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Chameleonology
Chameleonoculture
Chameleonopromotion

- Tongue Punching
- Chameleodactyly
- Panther Chameleon Challenges in Chameleonoculture
- Inbreeding
- The Language of Chameleons
- Silhouette

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# Tongue Punching, an unknown secondary antipredatory function of the tongue-shooting in chameleons (Reptilia: Chamaeleonidae)

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**Key words:** Tongue shooting, tongue punching, neologism, threat display, chameleons, antipredatory, Reptilia, Chamaeleonidae, *Furcifer pardalis, Chamaeleo calyptratus, Chamaeleo arabicus*

## INTRODUCTION

Chameleons are well known for their ability to use camouflage of their body shapes, colors and behaviors, to blend with the environment and become invisible for both prey as well as predators.

When they face a predator, they perform a series of antipredatory behavioral mechanisms to secure their survival, such as: bobbing, tail movements, gaping, biting, grasping, akinesis, thanatosis, swinging, buzzing, spine thrusting and others (NECAS, 1999; TOLLEY & HERREL, 2014).

Amongst all antipredatory mechanisms, however, an active use of the tongue has been mentioned in chameleons only as a part of "gaping", when a brightly colored tongue and mucous of the mouth of some species can scare the predators by a sudden appearance, similar to the threat display of the brightly blue tongues in the Bluetongue Skinks – *Tiliqua scincoides* (WHITE 1790)(see BADIANE & ALL. 2018), Shinglebacks – *Tiliqua rugosa* (Gray, 1825), Leaf-Tailed geckos of the genus *Uroplatus* DUMÉRIL, 1806 (see SVATCK & VAN DUIN 2001) or Gila Monsters – Heloderma suspectum (WIEGMANN, 1829)(see SCHWANDT 2019).

## EVIDENCE

In 2004, an anonymous local man in Ehiopia, Goba, N-slopes of the Bale Mountains, explained to me, that chameleons are very dangerous to humans for two reasons:

First: "If a man is envisioned by a chameleon with both eyes, it will crush his testicles and as result, he will become infertile until the end of his days."

Second: "If a man (or an animal) looks deep into chameleon's eyes from close vicinity, it will shoot the tongue in his eye and hurt him."

As both stories seemed to have a clear herpetoethnographical touch; and, as such, they should not be taken literally but rather metaphorically, I considered both a legend and interpreted them similar to many other stories about chameleons in Africa, as an expression of the fear of the unknown and strange animal.

It was only in 2007, when I observed at daytime an interaction of a Pearl-Spotted Owlet – *Glaucidium perlatum* (VIEILLOT, 1817) and a big male of the Yellow-Crested Jackson's Three-Horned Chameleon – *Trioceros jacksonii xantholophus* (EASON, FERGUSON & HEBRARD, 1988), sitting on a tree in a height of around 5m from the ground in the eastern suburbs of Meru, E-slopes of Mt. Kenya, Kenya. The owl was sitting motionless on a horizontal branch around noon and looking forwards. The chameleon was moving slowly through the canopy of same tree, it selected the same branch and unintentionally moved slowly closer to the owl and approached it from the side. As the branch was leafless and exposed, about 40 cm

**Fig 1.** *Chamaeleo calyptratus* tongue-punching a man in his nose
Foto courtesy ALEXANDER DUIROV

from the owl, it performed the chameleon-typical "leaf walking": swinging back and forth, imitating a leaf, and continued to move in the direction of the owl. It noticed the chameleon and turned the head towards it. This was the moment, when the chameleon first visibly noticed the owl, it opened the mouth and after about two seconds of gaping and side swinging, it shot its tongue towards the owl's eyes. The owl immediately took off and flew away and the chameleon continued to move on its trajectory in the canopy.

In early 2000s, E. ADRIGNOLA (IN LITT.) made the following observations on captive *Trioceros deremensis* (Matschie, 1892) from Tanzania: "I had a group of *Trioceros deremensis*, with the females together in a large open enclosure. They would shoot their tongue very far at the males - over a foot away. Most of the time it was stopped before striking them, as if it were part of the threat display. My female *Trioceros deremensis* would smack the males with their tongue when non receptive. They were the sweetest chameleons, really. But against the males when not receptive... Evil. Solid black, tongue smacking, evil."

**Fig 2.** *Furcifer pardalis* tongue-punching domestic cat. Foto courtesy PETR KREJČA

In 2018, I was personally shot into my eye by a captive gravid female of the Arabian Chameleon – *Chamaeleo arabicus,* MATSCHIE, 1893, during cleaning of its enclosure. The female was due to gravidity very aggressive. Besides of threat display, she attacked proactively. (PETR NECAS, PERS.OBS.) E. ADRIGNOLA (IN LITT.) confirms same observation in the case of an captive aggressive male *Chamaeleo calyptratus*.

In 2018, F. FINETTI (IN LITT.) made an observation on one of the captive *Furcifer lateralis* (GRAY, 1831), which she keeps: "the female punched with its tongue an imposing male to the head, when she was not receptive."

On 22th November 2018, PETR KREJČA (IN LITT.) recorded a video of a domestic cat, watching a captive, 14-months old male of the Panther Chameleon – *Furcifer pardalis* (CUVIER, 1829) from Ambanja, Madagascar from a distance of about 30cm. The chameleon noticed the cat and after few seconds of gaping, it shot with its tongue between the cat's eyes. The cat ran away immediately. It was incidentally filmed and the video was posted in Facebook.

In 2019, BETTINE WEBER VD GALLIËN (IN LITT.) reported about an unusual behavior of her captive, 6 years old female of the Yemen Chameleon – *Chamaeleo calyptratus* DUMÉRIL & DUMÉRIL, 1851, which shot against her eyes when approached while sitting in its cage. She delivered a video and photos demonstrating this phenomenon, which repeats randomly on the course of several years. Not only eyes, but any foreign body passed close to it is attacked by the tongue.

In 2020, ALEXANDER DIUROV (IN LITT.) shared a video of a captive adult male Yemen Chameleon – *Chamaeleo calyptratus*, repeatedly shooting the tongue towards his eyes when imitating and mirroring his gaping and aggressive movements while approaching it in its terrarium. This behavior repeats always, when a human face appears close to the chameleon individual.

In 2020, M. COLLEEN (IN LITT.) reported about being shot in the eye by an adult *Chamaeleo calyptratus* while cleaning its cage after the arm was attacked physically with open mouth.

In April 2020, an ANONYMUS (2020) posted a video in the internet, where a White-Bellied Caique Parrot – *Pionites leucogaster* (KUHL, 1820) approached in an artificially set up scene a adult male *Chamaeleo calyptratus*, which after wide gaping with abducted lips and hissing, punched the parrot into the head with its tongue. The parrot immediately escaped.

All the available original videos have been compiled into one and posted with a commentary on YouTube for further reference (NECAS 2020).

## CONCLUSIONS

The above described behavioral pattern, has always the same scenario: the chameleons notices a danger, it perceives the subject very likely as predator, warns it with body swinging and gaping and then shoots the tongue towards it, preferably at head, to hit the predator into or between the eyes.

Very likely, the main indicator of the predator in this ca-

se are big visible eyes, positioned on a more or less flattened frontal surface of the head and pointing forwards (like in birds and cats; and similarly primates including humans).

The probable function of this behavior is a threat display, to surprise the predator with an unexpected action, to which the latter may react with escape, leaving the approached or attacked chameleon alive. Based on all observed cases, and own experience of the attacked humans, the surprise is quite effective to shock the predator to stop the previous action and move away. Therefore, the "tongue-punching" should be introduced as a neologism for the newly defined antipredatory mechanism, found uniquely in chameleons.

## Acknowledgements

Special thanks belong to the colleagues who provided the valuable captive observations, photos and videos: Bettine Weber vd Galliën (The Netherlands), Alexandr Diurov (Александр Диуров)(Russia), Petr Krejča (Czech republic), Marie Colleen (USA), E. Adrignola (USA), Francesca Finetti (Italy).

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# Chameleodactyly: New term to describe the unique arrangement of digits in chameleons (Reptilia: Chamaeleonidae)

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**Key words:** Chameleodactyly, chameleodactylous, chamaeleodactylia, chameleons, digit arrangement, neologism, zygodactyly

Chameleons are lizards of the family Chamaeleonidae that are well known for many special morphological and physiological adaptations, such as laterally flattened body, pyramidal head, lungs with extensive pulmonary sacks, prehensile tail, color change, independently movable protruding eyes and long extendable tongues. Another unique anatomical feature is the special arrangement of the digits. NECAS (1999), TOLLEY & HERREL (2014).

Until now, the term zygodactyly has been incorrectly applied to chameleons (NECAS 1999; ANDERSON 2014). The term zygodactyly is derived from the Greek expression "ζυγος" (zygos) = "even" and δακτυλος (dáktulos) = "finger". It is an arrangement of digits in the four-fingered birds, with two digits facing forward (digits 2 and 3) and two backwards (digits 1 and 4). This arrangement is typical for arboreal bird species, particularly those that climb tree trunks, like some representatives of the orders Psittaciformes, Piciformes, Cuculiformes and Strigiformes.

**Fig 1.** Chameleodactyly in *Chamaeleo arabicus* MATSCHIE, 1893; Photo PETR NEČAS

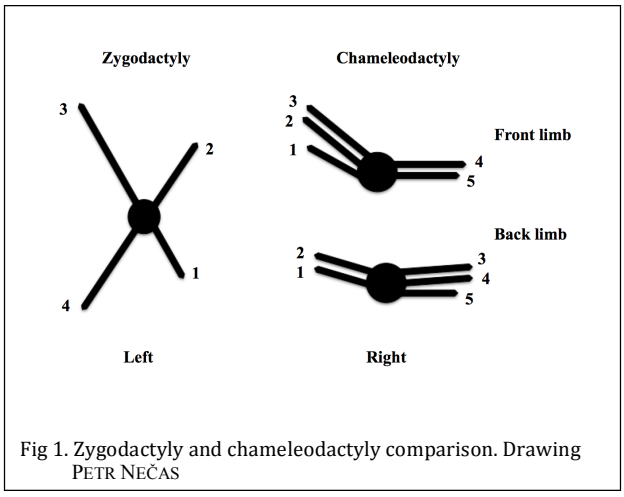


Fig 1. Zygodactyly and chameleodactyly comparison. Drawing PETR NEČAS

The number of digits in chameleons is 5, not 4 like in zygodactylous birds. In chameleons, the digits are divided into medial(inner) and lateral (outer) bundles and not into the longitudinal cranial (forward) and caudal (backwards) pairs like in birds. The front limbs of the chameleon feature three medial and two lateral digits whereas the hind limbs feature two medial and three lateral digits. The individual digits in the bundle are grown together up to the last phalanx, wearing claw. They build a pincer-like distal part of limb, unique in chameleons amongst all vertebrates.

ANDERSON (2014) recognized the inconsistency in nomenclature surrounding chameleon digits but did not propose a solution at the time. As a result of discussion of the author with Chris Andreson, and Mark Scherz, Darren Naish, Raul Diaz (in litt.), it is therefore proposed that the term chameleodactyly (adj. chameleodactylous; Lat. chamaeleodactylia) is universally adopted to describe the unique arrangement of digits in chameleons.

