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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.

PETR NEČAS & PETER DVORÁK

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

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

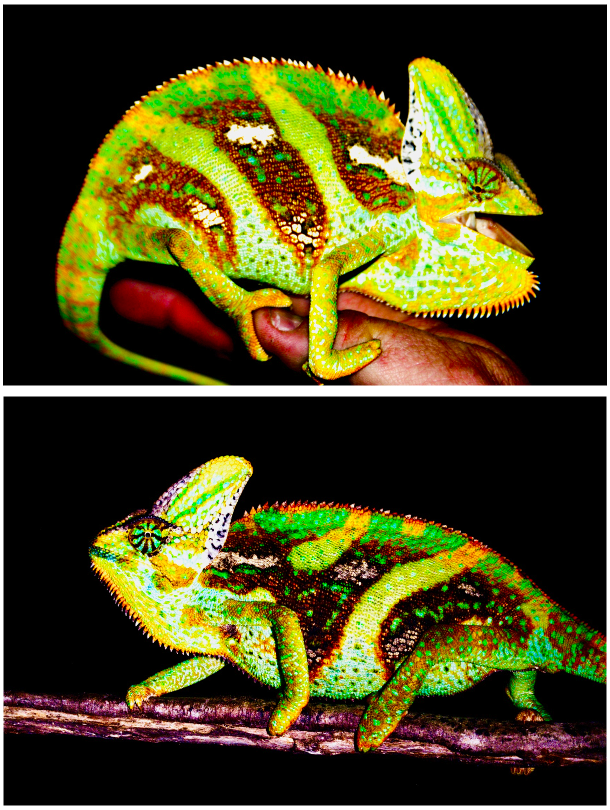

Fig 2. A feral male of *Chamaeleo calyptratus* from N of Fort Myers, USA; with asymmetrical aberrant pattern (2 instead of 3, diagonal instead of transversal yellow bands). Photo PETR NEČAS

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

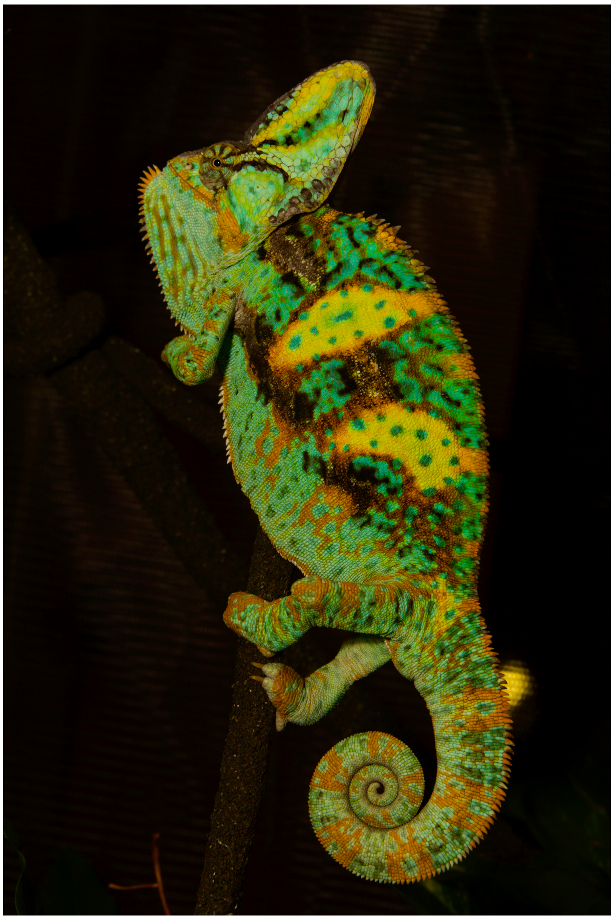

Fig 3. A captive male of *Chamaeleo calyptratus,* from Kharkiv, Ukraine; with aberrant pattern (2 instead of 3 transversal yellow bands). Photo SERGII PROKOPIEV

