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Physiological and behavioral responses of temperate seahorses (Hippocampus guttulatus) to environmental warming

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Ocean warming

- Increase in the mean global sea surface temperature of 0.13 °C per decade since 1979
- Increase in ocean interior temperature > 0.1 °C since 1961
- Global mean temperature rise of 2 °C by 2100 (estimated)

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Great influence on the biology and ecology of marine organisms

Hippocampus guttulatus: ecology and biology

- Patchy distribution, associated with structurally complex habitats
- Reduce mobility
- They live in shallow coastal waters, which will be more impacted by global warming than the open seas and oceans
- Male pregnancy and monogamy

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Aim of the study

- Investigation of the effects of ocean warming on the metabolic rates, feeding and behavior patterns of the temperate seahorse *H. guttulatus*

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- Get a more detailed view of the climate change effects on seahorses and predict the animal response to the future expected conditions

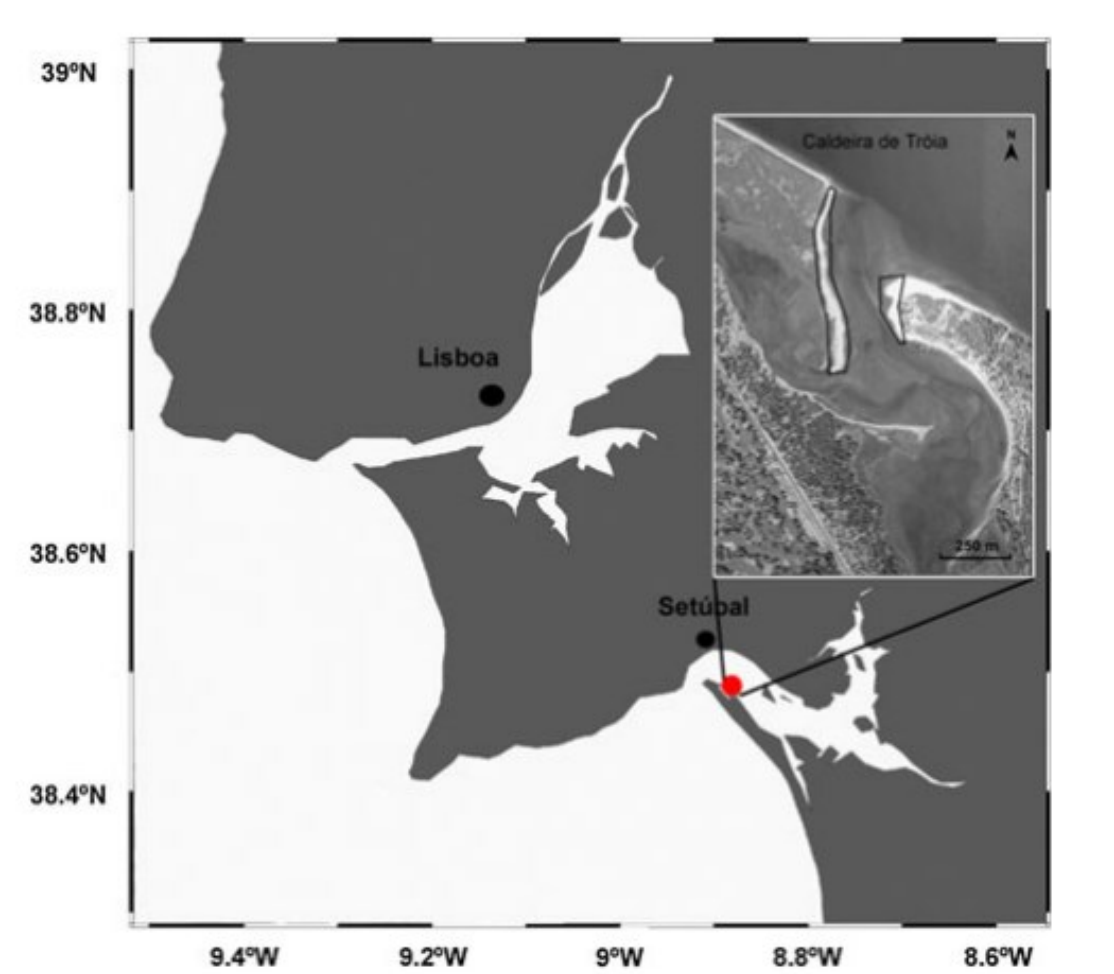

Fig. 1 Map of the sampling area (*red circle*) in Caldeira de Tróia, located in the mouth of the Sado estuary, Portugal

Specimen collection and stocking conditions.

- Twenty adult seahorses were collected in the Sado estuary, Portugal, between September and October 2011.
- Were transferred to the aquaculture facilities, wet-weighted and identified.
- During the first 4 weeks, seahorses were acclimatized.
- Female seahorses were acclimatized to four different temperature scenarios.
- At the end of the experiments, tags were removed and all adult seahorses were released.

Oxygen consumption rates.

Females were used to determine the oxygen consumption rates in the four thermal scenarios.

Animals were placed in a flow-through

