

Basic information and breeding guidelines
for *Tylototriton ziegleri*,
Ziegler's crocodile newt





Inhalt

1. **Characterisation**
2. **Why is *Tylotriton ziegleri* a Citizen Conservation species?**
3. **Biology and Conservation**
 - 3.1 **Biology**
 - 3.1.1 Taxonomy
 - 3.1.2 Description
 - 3.1.3 Sexual dimorphism
 - 3.1.4 Occurrence and Habitat
 - 3.1.5 Habit and Reproduction
 - 3.2 Threats and Conservation Efforts
4. **Husbandry and Breeding**
 - 4.1 Documentation Requirements
 - 4.2 Transport
 - 4.3 Socialization
 - 4.4 The Terrarium
 - 4.5 Terrarium Equipment, Temperatures, Humidity
 - 4.6 Feeding and Care
 - 4.7 Mating
 - 4.8 Breeding
 - 4.9 Larval development
 - 4.10 Raising the Larvae
 - 4.11 Raising the Juvenile
 - 4.12 Husbandry Challenges
5. **Further Reading**



1. Characterisation

Scientific name: *Tylototriton ziegleri* (NISHIKAWA, MATSUI & NGUYEN, 2013)

Vernacular name: Ziegler's crocodile newt

Length: 14–15 cm total length, a little more than half is accounted for by the tail

CC#Amphibians category: II

IUCN Red List: Vulnerable (VU)

Threat status according to CITES: Appendix II

Threat status according to Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora: Annex B

Protection status in Germany: „specially protected“ after the German federal nature conservation act

Husbandry: Rainforest terrarium with water part

Equipment required: For 3-5 animals terrariums with a base area of about 50-80 cm long and 40-50 cm wide.

Water part takes about 1/4 to 1/3 of the area, good exit possibilities important. Substrate of gravel, earth or similar. Furnishing with moss cushions, bark pieces, stones, planting. Simple lighting. Temperatures in the summer half-year approx. 22-24 °C, in winter approx. 18 °C. Simulation of dry season in the winter half-year, rainy season in the summer half-year. Incubation of clutches at maximum humidity. Rearing of larvae individually or in small groups in boxes with stagnant, slightly acidic water.

If rearing in groups, provide many hiding places; be careful: larvae very aggressive towards each other. Daily water change.

Feeding: Common animal foods such as crickets, earthworms, isopods etc. in suitable size, adults 1-2 times a week, terrestrials and juveniles daily. Larvae are fed with small animal food such as water fleas, artemia, *tubifex* or similar, preferably several times a day.





2. Why is *Tylototriton ziegleri* a Citizen Conservation species?

Ziegler's crocodile newt was discovered only recently. It occurs only in a very small distribution area in the border region of South China and North Vietnam. Based on this small distribution alone, the species must be considered potentially endangered.



The habitat of *Tylototriton ziegleri* in Vietnam's Ha Giang province is threatened by clearing for agriculture and agricultural use.
| Thomas Ziegler

Ziegler's crocodile newt is an obligate forest dweller that can cope with some habitat disturbance and is not necessarily dependent on primary forests, but large-scale logging and habitat conversion for agriculture have rendered much of its range uninhabitable for it. Only small, fragmented remnant forest stands remain. Breeding waters, in particular, are increasingly disturbed. *Tylototriton ziegleri* has therefore now been classified as „vulnerable“ on the IUCN Red List.

In addition to the main threat from habitat destruction, as with all crocodile newts, the collection of the animals for traditional medicine and for the international pet trade represents an additional endangerment factor. The genus *Tylototriton* was therefore included in Appendix II of the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).



Ziegler's crocodile newt is prototypical for the global threat to amphibians and the endangerment of biodiversity due to deforestation and can therefore serve well as an ambassador for these issues in enclosures. At the same time, the species is part of a comprehensive in-situ/ex-situ biodiversity conservation project in Vietnam, carried out by the Cologne Zoo and others, and thus demonstrates the possibilities of such a holistic species conservation approach according to the „One Plan Approach“ to biodiversity conservation.

In addition, a large part of the knowledge about Ziegler's crocodile newt was gained through terrarium husbandry, so that extensive biological knowledge of this species, which is important for species conservation, is already available a relatively short time after its discovery. *Tylototriton ziegleri* also exemplifies this important aspect of wildlife conservation.

