

**REGULATION OF BRAIN TEMPERATURE IN YELLOWFIN TUNA:  
EVIDENCE OF ALTERATIONS IN BLOOD FLOW**

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**EXTENDED ABSTRACT ONLY – DO NOT CITE**

**Introduction**

Tunas are regional endotherms, maintaining elevated temperatures in deep red swimming muscles by way of vascular counter-current heat exchangers (*retia mirabilia*) that trap metabolically produced heat (Carey and Teal, 1966). Many tunas also warm the viscera and brain with associated *retia*. These *retia* allow the tissues to be kept at temperatures higher than the surrounding water, enhancing metabolic capacity, but also act as effective insulators, slowing the rate of heat loss during forays into cooler waters. The yellowfin tuna *Thunnus albacares* is a tropical-subtropical species inhabiting the surface waters, but periodically makes rapid “dives” through the thermocline in search of prey, encountering water temperatures as much as 10°C cooler (Holland et al., 1990). Tunas of the genus *Thunnus* possess a carotid *rete* in the blood supply to the eye and brain, which can act as a thermal barrier (Linthicum and Carey, 1972). The objective of this study was to measure the ability of the carotid *rete* to insulate the brain of yellowfin tuna from rapid changes in environmental temperatures.

**Materials and Methods**

Yellowfin tuna (0.7 – 1.5 kg) were anesthetized and implanted with a thermocouple through the pineal foramen of the skull to record brain temperature, and exposed to step changes in ambient temperature (from 25 to 15°C and then back to 25°C). The effectiveness of the carotid heat exchanger in affecting heat flux was examined by calculating the thermal rate coefficient (*k*) from the rates of brain temperature change (Brill et al., 1994). To test for nervous control of *retial* efficiency, several tuna were injected I.M. with

bretylium tosylate (10 mg kg<sup>-1</sup>) to abolish the effects of adrenergic nerves on the circulatory system, and the step temperature change was repeated.

### Results and Discussion

Excess brain temperatures in the yellowfin were not significant (a few tenths of a degree above ambient). However, rates of brain cooling ( $k = 0.154$ ) during drops in ambient temperature ( $T_{\text{water}} < T_{\text{brain}}$ ) were significantly lower than rates of heating ( $k = 0.232$ ) when water temperature was increased ( $T_{\text{water}} > T_{\text{brain}}$ ) (Table 1). This difference indicates alterations in the effectiveness of the heat-exchanger to reduce heat loss during exposure to colder waters, and enhance heat gain upon return to warm waters. On average, the brain warmed about 50% faster than it cooled.

Table 1. Thermal rate coefficients [ $k$ , °C min<sup>-1</sup> (°C gradient)<sup>-1</sup>] for brain of yellowfin tuna during step changes in ambient temperature (25°C → 15°C → 25°C).

Fish No.	Control $k$ values			Bretylium Treatment $k$ values		
	Cooling	Heating	<u>Heating</u> <u>Cooling</u>	Cooling	Heating	<u>Heating</u> <u>Cooling</u>
1	0.108	0.185	1.71			
2	0.154	0.193	1.25			
3	0.307	0.458	1.49			
4	0.110	0.181	1.65	0.180	0.175	0.97
5	0.109	0.178	1.63	0.184	0.149	0.81
6	0.157	0.229	1.46	0.226	0.208	0.92
7	0.134	0.199	1.49			
Mean	<b>0.154</b>	<b>0.232</b>	<b>1.53</b>	<b>0.197</b>	<b>0.177</b>	<b>0.90</b>
S.E.	0.027	0.038	0.06	0.015	0.017	0.05

Similar modulation of heat transfer is seen in the deep red myotomal muscle of yellowfin tuna, although the effectiveness of the muscle *retia* is greater (lower  $k$  value when cooling) than we found for the carotid *rete* (Dewar et al., 1994). It has been hypothesized that temperature could be regulated in tissues with *retial* blood supply by shunting of blood either through the *rete* or partially by-passing it *via* alternate circulatory pathways and thereby altering the efficiency of the heat-exchange system (Linthicum and Carey, 1972). Following blockage of adrenergic nervous control of the circulation with bretylium, alterations of heat

transfer to the brain were eliminated (Table 1), suggesting active nervous control of heat-exchanger efficiency to regulate brain temperature.

Although we did not measure significant excess brain temperatures during steady-state conditions, we did find that the carotid *rete* was effective in minimizing heat loss, which would protect the brain (and perhaps eyes) during rapid dives into cooler waters. The heat-exchanger could then be turned “off” so that rapid warming could occur upon return to warm surface waters, with the overall effect of regulating more stable, and warmer, brain temperatures in the face of fluctuating environmental temperatures.

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