Temperature tolerance of captive salamanders during a heat wave

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INTRODUCTION

The summer of 2003 was the warmest summer The Netherlands has experienced in a long time. Between July 31 and August 13 the maximum temperatures recorded in De Bilt (near Utrecht, in the middle of the country) reached a daily average of at least 25.0°C ('summer day') and on seven days in this time period temperatures of 30.0°C ('tropical day') or higher were recorded. Those seven tropical days constituted a record high for August in De Bilt. This heat wave caused 12 consecutive tropical days in Arcen (near Venlo, in the southeast of the country). In fact, on three days the temperatures in Arcen exceeded 37.0°C (data by the Dutch meteorological service KNMI, http://www.KNMI.nl/).

After visiting Marc Stenssen, where I noticed that his recently metamorphosed *Triturus karelinii* were in the water at temperatures of more than 30°C and looked fine, I thought that it would be interesting to find out if the intense heat was causing any problems with the salamanders belonging to other members of the Dutch Salamander Society (Salamandervereniging). After all, the textbooks on salamander captive maintenance state that temperatures exceeding 25°C should be avoided as much as possible (e.g. RIMPP, 1985; GROSSE, 1994).

At that time, The Netherlands had already been subject to almost two weeks of tropi-

Outdoor enclosure for terrestrial salamanders.

Photo: S. Bogaerts

cal temperatures. Any problems caused by these high temperatures should be noticeable by this time. Therefore, I sent out an email on Monday August 11 to the members of the Dutch Salamander Society requesting they monitor the temperature changes in their terraria and aquaria. I also asked them to note any problems that had arisen with their animals. Twelve members replied and sent me their data. The results of this inquiry and a discussion of the role temperature plays in the life of a salamander are presented in this article.

Indoor enclosure for terrestrial salamanders.

Photo: S. Bogaerts

METHODS

From August 12 through August 15, seven members of the Dutch Salamander Society kept track of the minimum and maximum temperatures in their terraria and aquaria. Others did not read their email in time or could not measure the temperature precisely. They supplied me with more general descriptions of the course of events, which I have incorporated in with this text. Temperatures were measured in the early morning (lowest temperature) and evening (highest temperature). Tuesday August 12 turned out to be the last of the tropically hot days, and temperatures after that date gradually returned to 'normal' summer temperatures. Since the heat wave had been ongoing for two weeks by August 12, it is safe to assume that temperatures similar to those measured on that day had prevailed for the two weeks prior. Therefore, I will present only the temperatures measured on August 12 to illustrate the extremes. However, it can be assumed that the salamanders had endured similar temperatures for the two weeks leading up to this date. Of course, one cannot simply compare all these temperatures at face value, since the thermometers used were not calibrated. However, the numbers give a decent indication of the types of temperatures salamanders can endure.

RESULTS

I would like to distinguish between indoor and outdoor tanks. Indoor tanks are better protected from heat but also require more time to cool down. Outdoor enclosures, on the other hand, are subject to larger fluctuations in temperature.

Indoors

All of the survey participants mentioned that the temperature inside their salamander rooms remained around 28°C during the day and around 25°C at night (see table I). Only one of the participants reported a temperature that was several degrees higher. The overall picture seems to be that adult animals become inactive with an increase in temperature. On land, there seemed to be hardly any noticeable activity. The animals often burrowed down (*Ambystoma tigrinum*) or were hidden (*Mertensiella luschani*, *Triturus marmoratus*).
In the water, adults were often seen floating near the water surface or crawling onto land. The adults hardly ate, although juveniles took food. References to a similar situation in the wild could not be found.
Adult *Triturus carnifex, Triturus karelinii* and *Triturus marmoratus*, kept under aquatic conditions by one of the participants, were mostly seen at the water surface and climbed onto floating islands more frequently. This behaviour could indicate a lack of oxygen in the water. Juveniles did not display this particular conduct. None of the adults ate during this period. When the temperatures returned to a normal level by the end of the survey period, adults ceased to float near the water surface and frequented the bottom again. They also resumed eating. Temperatures had by then dropped to around 21°C. This behaviour appeared to occur in a similar fashion in all

