Avian energy use and its link to oxidative stress

ABSTRACT

Most organisms require energy for maintenance and functioning of the soma, and the main metabolic pathway for generation of required biochemical energy is *via* aerobic metabolism. Occasionally, animals do encounter situations that necessitate increased levels of energy metabolism but availability of energy is often limited, leading to trade-offs. Some of the common trade-offs, are known as the resource allocation between reproduction-related traits and survival, current and future reproductive success, soma-maintenance and performance traits, or even between maintenance traits. Any given energy allocation may also influence free radical production, since an inevitable consequence of aerobic metabolism is the production of reactive oxygen species (ROS). Antioxidants neutralize ROS but any imbalance in favor of ROS may damage various biomolecules inducing oxidative stress. It is hypothesized that oxidative stress is responsible for the progressive physiological decline of the organisms leading to the aging process, and eventually death. Thus, oxidative stress may act as a cornerstone factor of life-history strategies and has been widely studied in physiological ecology research. In my research, I focused on how oxidative stress is linked to the aerobic demands in birds, and its alteration. Our knowledge pertaining to the effects of energy allocation in different traits on oxidative stress, such as the link between components of energy budget (i.e. thermoregulation, reproductive effort) and somatic-maintenance traits (i.e. antioxidant defense mechanisms) is rather limited and still requires further investigation. Within the framework of my doctoral thesis, I conducted different experimental manipulations that affect components of avian metabolism, and tried to understand the link between energy metabolism and oxidative stress under energetically challenging conditions in two avian species; great tits (*Parus major*) and zebra finches (*Taeniopygia guttata*). I hypothesized that

oxidative stress acts both as a cost and a constraint along the lifespan of the organisms, representing a physiological mechanism mediating energy trade-offs between reproductive-related traits and soma-maintenance. In the first study, I manipulated brood size in a free-living species and compared energy expenditure at the level of daily activities and self-maintenance, and costs at the level of oxidative stress. Females raising enlarged brood increased daily energy expenditure compared to the females raising a natural brood size, but basal metabolic rate was similar for both groups. Even though females tried to compensate the demands of the enlarged broods through increasing energy expenditure for reproductive activities, their nestlings did not develop as fast as nestlings in the control group, perhaps due to increased sibling competition within the brood and energetic limitations of their mothers. Females with higher energy expenditure had lower antioxidant capacity (negative relationship). This came at the cost of higher oxidative stress (positive relationship), indicating that oxidative stress may act as a cost during reproduction. In the second study, I tested heat dissipation limit hypothesis, assuming that the ability to dissipate body heat produced during intensive workload may constrain animals from sustaining performance at high levels. I manipulated the capacity to dissipate heat in breeding zebra fiches through exposure to a cold (14 °C) or warm (25 °C) ambient temperature and later *via* a feather-clip manipulation around the brood patch in mothers, while I estimated oxidative stress before reproduction, during the peak and towards the end of food-provisioning. Females with the experimentally enhanced possibility to dissipate heat lost less body mass and raised heavier and larger offspring than the non-manipulated females. This suggests that the ability to dissipate more heat allowed females to invest more energy towards reproductive output without constraining self-maintenance, in line with the heat dissipation limit hypothesis. Even though feather-clip manipulation and ambient temperature had no effect on oxidative stress during reproduction, the antioxidant capacity decreased significantly towards the end of reproduction. This outcome corroborates the hypothesis that reproduction is costly in terms of oxidative stress. The present thesis provides evidence that the capacity to heat dissipate indeed acts as a constraint during intensive workload, especially under warm conditions, and oxidative stress may act as both cost and constraint during reproductive activities. Reproductive effort may come with lower antioxidant capacity and this may increase the risk of encountering oxidative stress. Thermal limitations can be expected to impose even bigger and more strenuous challenges for organisms in general, and during reproduction in particular, while oxidative stress avoidance during reproduction might be the key to understand the allocation of resources to either current or future reproduction.