Archaius, Vol. 1, No. 4: 8-28, 2020

AJOCC: Section Chameleonoculture

Submitted: 22. 04. 2020 *Published: 28. 04. 2020*

The Naturalistic Chameleonoculture – a breakthrough in captive management of chameleons

Part 2: Hydration and the Mystery of Fog-Drinking

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ABSTRACT

The natural hydration cycles for chameleons reflect the natural cycles of their occupied territories, biotopes and microbiotopes, with dry daytime, and humid often foggy or misty nights. Chameleons desiccate by exhaling humid air at low air humidity levels, while keeping the previous hydration level at high humidity levels. They hydrate during the night through inhaling aerosols by newly described "fog-drinking". The prevalent practice of chameleon captive management reverts the circadian humidity cycles. It is recommended to adjust the practice to simulate better the natural conditions by adding fogging at night, at low temperatures and with enough airflow as a part of Naturalistic Chameleonoculture.

Key words: NC, Naturalistic Chameleonoculture, chameleons, husbandry, fog, mist, fog-drinking, captivity, ultrasonic foggers

INTRODUCTION

I have been studying chameleons for 34 years now. In the wild and in the captivity. After many years, spending many months in the wild, observing and studying chameleons under the strangest circumstances: climbing mountains, crossing deserts, crawling through jungles, sleeping underneath the trees where chameleons were sitting to see what they do in the morning, and possibly get their fresh droppings to do some more fecal analysis, after all that time, one day I got astonished: I have never seen chameleons drinking in the wild. I have seen them basking, I have observed them fighting, mating and hunting. I've seen them digging nests and laying eggs. I've seen almost every single issue and activity of their natural history. BUT - I have not seen them drinking!

I thought this to be very strange, and very likely it was biased through my presence. They see me so they do not drink, but this didn't stop them from doing all the other activities in my presence - all but drinking.

I have seen them thousands of times drink in captivity. Many people would swear chameleons are heavy drinkers. like Yemen chameleons, Meller's chameleons, and Parson's chameleons. Even myself, with all my experience have not seen chameleons drinking so much in captivity like the others have reported. So, I must have done something different than all the others, right?.

Finally, I came to the extreme conclusion: CHAMELEONS DO NOT DRINK IN THE WILD (of course, they do, but much, much less, than we think). And, my colleagues confirmed my observations: JAN STIPALA IN LITT.: CARL CATTAU IN LITT: NICOLA LUTZMANN IN VERB.; CHRIS ANDERSON IN LITT.; with the remark, that especially the montane species are almost never observed to drink in the wild.

Then, the logical question arises, *How they do it?* They seem not to drink liquid water, and despite this stay perfectly hydrated. With very few exceptions, and this always only towards the end of dry season in the savanna, I have almost never seen a chameleon heavily dehydrated.

I knew there was a logical and clear explanation for this, so, I made it my task to find these answers. The following text is about my journey of discovery, and where not stated otherwise, all presented facts and observations should be considered as P. NEČAS, PERS. OBS.

CHAMELEONS HIDE FROM THE RAIN, AND SLEEP

One day, I had a fabulous opportunity to meet the first rain in Kenya after 4 months of absolute drought. It was in the Nyambeni Hills at the foot of the Mt. Kenya Massive. The locals reported there was not a single drop of water falling from the skies during this 4-month period. I was in the field just studying the local strong population of the Yellow-Crested Jackson's Chameleon, *Trioceros jacksonii xantholophus.* I observed at a time about 10 specimens in the field, all sitting on terminal branches of small bushes and trees around me. Suddenly, huge clouds came and covered the skies, it became significantly colder and darker, the air started to smell of the ozone, and a tropical downpour started. Gently at first, not with the biggest intensity - that came few hours later.

Fig 1. *Chamaeleo arabicus* from Oman (N of Salalah) hiding from rain in the middle of bush; Photo PETR NEČAS

Now, I was curious what the chameleons will do. They had 4 months no opportunity to drink any drop of water. No rain and no dew. So, what was expected of these chameleons that have been totally deprived of water for 4-months? Logically: they will start running hysterically after each droplet of water, get it and drink it completely and seek another one, and another one.

Well, this is theory. The reality was astonishing. Instead of running after water, all chameleons did the same, the exact opposite: they turned around, crawled into the canopies of the trees or deep inside the bushes, often seeking a leaf cover just above them like an umbrella. Then, they rolled together in the same position, like in the night, they closed their eyes and started to sleep! Instead of welcoming the rain and utilizing the liquid water, they started to hide from water protecting themselves paradoxically (or logically?) from the rain.

Why they protect themselves from the rain?

Hard to understand.

What is wrong? It is just water.

Chameleons vigorously hate anything touching their bodies, and, even if they crawl through vegetation, they tend to do it in a way that their skin does not even touch a leaf, and it never touches a branch either.

Why is that?

There are basically three reasons:

1. **Chameleon skin is very fragile and sensitive**.
   In some species, e.g. *Chamaeleo zeylanicus,* the skin is so sensitive, that only touching the plants while trying vigorously to escape, is causing black discoloration of their skin that last for weeks to heal.

Fig 2. *Chamaeleo zeylanicus* from India (Bengaluru) showing discolorations on skin after touching vegetation; Photo PETR NEČAS

2. **The rain is painful**
   for their sensitive skin and bodies.
   Why? Imagine, as a human, the skin area of the body is roughly 2 m^2. In an average chameleon species, it is about 2.000 times less: 0,001 m^2. One drop of water hits an area of about 0,25 square centimeter. It means, about 1/80.000 of the body area of the human, but, 1/40 body surface of a chameleon - means proportionally 2.000 times more! Imagine, that you would be exposed to a rain consisting of basket balls! Would you enjoy it, or run away to hide?

3. **They are afraid of being touched.**
   The Chameleons touch the environment proactively, only with the soles of their feet and underside of the tail. There are only two occasions when under normal

circumstances, their body gets touched naturally passive way (by something):

a. The second in importance occasion applies only for **females while mating**, when the female is hormonally conditioned to allow the male to climb its body and pass the necessary time to fertilize its eggs.
b. The first in importance occasion is, when chameleon body is touched is **when they get predated** and eaten - and this is what they vigorously try to avoid. By the way, this is also why the manipulation with chameleons is also so problematic from the side of human and only letting them crawl on the hand is tolerated under normal circumstances, considering you not a predator but a "strange tree".

So, it is logical to why they tend to escape the rain so vigorously. The smaller the species is, the more effort they pay to do so. Some of the biggest species (like *Calumma parsonii* and *Trioceros melleri*) tend to care significantly less.

But why did they start to sleep instead of staying active at daytime? The reason is quite spectacular. It was their natural reflexive reaction on the changes in the environmental factors.

What changes happen as a rule in the environment in the moments when the chameleons go to sleep?

1. The **temperature drops down** (as the result of the sun rays of IR light passing longer and longer way through the atmosphere causing energetic losses and final hiding behind the horizon and stopping the irradiation with IR rays).

2. The **intensity of light gets lower** (as the result of the sun rays of visible light passing longer and longer way through the atmosphere causing energetic losses and final hiding behind the horizon and stopping the irradiation with the rays of visible light).

3. The **concentration of CO_2 in the air raises** and the **concentration of O_2 drops** (due the stopped photosynthesis of plants that produces O_2 and start of the breathing phase which consumes the O_2 and produces CO_2 as byproduct, known. for its light anesthetic properties).

4. The **air humidity raises** (due to the drop of temperatures caused by the hiding of sun behind the horizon, the amount of water vapor dissolved in the air remains same, but the air shrinks with the drop of the temperature and therefore, the concentration of the vapor increases).

And, what happens at the beginning of the rain typically? Surprisingly the same!

1. The **temperature drops down** (as the result of the sun rays of IR light are absorbed by the cloud cover, the irradiation with IR rays is strongly reduced).

2. The **intensity of light gets lower** (as the result of the sun rays of visible light get shielded by the clouds, the irradiation with the rays of visible light lowers).

3. The **concentration of CO_2 in the air raises** and the **concentration of O_2 drops** (due the significantly reduced photosynthesis of plants that produces O_2 and start of the breathing phase which consumes the O_2 and produces CO_2 as byproduct, known for its light anesthetic properties).

4. The **air humidity raises** (due to the drop of temperatures caused by the blockage of sun rays through clouds and due to the rain, itself).

5. The **air pressure i**ncreases (the rain usually happens in areas of lower atmospheric pressure, during the rain, the air pressure raises).

So, it is very logical, that the same combination of environmental factors as at the end of their day actually initiates their sleep during these storm conditions.

But why they do not run for the water to drink? Especially, when they have not drunk any drop of liquid of water during the dry season which is often many months?

The answer is as surprising as it is simple: because they did not need to, as they were perfectly hydrated! I inspected about 50 animals and found out, they were perfectly hydrated, because:

1. **skin** was **elastic** and skin test passed properly,
2. **eyes normally protruding**, not sunken in the eyeholes,
3. **mucous moist** and not sticky,
4. **feces normally moist**, not dry,
5. **urates white** with the orange crystalline portion of about 25% on average only.

Miracle? After 4 months of no liquid water available, means after same time not having drunk, the animals were perfectly hydrated. How is it possible?

In the dry season, the daytime temperature raise high to the yearly maximum (up to above 35°C) and the humidity at daytime drops to the yearly minimums (even under 30%), thus absolutely necessarily causing the biggest water losses and desiccation during the year due to the environmental factors at daytime. Where, and importantly *how* do they get access to water in such conditions?