**Fig 2.** Left fore-limb of *Trioceros jacksonii xantholophus* (EASON, FERGUSON & HEBRARD, 1988); Photo PETR NEČAS

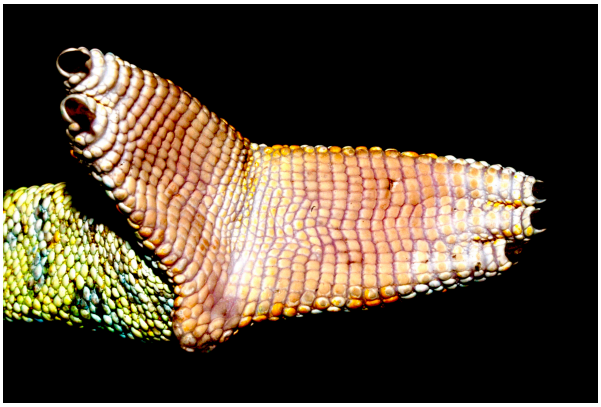

**Fig 3.** Left hind-limb of *Chamaeleo calyptratus* DUMÉRIL & DUMÉRIL, 1851; Photo PETR NEČAS

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# Panther Chameleon Challenges in Chameleonoculture: an integrative approach: wild – trade – captive propagation

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**Key words:** Panther Chameleon, Furcifer pardalis, wild, trade, captive propagation, chameleonoculture

## INTRODUCTION

Panther Chameleons – *Furcifer pardalis* (CUVIER, 1829) are very popular in herpetoculture for many decades. It is thanks to their relatively big size (some forms easily exceed 50cm total length and weight of 200g) and stunning variability of colors and patterns they create on their bodies, especially in adult males (NECAS 1999). Many specimens have been imported. Yearly, thousands of CITES quotas (CITES 2020) for this species are allowed to be exported out of Madagascar. Despite of the fact, that *Furcifer pardalis* is relatively well established in the breeding programs across the US and Europe, the breeding success, if measured in relation to the huge numbers of exported animals is still miserable.

Though many attempts of illegal introduction in the habitats of Florida have been made and many animals either were released as unwanted pet or escaped from captivity there, there are only incidental reports about their finds in Florida and reports about breeding feral populations are scarce so far. Yet, especially in last year, several breeding populations have been discovered, counting thousands of specimens (M. MAUGERI, IN LITT.; see NECAS 2020).

The breeders face lots of problems and unexpected issues arise, such as:

- No interest of males to mate
- Dystocia in females
- Low hatch rate
- Low growth rate
- High growth rate
- Weak hatchlings
- High mortality
- Problems of reproduction in further filial generations in captivity
- Infertile male-like females
- Malformations, etc.

There is a big question: "Why is that?" Some of the most important reasons are discussed in the following text, which is based on my own wild and captive observations and the information from many colleagues (PETR NEČAS, PERS. OBS. from FACEBOOK groups "LIFE WITH CHAMELEONS", "CHAMELEON CULTURE CLUB", CHAMELEONS GONE WILD"; CHAMELEON FORUMS; J. HOLLERAN, D. GORDINHO, L. GIBBS, M. MAUGERI, J. DUBAY. S. GOMEZ, S. PROPKOPIEV, M. UHER, I. NOSALOVA, L. NICKELSON, IN LITT.)

## WILD AND CAPTIVE OBSERVATIONS

### DIFFERENT ORIGIN OF MALE & FEMALE BREEDERS

Due to the fact, females of the individual populations are indistinguishable from each other, there is never a proof of the origin of the females and actually also of males. They can be mixed intentionally or by mistake or by ignorance:

- at the site of collection,

**Fig 1.** A male *Furcifer pardalis* from Ambilobe, Madagascar; Photo PETR NEČAS

- during the transport,
- in the facilities of the exporter,
- in the facilities of the importer,
- and possibly elsewhere.

Anonymous exporters confirmed repeatedly, they have no way to control where the females are collected and whether they really belong to the males (O. PRONK, IN MEMORIAM, IN LITT.).

Moreover, exporters' interest is to catch wild animals and sell them to the customers. It is directly against their interest, when people establish good breeding lines in captivity. Because then, imports will be not needed any more... So, intentional mixing of males and females from different locations happens too.

In captivity, sometimes erroneous origin of the animals is given just because lack of data or by mixing real info, belief or hope; seeking high profit, sometimes the origin is faked intentionally.

**Fig 2.** A subcutaneous filariasis in female *Furcifer pardalis* from Ambilobe, Madagascar; Photo PETR NEČAS

## PANTHER CHAMELEON IS NOT ONE SPECIES

Recent genetic studies have revealed an extreme complexity of the "Superspecies *F. pardalis*". As many as 4-11 separate evolutionary lineages with genetic distance equal to subspecies or even species status are contained in the genome of this entity (GRBIC & AL. 2015). So, obviously, some cross-breeds might be quite vital (if from very closely related evolutionary lineages) but some, due to genetic distance and limited genetic compatibility may end up to be weak or unable to hatch, grow and/or reproduce.

## THE BIOLOGY IN THE WILD IS WEAKLY KNOWN

Despite of the easy accessibility, only few people really pay a visit to the areas where Panther Chameleons live naturally. And lots of people rely on captivity reports from the heavily modified environment rather than on observations in the home country, ignoring that namely our deep knowledge on the life history in the wild is the only real key to proper and successful husbandry in captivity.

The situation is moreover heavily complicated by the fact, the areas where *Furcifer pardalis* live now, are almost all totally degraded and their original biotopes are replaced by cultural landscape. So, understanding their real needs, based on the secondary replaced landscape with modified climate and spatial structure, is very hard.

## HIGH PARASITE INFESTATION IN WILD SPECIMEN

The wild caught specimens are often heavily infested by parasites. Parasites, under natural conditions, rarely tend to kill their host - it is against their interest to save their lives and care for next generations. However, the broken homeostasis during transport, quarantine and stress, connected with it, often conditions the parasite invasions to be lethal. Same applies for "prophylactic" or wrong amateur treatment of parasites like the wrong obligatory "de-worming" with chemicals of high toxicity and unwanted side effects.

## TOO SMALL GENETIC POOL

In captivity, the breeding lines are often based on individual specimens only. A success of one breeding pair usually results in tens or even hundreds offsprings. They are then distributed and breed further... Sibling breeds to sibling; closely related animals amongst themselves. This results in (sometimes unintentional or ignored) inbreeding with all its ill-effects.

## INBREEDING

Trying to fix a desired treat or feature in a breeding line, breeders often do ruthless inbreeding justifying it with their commercial interests and often ignoring and hiding deliberately the negative effects of it. The result, however, is an exponentially decreasing heterozygocy, fixing genetic diseases and degrading of the gene-tic variability within the inbreeding lines. In another chameleon species, bred often in captivity – *Chamaeleo calyptratus* DUMÉRIL & DUMÉRIL, 1851 – the genetics in captivity is so deteriorated, that some breeding lines became already extinct, due to inability to reproduce further or due to producing a high portion of malformations (NECAS & DVORAK, IN PREP.).

## CROSSBREEDING

In seeking "designer" phenotypes, some breeders intentionally crossbreed animals of different origin to produce hybrids of absolutely not identifiable genotype and anyway unstable phenotype. Sometimes, cross-

breeding is result of lack of any information of the origin of the animal, as it is only a guess in the case of males, based on their external morphology, which can be misleading. Females can virtually not be allocated to any local population based on appearance. Sometimes, cross-breeding happens due to lack of breeding stock. Starting second generation in crossbreeding, there is no way how to know what is the composition of the genome, due to free recombination of the genes. Therefore, such hybrid breeding lines are absolutely worthless, as they represent an entity of unknown genetic composition, moreover, not equal to any genetics in the wild. Building good breeding lines from hybrids (which is often the layman intention of breeders) is illusory and the created genetic mess is often accompanied by weak or dying offspring as the result.

## PHENOTYPE IDENTIFICATION AS A RULE

Due to unknown origin, breeders in captivity tend to judge the assignment to individual populations based on phenotype and outer appearance. The variability of many populations is immense, and it is not known in general (see NECAS 2020; MADCHAM 2020). For example, in the Panther Chameleon populations from Nosy Be, you can find individuals resembling typical phenotypes of Nosy Komba, Ankify, Ambanja, Nosy Mitsio, Nosy Faly (P. NECAS, PERS. OBS.). Therefore, many breeding lines get polluted by animals from different locations only due to their superficial similarity, not based on guaranteed origin. Moreover, selective breeding of special traits in captivity (sometimes combined with crossbreeding for the desired "design") modifies the breeding line in several generations in such an extent, that they do not resemble the wild phenotype any more. This is the case e.g. of the population from Nosy Faly. These animals are very attractive in their appearance by light blue basic coloration with high content of white and the s.c. "red rain" consisting of dark red dots scattered on the head and body. As a rule, in the wild, they are colored much less conspicuously. Due to small population density, the local catchers decided to support the Nosy Faly population with new blood and released there several dozens of females from Nosy Be and Ambanja populations, thus polluting the genetics of this little island for ever (O. PRONK, IN MEMORIAM, IN LITT.). The population of Ankify is also an example of wrong identification. Most of nowadays in the US offered "true Ankify" are inn fact "orange headed specimens with blue-bars" from Ambanja. Just for the seek of selling this rare color variety expensive, the information is deliberately faked and animals are labeled as "Ankify". Another example is the population of Tamatave, where specially almost purely red and white males were selected for breeding leaving the public to believe this is the typical appearance of the local form, which in fact is much more green and less contrast in the coloration in the case of most of the males. All this leads to bad effects of crossbreeding, inbreeding, line breeding and genetic pollution.