Species	Aquarium (A) Terrarium (T) Aquaterrarium (A/T)	Highest / lowest temperature on 12 August, 2003	Remarks
Ambystoma mexicanum	A	27.8°C / 27.4°C	No problems.
Ambystoma tigrinum	T	28.5°C / 28.1°C	No problems.
Bolitoglossa mexicana	T	28°C / 25°C	Animals were particularly active during the heat, especially after they were sprayed.
Cynops cyanurus	T	27.5°C / 24°C	Animals in terrestrial phase ate very little.
Cynops orientalis	A	32.1°C / 31.7°C	No problems.
Desmognathus fuscus	A/T	28°C / 26°C	Animals spent more time in the water. Little observable activity. Food intake unknown.
Euproctus platycephalus	A	27.4°C / 26.2°C	Animals inactive. Once the temperature lowered to less than 23°C, they started eating again.
Eurycea bislineata	T	27.5°C / 25°C	Remained in a bowl with two mm water. Active at night and ate.
Mertensiella luschani fazilae	T	29°C / 26°C	Animals inactive and did not eat.
Paramesotriton chinensis	A	27.5°C / 25°C	No problems.
Pleurodeles waltl (adult)	A	27°C / 25°C	Adult animals did not eat well and floated in the upper stratum of the water with their head above water. Did not climb on land.
Pleurodeles waltl (juveniles, seven months old)	A	30°C / 28°C	Tank is located in the kitchen, facing south. An identical tank is in a cooler location (27°C / 25°C). Animals in both tanks ate normally but spent a lot of time in the upper stratum of the water. Did not leave the water much.
Taricha granulosa	A	27.4 °C / 26.9°C	No problems.
Triturus carnifex	A	27.4°C / 26.9°C	No problems.
Triturus carnifex	A/T	28°C / 24°C	11 August a dead female found in the water. Remainder of animals found on land. On August 16 another animal died.
Triturus dobrogicus	A	26°C / 24°C	Animals kept eating and remained in the water or between pieces of wood or rock near the water surface.
Triturus marmoratus	T	28°C	Animals inactive and the six of them holed up in a hollow piece of cork bark. Did not eat but looked healthy.
Triturus marmoratus	A/T	28°C / 24°C	August 10 two females found dead in the water. August 11 all other animals on land. August 16 and 20 two more males died.
Triturus montandoni	T	27.5°C / 25°C	Animals searched out humid parts of the tank. Ate, but were still losing weight relatively quickly.
Tylototriton verrucosus	A	27.5°C / 24°C	No problems.

Table I: Night-time and morning temperatures of indoor tanks that exceeded the 25°C boundary on 12 August 2003.

Triturus species.

Hardly any changes could be noted for *Cynops* species. According to the participant who reported on *Cynops orientalis*, temperatures of more than 30°C did not pose any problems for his animals. His *Cynops pyrrhogaster* were maintained at a water temperature of 24-27°C, being somewhat lower at night when an open window in his salamander room cooled everything to some extent. The animals remained in the water, stayed calm and definitely did not appear agitated. *Cynops ensicauda*, both *C. e. ensicauda* and *C. e. popei*, also stayed in the water and did not appear to act any differently than when they were kept at temperatures of 18-24°C. All of these animals ate well and did not appear any more or less active than usual. A lot of food was offered to quickly raise the juveniles (first year on land) and subadults (in the water). The water was not changed more frequently than usual (i.e. once every two or three weeks).