Fig 3. *Trioceros jacksonii xantholophus* from Kenya (Meru) at the end of dry season after 4 months of no liquid water availability; showing perfect hydration; Photo PETR NEČAS

The journey of discovery continued…

There are only few options, how to obtain some water for the chameleon organism, the question is, whether it is enough:

1. Through **drinking…**
   Not the case, as proven above. There is no rainwater and no dew available, there is no river or creek available (and, as a rule, chameleons do not descend to water bodies to drink with some very anecdotal exceptions), liquid water in no other form available.
   So, is this the hydrating mechanism? **NO!**

2. Through **eating the insects containing water**…
   Yes! But in no case enough to cover the needs, moreover, the availability of insects in the dry season is limited, much less than in the rainy season, and those available, are also relatively dry due to the lack of water in the environment.
   So, is this the hydrating mechanism? **NO!**

3. Through **eating plant matter…**
   Well, *Trioceros jacksonii* has never been reported to actively feed on plants, neither have samples of about 130 wild jackson's chameleons examined by me revealed any plant matter in their faeces except of some pollen and remnants of the plants eaten by the insects prior to predation.
   So, is this the hydrating mechanism? **NO!**

4. Through **metabolic production of water**…
   Indeed, some molecules of water are synthetized as a side-effect of Krebs' Citrate–Cycle But the volumes of water synthetized this way is so minute that it can be ignored.
   So, is this the hydrating mechanism? **NO!**

5. Through some **unknown mechanism…**
   Yes, there must be something, that we do not understand yet…
   So, is this the hydrating mechanism? **YES!**
   But what is it?

GAINING WEIGHT AT NIGHT

The next part of the journey of discovery lead me to Oman, which is home to locally strong populations of the Arabian chameleon, *Chamaeleo arabicus,* especially in the vicinity of Salalah.

I have visited this population in late October, it means in the dry season and I made a very simple field experiment. I have located several specimens during the daytime and marked their position to find them at night. On three consecutive days, I repeated the following procedure:

1. **Locating:**
   Several specimens were located in late afternoon or beginning of night.

Fig 4. *Chamaeleo arabicus* from Oman (W of Salalah) in its natural biotope on an *Acacia* tree; Photo PETR NEČAS

2. **1st measurement:**
   I visited their sleeping place after dark between 20:00 and 22:00.
   I carefully took them down from their sleeping

position.
I measured their weight and examined them.
Then I put them back to their exact sleeping place and waited till they closed their eyes and slept-in again.

3. **2nd measurement:**
I visited their sleeping place in the early morning hours just before sunrise between 03:40 and 05:10.
I carefully took them down from their sleeping position again.
I measured their weight and examined them.
I took a paper tissue, measured its weight, wrapped it around their bodies, and pushed gently against the skin of the body and head to wipe off a possible moisture.
Then I weighed the tissue again.
Then I put the chameleons back to their exact sleeping place and waited till they close their eyes and sleep-in again.

4. **3rd measurement:**
I visited their sleeping place in the early morning hours after sunrise between 7:30 and 09:30 when they started to bask.
I carefully took them down from their (unchanged or slightly changed position) again and repeated the second measurement of their weight.
Then I released them back.

More measurements were not executed, as standard same conditions could not be ensured further on. The animals behaved their individual way in relation to location, resources, sun exposition, food availability, basking choice etc.

The interesting observation in the environment was, that already after sunset, the temperature drops and humidity raise was quite significant (from max 29°C and below 35% at daytime to 21°C and 86% after sunset). In the morning, the temperatures dropped even more and heavy fog formed condensing on the vegetation (but not chameleon bodies) in form of dew. (17°C and 100% in the early morning before sunrise).

Period		**Mid-day**	**After sunset**	**Before sunrise**	**After sunrise at start of basking**
Time	from	12:00	20:00	03:40	07:30
Time	to	14:00	22:00	05:10	09:30
Ambient temperature		29°C	21°C	15°C	23°C
Air humidity		Below 40%	86%	100%	63%

This all I expected and knew from many other field visits to Yemen, Socotra and Oman and diverse analogical parts of Africa and Asia.

The biggest surprise however waited for me in the form of the results of the measurements.

All chameleons gained significantly weight through nighttime! They were heavier by up to 1g in the morning if compared to the evening. The weight gain was stable before and after the sunrise at the beginning of basking.

But: they were sleeping all night in same position and at same place: same tree, same branch, same twig! They were totally inactive, immobile and cold!

Where did they get the gain in weight from? What are the possibilities?

1. They have **eaten** something? - *NO!*
They do not eat at night; they do not see well in these conditions, so food intake is impossible.
2. They have gained weight through **metabolic processes**, especially digestion through oxygenating the nutrients? - *NO!*
The minute gain, theoretically possible through this process is even under normal circumstances hardly measurable. Moreover, all metabolic processes in heterotherms are heavily inhibited and slowed down in the night, due to the low night temperatures.
3. They became heavier through **water condensed on their bodies**? - *NO!*
The bodies were at the very moment of measurement, dry, no excessive moisture was detected at their bodies as the paper tissue weight was same before and after wiping their bodies off. There was also almost no difference between the weight before the sunrise and at the beginning of basking and if, then there was a very slight loss of maximum 0.1g.
4. They became heavier through the **water** condensed on their bodies that was **soaked in by their skin**? - *NO!*
The chameleon skin is impenetrable by water, the level at which the water can penetrate it, is barely measurable. Their weight was also almost same or even minutely higher before the sunrise and at the beginning of basking.
5. They became heavier because the **water condensed on the casque** of their head and were led by capillary powers as known by "rain drinking" in some other lizards to the angles of their mouth and subsequently reflexively swallowed? - *NO!*
There was no condensed water on the head as proven by the tissue test as well as the third measurement.

Date	Ani-mal	Sex	Perch height in m	Evening weight in g (0)	Morning weight in g (1)	Morning weight in g (2)	Net weight gain in g (1-0)	Net weight gain in g (2-1)	Net weight gain in % (1-0)	Net weight gain in % (2-1)	Average net weight gain in %	Males average net weight gain in %	Females average net weight gain in %	Average perch height in m	Males average perch height in m	Females average perch height in m
19.10. 2017	CA01	m	2,0	112,3	113,1	113,0	0,8	-0,1	0,71%	-0,09%	0,80%	0,91%	0,67%	1,70	1,67	1,74
	CA02	f	2,5	76,1	76,5	76,5	0,4	0,0	0,53%	0,00%						
	CA03	m	1,4	44,4	45,0	45,0	0,6	0,0	1,35%	0,00%						
	CA04	m	1,7	101,8	102,8	102,7	1,0	-0,1	0,98%	-0,10%						
	CA05	f	1,4	78,7	79,1	79,1	0,4	0,0	0,51%	0,00%						
	CA06	f	2,0	73,2	73,9	73,8	0,7	-0,1	0,96%	-0,14%						
	CA07	f	2,1	95,3	95,9	95,9	0,6	0,0	0,63%	0,00%						
	CA08	f	0,7	27,0	27,2	27,2	0,2	0,0	0,74%	0,00%						
	CA09	m	0,8	21,0	21,2	21,2	0,2	0,0	0,95%	0,00%						
	CA10	m	2,3	139,7	140,8	140,7	1,1	-0,1	0,79%	-0,07%						
	CA11	m	1,8	90,2	90,8	90,8	0,6	0,0	0,67%	0,00%						
20.10. 2017	CA02	f	2,4	74,2	74,4	74,3	0,2	-0,1	0,27%	-0,13%	0,77%	0,89%	0,65%	1,64	1,70	1,58
	CA03	m	1,2	44,9	45,3	45,2	0,4	-0,1	0,89%	-0,22%						
	CA07	f	2,1	96,2	96,7	96,7	0,5	0,0	0,52%	0,00%						
	CA08	f	0,6	27,3	27,6	27,6	0,3	0,0	1,10%	0,00%						
	CA10	m	2,3	140,9	142,1	142,1	1,2	0,0	0,85%	0,00%						
	CA11	m	1,8	89,7	90,6	90,6	0,9	0,0	1,00%	0,00%						
	CA12	m	1,5	85,0	85,7	85,6	0,7	-0,1	0,82%	-0,12%						
	CA13	f	1,2	56,9	57,3	57,3	0,4	0,0	0,70%	0,00%						
21.10. 2017	CA01	m	2,2	111,8	112,1	112,0	0,3	-0,1	0,27%	-0,09%	0,86%	0,90%	0,83%	1,66	1,97	1,42
	CA02	f	2,3	76,3	76,7	76,7	0,4	0,0	0,52%	0,00%						
	CA03	m	1,8	44,4	44,9	44,8	0,5	-0,1	1,13%	-0,22%						
	CA05	f	1,3	78,2	79,2	79,1	1,0	-0,1	1,28%	-0,13%						
	CA06	f	1,9	72,2	72,2	72,2	0,0	0,0	0,00%	0,00%						
	CA07	f	1,5	95,0	95,8	95,8	0,8	0,0	0,84%	0,00%						
	CA08	f	1,2	29,1	29,5	29,5	0,4	0,0	1,37%	0,00%						
	CA10	m	2,3	141,0	142,3	142,2	1,3	-0,1	0,92%	-0,07%						
	CA11	m	1,8	89,9	90,3	90,3	0,4	0,0	0,44%	0,00%						
	CA12	m	1,6	84,0	84,9	84,8	0,9	-0,1	1,07%	-0,12%						
	CA14	f	0,6	29,2	29,5	29,5	0,3	0,0	1,03%	0,00%						
	CA15	f	0,8	33,0	33,3	33,3	0,3	0,0	0,91%	0,00%						
	CA16	f	1,5	68,6	69,0	69,0	0,4	0,0	0,58%	0,00%						
	CA17	m	2,2	101,1	102,7	102,7	1,6	0,0	1,58%	0,00%						
	CA18	m	1,9	97,9	98,8	98,8	0,9	0,0	0,92%	0,00%						
	CA19	f	1,7	66,3	66,9	66,9	0,6	0,0	0,90%	0,00%						
AVE, SUM	**19**	**9m, 10f**	**1,7**	**76,9**	**77,5**	**77,5**	**0,6**	**-0,034**	**0,82%**	**-0,043%**	**0,81%**	**0,90%**	**0,72%**	**1,67**	**1,78**	**1,58**