After all, it is an attractive, charismatic and easy to keep species, which allows interesting observation possibilities and is easy to maintain in the terrarium.



Central point in the conservation breeding network for *Tylototriton ziegleri* is the Cologne Zoo. | Christian Niggemann



3. Biology and Conservation

3.1 Biology

3.1.1 Taxonomy

Ziegler's crocodile newt belongs to the family of salamanders (Salamandridae) within the caudate amphibians.

The genus *Tylotriton* has become the subject of intensive systematic research in recent years, which has led to an enormous gain in knowledge.

Thus, it became apparent that two species previously assumed to be widely distributed (*T. asperrimus* and *T. verrucosus*) actually conceal many independent species that have been newly described in recent years. The genus is divided into these two groups, i.e. the *T. asperrimus* and the *T. verrucosus* groups.

Partly these groups are also subdivided as subgenera (*Yaotriton* for the *T. asperrimus* group and *Tylotriton* for the *T. verrucosus* group). *Tylotriton ziegleri* was recognized and described as a distinct species only in 2013. It belongs to the *T. asperrimus* group and the subgenus *Yaotriton*, respectively.



Citizen Conservation Advisory Board member Prof. Thomas Ziegler with the crocodile newt named after him.

| Anna Rauhaus



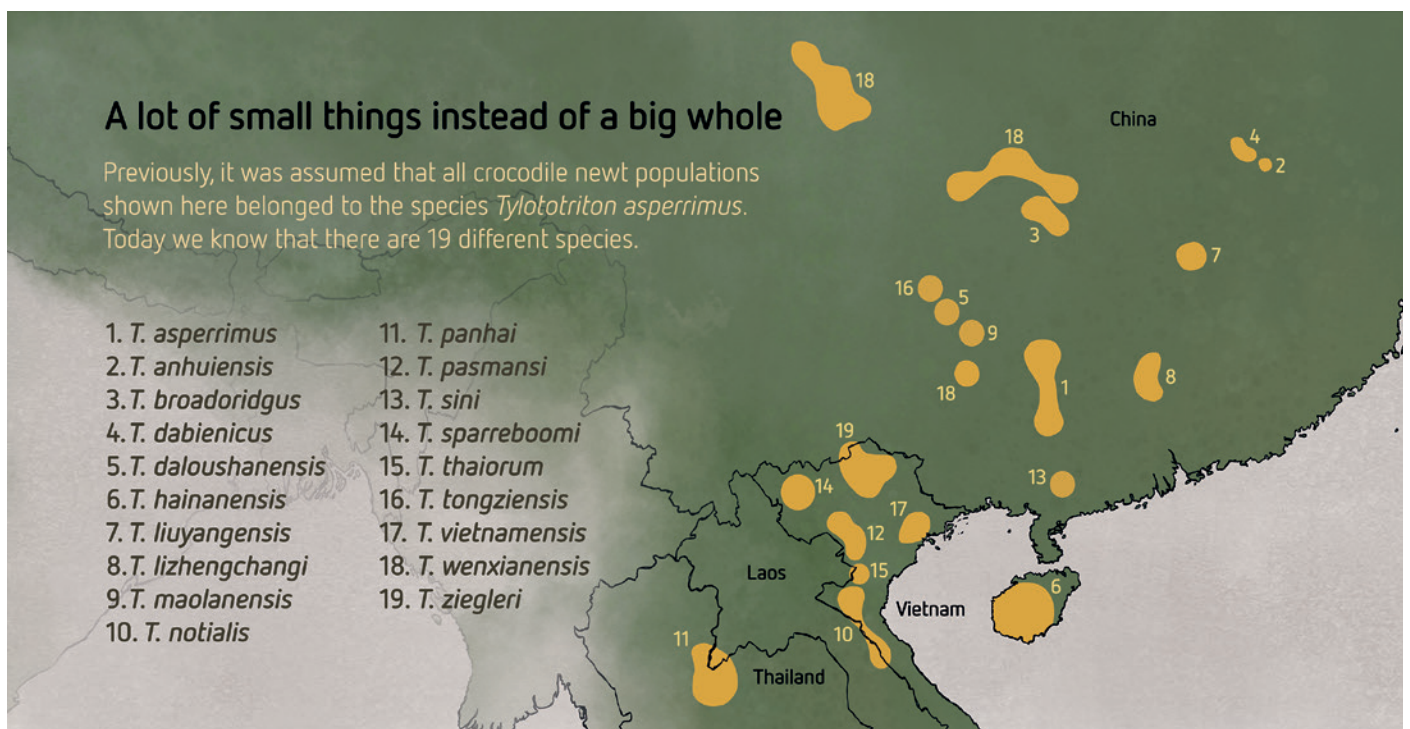
The realization that *T. asperrimus* and *T. verrucosus* are extensive species complexes not only means that the genus *Tylostotriton* is now the most species-rich within the family Salamandridae with now 37 species, but it also means that many crocodile newt species have only a very small distribution and their continued existence is therefore often endangered.