Another participant reported temperatures reaching 26°C, but he did not suffer any casualties. *Salamandrella keyserlingii, Hynobius dunni* and *Hynobius leechii* ate less. His *Pleurodeles waltl* and *Pleurodeles poireti* were on land and did not show much activity. They were found in the least humid parts of the tank. His *Tylototriton verrucosus* and *Tylototriton shanjing* were very active at temperatures of 20°C. For the first time, recently metamorphosed *T. verrucosus* crawled on land, perhaps because of the increase in temperature and the resulting change in water quality.

but at night when the temperature decreased almost all animals would be perched on top of the emergent water mint at a temperature of 25°C. The animals clearly moved into the coolest areas inside the tank. All of these animals survived the ordeal and still appear healthy. The temperature above the water was on average about two degrees higher than in the water. The participants also reported that the water temperature varied according to the water depth (with a 3-degree margin). Their animals that were located inside the shed (*Ambystoma mexicanum*, *T. carnifex, T. marmoratus, T. karelinii, T. vittatus ophryticus, T. montandoni, Pleurodeles waltl* and *Tylototriton verrucosus*) withstood the 31°C water temperatures and 35°C land temperatures. None of their animals died during this period. These findings confer with those of another participant who keeps larvae and subadults of several *Triturus* species in his shed, and whose water temperatures also climbed to 35°C. His adult animals were located in outdoor tanks, which resulted in a larger drop in temperature overnight. Adult animals became lethargic and ate less. Juveniles and larvae appeared to eat normally.

Only one participant experienced problems with his *Triturus,* which were kept in an aquaterrarium. He lost a large number of both *T. carnifex* and *T. marmoratus*. His *Triturus dobrogicus* did not appear to experience any adverse effects from the heat.

Triturus marmoratus, female in terrestrial phase. During the summer they are very secretive.

Photo: S. Bogaerts

Outdoors

Some of us maintain our animals in an enclosure outside or in a shed. The advantage of an outdoor enclosure is that during the night-time the temperatures drop more rapidly, although they rise more quickly during the day. Two participants have a glass tank (60x40 cm) in their back yard, each of which contained fifteen juvenile *T. marmoratus* that had hatched that year. They were recent metamorphs in their aquatic phase. The water depth was six centimetres in a tank full of plants (*Elodea* and water mint). The tank was located in a sunny spot and covered halfway with a sheet of glass. Because of inattentiveness during the heat wave the temperature inside the tank climbed to 37°C! The animals would be in the water,

DISCUSSION

When reviewing the pertinent literature it is clear that there exists a fair amount of information on temperature tolerance in salamanders. There have been field studies where temperatures were measured in-situ, and salamanders have been ‘pestered’ under experimental laboratory conditions. In the wild, salamander body temperatures often are very different than one would expect. For example, *Necturus maculosus,* a species that inhabits the Great Lakes in the USA, maintains a body temperature of approximately 4°C throughout most of the year. In aquaria where they were kept at 15°C the animals appeared to prefer higher temperatures at night (when they are active) than during the day. STEBBINS & COHEN (1995) indicate that *Ensatina escholtzi* in the wild prefers temperatures of 0-20°C, with a peak of around 8–14°C. GRIFFITHS (1996) reports that most north-west European newts inhabit bodies of water with a temperature of 8-18°C in the spring. For the more southern species this value will undoubtedly be higher. Max Sparreboom (pers. comm.) indicated that, while in Japan in 1993, he would catch active adult *C. ensicauda* during the day in slowly moving, shallow water with a temperature of 28°C.

For some species temperatures exceeding 20°C are actually required. This is the case in the spermatogenesis of *Plethodon cinereus* (WERNER, 1969). This effect of a seasonal temperature variation on spermatogenesis was also found in *Paramesotriton hongkongensis* (LOFTS, 1974).

In larval salamanders, the section of their habitat that has a higher water temperature usually harbours the larger larvae, whereas the smaller ones are in sections with a lower temperature. For example, larval *Ambystoma macrodactylum* that are about to complete their metamorphosis have an average body temperature of 26.5°C. The younger larvae are found in water with a temperature of 21.5 to 22.9°C (ANDERSON, 1968). I once measured water temperatures exceeding 25°C for larvae of the stream inhabiting species *Neurergus crocatus*, a temperature they were obviously able to endure just fine (BOGAERTS, 1996).

However, there is a definite difference between adults and juveniles. For example, it is known that Israeli *Salamandra infraimmaculata* that are slowly acclimatized to higher temperatures, usually experience no problems. However, if given the option to

Mertensiella luschani fazilae. Impossible to find in the wild during the summer, and inactive in summertime in captivity.