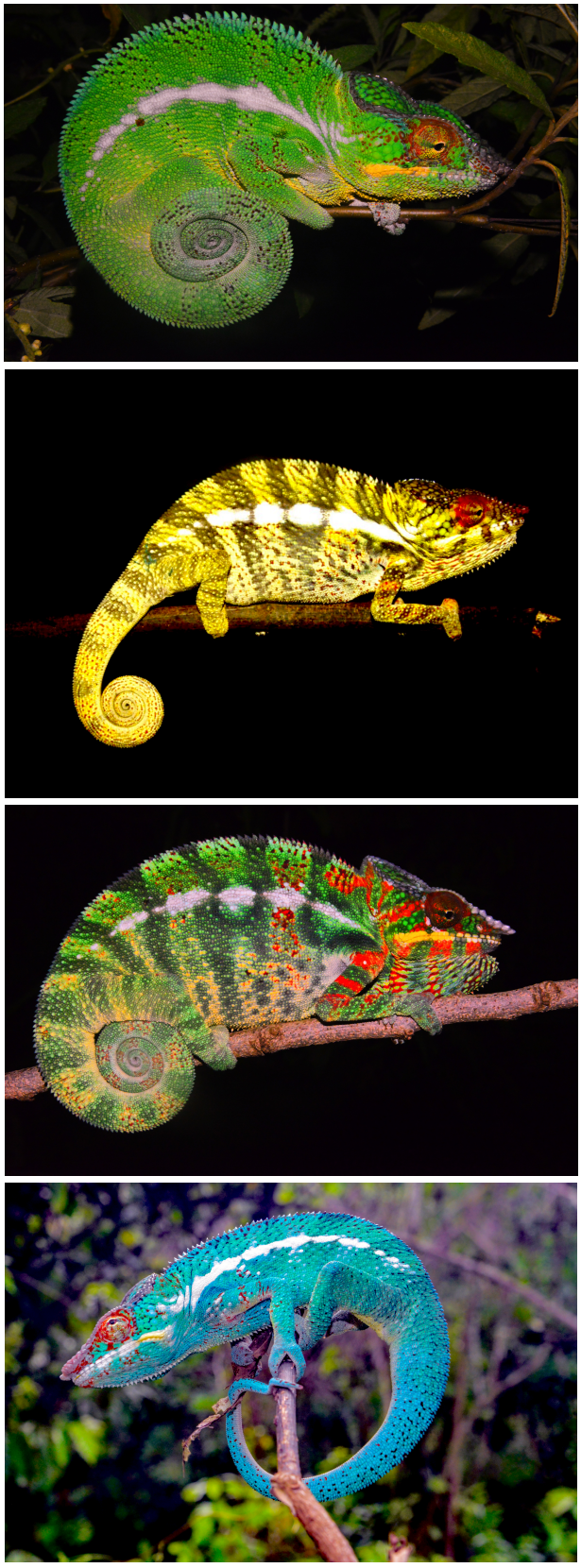

**Fig 3.** Variability in males of *Furcifer pardalis* from Nosy Be island, Madagascar; Photo PETR NEČAS

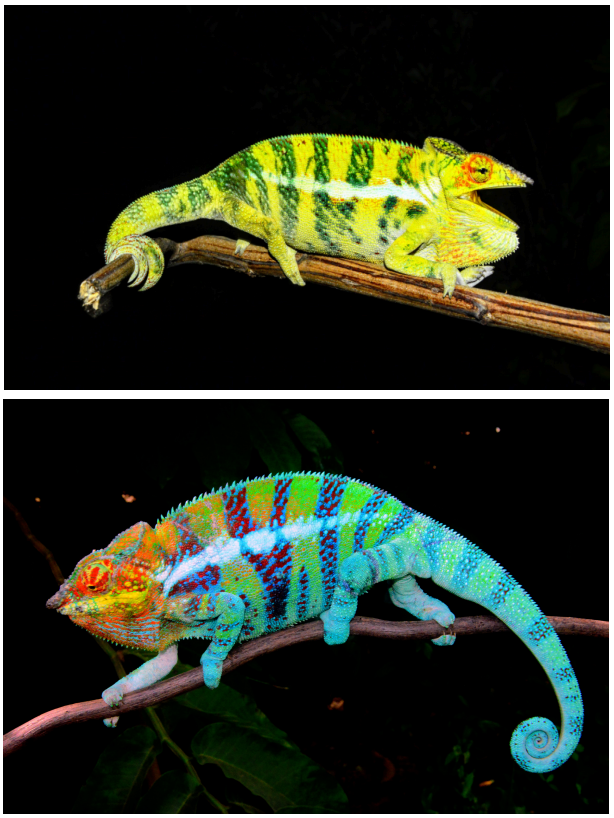

**Fig 4.** Males of *Furcifer pardalis* from Ankify (upper) and Ambanja (lower), Madagascar; Photo PETR NEČAS

## GLOBAL AND LOCAL WARMING

Heavy to total deforestation (especially in the last 120 years) together with heavy agriculture modification of the landscape and global warming increases the temperature of the environment. This can have a destructive effect on many natural processes.

The incubation of the eggs happens at higher, not natural temperatures, it is therefore shorter and the young are forced to hatch much sooner than they would normally do: in the dry season instead of in the rainy season. This modifies their survival strategies and has influence on natural selection.

Higher temperature challenges the thermal comfort of the animals, they have to survive much higher temperatures, their metabolism speeds up, food intake necessarily rises or if not enough food available, leads to starvation and death.

Higher temperatures negatively influence spermatogenesis, and the hormonal processes tied to it, especially the onset of breeding season. Overheated males can easily become sterile or do not show interest in mating, or their sperm can be of low quality. All are indications, we have from captive breeding programs.

The warming can cause together with high UV exposure an increased frequency of mutations.

## POLLUTION

Chemical pollution due to extensive agriculture and usage of fertilizers and pesticides and urban pollutants can also cause mutations and intoxications. As a paradox, one of the strongest populations of Furcifer pardalis on Nosy Be is around the municipal garbage place. The garbage attracts a great number of flying insects, which feed on it, and get polluted with chemicals, detergents, smoke from burning plastics etc. There is no possibility that this does not influence the health of the chameleons, feeding on insects from this area. Exactly this area, is paradoxically, the target area for local chameleon catchers, because it is the easiest place where to find the most chameleons in short period of time.

## WRONG INCUBATION

Lack of the knowledge about the nutrition of the females leads often to weak eggs. Too deep and loose substrate to dig leads to exhaustion of females and dystocia. And, wrong incubation of eggs (especially unnatural humidity and temperature cycles) leads to low hatch rates, weak babies and problems with their vitality, growth, sex and development. Breeders often either experiment with the incubation temperatures and then blindly follow receipts of the more experienced colleagues, or they try to simulate the temperatures of the region, where the chameleons live. The data are however almost missing and if present, then from the urban areas, where the temperatures can be substantially different from where the eggs are laid.

## HUGE RANGE

The problem of the Panther Chameleons is, that they occupy regions from sea level to over 1.000m a.s.l. and

**Fig 5.** An overheated and dehydrated male of *Furcifer pardalis* from Ambilobe, Madagascar; Photo PETR NEČAS

live both on the extreme northern tip of Madagascar at Antsiranana (Diego Suarez), just 12 degrees under Equator, but reach 650km as far south as Toamasina (Tamatave), 18 degrees under Equator. The temperatures at night can therefore range e.g. from 27°C in the north at sea level to freezing point in the south at Andasibe (Périnet) at almost 1.000m a.s.l.

**Fig 6.** Female of *Furcifer pardalis* from Nosy Be, Madagascar; with a skin mutation: partial albinism. Photo PETR NEČAS

### CLIMATIC CYCLES

The climate within the huge range of *Furcifer pardalis* is not stable but undergoes heavy seasonal changes and volatility. It is a big difference how the climate feels in the wintertime and in the summer; and, in the rainy monsoon season and in the dry season. All seasons differ from region to region and in dependence from the altitude substantially.

### REVERSE CLIMATIC CYCLES IN CAPTIVITY

The vast majority of captive *Furcifer pardalis* live on the northern hemisphere, while their home country, Madagascar, lies in the southern hemisphere. The respective climatic cycles are therefore reversed, same as is the length of the day. The adaptation to these conditions is also an issue in captivity, especially in the case of wild caught specimens kept outdoors, e.g. in Florida and California, (Northern America, USA), or in Southern Europe such as France and Spain.

### TRANSGENDER SPECIMENS

The appearance of male-like females, not able to reproduce has been reported in the captivity. And, up to 50% of the females in some wild populations are male-like, probably due to increased substrate temperature and modifications of the environment resulting in hormonal disballance of the embryos and young specimens and consequent developmental aberrations and deformities.

### GENETIC MUTATIONS

Modifications of the environmental factors, extensive agriculture with mutagenous pesticides and other chemicals, exhalations etc. lead to mutations in the wild and same way also in the captivity. This all leads to pollution of the genome, not always visible in the phenotype, but having influence on their development and behavior, and increasing their mortality. The first partially albinotic *Furcifer pardalis* has been found in Nosy Be in November 2019 (P. NECAS, PERS. OBS.), the second has been reported by MIKE MAUGERI (IN LITT.) from a feral population in Florida.

### MISINFORMATION

The period we live in, is typical with searching for the information in internet and on forums rather than in peer-reviewed periodicals and books. As a result, lots of wrong information is spread due to lack of quality control, writings of incompetent authors, hiding info or spreading intentional lies for securing the commercial interests.

**Fig 7.** A male-like infertile female of *Furcifer pardalis* from Ambanja, Madagascar; Photo PETR NEČAS

## CONCLUSIONS

All this and even more, we are facing now. We desperately need to find answers to the question: "What can be the solution?"

The solution is to address as many of the negative phenomena as much as possible.

It means in concrete:

- To use correct life history data derived from the wild
- Secure a guaranteed origin of the breeding stock at the time of origin as well as during the whole breeding process

- Avoid inbreeding
- Avoid crossbreeding
- Secure a wide genetic base for building a genetically diverse breeding pool of individual populations
- Providing correct and up-to date information based on science and real wild observations and measurements
- Produce parasite- and illness-free filial generations and endorse their isolation from the sources of infection
- Provide information and education of keepers and breeders on all aspects of the proper husbandry to secure correct captive management
- Provide proper caging and captive management based on naturalistic approach simulating all vital factors and eliminating lethal ones.

All this and even more, is the aim of a special project of BION, that I have the honor to take part in and supervise.

A field expedition to the range of four local forms of Furcifer pardalis was conducted: Nosy Be, Ambanja, Ambilobe, and Ankaramy. Measurements and detailed field studies comprising tenths to hundreds of individuals were conduced that will be base of scientific papers and publications at one side and captive management setup of in the BION's facilities at the second.

From the four local forms, several tenths of individuals were selected individually and unmistakably marked and exported to the facilities of BION where they receive proper naturalistic care. I have been able to personally inspect each single individual and exclude all malformations, sterile females and diseases.

Each single individual is registered in a pedigree system and it will be kept for all individuals in the breeding program of BION as well as for all in the future obtaining breeding material from these breeding lines to ensure genomic purity and prevent inbreeding and crossbreeding.

Full info about the results of field studies will be shared with the community and made available on specialized sites, forums and shared with exclusively all buyers. This way, we will ensure the genome quality on such level, that it will potentially be available for reintroduction programs if necessary.

Doing this, the chameleonoculture community will obtain a new function in genomic preservation, in which breeders will be able to co tribute to, as a part of a global network.

This all will bring solutions to the above mentioned problems and will secure a future oriented breeding program worldwide, in the frames of BION's project "Responsible Herpetoculture".

**Fig 8.** A male of *Furcifer pardalis* from Nosy Be island, Madagascar; Photo PETR NEČAS

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# A brief review of captive history of *Chamaeleo calyptratus* DUMÉRIL & DUMÉRIL, 1851 (Sauria: Chamaeleonidae), with notes on degeneration of the captive and feral populations, including inbreeding effects, and the first report on a two-tailed chameleon in history.

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## ABSTRACT

An overview of the history of captive management of *Chamaeleo calyptratus* is given, reconstructing the origin and the spread of the species in captivity and territories, where they have been introduced. A comprehensive list of malformations and effects of the captive management is given and discussed with special reference to inbreeding. First case of a two-tailed chameleon in history is presented. Captive management of small original breeding stock leads to alarming tendencies indicating destructive effect of inbreeding.

**Key words:** Yemen Chameleon, *Chamaeleo calyptratus*, wild, feral, captive, chameleonoculture, genetics, inbreeding, two tails, defects

## INTRODUCTION

*Chamaeleo calyptratus* DUMÉRIL & DUMÉRIL 1851, the Yemen chameleon, sometimes called the Veiled Chameleon, is a large, impressive, colorful species of chameleon, one of the more than 200 species in total and one of the 5 species occurring in Asia.

Though originally (by error) described from Madagascar (type locality: Bembatuka = Bombetoka, SE to coast of Madagascar, DUMÉRIL & BIBRON in DUMÉRIL & DUMÉRIL 1851), it in fact inhabits the south-eastern part of the Arabian peninsula: Yemen and Saudi Arabia (HILLENIUS & GASPERETTI 1984; NECAS 1990, 1997, 1999; TILBURY 2010; GLAW 2015).

Due to inaccessibility of this territory and scarce scientific research, the species was rarely considered by the scientific and amateur community for another more than a century… Only in the eighties of the last century, new data about the species and first color photographs impressed the world (HILLENIUS & GASPERETTI 1984; FRITZ & SCHÜTTE 1987; MEERMAN & BOOMSMA 1987).

Thanks to the work of some experts from the former DDR (Democratic Republic of Germany) and Czechoslovakia in this period of time, as well as through private imports of few individual travellers, the first specimens of this species were imported to Europe and kept in captivity (P. NECAS, PERS. INFO; FR. HAIKAL IN LIT., W. SCHMIDT IN LIT.).