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…

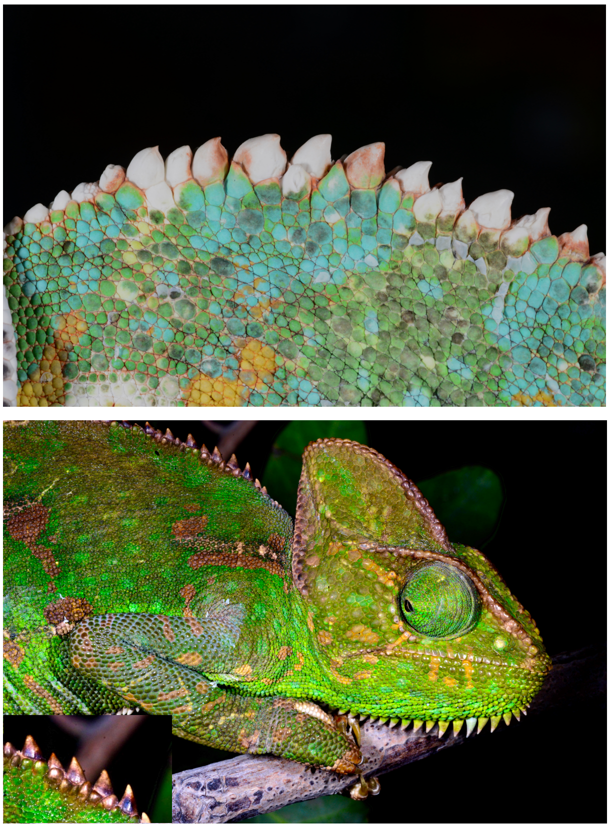

Fig 4. Feral females of *Chamaeleo calyptratus* from N of Fort Myers, USA; with scale abnormities at dorsal crest (both) and aberrant pattern (lower). Photo PETR NEČAS

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

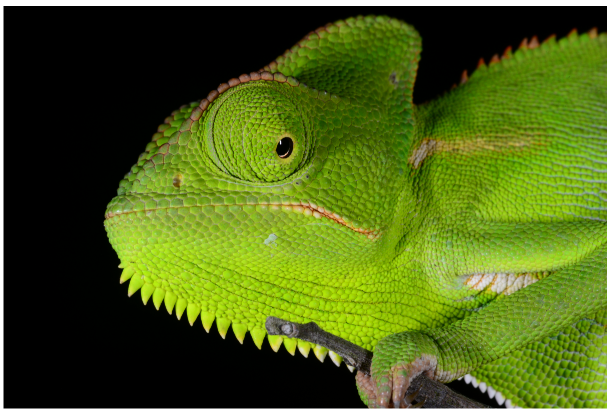

Fig 5. A feral female of *Chamaeleo calyptratus,* from Fort Myers, USA; with aberrantly colored gular crest (green instead of white). Photo PETR NEČAS

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.