Tab 1. Weight gain experiment with wild *Chamaeleo arabicus* in the vicinity of Salalah, Oman

6. The moist air was **condensing in the mouth at the hard palate** (palatum durum) and swallowed down to the digestive tract. (speculation presented by NATHALIE NORRIS at FB group Chameleon Central)? - *NO!* Chameleons do not breathe at night with mouth open, but through nostrils while the mouth is closed. The air therefore, has no way how to get to mouth, as it is directed directly through the nasal cavities to trachea and further to lungs and it cannot condense on hard palate, as it simply does not get in contact with it.
7. They gained weight through **resorption of water led to the cloacal opening**? – *NO!* There was no condensed water on the body as proven by the tissue test as well as the third measurement. There is also no way how it should be led to the cloacal opening, it remains closed whole night. Even though the cloaca is theoretically capable of a limited fluid resorbing, as utilized by some other reptiles for rehydration and therapeutic purposes, this does not apply here at all.
8. They **inhaled moist air and fog and resorbed it in the respiratory tract?** - *YES!* The detailed physiological basis is not yet known but this is the only realistic way in which the body weight can be gained. The ability of vertebrate lungs to resorb tiny water particles such as fog is known. This ability is utilized as nebulization in human and veterinary practice for the transport of water and water-soluble-medicaments. It is also possible that the water might partly condensate in the nasal cavity and then be swallowed. An indication of this possibility delivered recently by GRANT TAYLOR, who filmed a swallowing of an adult *Calumma parsonii* (CUVIER, 1824) at night when exposed to fog produced by a commercial fogger.

Experiments of same process have been conducted on following places with same principal result.

Country	Place	Species, form	Observer
Madagascar	Nosy Boraha	*Furcifer pardalis*	SERGEI PROKOPIEV
Kenya	E foothills Mt. Kenya	*Trioceros jacksonii xantholophus*	PETR NECAS
Kenya	Machakos	*Trioceros jacksonii ssp.*	PETR NECAS
Mauritius	Vanilla	*Furcifer pardalis*	PETR NECAS
USA, FL	Fort Myers	*Chamaeleo calyptratus*	PETR NECAS

Fog Drinking

As the discovered phenomenon has never been mentioned in the literature, and the likelihood, it applies to more lizard families exposed to high nighttime humidity (which is the case actually of many reptiles), regardless whether diurnal or nocturnal, it seems feasible to define a new physiological term: **Fog-Drinking**. It refers to the ability of reptiles, especially chameleons, and their regular practice, to hydrate using the capabilities of respiratory tract to resorb water from fog.

As indicated, the physiological basis of the fog drinking is very likely a combination of swallowing the condensate from upper respiratory tract and nebulization; the detailed explanation of the physiological mechanism is to be studied in the future. As a "black-box" approach so far, let us take as a fact, that fog-drinking is the actual reason is why chameleons rarely to never are seen to drink liquid water in the wild, and, is actually a reason why in captivity, on contrary, chameleons are considered as heavy drinkers, in need to compensate the hydration disbalance the available way, when the natural fog-drinking hydration way is not as a rule offered and facilitated properly.

Fig 5. *Chamaeleo arabicus* from Oman (NE of Salalah) in its natural biotope in fog at 9AM; Photo Petr Nečas

Chameleons' distribution pattern

A preliminary analysis of the weather patterns in regions, naturally inhabited by chameleons, allows us to make the following conclusion:

Chameleons inhabit regions with a typical circadian pattern, applicable at least 8 months in a year:

- relatively **dry daytime** (except for rainforests, and rainy seasons) with air humidity levels below 50%)
- significant **night-time drops of temperatures**,
- appearance of **air humidity over** 90% at night,
- **regular** appearance of **fog, clouds and mist**,
- at least in 50% of the days falling in the 8 months above mentioned.

For the majority of known species that inhabit special regions, such as the ones listed below, the pattern is very much the same:

1. **High mountain chameleon forms** of the alpine zone, *Erica*-zone such as *Trioceros harennae, kinangopensis, nyirit, ntunte, rudis, schubotzi.*
2. **Montane continental species** confined to various sub-zones of the afromontane forest or the s.c. cloud-forest, such as members of the genera *Trioceros* (e.g. *T. affinis, bitaeniatus, balebicornutus, conirostratus, fuelleborni, harennae, hoehnelii, jacksonii, johnstonii, montium, narraioca, quadricornis, serratus, sternfeldi, werneri, wiedersheimi, ...*), *Kinyongia* (e.g. *K. asheorum, excubitor, fischeri, matschiei, multituberculata, tavetana, tenuis, uluguruensis, uthmoelleri, vanheygeni, ...*), *Nadzikambia* (*N. baylisi* and *mlanjensis*), *Chamaeleo* (*C. dilepis* from high altitudes), *Rhampholeon* (*R. acuminatus, chapmanorum, nchisiensis, platyceps, uluguruensis, viridis*) and *Rieppeleon brevicaudatus*.
3. **Southern African** representatives of the genus ***Bradypodion*** (all known species).
4. **Mediterranean forms** of the genus *Chamaeleo* (*C. africanus, chamaeleon* incl. all its subspecies).
5. **Middle to high altitude madagascan species** of the genera *Calumma* (Tiny species of the *C. nasuta-linotum* complex; mid-sized *C. brevicorne, crypticum, malthe*; as well as huge *C. oshaughnessyi, parsonii, globifer*) and *Furcifer* (*F. campani, hilleniusi, lateralis, petteri, timoni, wilsii*)
6. **Lowland moist forest madagascan species** like representatives of the genus *Brookesia* (*B. decaryi, minima, superciliaris, therezieni, ...*)
7. **Lowland moist forest west African species** of the genera *Trioceros* (*camerunensis, cristatus, ...*) and *Chamaeleo* (*C. anchietae, quilensis, ...*).
8. **Seycheles endemic** *Archaius tigris*.

But, surprisingly, the climatic pattern also applies to species, in which it is not so obvious, such as:

1. ***Chamaeleo zeylanicus***, which is confined with its distribution either to (sub-)montane humid forested areas, montane isolates or desert oases with high level of subterranean water.
2. ***Chamaeleo calyptratus*** which is confined with its distribution to unique climate of the high altitude (1,000 - 2,500 m a.s.l.) "wadis" (from Arabian: deep valleys) having daily fog/clouds at night all year around despite of quite dry winter / dry season.
3. ***Chamaeleo arabicus*** which is exposed to the June-September Monsoon "Khareef" and living in

mountains and wadis with heavy fog at night.

4. Subsaharran members of the polytypic **species complex of *Chamaeleo dilepis*** (incl. subspecies of *C. dilepis* per se and independent species like *C. necasi, quilensis, ruspolii, ...*) and two sibling species *C. laevigatus* and *C. senegalensis*, all living in the semi-deserts and African bush covering the territory not fully and widely, but confined to areas where either a permanent or non-permanent river flows and subterranean water bodies often enable forming fog at night.
5. ***Chamaeleo gracilis*** confined (at least in E Africa) to the feet of high mountains, enabling the forming of the night fog either through sourcing the rivers flowing from these mountains or through daily drop down of the cold moist foggy air at nighttime from the higher altitudes above.

Fig 6. Harenna forest (top), Ethiopia from above hidden in clouds (fog) and building the biotope (middle) for two endemic chameleon species: *Trioceros harennae* (male)(bottom left and *T. balebicornutus* (female)(bottom right); Photo PETR NEČAS

And even true desert chameleons inhabit areas where fog is a regular appearance:

1. ***Rieppeleon kerstenii*** and ***R. robechii*** inhabit either foothills of bigger mountains or micro-enclaves with subterranean moisture
2. The **desert forms/populations of the genus *Chamaeleo*** (*C. africanus, calcaricarens, chamaeleon*) live either in desert oases or are confined to inundation areas of rivers and/or penetrate to higher altitudes and/or makes advantage of the coastal mist and fog along the Atlantic Ocean or Mediterranean Sea.
3. The Desert Chameleon, ***Chamaeleo namaquensis***, despite being often depicted sitting on dunes, lives in fact in belts, typical with extensive nighttime moisture and morning fog in particular (along rivers or coast) and does not penetrate areas without this specific climatic pattern other than marginally.

To be precise, chameleons might also be found outside of these areas, travelled there from the above-defined biotopes, where they reproduce. In areas without subterranean moisture they are (if considered the dryland inhabiting species) incapable to survive as a population, as the eggs need moisture to develop and if exposed to drought, they die. The viviparous species are confined with their distribution to cold regions either at high altitudes of equatorial African mountains (members of the genus *Trioceros*) or to regions within Mediterranean climate of Southern Africa.

The periods of the year, when the climatic circadian pattern deviates from the one postulated towards drought, the chameleons desiccate, starve to dead or even die.

Some species seek in these situations shelter with protection from high temperatures and with low airflow to prevent desiccation: e.g. *Chamaeleo dilepis* have been found dug in the soil, hidden in holes or under the stones. *Rieppeleon kerstenii* has been found in Marsabit NP in N Kenya under a stone in dry season (P. NEČAS, PERS.OBS.).