The source of almost all original imports (with the exception of few animals imported to DDR), and with highest probability of exclusively all that then followed in further decades (P. NECAS, P. DVORAK, P. NAGY, PERS. OBS.), was one population extending along the road between the cities Ibb and Taizz in Yemen. The reasons for selecting of this limited collection site were three:

- It was known from the literature and easy to find,
- Population density exceeds 1.000 specimen per hectare (P. NECAS, PERS. OBS.) here, so that collecting the animals in favorable periods of the year was easy,
- The accessibility of the population just next to the main road connecting Sana'a with Aden was simple and did not require special permits, on contrary to other, by

**Fig 1.** A wild male (above, middle) and a female (below) of *Chamaeleo calyptratus* from Ibb (above) and Yarim, Yemen; Photo PETR NEČAS

military more controlled areas of the Arabic Republic of Yemen.

The first breeding reports were published in the nineties (NECAS 1990, 1991; HROMADKA 1991; TIEDEMANN & TIEDEMANN 1992; SCHMIDT 1996; VAN TIGGEL 1996) in Europe. In the early nineties, it made its way to the USA through P. NECAS and R. TREMPER (PERS. OBS.). The species spread in the captivity with geometrical speed, because of its big breeding potential (the female lay every 2-3 months 30 to over 100 of eggs – P. NECAS, PERS. OBS.) and relatively simple captive management. Nowadays, it is considered one of the most frequent chameleons kept in captivity at all (ROGNER 2008). Even numerous monothematic books have been published about this species (e.g. SCHMIDT 2001, 2007, 2009; SCHNEIDER 2007; VELENSKA 2009; BARTLETT & BARTLETT 2011; DAVIS 2014; PRIDE 2014; JEPSON 2016; DURHAM 2017).

Nowadays, the Yemen Chameleon is bred in captivity in hundreds of thousands of specimens per year (P. NECAS, pers. estimate based on internet and pet store data) and it has become one of the favorite reptiles pets not only in the USA and Europe but also across the globe. As it became relatively affordable, it became a standard stock in pet store chains, frequent pet or a model organism for studies of diverse kind (e.g. DIAZ & AL. 2015A,B).

The Yemen Chameleon was also introduced to Florida, USA (EDWARDS & AL. 2014; GILLETTE & KRYSKO 2012; KRYSKO & AL. 2004, 2011; MESHAKA & WALTER 2011), where it spreads and builds many strong wild populations, that serve as source of business for local hunters and breeding ventures, that take advantage of the acceptance of the climate by this species and free-of-cost wild raising to adulthood. It is impossible to separate the feral populations from the captive ones in appearance, as:

- All feral populations originate from captive specimens,
- Yemen Chameleons are collected in Florida and sold in thousands specimens yearly to pet trade under the label FLWC – Florida Wild Caught or without indicating their origin (anonymous reference of local catchers and traders),
- Yemen Chameleons are intentionally introduced to some areas in Florida, both on mainland as well as on islands, mainly in coastal areas in the vicinity (or within the area of) Miami, Fort Myers and Tampa, for the purpose of free farming,
- The Yemen Chameleons escaped from the private or professional breeding farms or gardens due to the popularity to keep them in outdoor cages or freely in the gardens by incident or by destruction of the cages by predators,
- The Yemen chameleons escape from the private or professional breeding farms or houses or flats or gardens as a result of the frequent cyclones and hurricanes.

The population on Maui (Hawaii, USA), where it seemingly has been intentionally (or incidentally) introduced also (ANONYMUS 2007; HILDENHAGEN 2005; KRAUS & DUVALL 2002), was very likely already eradicated by local wildlife protection initiatives (C. ANDERSON, PERS.COM.). A record on Oahu (Hawaii, USA) mentioned by HORGAN & POLLAK (2002) remains unconfirmed.

Inbreeding is defined as the reproduction of closely related individuals of the same species (such as brothers

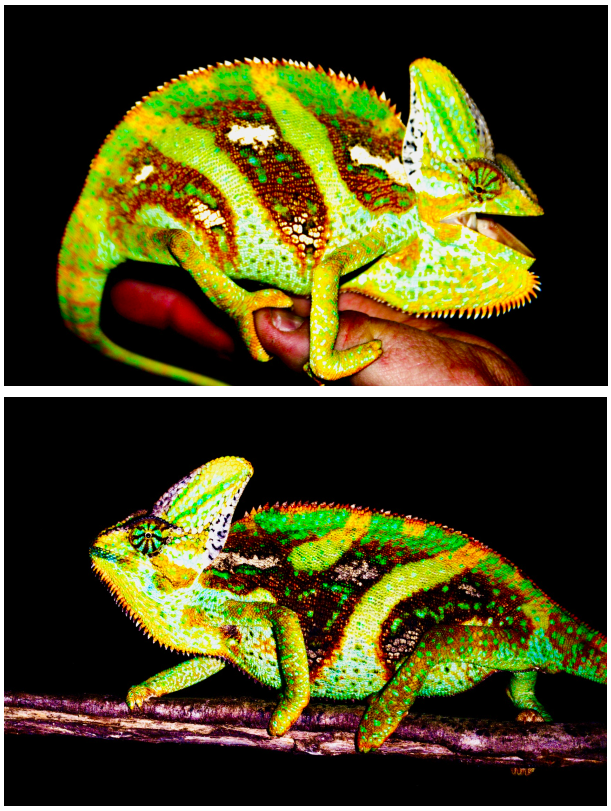

**Fig 2.** A feral male of *Chamaeleo calyptratus* from N of Fort Myers, USA; with asymmetrical aberrant pattern (2 instead of 3, diagonal instead of transversal yellow bands). Photo PETR NEČAS

and sisters, cousins, daughters and sons with their parents etc.), which tends to increase the number of individuals that are homozygous for a trait and therefore increases the appearance of recessive traits. By inbreeding, individuals are further decreasing genetic variation by increasing homozygosity in the genomes of their offspring. Thus, the likelihood of deleterious recessive alleles to pair is significantly higher in a small inbreeding population than in a larger inbreeding population.

In general, inbreeding is used in selective breeding to fix the selected beneficial phenotype (whatever it is, reaching from body size in marsupials, through special behavioral pattern such as aggression and readiness to fight in dogs, through desirable body shape, coloration or fur quality in cats to attractive color in aquarium fish or Koi carps) and is a driving power of domestication of animals for millennia. However, it also has many negative effects, such as:

- Increased incidence of recessive genetic diseases,
- Reduced fertility both in litter size and in the sperm viability,
- Fluctuating asymmetry (such as crooked faces, or uneven eye placement and size),
- Body proportions shifts,
- Lower hatch size,
- Higher neonatal mortality,
- Slower growth rate,
- Smaller adult size,
- Scale abnormities including loss of scales,
- Unknown unnatural coloration and pattern,
- Loss or weakening of immune system function,
- Neurological disorders,
- Etc.

In reptiles, and in chameleons in particular, the reports of inbreeding are scarce, leaving the false impression, it is not present or of least concern. Logically, breeders using inbreeding practices in their breeding programs for their mercantile purpose of increasing the price for new and unusual coloration, patterns, scale deformities, scale-absence, size etc., do not report on problems in their

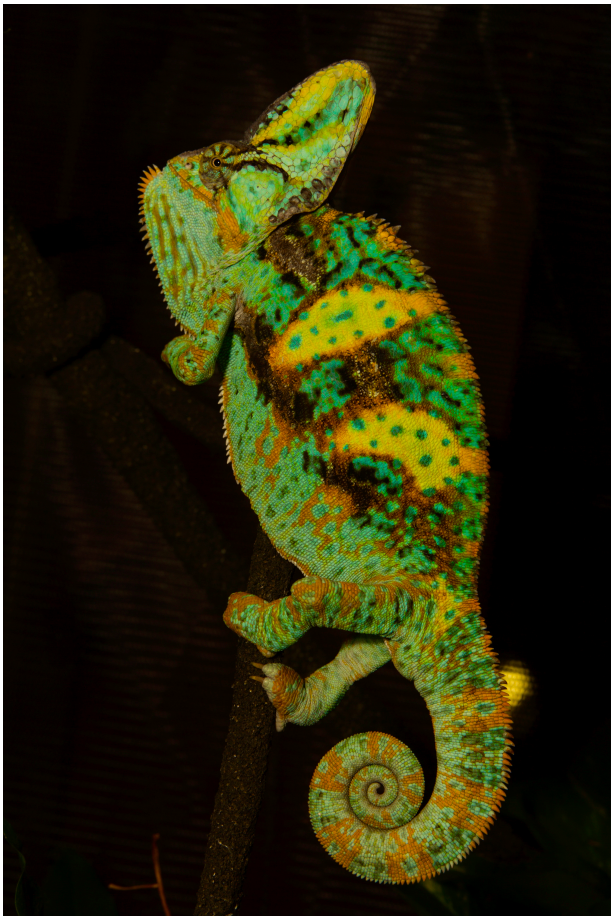

**Fig 3.** A captive male of *Chamaeleo calyptratus,* from Kharkiv, Ukraine; with aberrant pattern (2 instead of 3 transversal yellow bands). Photo SERGII PROKOPIEV

breeding stock and offspring, as it is in direct contradiction with their commercial interests. However, it is present, and, in inbred breeding populations, it occurs with increased frequency generation by generation…

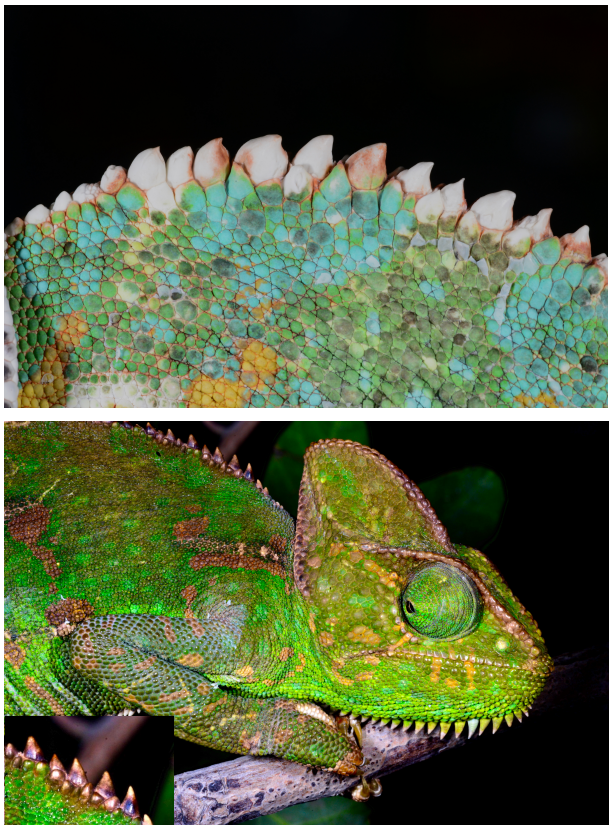

**Fig 4.** Feral females of *Chamaeleo calyptratus* from N of Fort Myers, USA; with scale abnormities at dorsal crest (both) and aberrant pattern (lower). Photo PETR NEČAS

## MATERIAL AND METHODS

The text is a compilation of own observations and data of the authors, collected through the many years of practice in keeping the *Chamaeleo calyptratus* in captivity and research and observations in the wild, We allow ourselves to compile the presented picture on the base of:

1. 33 years of continuous experience with *Chamaeleo calyptratus* in the captivity,
2. Observations from own breeding programs of *Chamaeleo calyptratus* (16 generations in captivity, more than 35.000 offspring produced),
3. Observations from breeding programs of *Chamaeleo calyptratus* of 6 anonymous large-scale breeders with approx. 300.000 offspring in total, 10.000 offspring and 5 years experience and collected evidence at minimum each,
4. Observation of individual keepers,
5. First-hand reports of anonymous wild farmers of chameleons in Florida (USA),
6. First hand reports of anonymous reptile hunters of chameleons in Florida (USA),
7. Internet data resources,
8. Pet-store chains anonymous reports,
9. Eye witnesses at the reptile shows in Europe: Hamm (Germany), Houten (The Netherlands), Prague, Brno (Czech Republic), Bratislava (Slovakia); and in the USA (San Diego, Daytona Beach),
10. Own research in Yemen,
11. Own research in Florida.

