Standard oxygen consumption of tropical scorpaenid fishes

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Introduction

Baseline metabolism is the minimum metabolic rate, which a fish requires to maintain the physiological systems needed for survival. By definition, this minimum rate excludes any kind of internal or external work, even digestion, and all movements, except for gill ventilation. The common method to estimate baseline metabolism is to measure or calculate a **Standard Oxygen Consumption (SOC)**.

A number of factors affect the oxygen demand of fish. Aside from the influence of the apparatus and methodology applied and the fish size, the foremost factors are: **temperature** (and availability of oxygen), and the **mode of life** of the fish, particularly its **spontaneous activity**. In earlier studies different approaches were tried, while the methods were further developed and improved. Most papers, however, did focus on the **influence of temperature**, whereas other factors were neglected.

In recent publications, attention has been paid to the **influence of activity** on the oxygen consumption by simply categorising fish as sluggish, moderate or active species and without defining activity quantitatively. As a consequence, activity of active fish was likely under-estimated and the SOC overestimated. In addition, most of the polar species that were investigated were sluggish and most of the tropical fish were rather active. **A latitudinal comparison** of fish metabolism was therefore likely to be biased and rather showed evidence for the different mode of life of the compared species than for a temperature effect.

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Aims

- to quantify spontaneous activity and oxygen consumption in tropical fish of the family Scorpaenidae
- to find species or taxonomic groups in other climates who exhibit the same level of activity and thus the same mode of life
- to conduct a preliminary comparison of standard oxygen consumption over a wider range of temperatures and to estimate the thermal sensitivity of resting metabolism

Results

The 6 respiration experiments evaluated lasted for a total of 351 hours (up to almost 98 h per experiment). From video recordings, more than 13700 movements were counted. Large individual differences in respiration as well as in activity were found between the specimens.
Relative **calculated standard oxygen consumption** (SOC) values varied between 32.3 mg O_2 h^{-1} kg wet $mass^{-1}$ for a large *Scorpaenopsis oxycephalus* (82 g WM) and 68.9 mg O_2 h^{-1} kg WM^{-1} for the smallest investigated specimen, a *Parascorpaena aurita* (16 g WM). The latter also showed the highest **spontaneous activity rate** (mean 98 movements h^{-1}, max 870 h^{-1}), while the values for the most sluggish individual did not exceed 24.6 h^{-1} (mean) and 480 h^{-1} (max), respectively. The longest phase of inactivity detected in the course of the experiments was not longer than 1 h 16 min. The mean duration of pauses was shorter than 3 min.

Intercept of the regression = calculated SOC

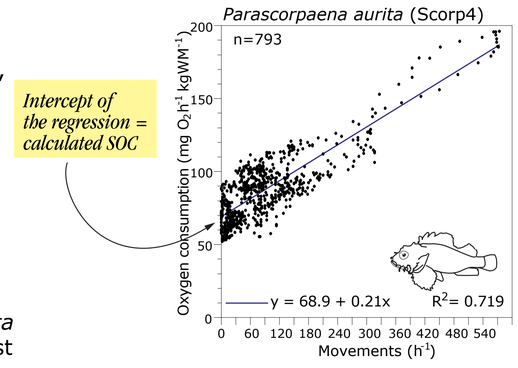


Fig. 2: *Respiration vs. activity for one of the animals*

Most animals showed an increased activity during night

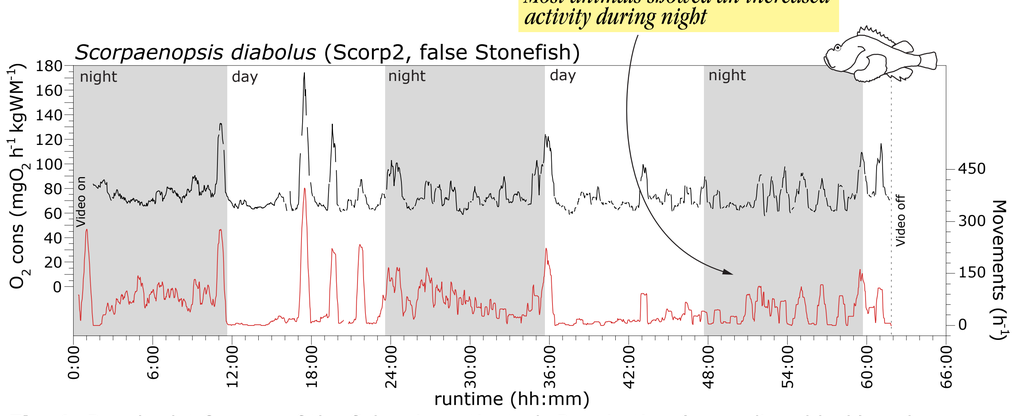


Fig. 1: *Result plot for one of the fishes investigated: Respiration (upper line, black) and spontaneous activity (lower line, red) versus runtime. Both parameters are smoothed over 15 values (30 min) and synchronised. Night time (1845-0645 h) is indicated with grey pattern.*