Some populations do not survive the hard pressure of the environment and die completely off to keep as a next generation merely the eggs in the earth waiting for the next rainy season to hatch. This phenomenon is known e.g. from *Chamaeleo calyptratus* in Yemen (NEČAS & MANCHEN 2020), *Chamaeleo ruspolii* in Somaliland (T. MAZUCH, IN LITT.), *Furcifer labordi* in SW Madagascar (ECKHARDT 2017).

To simplify, chameleons live long-term and reproduce only in areas, where the natural conditions allow in the majority of the year, on regular basis the appearance of fog (or clouds or mist), the exposure to cold humid air with contained small water particles is absolutely natural for them.

THE MYSTERY OF AIR HUMIDITY AND FOG

A simple experiment has been conducted in captivity to test to what extent the fog-drinking and related weight gains or losses related to the humidity of air and fog in combination, and separately. The results were surprising, but very logical. Captive chameleons of three species (*C. arabicus, calyptratus and zeylanicus*) where exposed, while sleeping, to three and humidity regimes:

1. Air humidity of 30 - 35%
2. Air humidity of 90 - 100%
3. Air humidity of 90 - 100% and fog produced by infrasonic foggers.

Analogically, like in the field study, the chameleons were weighed. We did this in the evening after they started to sleep (20:00-22:00) and then second time early in the morning (04:00-06:00).

Experiment 1

- **Regime:** Air humidity of 30 - 35%
- **Result:** All measured individuals lost significantly weight during the night, details are contained in the Table 2

Experiment 2

- **Regime:** Air humidity of 90 - 100%
- **Result:** All measured individuals remained exactly same weight the whole night

Experiment 3

- **Regime:** Air humidity of 90 - 100% and fog produced by infrasonic foggers.
- **Result:** All measured individuals gained significantly weight during the night, details are contained in the Table 2

The experiments in captivity allow us to make the following three principal conclusions:

The low night-time humidity causes water loss. The humidity of the air in the lungs at expiration is around 100%. While inspiring dry air, the lungs dry off from inside and compensate this loss in hydrating the tissues from internal reserves. This leads to water loss and desiccation. Chameleon skin is almost impermeable for water, so the only loss of water that happens either via defecating (the less excess water in the organism the drier the droppings are), urinating (the urates are partly white and partly crystalline orange, while the physiological share of the orange part comprises between 15 and 50%) and, mainly breathing.

Date	Species	Animal	Sex	Night fog Y/N	Evening weight in g	Morning weight in g	Net weight gain in g	Net weight gain in %	Average net weight gain in %
3.5.2018	*C. arabicus*	CALUF1	f	Y	143,1	144,0	0,9	0,63%	0,32%
	C. arabicus	CALUF2	f	Y	93,0	93,3	0,3	0,32%	
	C. zeylanicus	CZRUF	f	Y	125,5	125,9	0,4	0,32%	
	C. zeylanicus	CZRUM	m	Y	42,6	42,6	0,0	0,00%	
	C. calyptratus	CCRUF	f	N	73,0	72,5	-0,5	-0,68%	-0,51%
	C. calyptratus	CCRLF	f	N	63,0	62,9	-0,1	-0,16%	
	C. calyptratus	CCLLM	m	N	38,8	38,5	-0,3	-0,77%	
	C. calyptratus	CCLUM	m	N	24,8	24,7	-0,1	-0,40%	
4.5.2018	*C. arabicus*	CALUF1	f	Y	142,2	142,7	0,5	0,35%	0,36%
	C. arabicus	CALUF2	f	Y	94,5	94,5	0,0	0,00%	
	C. zeylanicus	CZRUF	f	Y	126,0	126,8	0,8	0,63%	
	C. zeylanicus	CZRUM	m	Y	42,9	43,1	0,2	0,47%	
	C. calyptratus	CCRUF	f	N	72,0	71,8	-0,2	-0,28%	-0,28%
	C. calyptratus	CCRLF	f	N	62,0	61,8	-0,2	-0,32%	
	C. calyptratus	CCLLM	m	N	37,9	37,7	-0,2	-0,53%	
	C. calyptratus	CCLUM	m	N	25,4	25,4	0,0	0,00%	
5.5.2018	*C. arabicus*	CALUF1	f	Y	142,9	143,3	0,4	0,28%	0,48%
	C. arabicus	CALUF2	f	Y	91,1	91,9	0,8	0,88%	
	C. zeylanicus	CZRUF	f	Y	124,3	124,4	0,1	0,08%	
	C. zeylanicus	CZRUM	m	Y	42,8	43,1	0,3	0,70%	
	C. calyptratus	CCRUF	f	N	70,9	70,5	-0,4	-0,56%	-0,52%
	C. calyptratus	CCRLF	f	N	62,4	62,1	-0,3	-0,48%	
	C. calyptratus	CCLLM	m	N	39,6	39,5	-0,1	-0,25%	
	C. calyptratus	CCLUM	m	N	25,9	25,7	-0,2	-0,77%	
6.5.2018	*C. arabicus*	CALUF1	f	Y	141,8	142,5	0,7	0,49%	0,31%
	C. arabicus	CALUF2	f	Y	92,3	92,7	0,4	0,43%	
	C. zeylanicus	CZRUF	f	Y	126,3	126,7	0,4	0,32%	
	C. zeylanicus	CZRUM	m	Y	43,4	43,4	0,0	0,00%	
	C. calyptratus	CCRUF	f	N	71,9	71,8	-0,1	-0,14%	-0,60%
	C. calyptratus	CCRLF	f	N	63,6	63,2	-0,4	-0,63%	
	C. calyptratus	CCLLM	m	N	40,0	39,8	-0,2	-0,50%	
	C. calyptratus	CCLUM	m	N	26,3	26,0	-0,3	-1,14%	
7.5.2018	*C. arabicus*	CALUF1	f	Y	144,0	144,7	0,7	0,49%	0,42%
	C. arabicus	CALUF2	f	Y	91,5	91,9	0,4	0,44%	
	C. zeylanicus	CZRUF	f	Y	128,7	129,1	0,4	0,31%	
	C. zeylanicus	CZRUM	m	Y	43,6	43,8	0,2	0,46%	
	C. calyptratus	CCRUF	f	N	73,0	72,6	-0,4	-0,55%	-0,57%
	C. calyptratus	CCRLF	f	N	63,2	62,9	-0,3	-0,47%	
	C. calyptratus	CCLLM	m	N	40,4	40,2	-0,2	-0,50%	
	C. calyptratus	CCLUM	m	N	26,6	26,4	-0,2	-0,75%	
AVERAGE	*C. arabicus*	CALUF1	f	Y	142,8	143,4	0,6	0,45%	0,38%
	C. arabicus	CALUF2	f	Y	92,5	92,9	0,4	0,41%	
	C. zeylanicus	CZRUF	f	Y	126,2	126,6	0,4	0,33%	
	C. zeylanicus	CZRUM	m	Y	43,1	43,2	0,1	0,33%	
	C. calyptratus	CCRUF	f	N	72,2	71,8	-0,3	-0,44%	-0,50%
	C. calyptratus	CCRLF	f	N	62,8	62,6	-0,3	-0,41%	
	C. calyptratus	CCLLM	m	N	39,3	39,1	-0,2	-0,51%	
	C. calyptratus	CCLUM	m	N	25,8	25,6	-0,2	-0,62%	

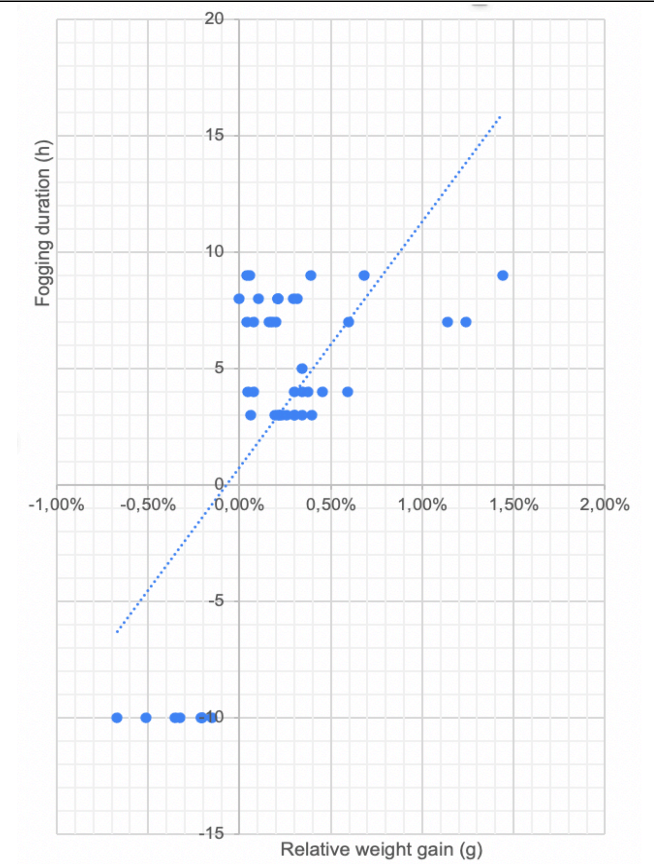
Tab 2. The results of experiments with and without fogging in captivity

The high night-time humidity prevents the water-loss. The high nighttime humidity serves primarily to the prophylaxis of desiccation and dehydration; it means it prevents the water-loss. The chameleons exposed to low humidity at night lose weight and show soon signs of severe dehydration. They have a high demand to drink the liquid water either the (semi-)natural way through licking the droplets of water from vegetation and objects or artificially through drippers, pipettes etc. The chameleons exposed to high humidity at night but with no fog, desiccate and dehydrate slower. They still have demand to drink the liquid water either the (semi-)natural way through licking the droplets of water from vegetation and objects or artificially through drippers, pipettes etc. The probable mechanism is simple osmosis. The humidity of the air in the lungs at expiration is around 100%. While inspiring dry air, the lungs dry off from inside and compensate this loss in hydrating the tissues from internal reserves. While if the air is also of high humidity, the tissues do not desiccate and do not loose water from internal reserves.