## RESULTS

The original breeding stock of the imported animals was hardly 50 specimens, out of which only part reproduced. Almost all US population originates from 5 original females only, from the breeding stock of the first author (R. TREMPER IN LIT.). At the beginning of the breeding boom in the 90s, hardly anyone cared for preventing inbreeding, so, sibling matings were (and sadly are until now) a rule. It is driven by lack of knowledge of inbreeding effects on the captive or feral populations, partly driven by the purpose of creating breeding lines of aberrant specimens, that are valued in the pet trade, this is particularly the case of the s.c. translucent specimens, where inbreeding is practiced (esp. in the Canada, USA, Ukraine) by breeders to increase the white, pink, black aberrant portion of the body and create unseen unnatural patterns and coloration.

The "wild farming" of Yemen Chameleons in Florida (USA) has also disastrous influence on the genome. Based on anonymous confidential reports, wild breeders take as a rule single gravid female (or maximum few specimens) and put them on a new locality, best well isolated like a small island or a farm in living area. The animals are left

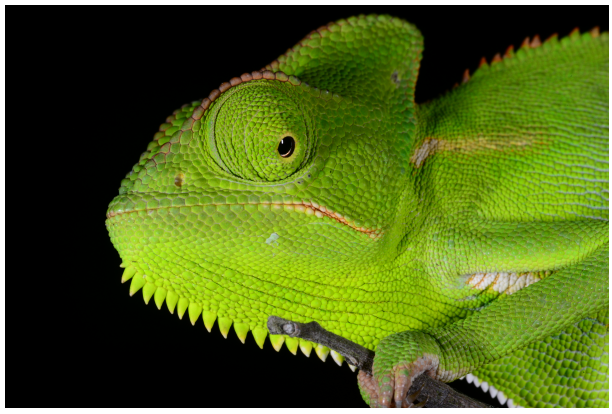

**Fig 5.** A feral female of *Chamaeleo calyptratus,* from Fort Myers, USA; with aberrantly colored gular crest (green instead of white). Photo PETR NEČAS

alone to reproduce. After two or three years, the entire area is collected at night (very efficient), so that intentionally, again, only a single (or few) gravid females are left on the spot, the rest is traded with wholesellers and delivered to private breeding facilities or to shows or to pet store chains. This way, the populations of feral chameleons loose step by step the heterozygocy.

The so far noticed phenomena, that are found in captivity or in feral populations of *Chamaeleo calyptratus* and that can be with highest probability linked to inbreeding, are as follows (due to unwillingness of many respondents to disclose the data and info publically, we abscond here from naming the sources for the benefit to reveal confidential information despite the sources remain anonymous); the suspected inbreeding effects are indicated with (IB):

1. **Defects of pattern** (IB)
   a. Washed-out typical pattern,
   b. Abnormities in the typical pattern,
   c. High level of orange markings,
   d. Increased size of dots (panther-like pattern),

**Fig 6.** Two feral males of *Chamaeleo calyptratus* from Fort Myers, (upper) and Miami (lower), USA; with aberrant patterns, especially upper on casque and both in the color of transversal stripes, which should be lemon yellow. Photo PETR NEČAS

**Fig 7.** A feral female of *Chamaeleo calyptratus,* from Fort Myers, USA; with male-like treats (high and orange colored gular crest, high casque. Photo PETR NEČAS

   e. Irregularities in forming the yellow transversal bands in males, such as:
      i. Reduction in height,
      ii. Reduction in width,
      iii. Fusion,
      iv. U-shape,
      v. Changing from transversal to partly longitudinal,
      vi. Changing from transversal to fully longitudinal,
   f. Change of the number of the yellow transversal body bars in males (and analogous skin areas in females):
      i. Reduction from 3 to 2 or even 1 – unilaterally or bilaterally,
      ii. Increase from 3 to 4, 5 or even 6 – unilaterally or bilaterally,
   g. Disappearing (partly or fully) of the white longitudinal rows of white (or black) fields,
   h. Anomalies of the casque-pattern,
   i. Anomalies or loss of the radial eyelid pattern.

2. **Uniformly colored specimens (not black, white, colorless) (partly IB)**
   a. Pattern-less orange colored specimens (IB),
   b. Pattern-less lime yellow colored specimens (IB),
   c. Pale pattern-less specimens have been reported repeatedly, but none is known to have reached the maturity, some might have simply represent weak animals that die to weakness have not been able to show a pattern (J. HOLLERAN IN LIT.),
   d. Pattern-less violet/maroon/purple specimens have been reported in young-hood, in all cases they either deceased or developed in normally or aberrantly colored/patterned specimens not keeping the juvenile color till adulthood.

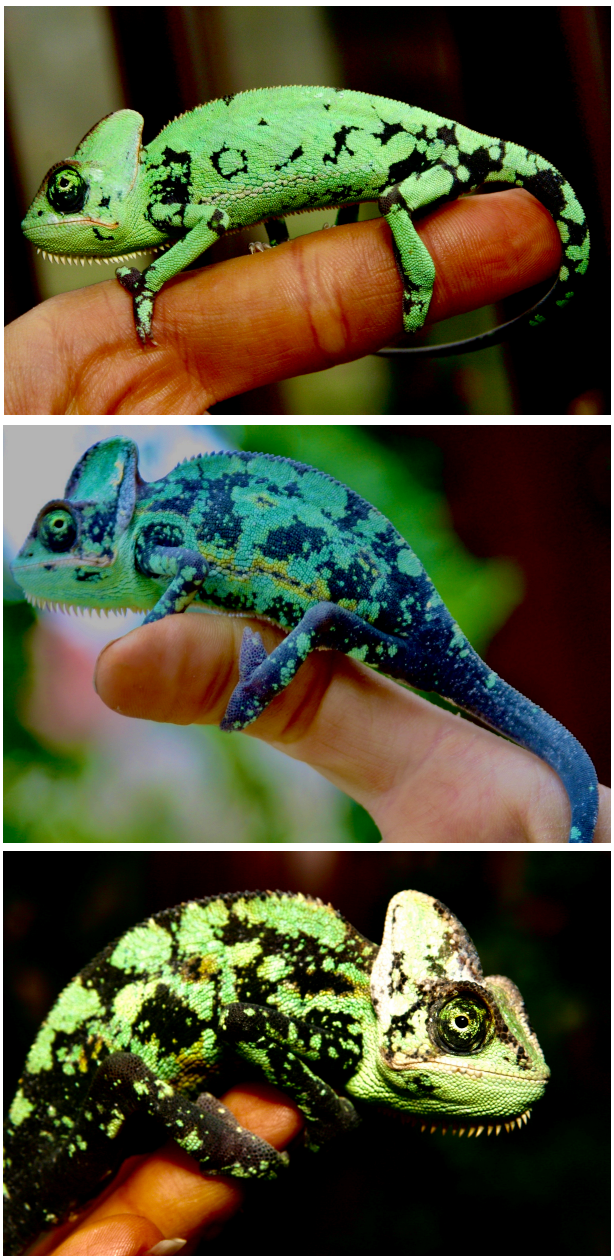

**Fig 8.** Three partly melanistic specimens of *Chamaeleo calyptratus* from Bratislava, Slovakia; a result of 7 consecutive generations of inbreeding. Photo PETER DVORÁK

**3. Melanistic specimens (IB)**

a. Partly melanistic specimens,
   i. Specimens with small black dots spread over head, body and extremities,
   ii. Specimens with bigger areas of completely black skin areas on head, body and extremities,

b. Hypermelanistic specimens,
   i. Specimens with bigger, irregular hypermelanistic (but not fully black) parts of the body expressed as grey areas,

c. Specimens with melanistic iris,
   i. Fully melanistic iris,
   ii. Partly melanistic iris,

The melanistic skin areas are without any ability to change color, covering up to 25% of the total body surface. Fully melanistic specimens have not been reported so far, though a temporary, completely black color phase in the wild and captive animals is known.

**4. Albinotic/Leucistic specimens (IB)**

There are quite popular breeding lineages of the so-called translucents or piebalds in the pet trade nowadays. They all originate from aberrant specimens that appeared in 2011-2012 in Europe and have been then distributed to the USA and to Japan first, nowadays present in the global trade. The skin color of the affected parts of the body (typically situated on the legs and head) is without or with very limited ability to change color and appears in two types (expressed separately or in combination in one specimen):

- uniformly pinkish and translucent (not transparent),
- uniformly white,

Fully albinotic specimens appeared as a result of inbreeding of the translucent breeding line, so far they have not been knowingly raised to adulthood yet.

**5. Combined partially melanistic and partially albinotic specimens (IB)**

In many cases, the translucent/piebald pattern is even combined with small patches of totally melanistic areas, forming the so-called “calico” pattern.

**6. Coloration defects (IB)**

1. Total coloration defects,
   a. high orange specimens,
   b. high blue/turquoise specimens,
   c. pale specimens,
   d. dark specimens,
2. Partial coloration defects
   a. change of the color of the gular crest in males from orange to white,
   b. change of the color of the gular crest in females from white to orange,
   c. change of the color of the gular crest in females from white to green,
   d. discolored areas of the skin elsewhere

7. **Scalation defects (IB)**
   1. Scale-less eyelids (fully and partl y)
   2. Scale-less parts of the head
   3. Scale-less parts of the extremities
   4. Hypertrophied warty scales of the head crests (esp. canthus rostralis)
   5. Double row of enlarged scales of canthus rostralis and crista supraorbitalis
   6. Dorsal crest modified in zig-zag form, from single row of enlarged conical scales
   7. Paravertebrally situated scales of the dorsal crest
   8. Irregular size of gular crest's conical scales
   9. Irregular size of dorsal crest's conical scales
   10. Deformities of gular and dorsal crest's conical scales
   11. Increase of size of gular and dorsal crest's conical scales
   12. Reduction of size of gular and dorsal crest's conical scales

8. **Developmental defects (IB)**
   1. Hatched without one or both eyes,
   2. Deformities of the legs,
   3. Partly developed or absent spur on hind leg in males,
   4. Partly developed or present spur on hind leg in females,
   5. Disproportionally thinner and longer legs,
   6. Disproportionally shorter tails,
   7. Disproportionally smaller heads,
   8. Disproportionally smaller casques in males,
   9. Disproportionally higher casques in females,
   10. Additional, usually malformed leg(s),
   11. Crenulated or "broken" spine,
   12. "Broken" spine above the pelvis,
   13. Malformed tail, especially in the distal part.
   14. Two tails: the probably most obscure case is a specimen that has been born with two fully developed, equally sized, functional tails, with only slightly limited and coordinated mobility. The bifurcation of the tails was situated several vertebrae cranially to the pelvis. The pelvis and hind legs were deformed and the hind legs only partly functional. Otherwise, the specimen was normal. The total condition of this male specimen was from the beginning weaker than its siblings; it died at the age of 18 weeks.

**Fig 9.** Three partly albinotic specimens of *Chamaeleo calyptratus* from Kharkiv, Ukraine (upper), Photo SERGII PROKOPIEV, and Dolni Kounice, Czech Republic, Photo PETR NEČAS

**Fig 10.** A uniformly orange colored captive female of *Chamaeleo calyptratus,* from Dolni Kounice, Czech Republic. Photo PETR NEČAS

### 9. Lower hatch rate (IB)

The hatch rate of *Chamaeleo calyptratus* from the wild is usually well above 85% (PN pers. obs.), while in the inbred lines, it can drop significantly under 70%.

