RECOVERY AS REFLECTION OF ADAPTIVE CAPACITY

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Introduction

There is an increasing demand for more sustainable aquaculture and animal welfare is represented in the concept of sustainability. Animal welfare is defined in different ways (Spruijt *et al.*, 2001, Korte *et al.*, 2007, Broom, 2011, Hagen *et al.*, 2011, Ohl and van der Staay, 2012), but key to all definitions is that poor welfare is associated with overtaxing the coping capacity, *i.e.* allostatic overload, of animals (McEwen and Wingfield, 2003). Successive or cumulative exposure to stressors may compromise the allostatic capacity of an animal and lead to allostatic overload, *i.e.* chronic stress and poor welfare (Korte *et al.*, 2007, Ohl and van der Staay, 2012). Chronic stress consumes energy normally used for growth (Santos *et al.*, 2010), reproduction (Schreck *et al.*, 2001, Schreck, 2010) or resistance to pathogens. This reallocation of energy can influence the time to recovery from a new, acute stressor, *i.e.* change the fitness of an animal. Therefore, recovery from a standardized unpredictable, uncontrollable, acute stressor on top of the "normal" or experimental husbandry conditions (Koolhaas *et al.*, 2011) may reflect the allostatic load of that stressor and can be indicative of an animal's allostatic state under those husbandry conditions.
In fish cortisol is a prime mediator of allostasis as it influences both mineralocorticoid receptor mediated responses (regulation of hydromineral balance) and glucocorticoid receptor mediated responses, such as energy metabolism, immune system and reproductive system (Wendelaar Bonga, 1997). Release of cortisol seems to increase 'the cost of living' and the progression of the stress response after exposure to an acute stressor might reflect 'the cost' of that stressor (Ellis, 2012). Metabolically more demanding behaviour will be accompanied by a stronger HPI-axis activation (Koolhaas *et al.*, 2011). A normal short-term stress response produces a plasma cortisol peak whereafter the levels return to the pre-stress baseline conditions. Preceding life experiences can influence the duration of the recovery period (Rotllant and Tort, 1997, Manuel *et al.*, 2014).
Here we present a model of the acute response to and recovery from a standardized stressor that reflects the fish's adaptive capability under "normal" husbandry conditions. This model can be used to verify procedures in quality assurance systems at fish farms as described by Van de Vis (Van de Vis *et al.*, 2012), *i.e.* the model can function as a 'thermometer' in fish welfare assurance systems. For the development of this model we focussed on African catfish, one of the most produced fish species in The Netherlands.

Construction of the recovery model

Recovery from an acute stressor on top normal husbandry was studied in juvenile African catfish in a series of experiments. Fish were kept for 30 days under several different rearing conditions. After a month fish were challenged by 15 minutes air exposure to indicate their adaptive capacity. Blood was drawn from fish before air exposure, directly after, 15 minutes after, 30 minutes after, 45 minutes after and 60 minutes after air exposure and plasma cortisol was measured by radio immune assay. A database for plasma cortisol was constructed with the results from these experiments. Data indicative of allostatic load under "normal" husbandry situations were selected from this database. Normal husbandry situations signify that water quality parameters were within recommend limits for African catfish and that fish were free of known stressors, e.g. excluding stress experiments or extremely high stocking density. The selected data were integrated into a model reflecting the stress response of African catfish under normal husbandry conditions. Using the data, outer limits (5% and 95%)

of this stress response were calculated. Curve fitting was used to create a mathematical function representing the plasma cortisol peak and the recovery of cortisol to baseline levels. Using this function, a calculated recovery time was determined. A similar procedure for the outer limits (5% and 95%) was performed, providing a minimum and maximum calculated recovery time.

Discussion and conclusions

To our knowledge this model is the first that uses allostatic load based on the adaptive capacity of fish as an indication of fish welfare. This first version of the model should be substantiated with additional data that cover a broader range of husbandry conditions meeting the requirements of catfish. The model should also be compared with conditions that overtax the adaptive capacity of catfish. Subsequently the model should be tested at catfish farms to gain an idea of allostatic load/overload and hence welfare status on commercial farms. We anticipate that the implementation of the recovery model may be valuable in future welfare assessments of catfish farms or in interpreting results from scientific studies regarding catfish welfare. We foresee that the model can substantially contribute to a standardized welfare and allostatic load assessment for cultured fish.

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