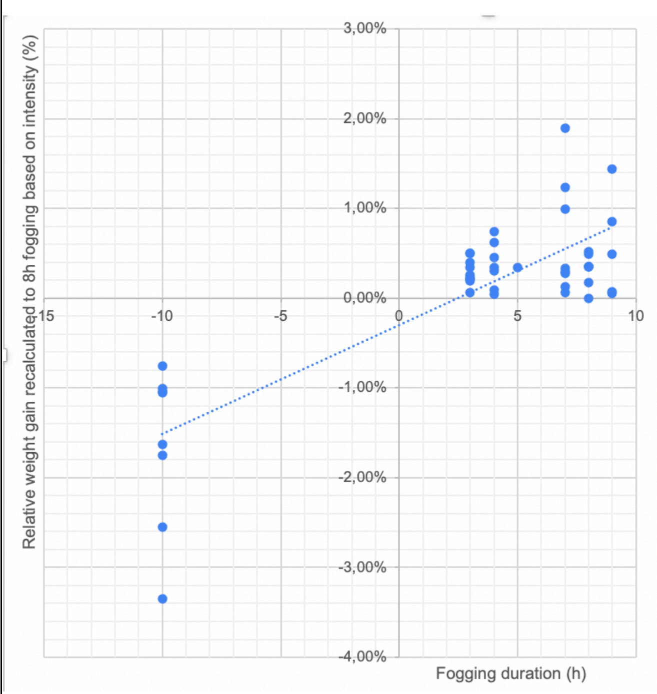
The night-time fog serves Fog-Drinking and hydrates. The night-time fog serves primarily to the hydration; it means it facilitates the water gain through Fog-Drinking. The chameleons exposed to fog at night gain weight and show signs of good hydration. They lose the demand to drink the liquid water and often stop drinking it at all even if water remains widely available.

An experiment lasting 31months with *Chamaeleo calyptratus* and 26 months with *Trioceros melleri*, when the animals were exposed to fogging by ultrasonic foggers from 1AM till 6 AM every day showed physiological urates, all signs of good hydration and executing all biological functions including repeated reproduction without any single drop of liquid water. How the actual water intake happens, must be a subject of further research. The probable mechanism is nebulization in the respiratory tract, very likely in the lungs. Another alternative is the condensation of fog in the nasal cavity and subsequent swallowing.

Hydration method	Desiccation	Hydration	Drinking
None	Yes	No	Intense, hysteric
High humidity	No	No	Occasional
High humidity and fog	No	Yes	Almost stopped



Graph 1. Relative weight gain during fogging in captivity



Graph 2. Relative weight gain recalculated to theoretical 8 hours of fogging in captivity, corrected by the intensity of fogging

To verify the results, another experiment was conducted, where the following colleagues from all around the world were involved: Filip Dvorský, Laramie Foster, Kasey Henzman, Petr Hrouzek, Stuart Miller, Rastislav Sedláček, Eva Žilková. The colleagues made semiadult and adult specimens of both sexes of the following captive species available:

Chamaeleo calyptratus,
Furcifer pardalis,
Trioceros quadricornis.

The principle of the experiment was to collect, under diverse captive conditions, data supporting or excluding the above-mentioned findings and exclude bias of one type of captive conditions at one keeper's facility. The task of the participating keepers were to make, upon availability, the evening and morning weight measurements (same as in the original experiments) of their chameleons, at different durations of fogging (measured by hours of exposure to fogging) and at diverse intensities of fogging (a 5 steps empirical scale was used to quantify approximately the intensity of fog from 0 – no fogging to 5 – maximum intensity fogging). In all animals, data were collected both during fogging as well as during nights with no fog and then, following main indexes were analyzed:

- Absolute net weight gain per specimen and night
- Relative net weight gain per specimen and night (related to its original weight)

- Relative net weight gain per specimen and night (related to its original weight and recalculated to 8 hours fogging period).

All data supported the previous findings and added the following insights:

- Low humidity at night without fog desiccates,
- Fogging hydrates,
- Intensity of hydration is directly proportional to the duration of the exposure to fog,
- Intensity of hydration is directly proportional to the intensity of fogging.

These observations can be made much more precisely and concretely if more rigorous experiments will be conducted focused on each discrete factor influencing the intensity of the hydration during the fog drinking. The aim of all these preliminary studies was to find out the main principle and logic, that is crucial for the captive and possibly other implications also and put a base for more detailed future studies.

Fig 7. *Chamaeleo monachus* (male) from Socotra (Yemen) sitting at 100% relative air humidity at night (top) and its biotope at Homhil with rising fog at 7AM (bottom); Photo Petr Nečas

Captive implications

In captivity, specifically in the predominant situation while keeping chameleons indoor, the classical (wrong, unnatural) practice, practiced till today by a vast majority of keepers and breeders, is to provide water at daytime in liquid form and at nighttime leave the chameleons to desiccate. The temperature regime supports this often.

The best example is the most frequently kept chameleon species nowadays, the Yemen chameleon, *Chamaeleo calyptratus*. The original population, from which the majority of captive animals are originating, is the vicinity of Ibb, Yemen (Nečas & Dvorak 2020), where they live in specific climate at an altitude of about 2,000m a.s.l. The average monthly daily temperature maximum ranges between 20°C in January and 28 °C in June, while the average monthly daily temperature minimum ranges between 8°C in January and 16°C in June. The months of October to March are very dry, followed by the small rainy season in April and May and the big rainy season in July and August. The weather, to which the chameleons are exposed, is therefore defined in general by very cold nights with high humidity levels all around the year and relatively warm and dry days with the exception of peeking rainy season in summer, when the daily humidity heavily fluctuates in dependence on whether it is raining or not.

If you look through the most of the care sheets recommendation of keeping the Yemen Chameleon in captivity, surprisingly, you'll find out in the majority of cases that the temperature recommended are confusingly wrong (Nečas & Dvorak 2020): they lay substantially higher for both daytime as well as the night time and the recommendation of hydration facilitated my misting or spraying it's recommended to do at daytime. Obviously, the cycles are totally reverse and do not reflect the natural conditions of the home country, because instead of cold and humid nights followed by warm and dry days actually in the opposite is recommended: warm and dry nights followed by hot and humid days. Logically, the metabolism of the chameleons at night speeds-up significantly, due to the higher temperatures resulting in higher heart rate and breathing frequency, which causes a very high-water loss. In other words, the chameleons experience in the result a hydration deficit, which is composed by two components:

1. The physical water loss and desiccation, caused by the above-mentioned mechanism
2. The 'non' received hydration due to absence of the natural conditions. Those being, low temperature, high humidity, and presence of fog.

It is, therefore, very logical, that this double deficit the chameleons tend to compensate by vigorous and unnatural drinking at the daytime, when the keeper offers them the water in the liquid form. Every single day, this way, the chameleon's homeostasis is unbalanced and forced to cope with the sinusoidal water management from overdesiccating at night and over-hydration compensating through drinking at daytime. The latter is done moreover in a shock-way, as the hydration doesn't occur slowly on the course of many hours (10-12 hours through fog-drinking) but within seconds or minutes (while ingesting big amounts of liquid water).

The water loss is compensated by hysterical and fast drinking. So, species in the wild must survive many months without any drop of liquid water, in-turn get the label of being heavy drinkers in captivity. Reverting the humidity cycles is unnatural and wrong practice and leads to collapse of homeostasis, health problems of various kinds (from renal failures, through osmosis induced micro-traumata of the intestinal tract and subsequent chronic light intestine inflammation, to respiratory diseases), discomfort and early death.

Fig 8. *Kinyongia multituberculata* (juvenile male) from Tanzania (Lushoto) in its natural biotope in fog at 2AM at perch height 20cm with condensing dew on its body; Photo PETR NEČAS

Stealth drinking:

Some breeders even practice a sort of soft forceful drinking methodology called "stealth drinking". This term has been discovered and propagated by TREVOR NEUFELD (IN LITT.) in diverse Facebook groups (especially "Chameleon Central" and "Veiled chameleon") and even supported by video materials.

The principle comprises directing so much water (through shower, sprayer, mister, garden hose) directly on the chameleon's head so that both nostrils as well as the whole mouth fissure is covered with a layer of running water.

This state is unnatural, and as such a situation that is never happening in the wild, if it does, it's only by rare accident. Chameleons do not expose themselves deliberately to water in any form including rain, as it has been demonstrated and explained above.

While being exposed to the water touching firmly their head, they:

- **close** their **eyes**,
- **retract** the **eyes** deep into the eyeholes,
- reflexively "**freeze**" and
- remain in this state of "**akinesis**" for some time.

The necessity to breathe initiates then the following sequence of actions:

1. The chameleon starts to breathe trying to inhale while the mouth is closed. As its nostrils are covered with water, it sucks some water inside the upper respiratory tract.
2. The inhaled water runs through the nasal cavities to the laryngopharyngeal crossing and is passed to the mouth and throat.
3. Water, suddenly appeared in mouth causes reflexive swallowing
4. Blockage of nostrils disabling to inhale causes the opening of the mouth to enable breathing
5. Through opening the mouth fissure, even more water is sucked into the mouth and swallowed.
6. This process continues until the chameleon cannot swallow more water and it runs out of its mouth or until the reflexive akinesis is relieved and it escapes from this situation.
7. Often, it stops nearby, elevates the head in a special position trivially called "stargazing", stretches the throat and follows pushing the water deeper in the digestive tract with swallowing movements.