Photo: S. Bogaerts

choose within a 10-35°C gradient, adults prefer temperatures between 15 and 25°C. Metamorphs, on the other hand, prefer temperatures below 20°C (DEGANI, 1996). In short, there appear to be different temperature requirements depending on the species, time of year or stage in their life cycle.

But when does the temperature become fatal? This can obviously go two ways. There is a critical minimum temperature, which is around the freezing point for many salamanders. Some species can survive temperatures below freezing, with *Salamandrella* (*Hynobius*) *keyserlingii* as the absolute champion. This species is known to survive temperatures of -40°C (KUZMIN, 1995). However, in this article we are obviously more interested in the maximum temperatures that these animals can withstand.

The critical maximum temperature differs strongly between species. In *E. escholtzii* an increase in skin mucus production initiates at 25–29°C, between 29–31°C the animals appear uncomfortable and are actively searching for cooler places. At even higher temperatures, the animals become paralysed and lose their co-ordination. Juvenile *Salamandra infraimmaculata* from Israel appear to succumb to temperatures over 31.8°C and adults when temperatures exceed 32°C if the animals were previously housed at 10°C. However, if the adults were previously kept at 30°C, they can survive temperatures up to 35.6°C (DEGANI, 1982). There appears to be some adaptation to temperature increase, provided it happens gradually.

Previous examples indicate that independent of whether the animals are on land or in the water other factors come into play, but also that developmental stage (larva, juvenile, adult), habitat (mountains, temperate climate or tropical) and time period (day/night or season) are important factors.

Generally, with increased temperatures desiccation is the biggest risk for terrestrial animals. This is why terrestrial *Pleurodeles* develop a thicker, horny skin that is more resistant to dehydration. In the water, the effects of temperature change on metabolism and changes in water quality are more important.

For example, high water temperatures lead to a faster metabolism. That is why recently metamorphosed *Pleurodeles*, *T. carnifex, T. dobrogicus* and *Tylototriton* can be very small (Ad Bouwman and Harry Dresens, pers. comm.). Some other salamanders metamorphose always at a specific size, such as *Triturus vittatus ophryticus*. It is recommended to divide salamander larvae over more tanks at higher temperatures. If something goes awry, this will help prevent all of the offspring being lost at once. Larval and juvenile *Triturus* and *Pleurodeles* will continue eating and remain active at higher temperatures, whereas adults become inactive.

Characteristic habitat of *Mertensiella luschani*: talus slope with pine forest near Termessos, Antalya, Turkey.

Photo: S. Bogaerts

In a natural setting, salamanders will attempt to escape the summer's heat. In Turkey you will never find *Mertensiella luschani* during the summer, even though in the winter you can easily find these animals in exactly the same location. Tonnie Woeltjes (pers. comm.) tried to excavate a talus slope during the summer and did not find any salamanders at a depth of one meter. Michael Veith (pers. comm.) interred data loggers in the habitat of this species at a depth of 70 cm on a north facing slope (which does not receive any direct sunlight) and measured temperatures exceeding 30°C in the summer. In short, these animals need to retreat to a considerable depth underground to avoid the heat of summer. Unfortunately, very little attention has been given to the summer retreats of these animals and at what temperatures they aestivate.

As an aside: VEITH & STEINFARTZ (2004) have placed *Mertensiella luschani* in a new genus and also elevated several subspecies to species status. *Mertensiella luschani fazilae* is now called *Lyciasalamandra fazilae* (Veith & Steinfartz, 2004).

CONCLUSIONS AND ADVICE

Apparently, a temporary temperature increase (over 25°C) is not too big a problem for salamanders. However, because of the higher temperatures inside the terrarium or aquarium, a few environmental variables may change that need to be watched carefully in order to help the salamanders survive. Here I present some advice to deal with these particular circumstances.

