and water jacket. Power output of the heart was calculated from the mean P_{VA} times $\dot{Q}_{VA}$.

RESULTS

The results (Table 1) quite clearly demonstrate that the resting eel pout heart develops a significantly greater P_{VA} compared to the sea raven. This presumably reflects a higher peripheral vascular resistance in the eel pout. As a consequence the eel pout heart generates 40% more power per kg body weight than the sea raven heart. More interesting

Table 1.--A Comparison of Cardiovascular Variables for the Eel Pout and Sea Raven at 17°C

	Eel Pout	Sea Raven
P_{VA} mean, cm H_20	46.8 ± 2.7*	39.6 ± 1.3
pulse, cm H_20	20.7 ± 1.8*	14.1 ± 1.7
heart rate, beats•min^{-1}	50.9 ± 8.7	41.0 ± 5.5
	n = 5	n = 3
$\dot{Q}$ mean, ml.min^{-1}.kg^{-1}	17.6	15.4
stroke volume, ml.kg^{-1}	0.45	0.35
heart rate, beats.min^{-1}	41.5	46.0
	n = 1	n = 2
P_{V0_2}, mm Hg	32.3 ± 3.1*	53.2 ± 0.7
	n = 5	n = 4
Ht, %	41.1 ± 1.1	12.2 ± 0.7
	n = 5	n = 4
Myocardial power output, ergs.s^{-1}.(kg body wt.)$^{-1}$	1.37 x 10^4	1.02 x 10^4
Heart wet wt., g.(kg body wt.)$^{-1}$	0.69 ± 0.03*	0.86 ± 0.04
	n = 12	n = 12
Myocardial power output, ergs.s^{-1}.(g dry wt. of heart)$^{-1}$	1.32 x 10^5	0.80 x 10^5

*Denotes a statistically significant difference between the two fish species at the 95% confidence level.

Values are expressed as mean values ± standard error for n fish wherever possible.

Power output is the product of the P_{VA} and $\dot{Q}$ mean values.

The heart wet wt. was determined from fish other than those used in the cardiovascular experiments and the heart dry wt. = 15% the heart wet wt.

is that the eel pout does this with a comparatively smaller heart. Thus on a per gram dry weight of myocardium basis, the power output of the eel pout is 66% greater than that of the sea raven. In light of the power output generated by the eel pout heart, the significantly lower P_{VO_2} (about 40% lower) is surprising.

That the myoglobin-less eel pout heart can function at least as well as a myoglobin-rich heart and with a presumably lower O_2 gradient is the opposite of the expected finding.

DISCUSSION

It should be stressed that results are preliminary findings and compare only two teleost species. The P_{VA} and $\dot{Q}_{VA}$ for both fish are within the ranges for other marine teleosts. Consequently, the difference in power output is not too outstanding if the range of power output values found in other teleosts is considered. For instance, the power output in the red heart of the lingcod (Ophiodon elongatus) at 10°C is 0.9×10^4 ergs. s^{-1}.kg body wt^{-1}, which probably lies between the eel pout and sea raven values for 17°C, given an allowance for the 7°C temperature difference.

The resting P_{VO_2} of the sea raven is similar to the P_{VO_2} found in other teleosts. Thus the P_{VO_2} of eel pout is low amongst teleost fish. Whether ventral aortic P_{O_2} indicates the true ventricular lumen blood P_{O_2} may be challenged. We feel that the measured P_{VO_2} is however a representative value since Kiceniuk and Jones (J. Exp. Biol. 69:247-260, 1977) could not detect a significant P_{O_2} difference between blood entering and leaving the heart in the trout (Salmo gairdneri).

The present findings illustrate that a myoglobin-less fish heart can perform equally as well as a myoglobin-rich one, but with a less favorable O_2 gradient. These findings are contradictory to those expected and therefore raise profound questions as to the role of myoglobin in fish hearts. This work was supported by a grant to W.R.D. from the New Brunswick Heart Foundation, Canada. The use of Dr. B. Kent's P_{O_2} meter was appreciated and M. Levy is thanked for his assistance with the P_{O_2} measurements.

RATES OF OXYGEN CONSUMPTION AND LACTATE OXIDATION BY PERFUSED ISOLATED OCEAN POUT AND SEA RAVEN HEARTS

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In contrast to most vertebrate species the heart of the ocean pout (Macrozoarces americanus) is almost devoid of myoglobin. It would be of interest to ascertain if the absence of myoglobin which is thought to facilitate intracellular oxygen diffusion is associated with alterations in the organization of aerobic energy metabolism. This problem is being approached by determining the rates of oxygen consumption and $^{14}CO_2$ production from labelled substrate by perfused isolated hearts. For comparative purposes studies are being conducted with myoglobin poor white hearts from ocean pout and myoglobin-rich red hearts from sea raven (Hemitripterus americanus). These species present ideal experimental models since both animals are lethargic bottom dwellers, suggesting similar levels of blood gases and moreover both species have very poorly developed coronary arteries, thus their myocardia must receive oxygen and nutrients from the blood which is in the ventricular lumen.

MATERIALS AND METHODS

Ocean pout (Macrozoarces americanus) and sea raven (Hemitripterus americanus) were captured by otter trawl in either Passamaquoddy Bay, N.B. or Seal Cove, Maine. The fish were transported to the laboratory and maintained at 10° - 13°C. Animals were sacrificed by severing the spinal cord, the hearts were exposed, excised and placed in