This mechanism is clearly enabled through the anatomical features common to terrestrial vertebrates but not evolved to do so, it is just an artifact of it. All reptiles, birds and mammals can do so, even humans can inhale water through nostrils, but logically never utilize this way.

It is unnatural, forceful and harmful: it causes sudden heavy hyper-hydration and osmotic damage of tissues in the nasal cavities, therefore, it is to be considered an unacceptable captive practice by NC.

The hyperhydration leads to following disorders:

1. Breakdown of the homeostasis
2. Breakdown of the balance in body liquids in lowering their concentration
3. Edematic swellings
4. Impossibility of re-filtration of primary urine
5. Rupture of cells through osmosis
6. Breakdown of digestion through excess water and osmotic damage of the enterocytes

The argumentation of some breeders practicing this way of hydration is, that their chameleons deliberately seek this position in the stream of water. They would never do if they would be hydrated naturally, plus, if this is the only or one of the few options offered or forced to, they have no other choice than to accept it and then they react reflexively as described.

In the nature, the presence of such hydration sources is anecdotal in chameleons' environments; chameleons as a rule do neither drink from water bodies, nor from waterfalls.

Such practice is from the principles of NC to be considered as inacceptable

Fig 9. Yemen landscape around Yarim covered with fog in the morning, biotope of *Chamaeleo calyptratus calyptratus* in the middle of dry season at 10AM; Photo PETR NEČAS

From the above mentioned, the implications for the Naturalistic Chameleonoculture are obvious. Instead of reverting temperature and humidity cycles and compensate the water deficit with excessive unnatural drinking, it is necessary to provide the natural gradients and forms of hydration same as in the wild:

1. Cold temperature, high humidity, fog at night,
2. Warm temperature, low humidity at daytime.

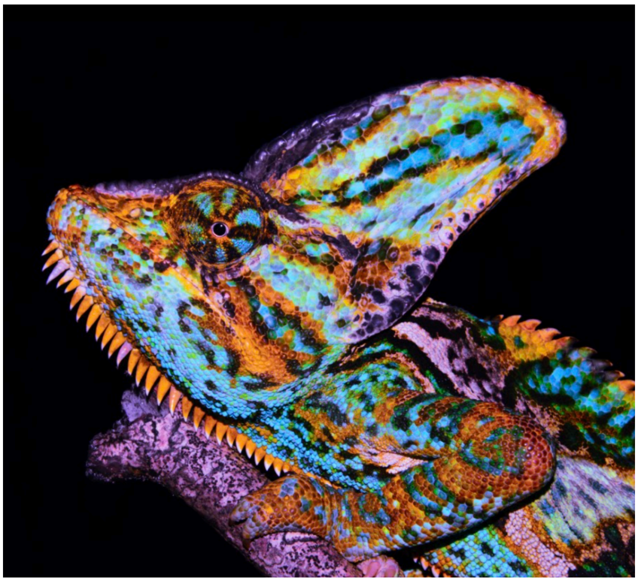


Fig 10. *Chamaeleo calyptratus calyptratus* (male), Florida (USA) feral specimen; Photo PETR NEČAS

In terms of hydration, therefore, within CN, a safe hydration approach is recommended:

1. Fog at night
2. Mist at dusk and dawn
3. Provide drops of water during daytime
4. Monitor and adjust

Fog at night

Use fogger at night at low temperatures.

Foggers (electronic, ultrasound piezoelectric nebulizers) are to be used properly, as my experiments and long-term practice shows, respecting the following rules:

- exclusively at night, never at the daytime except of early morning hours;
- exclusively at temperatures below 20°C;
- always with good airflow and ventilation.

In mesh cages, the fogger can run uninterrupted for several hours, in glass terrariums, either a force movement of air by ventilators are practiced or intermittent fogging with pauses in-between.

Allow a weak light source resembling low moon light in the facilities where chameleons are kept, either through window and access to moonlight or with a small light source. Chameleons have been repeatedly observed to find the stream of the fog at night to change their original sleeping position and move to a place where the fog is more intense (RADEK FRÝŽELKA IN VERB, EVA ŽILKOVÁ IN LITT, PETR NEČAS PERS. OBS.). It however does not happen in totally darkened facilities.

Fig 11. *Chamaeleo calyptratus calyptratus* (male), captive specimen; exposing himself to a fog stream at night; Photo EVA ŽILKOVÁ

I have used foggers since early 1990s on the base of piezoelectric ultrasonic nebulizers, the first were obtained from medicinal nebulizers used in human medicine, then they started to become available commercially. The experience of myself and during the years of hundreds keepers and breeders, that I have either advised and supervised (e.g. P. BROCKSCHIEDER, A. REIMANN, R.R. JOHNSSON, M. JOHNSON, C.E. MAES, A. SCHMIDT, R. RICCI, J. DUBAY, A. DIUROV, N. ARNOLD, M. WENDSCHE, M. SAVONCHIK, J. VAN OVERBEKE, B. ŠAMONILOVÁ, T. MANN, E. ANDRIGNOLA, B. STRAND, B. COCHRAN, K. PATEL, S. MILLER, K. RASMUSSEN, U. NUNN, F.S. LEON, J. GENTILLE, J. MOKRY, N. LUCAS, N. NORRIS, A. DUNN, T. JAKUBOV, G. TAYLOR, F. HERREL, D. CAHEN, P. HROUZEK, Z. SAUEROVA, J. SLAVIMRAD, J. SAJFRTOVÁ, M. REŽNÁ, T. BORBELYOVÁ, E. HOLASKÁ, V. VACHRLON, M. MISKUFF, E. ŽILKOVÁ, P. KREJČA, P. DVORÁK, P. NAGY, IN LITT.) or came to same conclusions independently (M. JUNGMANN, D. TAMURA IN LITT.) is very consistent:

- animals perfectly hydrated,
- tendency to sleep directly in the fog stream,
- no health issues in terms of fungal or bacterial skin or respiratory infections,
- heavy reduction of drinking to stopped drinking even if offered and permanently available in the natural form of drops on the vegetation,
- perfect shedding,
- strong health,
- resistance to parasites infections (in captive born animals)
- tolerating natural parasite faunas (in wild-caught, captive animals)
- higher age achieved than in animals kept "traditional way".

Mist at dusk and dawn

Mist in the early morning and late evening,

means before the heat lamps go ON and after they go OFF. The morning misting might simulate the natural dew, some species have been reported to drink in the wild. Evening misting simulates the evening increase of humidity. In the most species, misting at daytime is not necessary. And, it brings several technical, as well as physiological annoyances.

Technical annoyances:

- automatic misters are relatively complex and sensitive technical devices, that can break,
- if tap-water is used, the nozzles can get blocked by stain, salts and cause either un-functionality or wrong stream or inability to close,
- misters while using tap-water stain the glass and interior of the cages (the two points above can be solved or partly solved by using demineralized water, reverse-osmosis water or distilled water),
- While automatic misting, big amounts of water usually are used, that cannot be adopted by the environment of the cage itself and a drainage system must be installed to get rid of excess water,
- Automatic misting systems can negatively interact with other technical, especially electric devices in the cages.

- Misting in mesh cages usually contaminates with water penetrating the mesh the surrounding walls, ceiling, floor etc.

Physiological annoyances:

- Automatic misting might increase the air humidity for too long and at unnaturally high levels and if used at high temperatures, or, while heat sources are ON, it can contribute to and/or initiate respiratory diseases, as well as skin mycoses and bacterioses. If for whatever reason, daytime misting is practiced (simulation of rainy season, rain, too low ambient humidity of the facilities etc.) it must be practiced that heat sources and light sources are switched off several minutes before misting, and then switched back on several minutes after, to prevent the bad combination of high temperature and high humidity, known as precursors of respiration infections – and of course, to protect the electric devices from damage.
- Pressurized water is never found in nature and as such it must be considered as unnatural.
- Pressurized water can (and does) penetrate the eyes and causes osmotic damage of the conjunctive tissues and eye discomfort or even inflammations. If the chameleons to appears too close to a nozzle, the sudden strong stream of pressurized water can even cause trauma in his eyes or in case of very small chameleons also on other parts of the body.
- In small chameleons or babies of larger species, the excess water in the environment can lead to the drawing in a drop of water, which is forming around their mouth and nostrils. If the water covers their bodies, their reflective behavior is to turn with the head down.
- Misting systems spray water around and spray also chameleon bodies, that causes stress and discomfort, as chameleons try to avoid the contact with anything, including water - as explained above.
- Misting systems can easily oversaturate with water the interior of the cage and can cause complicated and long healing plantar infections and lesions, the more intensively the more unnatural equipment, like mossy vines, ropes and artificial plants are used.
- Excessive water in the cage as result of misting can cause mold and especially in case of absorbent material like dead moss, ropes, fabric, artificial plants, they can, together with biological dirt and dust become breeding grounds and a contamination source of bacteria and fungi, that not only increase the concentrations of their reproductive and infectious stadia in the cage itself, but can contaminate also the facilities, often placed in living space of humans. This way, they can be sources of discomfort, smell, allergies or infections for both the animals as well as keepers and other inhabitants of the space, such as pets or family members.

Providing drops of water during daytime

Allow dripper for safety.

The 2nd NC axiom is “In doubt go safe”. Even if all the hydration methods before work, there is still a change that something goes wrong, or, that something unexpected happens. So, for any case, as a backup, it is advisable to provide for safety a dripping water for the chameleon to have the opportunity to drink, if necessary or if it chooses to.

Monitor and adjust

Observe the condition and behavior

of the chameleons and the quality of urates and excrements and adjust the water supply methods and amounts and timing if necessary. Correct hydration is extremely important for wellbeing of the animal, while both overhydration as well as dehydration are destroying the homeostasis and lead to discomfort, failure of organs, and eventually death.

