RESPIRATORY PHYSIOLOGY OF THREE INDO-PACIFIC FIDDLER CRABS: METABOLIC RESPONSES TO INTERTIDAL ZONATION PATTERNS

BY

ANA G. JIMENEZ and WAYNE A. BENNETT

Department of Biology, University of West Florida, 11000 University Parkway, Pensacola, FL 32514-5750, U.S.A.

ABSTRACT

We measured aerial and aquatic oxygen consumption values at typical diel extreme temperatures for Uca vocans, Uca tetragonon, and Uca crassipes from Hoga and the Kaledupa Islands in the Wakatobi National Park, Sulawesi, Indonesia. These fiddler crabs exhibit distinct intertidal distributions that may affect air and water oxygen extraction rates. Uca vocans and U. tetragonon occupy low intertidal zones that experience long submersion times, whereas U. crassipes inhabits high intertidal habitats having long emersion periods. Respective aerial oxygen consumption rates were 0.312, 0.300, and 0.193 mg/l at 26.0°C, and 0.600, 0.554, and 0.357 mg/l at 32.1°C. Aquatic oxygen consumption rates at 26.0 and 32.1°C were 0.0041, 0.0065, and 0.0028 mg/l, and 0.0063, 0.0047, and 0.0050 mg/l, respectively. Temperature quotients (Q10) for all crabs were approximately 2 in air; however, U. vocans and U. tetragonon increased Q10 to approximately 3 when moved to water, whereas U. crassipes Q10 values remained essentially unchanged. High oxygen extraction rates and Q10 responses in aerial environments may allow U. vocans and U. tetragonon to repay oxygen debt quickly during short emersion periods. Because U. crassipes spends most of its time emerged, it is less dependent on anaerobic respiration, and may not need to rapidly pay back oxygen debt.

RÉSUMÉ

Nous avons mesuré les valeurs de la consommation d’oxygène, aérienne et aquatique aux températures extrêmes typiques diurnes chez Uca vocans, Uca tetragonon et Uca crassipes des îles Hoga et Kaledupa au parc national Wakatobi, Sulawesi, Indonésie. Ces crabs violonistes montrent des répartitions intertidales distinctes qui peuvent affecter les taux d’extraction d’oxygène de l’air et de l’eau. Uca vocans et U. tetragonon occupent les zones intertidales basses qui subissent de longues périodes de submersion tandis qu’U. crassipes habite les zones intertidales hautes qui ont de longues périodes d’émersion. Les taux respectifs de consommation d’oxygène aérien étaient de 0,312, 0,300 et 0,193 mg/l à 26°C, et 0,600, 0,554 et 0,357 mg/l à 32,1°C. Les taux de consommation d’oxygène aquatique à 26,0°C et 32,1°C étaient de 0,0041, 0,0065 et 0,0028 mg/l, et 0,0063, 0,0047

1) Author for correspondence; e-mail: wbennett@uwf.edu

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et 0,0050 mg/l, respectivement. Les quotients de température ($Q_{10}$) pour tous les crabes étaient approximativement 2 dans l’air ; cependant, *U. vocans* et *U. tetragonon* avaient leur $Q_{10}$ augmenté à environ 3 quand ils allaient à la mer, tandis que les valeurs de $Q_{10}$ de *U. crassipes* restaient pratiquement inchangées. Les taux élevés d’extraction d’oxygène et les réponses du $Q_{10}$ dans les environnements aériens pourraient permettre à *U. vocans* et *U. tetragonon* de compenser rapidement leur déficit en oxygène au cours des courtes périodes d’émission. Comme *U. crassipes* passe la plupart de son temps émergé, il est moins dépendant de la respiration anaérobie, et peut ne pas avoir besoin de compenser son déficit en oxygène.

**INTRODUCTION**

Fiddler crabs (family Ocypodidae, genus *Uca*) are intertidal crustaceans that are well-suited for semi-terrestrial life. The morphology and physiology of air breathing is well known in this group, and most previous research has focused almost exclusively on the crabs’ air-breathing abilities. It is clear that fiddler crabs use moist epibranchial surfaces as lungs (Eshky et al., 1996). Indeed, *Uca pugilator* (Bosc, 1802) is so completely dependent on air breathing that the crabs must retain air in their burrows to utilize at high tide (Teal, 1959). As they move from water to air, fiddler crabs markedly alter their ventilatory pattern. Eshky (1990) demonstrated that crabs moved from water to air, initially engage in reverse pumping to empty water from their epibranchial cavity, followed by alternating periods of apnea with reverse air pumping ventilation. During air breathing, gills are kept moist by a small amount of water retained within the epibranchial spaces (Burggren, 1992; Eshky, 1992). The efficiency with which *Uca* utilize aerial respiration has engendered a large body of literature, however, their water breathing capabilities have been largely ignored and it is unclear how they meet their oxygen demand while submerged.

Crane (1975) suggests that *Uca* gill structures are not in conformity with the crustaceans’ ecological requirements. All fiddler crabs have gills present in the epibranchial chambers, but the anterior gills are reduced, though not lost (Coyer, 1975; Crane, 1975). The reduction is so extensive in some species that the 3rd maxilliped gills are only a “nubbin,” and are believed to be non-functional (Crane, 1975). Intra-species variability in gill morphology is common in fiddler crabs and some *Uca* show maximum development within species norm (Crane, 1975). The ventilation pattern in water-breathing fiddler crabs is similar to that of aquatic crabs, suggesting possible aquatic oxygen uptake across the gills or epibranchial surfaces (Eshky, 1990). When crabs are submerged, water is taken in through the limb bases and passes anteriorly through the branchial chambers and out the prebranchial apertures.

In addition to changes in the ventilatory pattern from air to water, oxygen uptake rates are also affected by changes in ambient temperature (Vernberg & Vernberg,