Narrative 8: Mammalian life history

We aim to understand fundamental patterns in mammalian life history that are also of relevance for the management of animals in zoos. We demonstrated higher longevity in captive vs. free-ranging mammals

Tidière, ..., Müller, ..., **Clauss**, Lemaître (**2016**) Comparative analyses of longevity and senescence reveal variable survival benefits of living in zoos across mammals. ***Sci Rep*** 6:36361,

thus also demonstrating, indirectly, that many life table-derived life history measures should not be considered 'species-specific' like physiological properties, but are environment-specific, requiring a concept of how to characterise a 'species' by its life history measures.

We developed an approach to compare the relative longevity of zoo animals, establishing the concept and showing results in ruminants

Müller, ..., **Clauss** (**2011**) Mating system, feeding type and *ex situ* conservation effort determine life expectancy in captive ruminants. ***Proc R Soc B*** 278:2076-2080.

Dennis' work (his first proof-of-concept paper from 2010) was mentioned in the Veterinary Record of April 2010 under 'selected **highlights** from other veterinary journals'.

For his complete thesis, Dennis Müller received the **Award Semesterpreis of the University of Zurich 2010** and the **Research Award of the International Society of Livestock Husbandry 2010**. In her review on species differences in responses to captivity, Georgia Mason (2010, *TREE*, 25:713-721) mentions this work on p. 716-717 as *"innovative"* and of *"superb quality"*.

and also demonstrated that population dynamics based on density dependency can be traced in zoo data

Müller, ..., **Clauss M** (**2013**) A conceptual approach to density-dependent management of zoo animals kept in herds. ***Int Zoo Yb*** 47: 208-218

We also showed that data gained from captive wild mammals can be used to explore biological characteristics, such as the seasonality of reproduction

Zerbe, **Clauss**, ..., Müller (**2012**) Reproductive seasonality in captive wild ruminants: implications for biogeographical adaptation, photoperiodic control, and life history. ***Biol Rev*** 87:965-990,

For his thesis (the Biol. Rev. paper), Philipp Zerbe was awarded the **Annual Award of the Vetsuisse Faculty** of the University of Zurich, 2012

Heldstab, ..., **Clauss M** (**2018**) Geographical origin, delayed implantation and induced ovulation explain reproductive seasonality in the Carnivora. ***J Biol Rhythms*** 33:402-419.

Clauss et al. (**2021**) Basic considerations on seasonal breeding in mammals including their testing by comparing natural habitats and zoos. ***Mamm Biol*** 101: 373-386

also assessing the seasonality of zoo-based mortality

Carisch, Müller, ..., **Clauss**, Zerbe (**2017**) Seasonal mortality in zoo ruminants. ***Zoo Biol*** 36: 74-86.

and most recently developing a method to test the historical development of the global zoo community in terms of husbandry success

Roller, ..., **Clauss** (**2021**) The historical development of juvenile mortality and adult longevity in zoo-kept carnivores. ***Zoo Biol*** 40: 588-595

Scherer, ..., **Clauss** et al. (**2022**) The historical development of zoo elephant survivorship. ***Zoo Biol*** 42: 328-338

Our work on how zoo animal data can contribute to both fundamental biological research and husbandry-relevant insights led to two subsequent plenary lectures at the EAZA conferences (both digitally) in 2020 on *How zoos contribute to fundamental biological knowledge the example of reproductive seasonality* and 2021 on *Birth and death: implications of zoo data for biology and husbandry – what we can and what we can't derive*

During the involvement with the DFG Research Group on Sauropod Dinosaurs, Daryl Codron and me started dealing with basic life history aspects. We found an elegant, simple explanation why, after the K/T extinction event, oviparous non-avian dinosaurs could not recover as compared to viviparous mammals

Codron, ..., **Clauss** (**2012**) Ontogenetic niche shifts in dinosaurs influenced size, diversity and extinction in terrestrial vertebrates. ***Biol Lett*** 8:620-623

In 2012, this paper was ranked 1st on that year's top ten list of media-attention-generating publications of the University of Zurich.

This paper was also mentioned in *Nature*: Kaplan M (2012) Dinosaurs grew to outpace their young. *Nature* https://doi.org/10.1038/nature.2012.10465.

and an elegant, simple way to prove Bergmann's rule for the first time across all mammal species.

Clauss, ..., Müller, ..., Codron (**2013**) Bergmann's rule in mammals: a cross-species interspecific pattern. ***Oikos*** 122:1465-1472.

The life history work led to fundamental insights into aspects of using phylogenetic statistics and identified gestation length as a phylogenetically particularly conservative life characteristic

Clauss, ..., Müller, ..., Codron (**2014**) Low scaling of a life history variable: analysing eutherian gestation periods with and without phylogeny-informed statistics. ***Mamm Biol*** 79: 9-16

and this work thus provided evidence against the prevailing Metabolic Theory of Ecology

Lemaître, Müller, **Clauss** (**2014**) A test of the metabolic theory of ecology with two longevity datasets reveals no common cause of scaling in biological times. ***Mamm Rev*** 44: 204-214

The most momentous output of the work with life history data, so far, is in my view, the concept of understanding life history as a set of properties that is not subject to a fixed set of trade-offs, but as subject to evolution, hence something whose efficiency and trade-off conditions can change, and therefore a major characteristic by which taxa compete for niche space. This was showcased for bovids and equids, using zoo data

Tidière, ..., Müller, **Clauss** (**2020**) Do equids live longer than grazing bovids? ***J Mamm Evol*** 27: 809-816,

and on the general level of eutheria using published datasets in a paper that I would chose if I anyone wanted to read only a single one of my works

Clauss, Müller, Codron (**2019**) Within-niche pace of life acceleration as a fundamental evolutionary principle: a mammal pilot test case. ***Evol Ecol Res*** 20:385-401.

Finding ways to explore the underlying phenomena – the difference in developmental speed so evident in different gestation periods between mammal taxa – remains my hardest challenge; for years, I have spoken about this with colleagues and not found a good leverage point to explore this further.

Life history evaluation of zoo animals, particularly its historical aspect, is continuously ongoing.