Appearance

One of the best indications of chameleon dehydration is their appearance. There are several diagnostic factors:

General appearance: dehydrated chameleons look skinny with bones and muscles visible under the skin, Hyperhydrated chameleons appear edematic.

Color: Healthy animals have vivid colors. Dehydrated animals usually turn light, pale (probably to prevent heating and water loss); hyperhydrated chameleons become usually dark (probably to attract heat rays which would help them, to evaporate more)

Skin texture: The skin of well hydrated chameleons is stretched over underlying structures, especially bones and muscles to cover them and becoming visible only while moving. Dehydrated chameleons look skinny with muscles and bones clearly visible under the skin. Overhydrated chameleon skin might look edematic, swollen, or even build a gular edema or edematic swellings of the limbs and in the pelvic region.

Skin elasticity: The hydrated skin is stretched and elastic. If folding a piece of skin, it immediately turns back to original position. Dehydrated chameleons can develop various wrinkles and skin folds and the skin, if folded with two fingers build a fold that remains existent for several seconds and turns back only slowly. Hyperhydrated chameleons can develop skin that seems to move on the body of the chameleon unnatural way and even hand freely and not stretched way.

Eyes: Well hydrated chameleons have their lid turrets naturally protruding from the sides of the head and will be active and movable. Dehydrated chameleon can retract the eyes deep into the eyeholes and the eyes become slightly closed and less movable. Hyper-hydrated chameleons might develop preocular or circumocular swellings or can remain with eyes edematically enlarged and bulged outside, especially after sleeping head down.

Behavior

A healthy and hydrated chameleon is contrary to the general belief quite passive. Dehydrated animals tend to be nervous, hyperactive, descending to ground; and if offered water, usually forgetting their shyness to hysterically drink for long time. Heavily dehydrated animals become apathetic, lethargic, sleepy, weak, may fall from branches or even stay in the branches or on ground laying in unnatural positions motionlessly.

Urates

In the captivity, we often hear, that orange crystalline urates should be absent and he whole urate deposit should be white like toothpaste... The composition of urates (incorrectly and too simplified) is taken as main or only indicator of the hydration level of captive chameleons, it is just one of the valid factors to be assessed.

Based on wild observation and extensive captive experiments and observations, the physiological norm of the volume-share of orange crystalline urates is between 15 and 50%. A heavily dehydrated animal can have more than 50% of the urate's orange and crystalline, while when its portion is reduced to less than 15% or even urates become completely white, the animals is overhydrated.

Fig 12. *Chamaeleo zeylanicus* from India (Bengaluru) natural faeces and urates in the dry season; Photo PETR NEČAS

Excrements

The physiological appearance of an excrements from the point of hydration is to be assessed based on the following aspects

- **Color**: Black (not light brown, yellowish)
- **Consistency**: Compact (not sluggish, soft, watery, flexible)
- **Water content**: moist to dry (dehydration leads to completely dry poop, overhydration leads to sluggish, watery, soft poop)

FOCUS ON FOGGERS

Fog and mist are a visible aerosol consisting of water droplets suspended in the air, usually near the surface. In principle, it is a type of low-lying cloud; in high altitude it is really a cloud. Fog reduces visibility to less than 1km, whereas mist is more transparent. Fog and mist (thus clouds) form, when the difference between air temperature and dew point is less than 2.5°C and the air has relative humidity near 100%. This happens either from added moisture in the air or falling ambient air temperature. At 100% relative humidity, the air cannot hold additional moisture and if the temperature further falls, or additional moisture (e.g. through evaporation) is added, the excess water is expelled and forms liquid tiny particles or dew/mist on surrounding objects, of lower temperature than the ambient one.

Some plants, forests and animals hydrate on fog as a principal source of water, particularly in otherwise desert or semi desert climes, as along many African and American coastal areas.

Cloud, fog and mist droplets are very small. Their mean diameter is typically only 10-15µm but in any individual cloud, fog, mist the individual drops range greatly in size from 1 to over 100µm (GULTEPE 2007; MUHAMMAD & AL. 2007)

In the practice, a nighttime aerosol of air and water droplets can be so dense that it reduces visibility to several meters (fog by definition)(mountain ranges of Yemen, Oman, Tanzania, Ethiopia, Kenya, RSA, Madagascar; coastal regions like Morocco, Spain, Namibia, RSA, Mauritius) or being present as mist and visible from several kilometers perspective only (Ambanja region in NW Madagascar, lowland coastal forest on Kenya coast)(P. NEČAS PERS. OBS.).

There are several technologies that are used for creating fog artificially for commercial and medicinal use. The medicinal nebulizers are used for delivering drugs for treatment of asthma, respiratory diseases, cystic fibrosis etc. through inhaling the fog with medicaments with the lungs. They are in general called nebulizers. Hydroponic foggers are used for transporting nutrients to plant roots in hydroponic cultures, their function is called aeroponics or fogponics. And there are fogging devices used for household, called foggers or humidifiers or nebulizers – the terminology is used chaotically.

There are basically three main technologies, that are used for creating fog:

- the high-pressure fogging,
- ultrasonic chip ceramic atomization and
- ultrasonic piezoelectric nebulization.

For the purpose of herpetoculture in general and Naturalistic Chameleonoculture, the latter comes to use.

In general, the nebulizers produce fog with particles in the size range of exactly the span of natural fog: from approx. 1 to over 100µm: e.g. FOGMASTER foggers produce particles of 7-10µm (dry fog), 10-15µm (intermediate fog) to 30µm and more (wet fog); ENTECH foggers produce particles from 0.5µm to 30µm; Electro-Tech-Online foggers produce particles in the range of 5-15µm with ultrasound and 5-50µm through their high-pressure technology. KOOIJ & AL. (2019) analyzed ultrasonic chip nebulizers from different fabricants and report about particle sizes from 1.1µm to 56µm.

Fig 13. *Kinyongia tenuis* from Tanzania (Amani, East Usambara Mts.), sleeping in fog in the dry season; Photo PETR NEČAS

From the above-mentioned facts it is obvious, that artificial systems producing fog or mist deliver the water particles all equal size as formed in the wild. Therefore, the usage ultrasonic piezoelectric or chip foggers is safe and recommendable from the perspective of NC. The experience counted in decades (P. NEČAS, PERS. OBS.; M. JUNGMANN, P. NAGY, P. DVORÁK, IN LITT.) as well as the recent, several months to years old experience of hundreds and thousands of keepers and breeders around the world, initiated by the philosophy of the "Naturalistic hydration in chameleon husbandry" by myself and heavily supported by educational activities of BILL STRAND (2018) and numerous colleagues, shows us that the benefits are obvious and risks are not appearing, if fogging is practiced using the three above mentioned rules, that just codify the imitation of natural processes in the wild.

Of course, there are some opponents what this method and they vocalize their opinions usually enclosed social group so that it is hard to get access to them. In general, they raise some issues that are off solely political basis and referring about non-documented cases of problems tied perhaps with fog. The argumentation is however as a rule very shallow, because they do not speak about experience but about theory. As an example, MADCHAM (2014) publishes a very negative account advocating against foggers. The text has been (probably several times) changed, so the 2014 mark is not true; the recent version brings so many inaccuracies and totally not backed and not referred to any single source, that it is hard to discuss it. The main issue is they declare they have never used and tested it, so their whole campaign against foggers, including their argumentation against the water intake through breathing remains a blank statement with no validity. A much more valid debates took place at CHAMELEON FORUMS (2020a,b), all commenting the right logic of fogging in the night and being cautious before more data will be available to justify the practice.

There are several possible constraints of the night fogging or usage of foggers in general:

Germs dispersal

While turning the liquid water into tiny droplets on the ultrasonic membranes, not only water gets into these droplets but also anything else included in it initially (like salts, chemicals, dust particles, germs) becomes a part of the droplets and the fog itself too. This is one of the most of vocal arguments of the opponents of this method, stating that through this process, we would deliver the germs deep into the lungs and make it easy for them to enter the body. In theory, it is at least partly true. However, there are arguments against and mitigation methods.

- To become the integral part of the droplet, the germs would necessarily need to be contained in the water initially. It is absurd to think that a breeder would deliberately use for hydration of his animals a heavily contaminated water. The water can however get contaminated by negligence or by accident. Fortunately, studies have shown the evidence the vast majority of germs are killed by in the interaction with the ultrasonic membrane due to damage of their body walls. So, these devices actually efficiently sterilize the water turned to fog. (ACHOOALLERGY 2020) Caution is always advised if using water, to check its quality and safety.
- For bacteria growth, something to metabolize is necessary, so if using distilled water, almost no bacteria can be inside and if, they cannot reproduce and are anyway inhibited in their life due to the hypotonic environment.
- Same as above applies to reverse osmosis water

- Not to contain germs, the water can be treated either with chemicals or (better) with sterilization laps based on UVA,
- If infection of animals with germs transferred by fog from fogger happens (extreme cases), then not the method is the reason, but the extreme contamination of the water used.

Bacteria growth in containers

A further danger is that there will be bacteria growing inside of the water containers. This is a real possibility, however heavily mitigated that foggers are usually water reservoirs that do not carry much water (2-4litres on average), so that the water must be refilled almost daily. Possible negative effects of this kind can easily be reduced to minimum by these solutions:

- using distilled water,
- using demineralized water,
- regular cleaning of the container mechanically,
- regular cleaning of the container with vinegar and water,
- regular sterilization of the container with UVA (e.g. InMyBathroom 2020),
- regular sterilization of the container with Ozone (e.g. SoClean 2020).