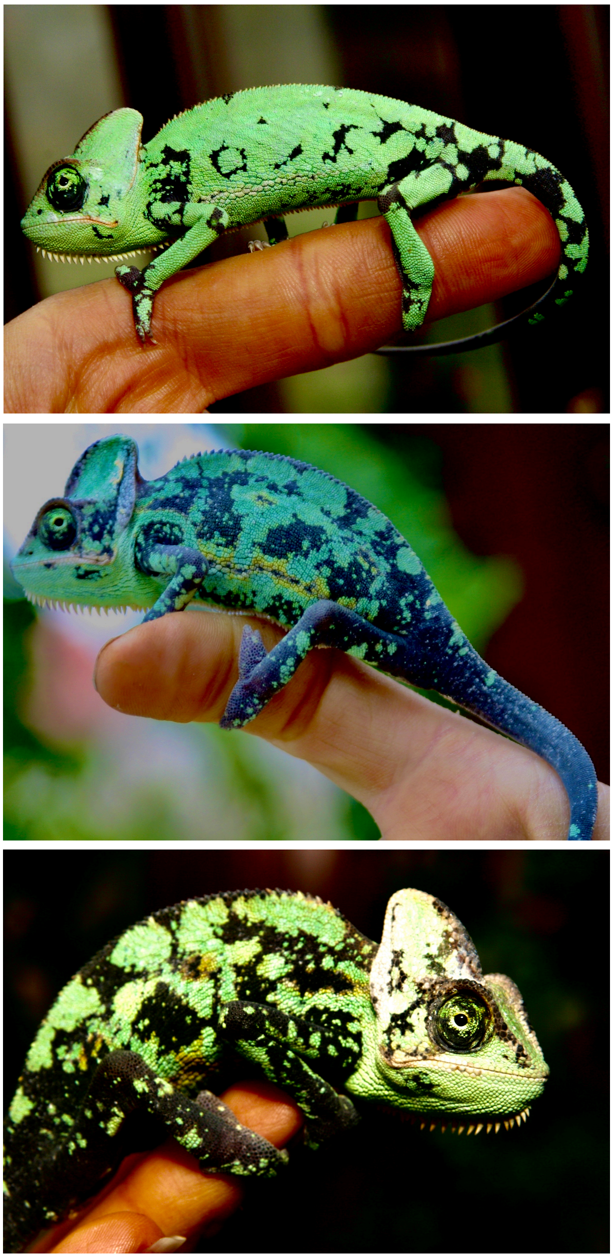

Fig 8. Three partly melanistic specimens of *Chamaeleo calyptratus* from Bratislava, Slovakia; a result of 7 consecutive generations of inbreeding. Photo PETER DVORÁK

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 in-breeding 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 4th 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 5^{th}– 7^{th} 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 10^{th} 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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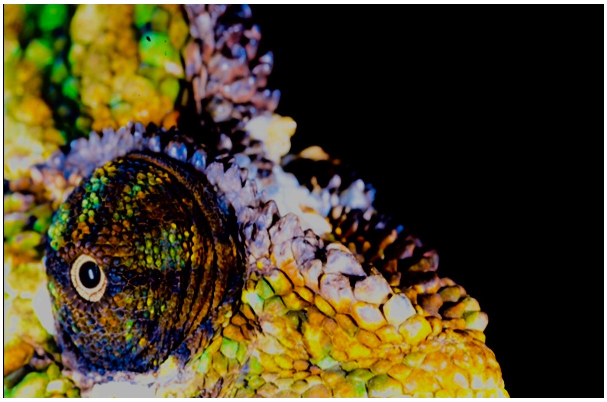

Fig 15. A feral aberrant male of *Chamaeleo calyptratus,* from Fort Myers, USA, with rugose enlarged and in double rows ordered scales on *canthus rostralis*. Photo PETR NEČAS

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

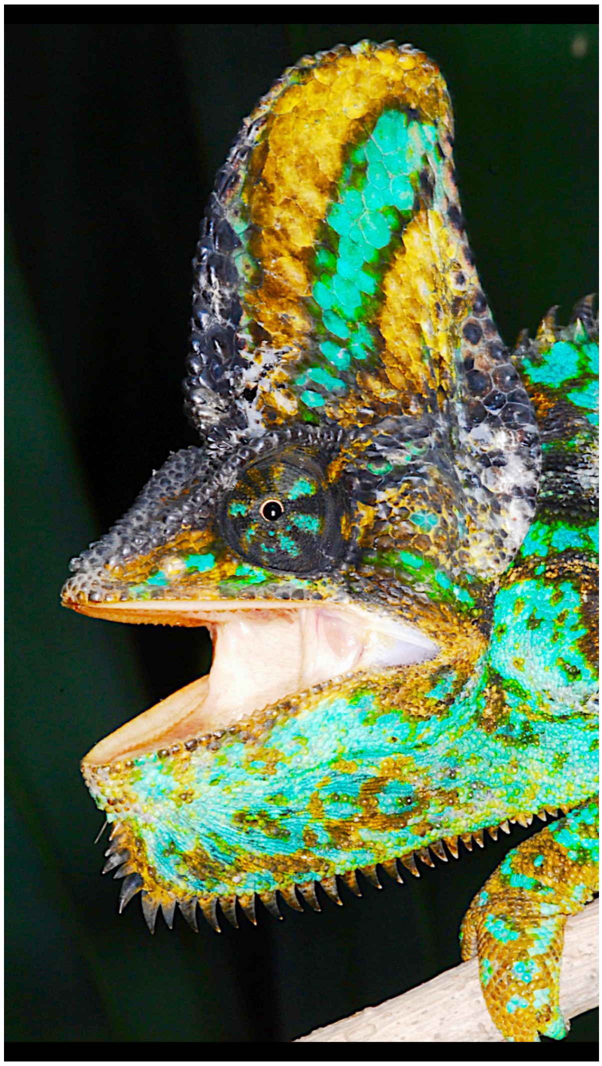

Fig 17. A wild male of *Chamaeleo calyptratus,* from Ibb, Yemen, while threat display. Photo PETR NEČAS

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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