Animals from Vietnam described as *T. asperrimus* in older literature may therefore also involve *T. zieglerei* or other crocodile newts described later. For differentiation of *T. zieglerei* from other crocodile newts, see NISHIKAWA et al. (2013) and BERNARDES et al. (2020).



The closely related Vietnamese crocodile newt (*Tylostotriton vietnamensis*), like *T. zieglerei*, belongs to the *T. asperrimus* group. The species, which has only a small distribution, is highly endangered and is also managed in Citizen Conservation.

| Thomas Ziegler



What was once thought to be *Tylostotriton asperrimus* has turned out to be a complex of numerous species, often with very limited distribution and thus often threatened species such as *T. zieglerei*. | Jonas Lieberknecht/Citizen Conservation



3.1.2 Description

Tylototriton ziegleri is a small representative of the crocodile newts. Typical for the genus are the many warts on the skin of the upper side and on the sides, also the large parotoid glands (ear glands) on the posterior sides of the head. Also typical for the genus are three warty, longitudinally running, well-developed dorsal ridges of strongly enlarged tubercle scales, which are responsible for the appearance reminiscent of crocodiles: one ridge runs along the middle of the back; it is somewhat lower, the individual tubercles merge more strongly into each other; the other two run dorsolaterally, i.e. at the transition from the back to the sides, and consist of clearly enlarged, strongly separated, button-like tubercle scales, which partly look like attached half tubercle scales, that look like attached bisected spheres. These three ridges are more pronounced in *T. ziegleri* than in the other more closely related species, giving the animals a very warty appearance.

Females reach a snout-vent length of about 7 up to 9.9 cm and are clearly more massive than the mostly 5.5-7 cm, at most 8.9 cm reaching males. The laterally flattened, tapering tail is usually somewhat shorter and has a fringe above and below. The total length of adults is about 13-16 cm, the weight is 6-16 g, in one documented exceptional case 23 g (ZIEGLER et al. 2018). The head is distinctly broader than the trunk and ventrally flattened. The bony ridges on the sides of the strongly broadened occiput are very large and conspicuous, especially in older animals, and more pronounced than in other crocodylian newts from the asperrimus group. Webbed toes are absent or present as a base on the toes of the hind legs.



In *Tylototriton ziegleri* the bony ridges on the broad head are particularly pronounced. | Thomas Ziegler



Ziegler's crocodile newts are uniformly black, brown to gray in color. While on land, they are noticeably darker than in the water. In sharp contrast to this rather dusky base coloration, the underside of the tail and usually the tips of the fingers and toes are bright red. Some animals show slightly orange colored rib knots, occasionally the uppermost part of the tail seam is also colored like that.

A detailed diagnosis with differentiation from the other crocodile newt species of the *asperimus* group can be found in NISHIKAWA et al. (2013), ZIEGLER et al. (2018) and BERNARDES et al. (2020).

Compared to the species *T. vietnamensis*, the Vietnamese crocodile newt, also maintained in Citizen Conservation, *T. ziegleri* can be distinguished mainly by the following characteristics: more distinct bony ridges on the head, more distinct longitudinal rows of enlarged tubercle scales on the middle of the back and at the dorsal/side transition, in comparison, the cloacal opening is shorter in *T. ziegleri*, the tail is thinner and lower.



The three longitudinal rows of enlarged tubercles on the middle and sides of the back are particularly striking.
| Thomas Ziegler

3.1.3 Sexual dimorphism

Females grow larger and have a much stockier build. In the breeding season they are more stout, while males then tend to develop stronger legs. The sexes can also be identified by carefully spreading the cloacal lips with the hand: Females then show a smaller, more punctate cloacal opening, while in males it is larger and slit-shaped. The tail of females is somewhat shorter in relation to males.