respirometry setup that were immersed in a large thermostatted

bath.

Each experiment was 6 h long: 2 h for acclimation and the following 4 h for oxygen measurement.

Seahorses were continuously observed in order to detect abnormal behaviors.

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Thermal sensitivity and ventilation rate change.

For each developmental stage, the temperature coefficient (Q10) for routine metabolic rates and ventilation rates was determined using the standard equation:

$$Q_{10} = [R (T_2) / R(T_1)]^{10/(T_2-T_1)}$$

where $R(T_1)$ and $R(T_2)$ represent the routine metabolic rates or ventilation rates at temperatures T1 and T2, respectively. Q_{10} values were calculated for the temperature intervals of 18–26, 18–28, and 18–30 °C.

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Ventilation rates, food intake, and behavioral patterns.

- Gill ventilation rates were measured by counting the number of opercular beats per minute, before feeding
- Food intake was determined by collecting and counting the leftovers at the end of the day.
- Behavioral patterns were analyzed for each seahorse during 15 min twice a day

Table 1 Ethogram of *H. guttulatus* activity patterns

Category	Behavior description
Swimming (S)	The seahorse swims, moving actively the dorsal and pectoral fins
Feeding (F)	The seahorse tilts the body toward the aquarium floor in search for food, points the snout toward the prey, and swallows the prey with a suction force while a clicking sound can be heard
Swinging (Sg)	The seahorse remains attached to the holdfast, with slight movements of the head or body
Inactivity (I)	The seahorse remains resting, without performing any kind of movement, while attached or unattached to the holdfast

Results

RMR were significantly affected by temperature and developmental stage. Mean RMR increased with temperature from 2.40 (18 °C) to 5.37 µmol O2/g per h (30 °C) in adult seahorses and from 7.36 (18 °C) to 16.68 µmol O2/gh (30 °C) in newborn juveniles.