### 10. Lower hatch size (IB)

The hatch size of *Chamaeleo calyptratus* from the wild is usually well above 84mm, even hatchlings above 100mm are encountered. Inbred lines' hatchling size was in some clutches under 80mm, even hatchlings 67mm long were encountered.

### 11. Higher frequency of twins in the clutches

The appearance of twins in captivity is quite rare but in detailed captive management of *Chamaeleo calyptratus* it can be registered. The frequency of the appearance of twins increases with the level of inbreeding, the highest can be seen e.g. in the heavily inbred partly albinotic (translucent, piebald) breeding lines, where in one clutch 7 cases of twins were found (S. PROKOPIEV, IN LIT., NECAS ET AL. IN PREP.).

### 12. Lower survival rate (IB)

The survival rate of *Chamaeleo calyptratus* from the wild after the first two months of age is usually well above 87% (P. NECAS PERS. OBS.), while in the inbred lines, it can drop significantly under 80%. S. PROKOPIEV (IN LIT.), confirms significantly lower vitality and survival rate in the partly albinotic (translucent, piebald) breeding lines, that are heavily inbred, which is also confirmed by anonymous breeders of the same inbred lines from Canada and USA.

### 13. Laying infertile eggs (partly IB)

Nowadays, the captive females, that are often kept as pets only, not for reproduction purposes, tend to lay unfertile eggs from the 6th month of age forward, once they reach sexual maturity and close-to-full size. Their penetration in population is guessed at around 80%. Females that do not do so, are quite rare. In the first three captive bread generations, from 97 observed females, no single case has been encountered, the females were allowed for reproduction only after minimum 10 months age and 27cm total length (both K.O. factors)(P. NECAS PERS. OBS.). The first cases, comprising less than 10% of the total gravidity cases were encountered in 4$^{th}$ filial captive generation. The factors, clearly supporting the laying of infertile eggs of unmated females are however also captive management issues like:

- Keeping them too warm in general with no or weak night drops,
- No simulation of the wintertime and natural seasonal changes,

**Fig 11.** A uniformly leucistic captive juvenile female of *Chamaeleo calyptratus,* from Prague, Czech Republic. Photo PETR NEČAS

- Overfeeding and obesity.

**14. Increase of the number of eggs per clutch (partly IB)**

The wild females lay normally about 25-35 eggs in their first clutch and 30-45 eggs in the second and further clutches. Nowadays, it is normal that females lay 50-70 eggs per clutch (both fertile and infertile), the absolute record we registered at 121 eggs in one clutch (P. SUCHÁNEK, IN LIT.). This phenomenon is partly for sure the function of the general overfeeding of the chameleons in captivity, as there is evidence (P. NECAS; E. ANDRINGOLA PERS. OBS.) that lower food intake drives

**Fig 12.** A two-tailed male of *Chamaeleo calyptratus* from Bratislava, Slovakia, a result of 7 and more generations of inbreeding. Foto PETR NEČAS

lover number of follicles, activated by the female during the conception leading to bigger egg size at oviposition, big ger hatchling size and higher survival rate of the hatchlings. Reversely, in overfed females, the number of eggs highly exceeds the physiological norm of 35-45 eggs maximum in wild females (P. NECAS, PERS.OBS.) and leads to smaller egg size, lower hatchling size, lower hatch rate and lower fitness and survival rate of the young. Anyway, it is very likely also one of the inbreeding effects, especially, when in commercial breeding programs, the high number of eggs per clutch is potentially considered as beneficial by the breeder.

**15. Transgender specimens (partly IB)**

1. Phenotypically typical big male specimen with high casque, well pronounced spur and typical male-like pattern died because of tumor of its fully developed ovaries (M. SLOBODA, PERS. OBS.),
2. Phenotypically atypical female with high casque and spurs laid infertile eggs (P. DVORÁK, PERS. OBS.),
3. Phenotypically atypical female with high casque and spurs laid fertile eggs (P. NECAS, PERS. OBS.),
4. Phenotypically typical female with no spur, typical female-like pattern and low casque was very aggressive towards males and after death, the dissection revealed absence of ovaries but presence of testes (P. NECAS, PERS. OBS.),
5. Males with typical male phenotype but absence of spurs,
6. Females with typical female phenotype but presence of partly grown or fully developed spur.
7. Females with typical female phenotype but presence of male-like sized casque.

The area of sex determination and sexual dependent behavior is a bit complicated due to the fact, that no definitive clarity is present on the TSD (temperature-dependent sex determination) phenomen in *Chamaeleo calyptratus*. While NECAS (1999; PERS. OBS.) and SCHMIDT (2001) report about clear dependency of the sex ratio (assessed by phenotype) at hatchlings incubated at different temperatures, ANDREWS (2005) doubts it with reference to his incubation experiments. ANDREWS however made three methodological mistakes in our opinion, namely, he made his experiments at constant 25, 28 and 30°C, commenting: "Incubation temperatures were selected that were known to result in high survival of eggs of *Chamaeleo calyptratus* in captivity (NECAS, 1999; SCHMIDT, 2001). These observations indicated that 25, 28, and 30°C would represent relatively low, moderate, and high incubation temperatures, respectively."

However, it is clear, that

1. TSD will give best evidence at the extremes, not in the median, safe zone, where logically the sex ratio will be insignificantly different or equal; one needs to go to below 21 and deeper and above 32 in our opinion to show a difference... Otherwise the experiment lacks sense.
2. Constant incubation temperature never happens in the wild, but: fluctuates significantly both during the day as well as during the whole incubation period, when the eggs need to overwinter a period

**Fig 13.** Three feral aberrant males from Clearwater (above) and vicinity of Fort Myers, USA; Photo MIKE MAUGERI (above, middle) and PETR NEČAS

when the temperatures can drop to the freezing point.

3. The sex determination was done solely on the presence of a secondary sexual feature: presence of spur in male even at embryos, not based on presence or absence of gonades. Therefore, ANDREWS cannot speak about "proof of sex" but "proof of the developed secondary sexual feature" only, which is subject of a great variability anyway.

For these reasons, we consider ANDREW'S conclusions as incorrect or conditionally correct but for incorrect reasons.

NIELSEN & AL. (2018) delivered a proof of heterochromosomally determined sex in *Chamaeleo calyptratus*. So, the ratio is set from the moment of the conception. The fact, that different ratio of males and females hatch at extremely low and high tepmpertures is therefore determined phenotypically and not genotypically, this means, that some of the specimens that show the phenotype of males are in genotype in fact females and vice versa.

The existence of transgender specimens can be, therefore, both result of inbreeding as well as incubation temperatures.

**16. Behavioral defects (IB)**

a. Aggression of females towards each other
b. Extreme aggression of male "translucents" towards females, when the mating has to be done assisted way, with mouths fixed by tape to prevent injuries or killing of the females (S. PROKOPIEV, IN LIT.).
c. Permanently unreceptive females
d. Males with no interest in mating
e. Extreme shyness and stress-sensitivity

## CONCLUSIONS

Some of the phenomena presented are clearly genetically determined and can be interpreted as a result of inbreeding, some of them might be (co-) driven by environmental factors and captivity conditions like diet, supplements, UV insolation, temperature and humidity. However, in their tendencies and frequency of cases during last 30 years, their relation to inbreeding is very likely.

The reason of all the above mentioned cases is simply the extremely small breeding stock, from which, thanks to the great breeding potential of this species, the whole captive and feral population, that is estimated to several millions specimens in total, originates. The original successful breeding stock from all the imports is estimated to less than 50 specimens in total. Moreover, the original population, from which almost all the original breeders originate, is a transect of several kilometers only.

The frequency of aberrant specimens in the samples of captive animals is logically much higher than in the indigenous wild populations, because

1. Wild populations have been very poorly studied,
2. Captivity eliminates many of the ecological selection factors and does not allow the natural selection to eliminate specimens which are aberrant and with lowered level of fitness from the population.

The introduced populations in Florida can serve as laboratories and research can be done in how negative

effects of inbreeding can be eliminated by nature. Due to the presence of natural selection factors, which eliminate most of the weak specimens from the population through the influence of abiotic factors as well as predation, the animals from those populations are a good option to be used for captive breeding programs. Their collection is not regulated by the US law, as they are considered an introduced invasive species. On the other hand, it should in no case support deliberate introductions of them to the wild, as this is against the law and against the nature.

**Fig 14.** One of the first visible inbreeding malformations is the break of the back in front of hip – captive female of *Chamaeleo calyptratus,* from Bratislava, Slovakia. Photo PETER DVORÁK

The key question for the captive husbandry remains: after how many generation the first degenerative treats are to be observed? The first not obvious signs appear as soon as in the 5th– 7th inbred filial generation, including deformities of tail, scale and pattern aberrations and typically "break" of the vertebral column just in front of the pelvis. Starting the 10th filial inbred generation, the frequency of malformations grow geometrically, leading further to degenerated breeds that tend to be liquidated due to the frequency of the malformations and limited or even lost ability to reproduce further.

For the future, to increase the overall fitness of the captive population, it would be beneficial to introduce some more wild specimens to the captive population to increase its heterozygocy level and diversity and introduce a studbook. As far as Yemen is now struggling politically and the country is virtually inaccessible due to war, we need to stay with what we have. For breeding programs, which are based on line-breeding, we will have to accept (same as in most domestic animals), that inbreeding might influence their fitness, especially if aberrant colorations are considered attractive and create a bigger economic value for the breeder and higher aesthetic value for the buyers. In all other cases, gathering the breeding pairs from genetically as distant as possible sources is highly recommended to leverage the situation.

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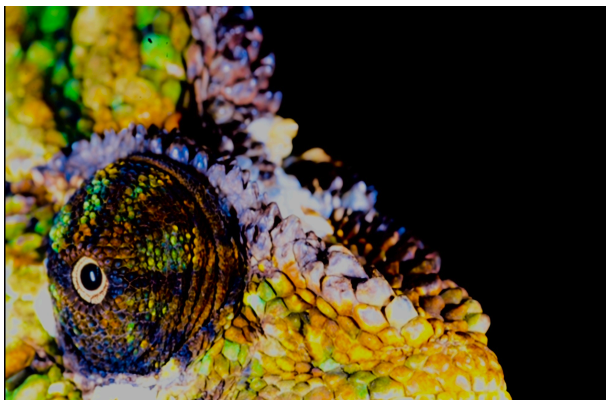

**Fig 15.** A feral aberrant male of *Chamaeleo calyptratus,* from Fort Myers, USA, with rugose enlarged and in double rows ordered scales on *canthus rostralis*. Photo PETR NEČAS

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**Fig 16.** A uniformly black temporary coloration (no melanism) of a wild male of *Chameleo calyptratus,* from Ibb, Yemen, while threat display. Photo PETR NEČAS