Distribution in Vietnam and China | Jonas Lieberknecht/Citizen Conservation

3.1.4 Occurrence and Habitat

Ziegler's crocodile newt is known from only a few localities in northern Vietnam and southern China. Evidence is available from the Vietnamese provinces of Ha Giang and Cao Bang, and also from Jingxi District in the southern Chinese province of Guangxi.

The animals inhabit dense evergreen subtropical primary forests with soil formed from limestone and karst, dominated by bamboo, with more open grassy areas.

Known localities are at elevations between 886 and 1,420 m (BERNARDES et al. 2017). SPARREBOOM et al. (2011) even report a locality at 1,600 m elevation.

In contrast, the closely related species *T. vietnamensis* inhabits lowland secondary forests (181-980 m a.s.l.) on soils formed over granitic rocks.

The region is dominated by the summer monsoon. The winter half-year is dry and somewhat cooler, the summer half-year hot and humid. During the breeding season from April to July, BERNARDES et al. (2017) recorded humidity that was always saturated (100%, compared to 68-100% (average: 94%) for *T. vietnamensis*) and air temperatures of 26-34.4 °C.



Habitat of *Tylototriton ziegleri* in the northern Vietnamese province of Ha Giang ... | Thomas Ziegler



... and in the Cao Bang Province | Thomas Ziegler



3.1.5 Habit and Reproduction

Ziegler's crocodile newt lives in the wild mainly as a ground dweller very secretly under stones and in other hiding places and is rarely found on land.



Both in nature and in the terrarium Ziegler's crocodile newts live very hidden. | Thomas Ziegler

The breeding period is from April to July (BERNARDES et al. 2017), coinciding with the rainy season. In April and May, newts migrate to their breeding waters. These may be small, shallow permanent waters or temporary waters created during the rainy season, areas flooded by streams, or meadows where water is present.

First, the males migrate and go to the water, where they wait for the arrival of the females. If rainfall fails and pools dry up, the animals continue their land-dwelling lifestyle. The females go into the water only for a very short time. Pools used by *T. ziegleri* were on average 79 cm deep (standard deviation 58 cm) in the studies of BERNARDES et al. (2017), significantly deeper than waters used by *T. vietnamensis* (25 +/- 14 cm). Water depths used by *T. ziegleri* ranged from 10-200 cm. Pool sizes ranged from 11 to 460 m² (mean: 84 m²). Thus, it can be seen that *T. ziegleri* is quite flexible in its choice of water bodies. The flexibility is also evident in the location of the water bodies - while the majority of them are overgrown by trees for 50% or more of their area, there are no trees or bushes over about one third of the pools.

The water values determined by BERNARDES et al. (2017) were pH 6.4-8 (average 7 +/- 0.5). In comparison, *T. vietnamensis* prefers slightly more acidic water overall (pH 4.7-7.5; average 5.6 +/- 0.7). Other water values in pools used by *T. ziegleri* were 0-8° carbonate hardness (average: 4), 1-9° German hardness (average 4), 0-0.4 mg/L nitrite, 0-20 mg/L nitrate.



Tylotriton ziegleri inhabits such forests of medium altitude. | Thomas Ziegler

Probably a short time after courtship and mating, the females move ashore, where they lay their clutches in the shore area, but on land. The eggs stick together to form a spawning mass, which is covered with leaf litter by the female. BERNARDES et al. (2017) found clutches on soil and rocks 10-100 cm (average 50 +/- 28 cm) from the water. For *T. vietnamensis*, this is 17-188 cm (average 80 +/- 41 cm).

After oviposition, females retreat deeper into the forest. One clutch comprised 10-109, average 67 eggs (+/- 32) eggs. The clutch size is thus smaller than in the closely related species *T. vietnamensis*, where 5-85 eggs (average 43 +/- 19) are deposited exclusively on the ground and at a greater distance (80 +/- 41 cm) from the water. The diameter of the individual round eggs is 7.2-11.2 mm, and they weigh 0.2-0.4 g. The eggs are surrounded by a clear gelatinous layer. Larval development in the egg until hatching is described and illustrated in detail in BERNARDES et al. (2017). Hatching occurs from about 20 days after egg laying.

At this time, the larvae have front legs, although not yet fully formed. The newly hatched larvae are about 14-15 mm long and are washed into the water during rainfall, where they then live until metamorphosis after about three months. The larvae are golden yellow to brownish in color on the upper side, with golden spots.