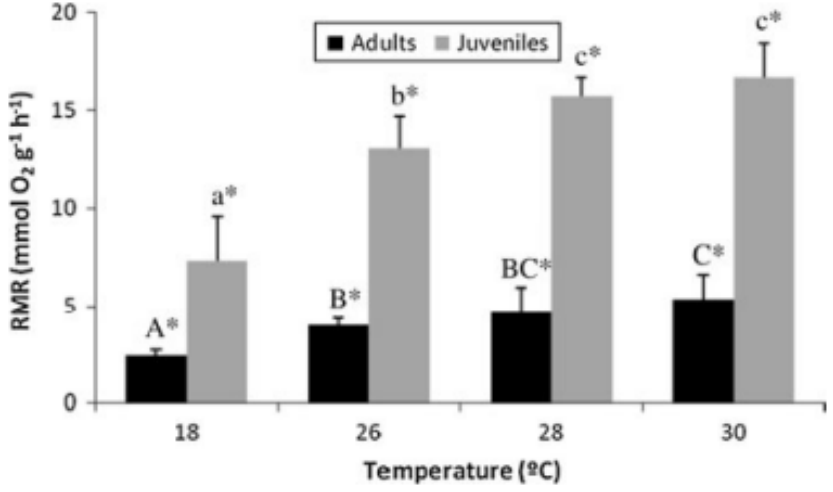

Fig. 2 Impact of environmental warming on the routine metabolic rates (RMR, µmol O_2 g^{-1} h^{-1}) of juvenile and adult seahorses, *H. guttulatus*. Values represent mean ± SD ($n = 5$ for juveniles and $n = 15$ for adults). *Different letters* and *asterisks* represent significant differences ($p < 0.05$) between temperatures and life stages, respectively. For more statistical details, see Table 2

Results

Q10 values related to adult and newborn **RMR** ranged mainly around normal values (2.0-2.5), except for juveniles at the highest temperature interval.

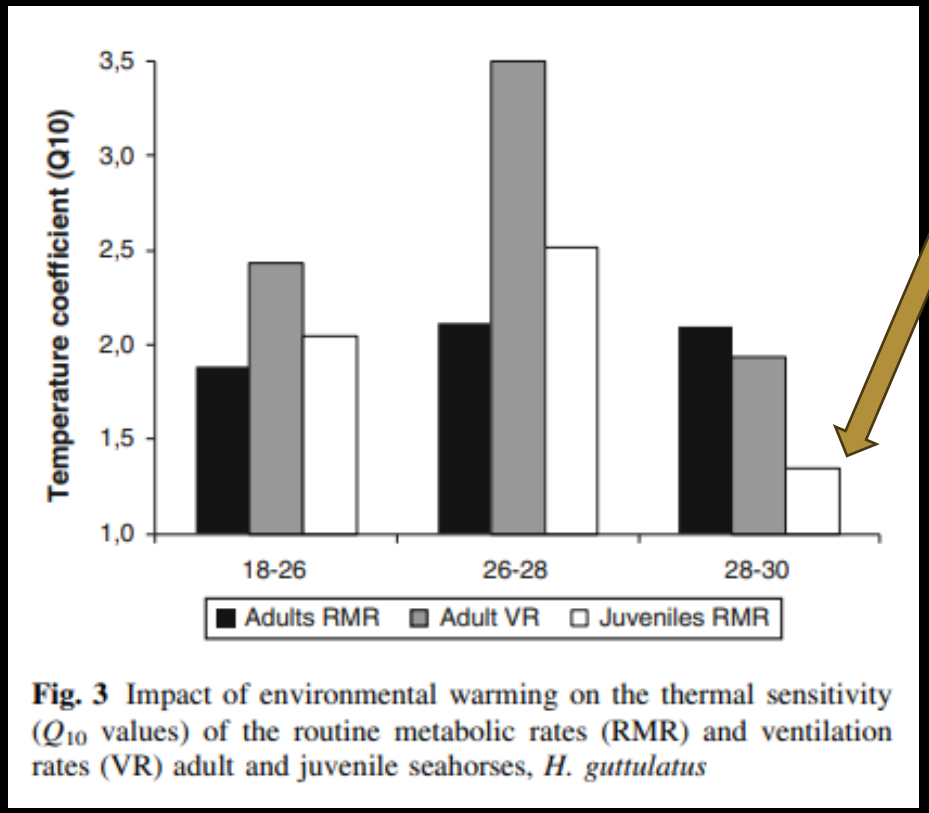

Fig. 3 Impact of environmental warming on the thermal sensitivity (Q_{10} values) of the routine metabolic rates (RMR) and ventilation rates (VR) adult and juvenile seahorses, *H. guttulatus*