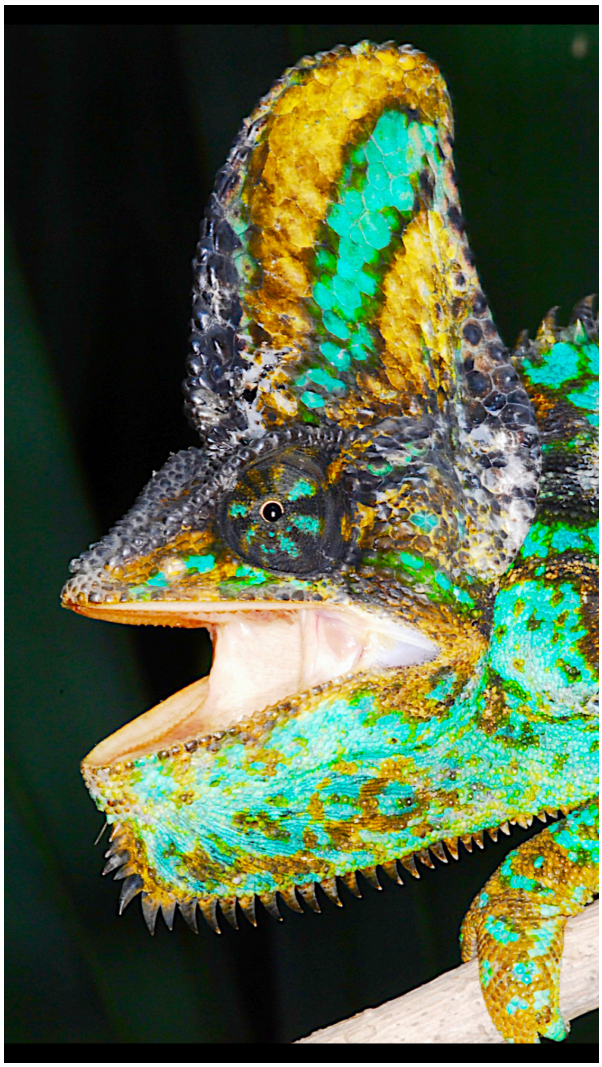

**Fig 17.** A wild male of *Chameleo calyptratus,* from Ibb, Yemen, while threat display. Photo PETR NEČAS

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**Fig 18.** A captive aberrant female of *Chamaeleo calyptratus,* from Bratislava, Slovakia, with a male-like developed tarsal spur. Photo PETER DVORÁK

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# The Language of Chameleons: how the animals, which cannot talk and do not hear, communicate

**PETR NEČAS**

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**Note:** this text is an example from the book dealing exactly with this topic, this is just an introduction

## INTRODUCTION

Chameleons are probably the most fantastic vertebrates living today on Earth. They belong to the squamate reptiles and are all classified in different genera within one family *Chamaeleonidae.* The so called "New World Chameleons", are not concerned here as this expression is nowadays considered quite archaic and marginally refers to chameleon-like Iguanids of the genera *Anolis* and *Chamaeleolis*.

Chameleons have attracted attention of people from ancient times. Nowadays, thanks to media and widespread herpetoculture, many people keep chameleons in captivity. They made their way to media as heroes of movies, books, and esthetic objects in art, design and industry.

The over 200 recognized recent species of Chameleons are well known by a combination of very outstanding and unique features, such as their ability to change color, their prehensile tail, their independently movable eyes, their chameleodactylous pincer-like feet, the long extendable tongue with which they catch their prey and their overall strange appearance and behavior. Their evolutionary history reaches almost 100 millions of years back: they survived the raise and the fall of great dinosaurs. They are masters of disguise and masters of survival. There are some of the smallest vertebrates in the world amongst them, with total adult length less than 2cm! They can grow over 80cm total length and can weigh over 1,5kg. Their bodies are ornamented with unbelievable colors and patterns and equipped with fantastic features like horns, crests, casques and spikes. They are indeed the dragons of the current age!

But, do we know them really well?

Chameleons are subjects of many superstitions and myths. The miracle, how they survive is even more mysterious, if we take into account their generally small size, slow motion, and the facts, that they almost can not smell anything, they almost can not taste anything and they practically can not hear anything!

Regardless all these handicaps, they stay at the top of their food-chain and do not build a primary source of food for any other animals, though they are occasionally predated by some other lizards, birds, mammals and snakes.

Why is that?

Because they can make use of many unique and unusual strategies, enabling their survival!

And, the most fairytale-like feature they possess is: despite of being unable to speak and hear, they CAN talk.

This book will unleash some of their communication and survival strategies and show you how they do.

We put together two approaches:

1. more than thirty years of chameleon research in the wild and captivity and experience from publications and teaching and unifying people interested in chameleons all around the globe in the person of the author of the text and photographs (PETR NEČAS), and
2. fresh, unbiased, youthful view of the young generation with free access to information technologies and adorable talent in the artistic view of the world in the person of the author of the illustrations and dialogues (ANASTASIIA SHIRIAEVA)

with the aim to write a book of a very unusual format and logic, that will inspire the readers in our modern world

and will target the minds and hearts of all generations from the young to the more mature ones.

Our dream and hope is, that this book will help to transfer our fascination and love to these fantastic and unique creatures to you, the readers.

We live in a world, when traditional values are questioned, nature is destroyed and we live on a margin, if not beyond a global collapse. The world is nowadays not ruled by spiritual leaders, who would care for culture, nature conservation and long-term sustainable wise existence, but under brutal dictate of military power and money. The Pandemic CoVid19 showed us clearly, how vulnerable the human rule of the planet Earth is. The majority of humans, became overnight caring for survival rather than for virtual intangible bait and charm and tease of the modern world's technologies and consumer lifestyle.

The chameleons are masters of survival. They survived many global crises, when continents were breaking apart and great animals became extinct. But, they ensured their existence even under the hardest pressure. They even resist the destructive influence of humans nowadays. They are, surprisingly, in many aspects very similar to humans. If compared to other powerful animals, they are similarly weak and handicapped like humans. Humans do not exceed any other biological entity in any physical feature except for the development of neocortex, enabling us logical thinking, and in our adaptability. Chameleons, on the other side, have powerful eyes and unique tongue and ability of spectacular color change. The extreme adaptability is a feature, which we have with the chameleons in common.

This book opens a field for human inspiration by chameleons' strategies of survival. We can learn a lot. We can understand better, what happens in the social systems around us, and, we can learn how to handle the challenges and develop further… How to do it concretely? This is, what we leave now up to you and your valued critical thinking. In case you need us, you will find a way.

We long for inspiring you for your own learning and growth, further studies, deeper understanding of the nature and for concrete actions in protecting the chameleons, their biotopes and in the end result, the ecosystems of the whole planet: saving her, …and us.

May the book be a good guide for diving deep into the mysterious world of chameleons, to find out more even about ourselves.

For the good of mankind and chameleonkind…

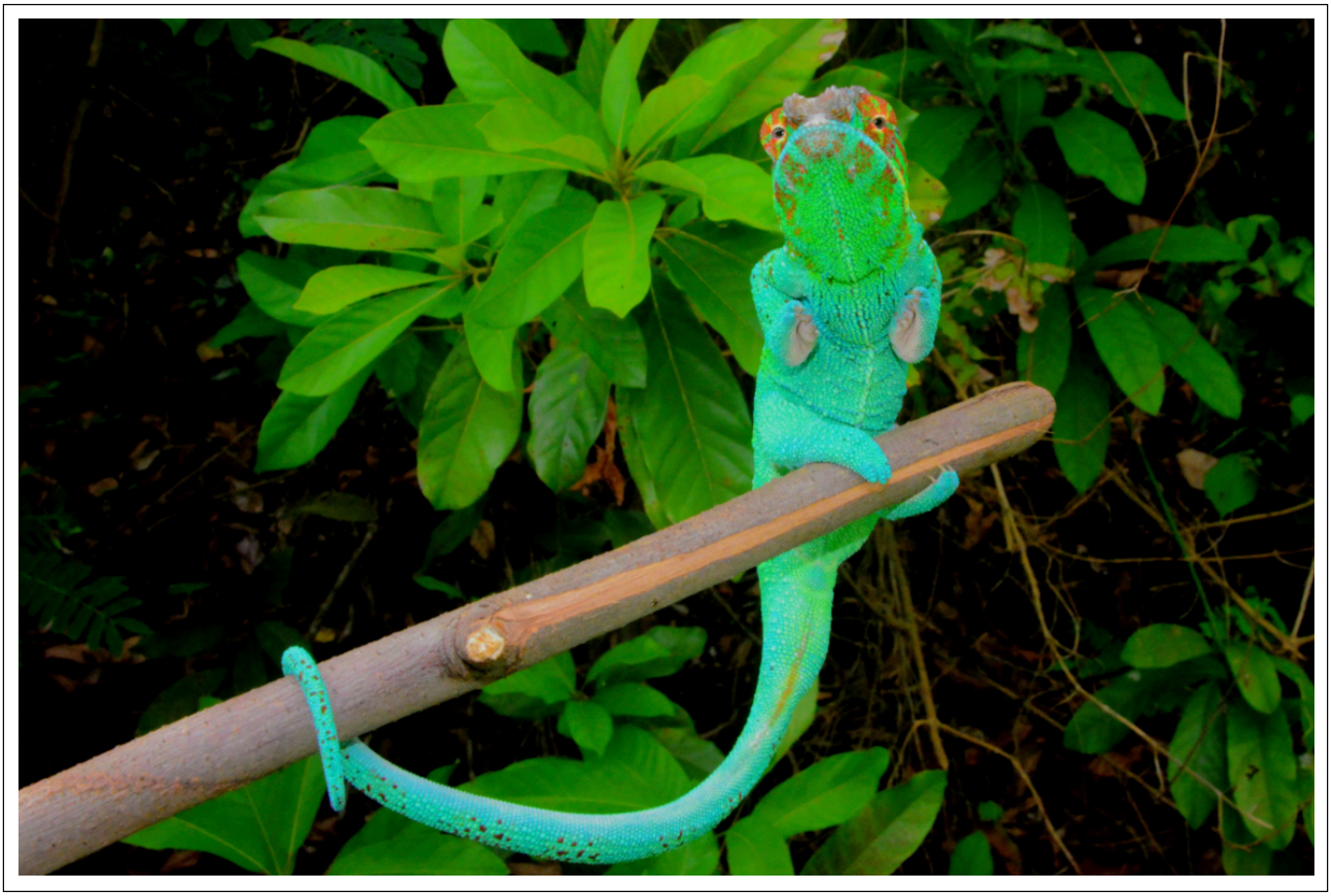
## System

The book consists of individual chapters, which describe always one phenomenon, one communication mechanism only. They might be combined in reality in their use by chameleons, but we decided to handle each separately.

Each communication mechanism is explained in the same logical structure, which combines exact scientific approach with popularization. We seek a compact, easy to understand and easy to comprehend way of description without trivialization and imprecise simplifications and allow ourselves a systemic fault in purposefully using anthropomorphization: depicting things from human perspective, lending the animals human properties and approaches and even thinking. We do so to bring a series of complex biological phenomena closer to the public. It is to be strictly understood and kindly pardoned as a deliberate misuse of this approach for the named purpose and is to be taken metaphorically and symbolically only. In no way does it mean, that in general, we attribute the human abilities to animals. We know, chameleon brain structure and function, despite of capable of surprising performance in many areas, lacks some parts, well developed in mammals including humans and therefore, it is not capable of thinking and communication in "human" sense.

Each of the many phenomena is described and elucidated in the same logic as follows:

**Name of phenomenon** – A short title standing symbolically for the phenomenon in discussion and using both exactly scientific as well as trivial terms and terms used in the practice of professional chameleonologists and amateur keepers, breeders and chameleoculturists.



**Headline** – An anthropomorphized wider definition of the pertinent topic, formulated as an imperative, elucidating the main principle of the individual chapter in a metaphorical way: like if an old, experienced chameleon guru would explain a young chameleon student what to do in order to master this particular area.

**Scientific-popular explanation** – A scientifically based, simplified, compact explanation of the phenomenon and its roots, based on the current state of understanding (the chameleon research is still scarce and incomplete, it does not yet provide the explanation of all phenomena in full) and experience of the senior author, sometimes slightly speculating and exaggerating, in service of understanding.

**Dialogue** – An anthropomorphized description of communicational sequences, depicting real situations from chameleons' life history in a form of a fictional dialogue, pretending that chameleons (and other animals involved) can think and speak same as humans. The events and reactions are real, just presented in that creative and easy-to-understand metaphorical way.

**Evidence** – Each phenomenon is depicted by pertinent photos from the wild and from captivity, demonstrating some aspects of the discussed topic. As most of them are of behavioral nature, and therefore dynamic and not static; the depiction is just representative. You can see demonstrations of these mechanisms in action dynamically in form of videos or time lapses at www.chameleons.info or on YouTube.