The ventral side is whitish transparent, and fingers and toes are yellow. The gills are yellow and reddish at the tips of the gill branches.

Just before transformation they turn black and have reached a length of about 58-63 mm. The land-walkers already have the typical black coloration with the orange red fingers and toes and orange red underside of the tail of the parents. The skin rapidly changes from smooth larval skin to granular, wartier adult skin. A detailed comparison of the larval development of *T. ziegleri* with *T. vietnamensis* as well as some other related species can be found in BERNARDES et al. (2017).

Again, as with the other ecological and reproductive biology data, there are clear differences between the species, supporting the species status of the various crocodylian newts in the *asperimus* group.

The life expectancy of Ziegler's crocodile newt is still unknown. ZIEGLER et al. (2018) reported a specimen that had been kept at the Detroit Zoo for 19 years, which they estimated to be 23-28 years old.



Larvae of *Tylotriton ziegleri* | Anna Rauhaus



3.2 Threats and Conservation Efforts

Ziegler's crocodile newt has only a very small range. The species is dependent on forests, which are increasingly being cleared in its native country to make way for agricultural land. Mining also poses a threat, as the range is located in a region with large coal deposits and the effects of the mines (infrastructure, pollution) are felt close to the borders of the protected areas.

Another threat, as with all crocodile newts, is the collection of the animals for traditional medicine as well as for the pet trade.

The species is therefore listed as „vulnerable“ (VU) in the IUCN Red List.

The most important conservation measure is the preservation of the natural habitat.

The Cologne Zoo, together with the Institute of Ecology and Biological Resources (IEBR) and the Vietnam Melinh Biodiversity Station, is caring for the species both through basic research and support of conservation efforts in the field, and through the establishment of an ex situ population in human care, to be achieved through a network of husbandries in domestic, German and international husbandry facilities.

This husbandry network also includes Citizen Conservation.



The most important factor threatening Ziegler's crocodile newt is large-scale habitat destruction, such as here in northern Vietnam within the habitat of Vietnamese crocodile newt and Vietnamese crocodile lizard,, from coal mining ...

| Thomas Ziegler



... or deforestation for agriculture. | Thomas Ziegler



Conservation efforts also include the establishment of an ex situ population on site in the amphibian room of the Melinh Conservation Station in Vietnam, a partner project of the Cologne Zoo.

| Anna Rauhaus



4. Husbandry and Breeding

The information on terrarium husbandry is based on the experiences at the Cologne Zoo (RAUHAUS, writ. Mittlg.). They are based on the overall similar terrarium husbandry of *T. vietnamensis*, which has already been documented in detail by the Cologne Zoo team (ZIEGLER & RAUHAUS 2019a; RAUHAUS & ZIEGLER 2021; see also the „Basic information and husbandry recommendations for *Tylototriton vietnamensis*, Vietnamese crocodile newt“ by Citizen Conservation, available for download at www.citizen-conservation.org).



View into the amphibian quarantine station at Cologne Zoo. The recommendations for care and breeding of *Tylototriton zieglerei* given here are mainly based on the experience of the team from Cologne Zoo. | Thomas Ziegler



Keepers who want to keep *Tylototriton ziegleri* for CC sign such a contract.

4.1 Documentation Requirements

The CC animals are property of the Citizen Conservation Foundation gGmbH. This also applies to all offspring. Owners are not allowed to sell or give away the offspring on their own.

The animals must not be mixed with other *Tylototriton*, not even with other *T. ziegleri*, unless this is explicitly agreed with the CC office. The purpose of a long-term conservation breeding over decades, as CC aims at, is the coordination of the animals. Only in this way can the genetic diversity of the source animals be preserved in the best possible way. If animals, which are not intended by the population management, are mated with each other this can affect the value of the whole stock in the long run. Therefore, we strongly request that these guidelines be followed. This also includes that adult offspring are not placed with the parents to avoid mating between parents and offspring.

According to the contract and guidelines of Citizen Conservation, deaths should be reported directly and informally to the CC office by mail (amphibien@citizen-conservation.org), so that a decision can be made whether a necropsy is advisable, if the cause of death is not clear. Dissections will only be done in justified cases, the costs will be borne by CC. The animals should be stored in a cool place until this decision is made. A separate information sheet is available on the shipment of dead animals or precautionary preservation.