Scorp2 was excluded because of an unusually high and increasing blank

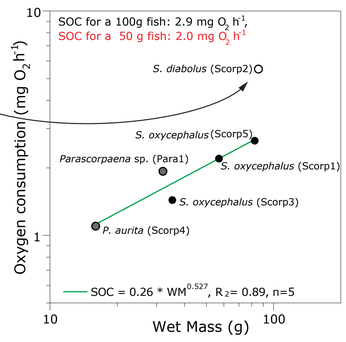


Fig. 3: *Respiration vs. wet mass for all experiments*

Conclusions

- **Activity patterns of fish investigated are similar to those of polar and boreal scorpaenids -> no temperature adaptation, spontaneous activity of a tropical fish can very well be as little as that of a polar fish**
- **SOC lowest ever recorded for tropical marine fish**
- **Compared to scorpaenids of other climates, the thermal sensivity of tropical scorpaenids might be reduced**

Material & Methods

Baseline respiration and **spontaneous activity** were determined simultaneously for 6 tropical scorpionfishes, belonging to 2 different genera: *Scorpaenopsis oxycephalus, S. diabolus* (false stonefish), *Parascorpaena* sp. and *P. aurita*. The experiments were conducted in a modified **inter-mittent-flow respirometer** at 24°C, at ambient light regime (12:12 darkness:light) and salinity (S=32) during March 1997 in the Lab of the Bung Hatta University, **Padang/Western Sumatra**.
Single fish were kept in circular, flat bottom respiration chambers, large enough to allow spontaneous movements. Water was continuously sub-sampled, the oxygen content and temperature was automatically determined (polarographic oxygen probe), and the water recirculated to the chamber. When the O_2 saturation dropped below 89%, the water was automatically exchanged with oxygenated seawater from a separate tank, controlled by a computer, which also calculated the oxygen consumption.
Permanent measurements of **fish activity** by an infrared video system (manual evaluation gives no. of movements) and oxygen consumption were coupled allowing the calculation of a standard oxygen consumption (SOC). The experimental set-up allowed a **quantification** of spontaneous activity. The whole set-up of the respirometer, the function of the software and all initial settings were modified iteratively following the results of some hundred experimental trials over the course of 10 years, always aiming at **reducing the stress** for the animal in the respirometer on one hand and gaining the **highest temporal resolution** on the other.

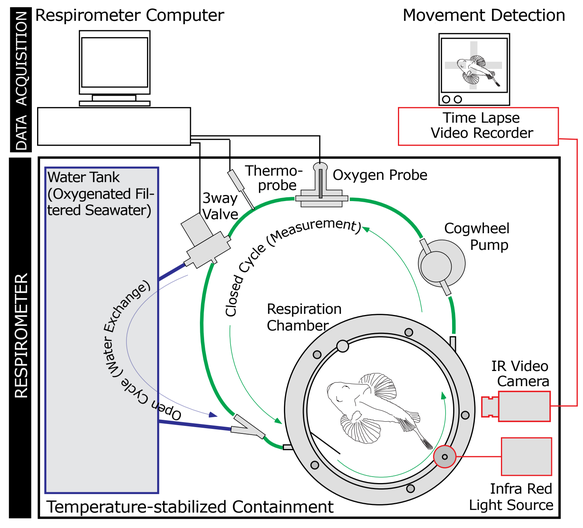


Fig. 6: *Schematic view of the respirometer set-up*

Activity and "mode of life" of the investigated tropical scorpaenids fit nicely to those of polar sculpins

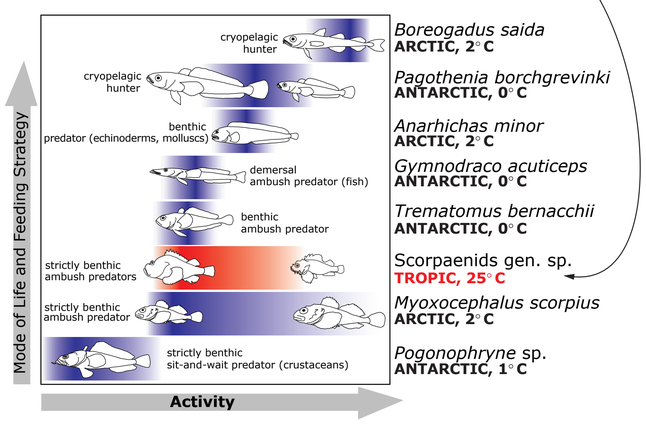


Fig. 4: *Comparison of the proposed quantitative measure for "mode of life" (the inverse quotient of max/mean activity) for fish of different climates, measured with the actual method.*