Bacteria growth in tubes

A further danger is that there will be bacteria growing inside of the water tubes directing the fog to cages. This is a real possibility, but easily to be reduced to minimum. Besides of the above-mentioned sterilization approach and application of distilled or demineralized water, the following possibilities are there:

- using distilled water,
- using demineralized water,
- regular cleaning of the tubes mechanically,
- regular cleaning of the tubes with vinegar and water,
- optional sterilization of the container with UVA (e.g. InMyBathroom 2020),
- optional sterilization of the container with Ozone (e.g. SoClean 2020).

Fogger suspect from causing RI

Opponents argue often with the belief that the use of foggers will cause RI. There is no single case described of this happening. Even in discussions within Chameleon Forums (2020a), this suspicion was even presented with the argumentation, that RI are often observed in animals from very wrong captive conditions, sometimes using foggers. First, there is no proof presented that there is any link between the RI and the fogger as such, so it must be considered as disjoint events.

Second, much more likely, the development of RI was reasoned by the wrong captive conditions rather than the fogger itself.

Third, if at all, the fogger played a role in that event, then very probably due it's wrong usage.

Fig 14. *Kinyongia multituberculata* (male) from Tanzania (Lushoto, West Usambara Mts.) in fog at night (top) and its biotope in the morning hours; Photo Petr Nečas

Foggers are recommended to be used at low temperatures, when the activity of bacteria including their reproduction is inhibited, as it is dependent on temperature. In case of using it in highly contaminated environment, at high temperatures, insufficiently ventilated cages and at daytime, it may well contribute through increasing the humidity to the development of R.I but will not cause it by any means. Again, not the fogger is causing it but its inadequate use in combination with wrong captive conditions. To prevent RI being in any relation with the fogger, following measures should be taken:

- use the fogger at night only (never use at daytime),
- use the fogger at low temperatures (meaningful for the species and the season) under 20° (never use at high temperatures or in combination with IR emitting devices, never use heated foggers or switch the heating function off),

- use the fogger in well ventilated cages with enough gas exchange and airflow, facilitated either by construction (mesh, ventilation openings) or/and by forced airflow (fans, chimney-effect) (never use foggers to create steady moist environment with no or bad airflow),
- provide gradient (the animals, though foggers are used at night, when they are inactive) are repeatedly reported to actively seek the stream of fog; provide them various places, where they can choose the level of fog exposure,
- provide alternative: provide places where the animals can hide and get rid of the influence of fog eventually (though in the wild this is not the case).

Fig 15. S Pare Mts. In N Tanzania, viewed from the northern rim of West Usambara Mts.) showing the low clouds at its slopes at 7AM; Photo PETR NEČAS

Tap-water mineral pollution

In case the tap water is used for the fog production, not only water particles appear but they contain also all the salts dissolved in the water. While drying on the interior of the cage including branches and plants, stains are deposited causing mineral pollution. These stains are more on less of aesthetic value but can also built up breeding ground for germs and limit the functionality of some parts of the cage, lights, electronic instruments etc. This negative effect is easy to avoid in:

- using distilled water,
- using demineralized water.

Interaction with ultrasound vibrations

Though no reports on any observation have been made public, that chameleons would react on foggers vibrations any way and all devices in question are suitable and certified for use in human occupied facilities and are reported as almost sound-free, the following measures remain feasible:

- place fogger always outside of the cage,
- do not place the fogger immediately on the cage,
- use some soft, vibration absorbing material like felt or fabric to isolate the fogger from firm surroundings.

Fig 16. Coastal mist on the Atlantic Ocean coast S of Agadir (Morocco), biotope of *Chamaeleo chamaeleon chamaeleon* in September (summer) at 9AM; Photo PETR NEČAS

Price, availability, affordability

Nowadays, the price of foggers used for individual captive care for reptiles vary between 30 and 120 USD, with more pricey industrial solutions for a big fogged volume. They are widespread, widely available and cheap.

Warranty/longevity

A regular fogger can easily stay functional even without extensive cleaning and warranty for several years. Then, it can be either refurbished or replaced. As relatively simple devices with few parts and simple regulation only, they do not brake often.

Fig 17. *Chamaeleo arabicus* from Oman (N of Salalah) in its natural biotope in mist at night, condensing on its body during Khareef; Photo PETR NEČAS

Conclusions

The provided evidence and logic allow us to make the following conclusions:

- the natural hydration cycles for chameleons reflect the natural cycles with dry daytime and humid, often foggy or misty nights,
- majority of chameleons lives in regions and biotopes, where aerosols of air and water particles of different size are o\present in majority of night during the year,
- chameleons sensitively react on the air humidity by desiccation or keeping the previous hydration level in dependence from ambient humidity during the nighttime,
- chameleons hydrate during the night through inhaling aerosols through newly described mechanism named fog-drinking,
- prevalent practice of chameleon captive management reverts the circadian humidity cycles, which has negative influence not only on water management but also on health and longevity,
- fogging at night, at low temperatures and with enough airflow is a practice, that is (to be) extensively added and recommended for the captive management of chameleons,
- fogging, as described, is compliant with the principles of Naturalistic Chameleonoculture,
- fogging as described brings numerous benefits and no negatives, potential risks are all easily to mitigate.

Acknowledgements

Many colleagues have helped me in organizing trips, experiments, providing field support, advice and data, of all, especially the following I am deeply indebted to: Chris Anderson, E. Andrignola, N. Arnold, F. Von Baalmoos, M. Bailey, Y. Benafrar, T. Borbelyová, P. Brockschieder, D. Cahen, C. Cattau, B. Cochran, A. Diurov, J. DuBay, A. Dunn, C, Durbin, P. Dvorák, G. Fritzsche, R. Frýželka, J. Gentille, M. Grimm, F. Herrel, T. Hoang Minh, E. Holaská, P. Hrouzek, N. Iakovleva, T. Jakubov, R.R. Johnsson, M. Johnson, M. Jungmann, P. Krejča, S. Lasapicho, F.S. Leon, N. Lucas, N. Lutzmann, C.E. Maes, T. Mann, O. Marushiak, S. Miller, M. Miskuff, D. Modrý, J. Mokry, P. Nagy, D. Nečas, N. Norris, J. Van Overbeke, K. Patel, S. Prokopiev, K. Rasmussen, A. Reimann, M. Režná, R. Ricci, B. U. Nunn, J. Sajfrtová, Šamonilová, Z. Šauerová, M. Savonchik, Schmidt, A. Shiriaeva, J. Slavimrad, B. Strand, J. Stipala, D. Tamura, G. Taylor, D. Tkachev, V. Vachrlon, M. Wendsche, E. Žilková.

Fig 18. *Chamaeleo arabicus* from Oman (W of Salalah) in its biotope in fog at night (top, middle), during Khareef (bottom), when Indian Ocean Monsoon reaches Dhofar Mts.; Photo Petr Nečas

Literature

ACHOOALLERGY (2020) Humidifier buying guide. https://www.achooallergy.com/blog/buying/humidifier-buying-guide/ (29. 04. 2020)

CHAMELEON FORUMS (2020a) Naturalistioc hydration. https://www.chameleonforums.com/threads/naturalistic-hydration.173365/ (29. 04. 2020)

CHAMELEON FORUMS (2020b) Foggers, a Tool or a Danger? https://www.chameleonforums.com/threads/foggers-a-tool-or-a-danger.173556/ (29. 04. 2020)

ECKHARDT, F.; KAPPELER, P.M.; KRAUS, C. (2017) High-ly variable lifespan in an annual reptile, Labord's chameleon (*Furcifer labordi*)". *Scientific Reports*. **7** (1): 11397

ELECTRO-TECH-ONLINE 2020 https://www.electro-tech-online.com/threads/piezoelectric-transducer-ultrasonic-fogger-for-fogponics.133998/ (29. 04. 2020)

ENTECH 2020 https://www.entech.cc/thermal-vs-ulv-cold-foggers (29. 04. 2020)

FOGMASTER (2020) https://www.fogmaster.com/faq.htm (29. 04. 2020)

GULTEPE, I. (2007): Fog and Boundary Layer Couyds: Fog visibility and Forecasting. – Birkhauser Basel – Boston – Berlin: 308pp.

IN MY BATHROOM (2020) https://www.inmybathroom.com/?gclid=Cj0KCQjwy6T1BRDXARIsAIqCTXpnSNCJyrZfuHDeV8bh4KSwL8vxKfA6XELwcYyLPGD3lqXp4fzvqK4aAiRjEALw_wcB (29. 04. 2020)

KOOIJ, S., A. ASTEFANEI, G.L. CORTHALS & D. BONN (2019) Size distributions of droplets produced by ultrasonic nebulizers. – Scientific reports. Nature Research https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6468117/#__ffn_sectitle (29. 04. 2020)

MADCHAM (2014) Fog and foggers. https://www.madcham.de/en/nebel-und-nebler/ (29. 04. 2020)

MUHAMMAD, S.S., B. FLECKER & E. LEITGEB (2007) Characterization of fog attenuation in terrestrial free space links. - Optical Engineering 466, 66001

NEČAS, P. & K. MANCHEN (2020) A Myth about longevity of chameleons unleashed: Chameleons live long! - Archaius 1 (2): 8-12

STRAND, B. (2018) Ep 90: Naturalistic Hydration for Chameleons. – Chameleon Breeder Podcast. https://www.chameleonbreeder.com/podcast/ep-89-naturalistic-hydration-for-chameleons/ (29. 04. 2020)

SOCLEAN (2020) https://www.soclean.com/ (29. 04. 2020)

STRAND, B. (2019) Ep 110: Fogging and airflow with Mario Jungmann. – Chameleon Breeder Podcast. https://www.chameleonbreeder.com/podcast/ep-110-fogging-and-airflow-with-mario-jungmann/

Fig 19. Chameleon in the mist - *Chamaeleo arabicus* in the vicinity of Salalah, Oman; Photo PETR NEČAS