The semi-annual reporting of the stock is contractually stipulated. This is currently done on the cut-off dates of 1.3. and 1.9. using the appropriate reporting forms, which will be replaced in the near future by an online procedure within the Wild at Home platform.

Reporting of offspring to the CC-#Amphibians office can be done at about six months of age, when the number of juveniles expected to reach adulthood becomes manageable. Also, special observations, problems encountered, etc. should be reported to the CC office during the semi-annual reports or in between to increase knowledge of the husbandry and reproduction of this species.

If keepers are no longer able or willing to keep the animals or offspring - whereby CC assumes that keeping the animals has been carefully considered beforehand and that the long-term nature of such an undertaking has been planned for and is explicitly desired - the CC office must be informed as early as possible that the animals are to be given up so that a successor can be organized. CC guarantees the acceptance of the animals.



The transport boxes with the newts are placed in a Styrofoam box, well secured against slipping, to protect them against temperature fluctuations during transport. In this way, even the journey in the airplane, as here in a project of the Cologne Zoo for the repatriation of the endangered Vietnamese crocodile newts for the purpose of establishing an ex-situ breeding group in Vietnam, is possible without any problems. | IEBR



4.2 Transport

CC animals, including their offspring, may only be transferred in consultation with the CC office.

Before each change of location within CC, a swab sample of the animals is to be taken according to CC instructions (see separate information sheet) and submitted for examination for the chytrid fungi *Bd* and *Bsal*. In addition, a fecal sample should be sent in for parasitological examination (use CC's examination order, available from the CC office; CC will bear the cost). After negative test results or confirmation that there is no parasite load requiring treatment are available, the transfer can take place. The handover takes place either personally or by a forwarding agency approved for animal transport. An information sheet from the CC office provides information about the appropriate contact persons. The costs for the transport are borne by the recipients of the animals.

For transport, the crocodile newts are placed in small, stable boxes with air holes, which are lined with moist cellulose paper or moss. The air holes should not have an inward rim to prevent skin injury to the newts.

Larvae can be transported in tightly sealed plastic bags or boxes filled with about 1/3 full of stagnant water. The boxes or bags are placed in a thermostable, larger container (Styrofoam box, insulated bag) to protect them from external weather influences and secure them against slipping, flinging around and falling over. If necessary, in winter or summer, it may be necessary to place a cooling battery or hot water bottle or heat pack in the container. Caution, such items must be safely separated from the animal containers to prevent overheating or hypothermia.



For transport, Ziegler's crocodile newts are placed in small boxes with moist substrate, such as moss. | Thomas Ziegler



Packing of (Vietnamese) crocodile newts into transport boxes in the Cologne Zoo | Thomas Ziegler



4.3. Socialization

Ziegler's crocodile newts can be kept in small groups, depending on the size of the terrarium. Intraspecific aggression is usually not an obstacle - but see the notes on raising larvae together.

Citizen Conservation generally recommends keeping them in species tanks, i.e. without socialization with other amphibian species. An additional stocking with invertebrates (e.g. water snails in the water part; isopods and earthworms in the land part) is possible and recommended.

In principle, it is not permitted to keep CC animals together with conspecifics that do not belong to the CC program or with their own offspring! When keeping several CC groups of *Tylototriton ziegleri*, please take care not to mix the animals and report them separately by group in the semi-annual population reports. The CC program is based on coordinated breeding, special attention must be paid to the genetic background of the animals to avoid unnecessary inbreeding and narrowing of the gene pool in the CC population. Therefore, animals may only be placed in other groups after consultation with the CC office or on the instruction of the studbook keeper.



Ziegler's crocodile newts can be easily maintained alone or in groups. | Thomas Ziegler



4.4 The Terrarium

Ziegler's crocodile newts are maintained in terrariums with a water section. The terrarium can be made of glass or plastic and must have adequate ventilation in the lid and/or sides.

As a rule of thumb for determining the terrarium size, the Urodela work group of the DGHT (the German Society for Herpetology and Herpetoculture) recommends the following for two crocodile newts: To determine the area in square meters, take the total length of the animals in centimeters and multiply by 0.01. For each additional animal, this area should be multiplied by 1.25. For two adult, about 15 cm long *Tylototriton zieglerei* this would result in an area of $15 \times 0.01 = 0.15 \text{ m}^2 = 1500 \text{ cm}^2$. This would correspond to terrarium dimensions of 50 x 30 cm (length x width).