Metabolic suppression due to the thermal limitation of oxygen supply

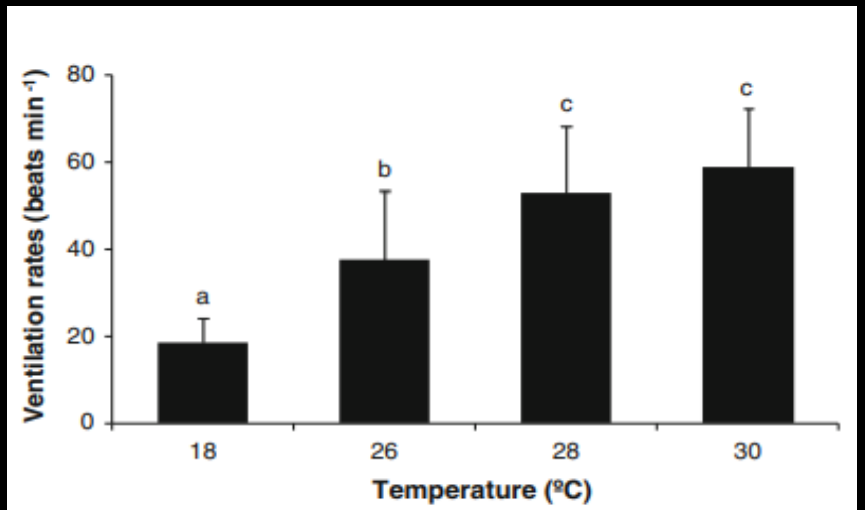

Fig. 4 Impact of environmental warming on the ventilation rates (beats min^{-1}) of adult seahorses, *H. guttulatus*. Values represent mean ± SD ($n = 10$). *Different letters* represent significant differences ($p < 0.05$) between temperatures. For more statistical details, see Table 3

Also the **ventilation rates** of adult seahorses were significantly affected by temperature.
Opercular beats increased with rising temperature from 18 (18 °C) to 59 (30 °C) beats/min.

Results

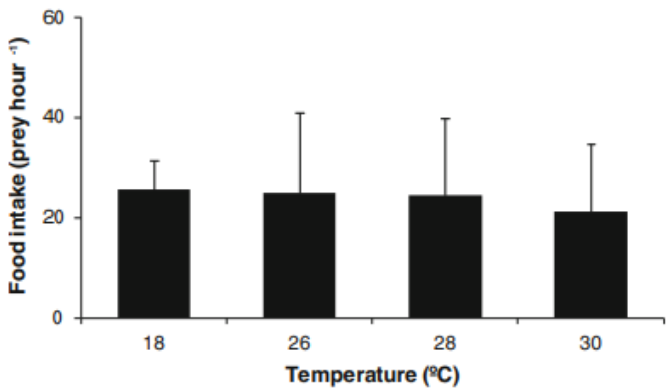

Fig. 5 Impact of environmental warming on the food intake (prey h^{-1}) of adult. For more statistical details, see Table 3

Food intake, swimming, feeding, swinging and inactivity frequencies remained unchanged with increasing temperature