**Caricatures** – All phenomena are in relation to the pertinent "dialogue" artistically elaborated in a form of a drawing, depicting the reality in the perspective of humor, art and metaphors. They do reflect the reality in main aspects but may differ in some aspects due to liberal artistic perception and creativity.

**Coloring** – To foster creativity, coloring charts both for children as well as for adults are prepared. While coloring, the learning is fixed more firmly. And we hope that creative artistic enhancement of the use of this book will contribute also to the falling in love with these fantastic creatures.

## FIVE CHAMELEON LANGUAGES

Chameleons' behavioral patterns, using which they communicate, can be divided into logical groups based on the way, how the communication is performed. Some of the phenomena are of hybrid or intermediate nature, therefore, the division and classification is to be considered formal only without the ambition of neither rigorous correctness nor absolute comprehensiveness.

### 1 Language of body

This language provides the possibility to express certain issues through the exposing of static features of their body and give this way an orientation to the observer about their identity: **who they are**.

It consists of chapters about the most prominent external morphological features of their bizarre bodies, such as: Silhouette, Horns, Crests, Spikes, Casques, Spurs and Fluorescence.

### 2 Language of movements

This language deals with mechanisms how to dynamically, with the use of their bodies and their parts, express their intentions: **what they want to achieve**.

It consists of chapters on behavioral patterns like: Leaf walking, Run-run-run, Dispersal, Pancaking, Elbowing, Knighting, Skinfolding, Disking, Descending, Bull-necking, Blowing up, Moving, Light-housing, Bobbing, Brumation, Occipital flapping, Tail magic, Shadowing, Pair-bonding, Riding, Digging, Eye retracting, Gaping, Biting, Gasping, Grasping, Limb swelling, Eye moving, Eyes shut, Casque bulging, Akinesis, Thanatosis, Swinging, Licking, Tongue magic, Poop & Urate, Quasimoding, Buzzing, Side stinging, Spine thrusting.

### 3 Language of smell

This language makes use of a very spectacular area of their existence, the smell and explains how they use the fact that they do not give any specific odor under normal circumstances (No smell) how they utilize their ability to produce a very remarkable odor proactively (Bad smell, Great smell).

They metaphorically talk about: **how to use the odor**.

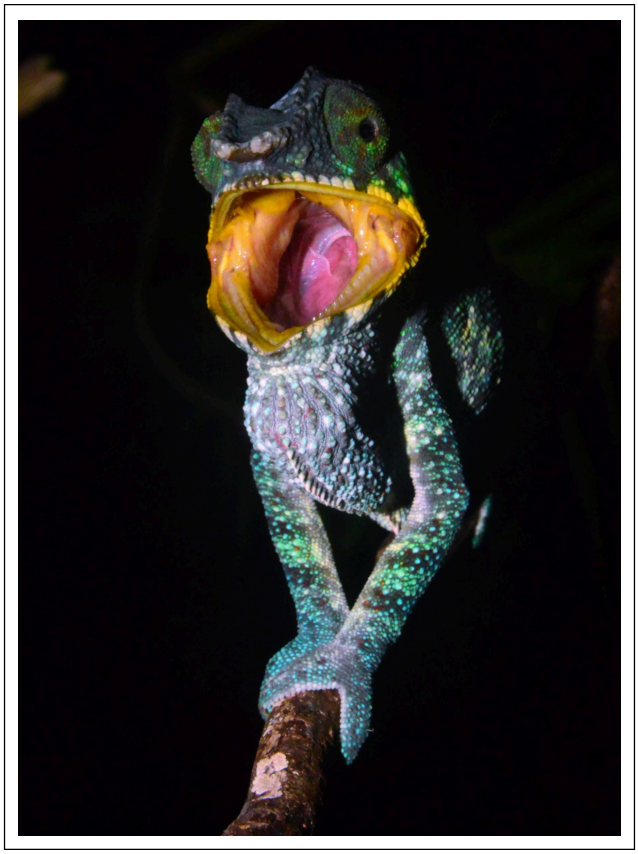
### 4 Language of colors

This language provides the possibility to express very complex communicational patterns within a species and amongst other chameleon species, and talk on: **how to express the will and emotions.**

This section consists of chapters on: Intraspecific communication, Interspecific recognition, Thermoregulation, Emotions, Health, Nutrition, Mimesis, Somatolysis, Color defects.

### 5 Language of sounds

This language comprises the only obvious loud and hearable sound, the chameleons produce proactively: Hissing. The Buzzing was technically put to "Language of movements" for the reason, that though sometimes weakly hearable, it seems to have the main function in performing vibration rather than hearable voice. There are some sounds that chameleons can produce when ill, like sort of coughing, sneezing, chirping or whistling, as passive side-effects of some diseases. And it is speculated, they can even use ultrasound.



### *OFFER*

*If you got inspired, let us show you step by step some chapters of the book in **Archaius**.*

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# The Language of Chameleons: how the animals, which cannot talk and do not hear, communicate

## Silhouette

**PETR NEČAS,**
with illustrations of **ANASTASIIA SHIRIAEVA** and photos of **PETR NEČAS**

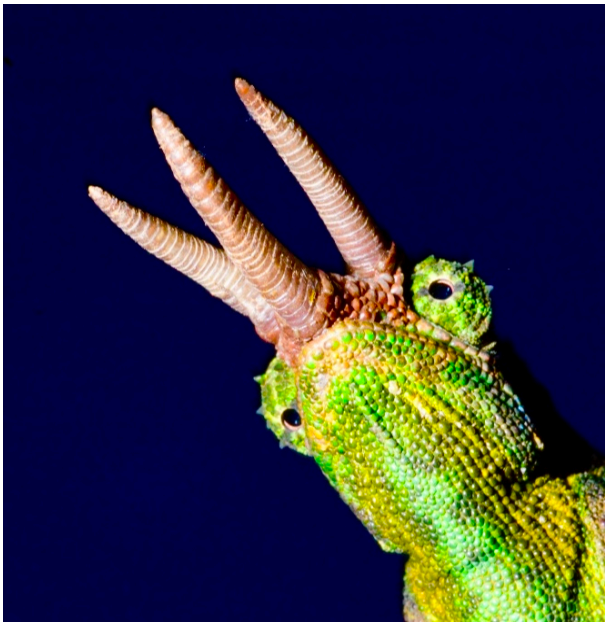
Corresponding author: *petr.necas@me.com*

**Note:** this text is an example from the book dealing exactly with this topic, this is just a sample

### SILHOUETTE

SHOW ME YOUR SILHOUETTE SO I KNOW, WHO YOU ARE!

Chameleons are mainly oriented in the environment through their vision. Their vision is crucial and it prevails over their other senses. In most cases, when a female chameleon sees a male chameleon approaching her, she sits in the middle of the bush or canopy and the male approaches her from above and from outside. Because of this, the female will see the male mostly against light and once the male will start imposing the female, it will turn its body sidewise, so the female can see it from the side. Therefore, the silhouette is the most important way for the male chameleons to expose themselves to the female. Based on the specific features that are visible as a black and white picture of the silhouette (horns, spikes, length of the tail, body form etc.) the female recognizes whether the male is a member of the same species and it is a potential sexual partner for her, or this is a member of a different species, which has to be rejected.



*Trioceros jacksonii jacksonii*, male, Machakos, Kenya
Photo PETR NEČAS

A male Flap-Necked Chameleon (*Chamaeleo dilepis*) meets a female of the Giant Monkey-Tailed Blade-Horned Chameleon (*Kinyongia matschiei*)…

Male: "Hey, darling! I would like to invite you to a walk close to the skies to the highest top of the tree to watch the sunset."

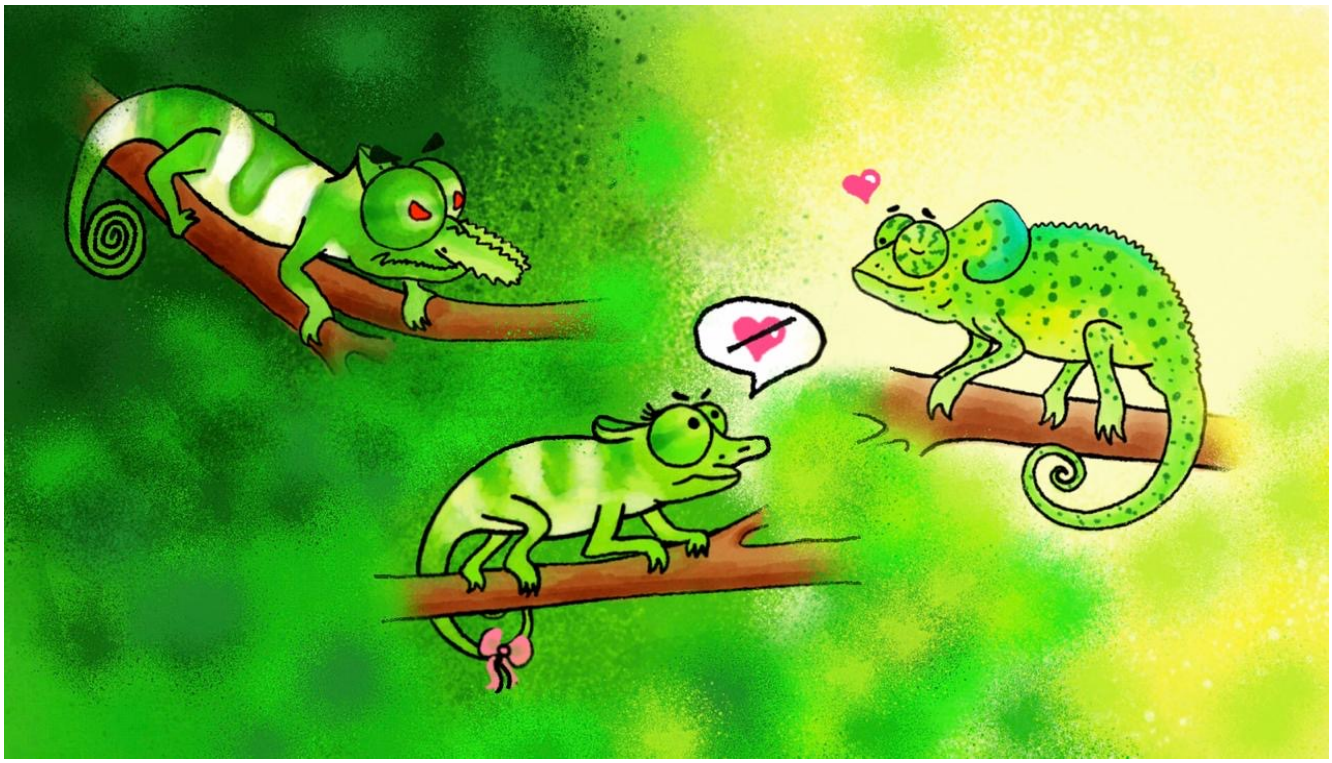
Female: "Let me see you first, show yourself properly from the side!"

Male: "Look how big I am! I have a big crest on my back and large occipital flaps; I hope you like me!"

Female: "I'm not interested in dating with you! My boyfriend doesn't have such an ugly crest and funny flaps - he has two lovely blade-like horns."

Male: "I have no horns but I am cutely spiky! And look, what I can do with the flaps!"

Female: "Hey, please beware and step back, otherwise he might come and hurt you."



Silhouette, Drawing ANASTASIIA SHIRIAEVA

*Kinyongia matschiei*, male, Usambara Mts., Tanzania, Photo PETR NEČAS

*Kinyongia matschiei*, male, Usambara Mts., Tanzania, Photo PETR NEČAS

*Chamaeleo dilepis*, male, Usambara Mts., Tanzania Photo PETR NEČAS