Overall health

The salamanders need to be in good health to be able to withstand higher temperatures. Sick or weak animals are more susceptible to additional stress in any shape or form. Higher temperatures increase their metabolism. If the animals lack fat reserves, they will be more susceptible to disease.

Oxygen

Higher temperatures require an increased oxygen intake in these animals, but also lead to a decrease in the dissolved oxygen level of water. The increased oxygen intake can cause problems, especially in an aquarium setting, since the water is occupied not only by salamanders but also by bacteria and plants. If there are not enough plants available in the water, a shortage of oxygen may arise. Max Sparreboom (pers. comm.) informed me that he keeps his fluorescent tube lights burning all day, in spite of the risk of increasing the water temperature even more. Without light the biological equilibrium in the water may shift and plants can no longer produce oxygen. He noticed in the past that after turning off the lights his animals would develop rotting toes and tail tips. During this summer, Max did not lose any of his *Cynops* species, including larvae and juveniles.

Food

In the wild, salamanders occupying Mediterranean areas (such as *Pleurodeles waltl*) are often not active during the summer. They will retreat on land into a burrow and wait for cooler times. They do not eat, but also do not move. When salamanders enter this aestivation period in good health, they can easily survive for several months. The same applies to captive conditions. My *Triturus pygmaeus* crawled on land by the end of May and did not receive any food during the summer months; they did not display any kind of activity. My *Mertensiella luschani* also underwent a clear aestivation period. They retreat into their burrows and stay there for a few months without moving. The only thing I need to do is ensure that they do not dehydrate. I checked the animals after the heat wave. They were a little bit skinny but still in overall good health.
Reducing the food supply is important for two reasons. First, the salamanders often eat less during the summer. However, prey animals (such as mosquito larvae, worms or maggots) also die sooner when exposed to warmer temperatures and will decompose. This will cause the water quality to deteriorate and, in turn, will have an effect on the salamanders. Because of the rotting food, the oxygen content of the water will decrease and certain disease-causing bacteria and fungi will develop more rapidly. If a salamander dies and its body is not discovered quickly, there is a chance that the others will follow suit within a day.

Terrestrial or aquatic

Temperature increases will lead to problems in an aquarium sooner than in a terrarium, since the quality of the water will change rapidly in response to a change in temperature. Therefore, it may be beneficial to aestivate your animals. Frank Pasmans (pers. comm.) indicated that he purposely aestivated some species in order to imitate their natural seasonal cycle. This could be beneficial for a numbers of reasons. Various people maintain their newts in an aquatic phase for many years (which also happens in nature). However, this does mean that the animals are at a higher risk during the high summer temperatures. Frequent water changes will surely reduce some of the risk.

Dead *Triturus carnifex.*

Photo: A. de Vries

Changes

Although it remains a guess, it was probably the change in conditions during the heat wave that killed the *Triturus* in their aquaterrarium. The animals (both *T. marmoratus* and *T. carnifex)* were transferred to a new tank in mid-July and nearly all of them immediately crawled on land. Some of the larger female *T. carnifex* became very easily spooked. Apparently, this change in conditions caused considerable additional stress. After a few days, the animals returned to the water but were very passive. I eventually removed one particularly unhealthy looking individual, which died the next day. The animals that died were invariably the fatter females. It appeared as if they had problems with ecdysis in the water and died in their old, unshed skin. These animals all displayed bloody spots on the body and obviously were affected by something. Since they were only housed together for a brief period they did not infect each other. The hot weather probably only finished off already sick animals.

Salamandrella keyserlingii, the species with the largest distribution range of all salamanders and also with a large tolerance for extreme temperatures.

Photo: S. Bogaerts

ABSTRACT

During the hottest summer in The Netherlands in a long time (summer of 2003), a brief survey was held to investigate the temperature conditions under which several members of the Dutch Salamander Society maintain their animals. At that point in time, The Netherlands had already been subjected to a two-week heat wave. Twelve members sent me information. The results of this survey and a discussion of the role temperature plays in the life of a salamander are presented in this article. The increased temperature, values of 25 to 30°C were reached on average, led to hardly any increased mortality or incidence of disease.

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