Discussion

The investigated scorpaenids showed a surprisingly **wide range of activity**. This reflects mainly individual differences and is hardly attributable to the different species the specimens belong to or to the body mass. It is clearly demonstrated that spontaneous activity has to be measured for every single fish. Generally, it became obvious that the determination of an SOC without simultaneous and permanent recording of activity would only be possible for extremely sluggish fish.
Compared to polar fishes measured earlier with the same method, tropical scorpaenids show **activity parameters similar to those of the arctic/boreal sculpin** *Myoxocephalus scorpius* (Fig. 4). The variability of all parameters was even larger for the Arctic animals, although they all belonged to a single species.
Among coral reef fishes, it is most likely that the scorpaenids are situated **at the lower end of the activity scale**. The few available investigations on respiration of tropical marine fish resulted in SOCs or '**resting metabolic rates' which were 1.5- to 2.6-fold higher** than those calculated in this work.
For the determination of the influence of the temperature on fish respiration, a **comparison of scorpaenid fishes from different climates** seems promising. Values from scorpaenids examined at their regular environmental temperature, rather than being cooled or heated in short time, are shown in Fig. 5. It is important to use only these values for comparison, as evolutionary temperature adaptation has produced a between-species relationship of temperature and resting metabolism that has a lower thermal sensitivity than is typical of within-species relationships. While **Q_{10}s for fish are usually found between 2 and 2.5** (that means, the oxygen consumption and thus the food requirements for fuelling baseline metabolism raises by 2-2.5 times when the temperature increases by 10°C), we found a **Q_{10} of 1.65** when using only data for scorpaenids. If only the values collected with the method described here are taken into account (temperature range 2°-25°C), there is some evidence for an even further reduced thermal sensitivity. While other authors attributed the reduction of Q10 to evolutionary mechanisms within taxonomic groups, we believe that the **mode of life is the driving factor in thermal sensitivity**.

This Antarctic species is far more sluggish than the Scorpaenids - what is its ecological equivalent in the tropics?

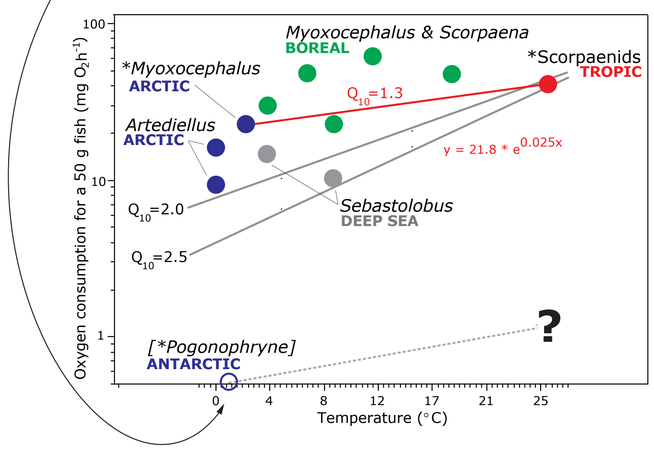
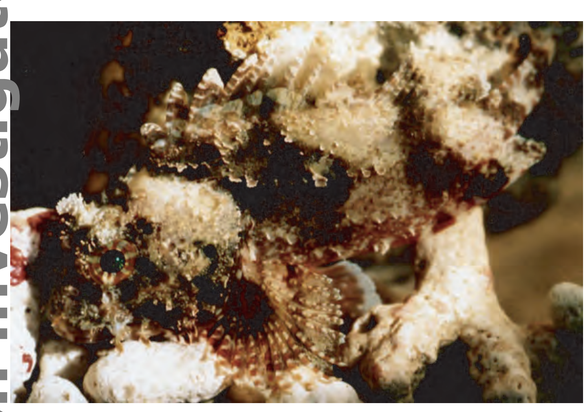


Fig. 5: *SOCs of different Scorpaenids, adapted to their environmental temperature, for a standard mass of 50g. Asterisks indicate experiments conducted with the actual method. For comparison, the most sluggish fish species ever recorded is also shown.*

Fish investigated



Parascorpaena aurita *(Scorp4), the smallest investigated animal, sitting in typical position elevated on a coral block*

Fishes of the **family Scorpaenidae** (cottids, sculpins) are nearly ubiquitous in the world's oceans, from North polar to tropical regions, and from shallow brackish to deep sea habitats. Only a few species are considered active, with a holopelagic lifestyle and pelagic larvae (e.g. the commercially important Redfishes *Sebastes* sp.), while most of them are sluggish and strictly benthic. These animals have acquired a variety of adaptations to the benthic habitat, such as the reduction of the swimbladder and the development of benthic larvae (Arctic *Artediellus* sp.). To prevent predation, a variety of defense mechanisms including camouflage, disruptive and/or signal colorations, armor plates, and venomous spines have evolved (among these is the strongest poison known from fishes, of the tropical stonefish *Synanceia verrucosa*). These adaptations enable scorpaenids to do without high escape velocities and to evolve an extremely sluggish mode of life. This lifestyle, the occurrence of Scorpaenid species over virtually all climatic zones, and the lack of extensive migration, make **Scorpaenids an ideal group for studying latitudinal effects on physiology and behaviour**, including baseline metabolism and activity.
For this study, we choose specimens of the genera *Scorpaenopsis* and *Parascorpaena*, which were found on coral rubble of reef flats or slopes, in 5 to 24 m depth. In the aquarium, they were observed to be typical ambush predators, preying on living fish from a close distance (without leaving their position), and being able to survive extended periods of lack of food: some specimens did not feed for more than 3 weeks after capture.

One of the **Scorpaenopsis oxycephalus** *(Scorp1), weighing 57 g, at the lab in Western Sumatra.*

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