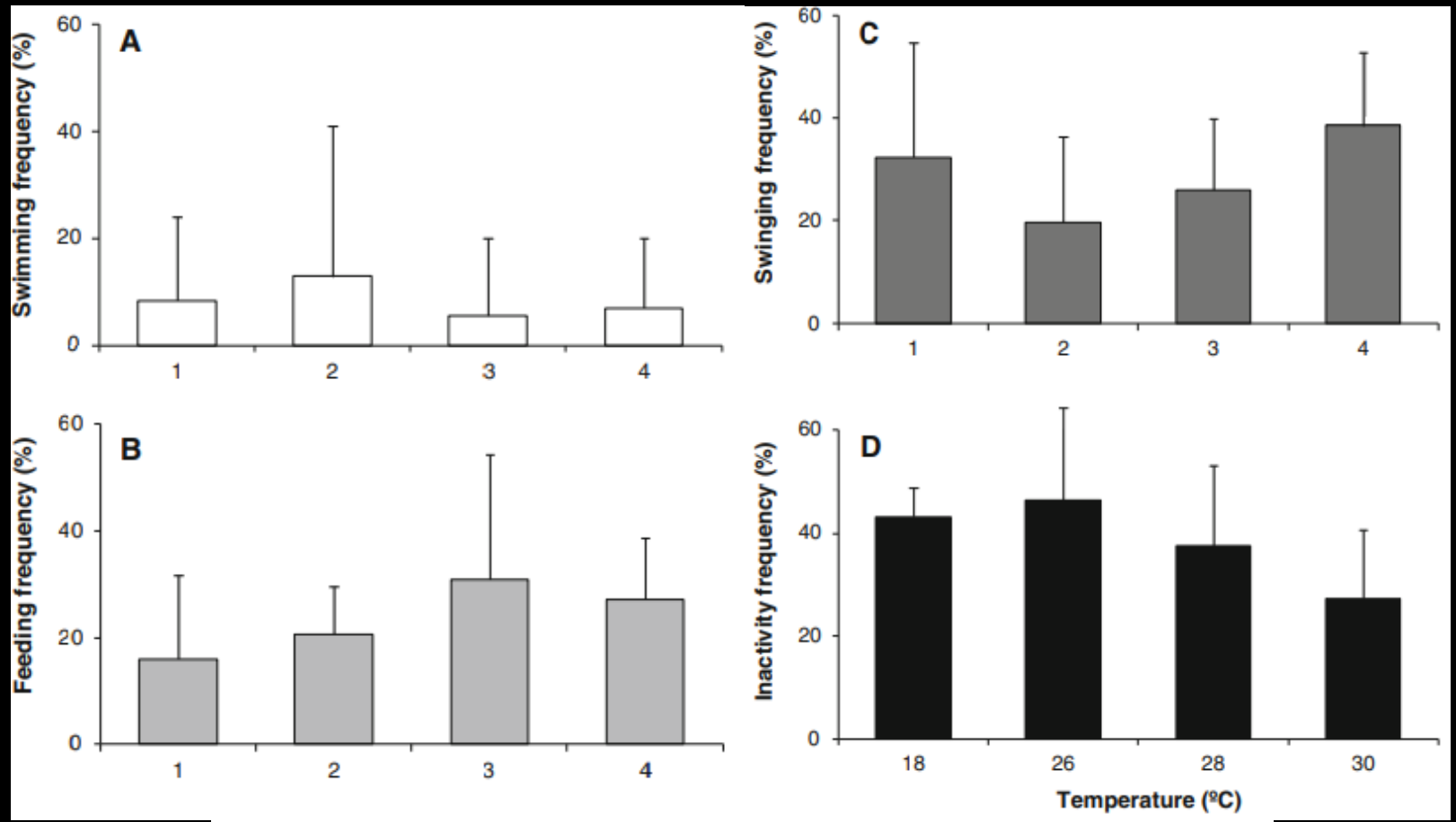

Fig. 6 Impact of environmental warming on the behavioral patterns (%) of adult seahorses, *H. guttulatus*: **a** swimming frequency, **b** feeding frequency, **c** swinging frequency, and **d** inactivity frequency. For more statistical details, see Table 3

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Discussion

H. Guttulatus will it be prepared for a warmer environment?

In **adults**, such increase resulted in normal values of Q10 (around 2 and 3.5), which suggests that they were **not** under severe thermal stress.

Temperature has been shown to have a positive effect on seahorse reproduction, but only until the **optimal temperature** is reached.

In contrast, H. guttulatus **juveniles** proved to more sensitive to warming.

These findings may be explained it the light of metabolic suppression.

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Discussion

The greater sensitivity of newborn juveniles to higher temperatures and their great vulnerability to ocean warming indicates that early stages can be the bottleneck for population adaptability in a climate change perspective.

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Grazie per l’attenzione.

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