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PHYSIOLOGICAL ECOLOGY – ORIGINAL RESEARCH

Anticipatory plastic response of the cellular immune system in the face of future injury: chronic high perceived predation risk induces lymphocytosis in a cichlid fish

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Abstract

Vertebrate cellular immunity displays substantial variation among taxa and environments. Hematological parameters such as white blood-cell counts have emerged as a valuable tool to understand this variation by assessing the immunological status of individuals. These tools have long revealed that vertebrate cellular immune systems are highly plastic and respond to injury and infection. However, cellular immune systems may also be able to anticipate a high risk of injury from environmental cues (e.g., predation-related cues) and respond plastically ahead of time. We studied white blood-cell (leukocyte) profiles in African cichlids *Pelvicachromis taeniatus* that were raised for 4 years under different levels of perceived predation risk. In a split-clutch design, we raised fish from hatching onwards under chronic exposure to either conspecific alarm cues (communicating high predation risk) or a distilled water control treatment. Differential blood analysis revealed that alarm cue-exposed fish had twice as many lymphocytes in peripheral blood as did controls, a condition called lymphocytosis. The presence of a higher number of lymphocytes makes the cellular immune response more potent, which accelerates the removal of invading foreign antigens from the bloodstream, and, therefore, may be putatively beneficial in the face of injury. This observed lymphocytosis after long-term exposure to conspecific alarm cues constitutes first evidence for an anticipatory and adaptive plastic response of the cellular immune system to future immunological challenges.

Keywords *Pelvicachromis taeniatus* · Hematology · Lymphocytes · Phenotypic plasticity · Alarm cues

Introduction

To protect themselves against pathogens, the vertebrate immune system has evolved highly effective cellular immunity, of which white blood cells, also called leukocytes, are an important component. There are different types of leukocytes, ranging from cells with phagocytotic activity (neutrophils) to those that produce proteins such as antibodies (specialized lymphocytes called B cells). Hence, both the absolute amount and the relative frequency of different leukocytes characterize the cellular immune system response. Therefore, hematology, the study of blood, was developed since the 1920s as a valuable and highly informative medical diagnostic tool (Wintrobe et al. 1974). Researchers have since used differential leukocyte counts for studying variation in wildlife immune responses (Davis et al. 2008), but this variation is still not fully understood (Maceda-Veiga et al. 2015). Most previous studies have been conducted in a medical, toxicological, and animal ethics context, and thus focus on the consequences of exposure to environmental factors that disturb physical integrity such as toxins (Eeva et al. 2005; Villa et al. 2017), parasites, and pathogens (Davis et al. 2004; Lobato et al. 2005; Burnham et al. 2006), suboptimal nutrition, temperature, or humidity levels (Bennett and Daigle 1983; Altan et al. 2000; Brown and Shine 2018;

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