For three animals $1500 \text{ cm}^2 \times 1,25 = 1875 \text{ cm}^2$ would have to be estimated, which would correspond to 50 x 40 cm and so on. At the Cologne Zoo, the animals are kept in pairs or in groups of up to five in terrariums measuring 55 x 50 x 35 cm and 120 x 60 x 60 cm (length x depth x height).

All tanks have a water section. It should occupy about 1/5 to 1/4 of the total area. This can be created by gluing a glass strip of maximum 10 cm height on the bottom, which separates the water part from the land part. Alternatively, the entire terrarium can have a water level, and the substrate then rises significantly toward one side of the terrarium so that it is above the level in the larger part of the terrarium and below it in the smaller part. This lower part is then naturally under water. It is important to have a largely „barrier-free“ access and especially exit for the crocodile newts. This is made possible by stones or a shallow rising shore zone of clay or gravel. The water should have a low hardness and a slightly acidic pH (6.4-6.8) - modeled on natural conditions. The maximum water depth is about 5 cm.

The water part is usually visited by the newts only for mating; the males sometimes spend several weeks in the water.

Moss cushions or other hiding places near the shore are suitable for egg laying. The substrate in the terrarium should be filled 8-15 cm high. For this, use gravel or, for example, a clay mixture over a layer of gravel and soil. It is important to have a mixture of drier and wetter areas. It is also possible to build up the substrate in layers: first a 2 cm high expanded clay ball layer as drainage, over which a garden fleece is laid to prevent the actual substrate from sliding in. On this fleece is then distributed deciduous forest soil, which was previously disinfected in the oven at 70 ° C for 20 minutes. A hilly structure provides different moisture ranges.



Hiding places must be available in both the wetter and drier parts of the terrarium. Moss helps to retain moisture and is therefore well suited for terrarium design. Suitable hiding places and structural elements include pieces of cork bark, clay bowls, caves in a designed back or side wall, bamboo canes cut in half, and so on.

A layer of foliage (oak, beech or bamboo leaves) not only looks attractive, but provides further hiding places and a natural structure.

The terrarium can be planted very well. Not only visually, but also geographically suitable are, for example, Aluminum plant (*Pilea cadierei*), Emerald tree (*Radermachera sinica*), Pogonatherum paniceum and various ferns (*Asplenium*).

Additionally, small invertebrates can be introduced into the terrarium, such as springtails, earthworms, and the isopod *Porcellio laevis*. These feed on organic waste material and thus ensure a cleaner terrarium, at the same time serving as a permanent staple food supply for the crocodile newts.

However, as the isopods can also fall into the water part and drown, regular cleaning should be ensured.



Terrariums for Ziegler's crocodile newt at Cologne Zoo
| Thomas Ziegler



4.5 Terrarium Equipment, Temperatures, Humidity



The lighting of the terrarium plays an important role – more for the planting than for the newts. | Thomas Ziegler

The lighting of the terrarium does not play a special role for the newts, they do not like it particularly bright. You can ultimately orientate the terrarium lighting to the requirements of the planting. Common systems such as LED light bars or fluorescent lamps are possible. Indirect lighting via the light in the room is also sufficient for the pigs. Artificial lighting can be on for 12 hours a day in summer, and somewhat shorter in winter (about 10-11 hours).

Between March and October the terrarium temperature is 22-24 °C. Higher temperatures in summer are tolerated for a short time. Cooler retreats in the terrarium are important. In winter the animals are kept at 18 °C; lower peaks do not cause any problems for the newts either.

In the winter months less spraying is done (dry season), also the water level of the water part is lowered.



4.6 Feeding and Care

The crocodile newts eat the usual range of „salamander food“. Well suited for adults are leafworms, crickets, house crickets and wax moth caterpillars. Adults are fed about twice a week. In winter, they eat only irregularly and much less.

It is important that the feeding animals have a high-quality diet. Crickets and house crickets are kept in plastic boxes and fed a varied diet of oatmeal, fruit and vegetables (grated carrots, peppers, cucumber, etc.). The feeding animals are dusted with vitamin-mineral preparations and thus enhanced. Daily sprinkling by hand (flower sprayer) or sprinkler system provides the necessary moisture. Frequency and amount depend on terrarium size and ventilation area.

In winter, as already mentioned, the animals are kept drier. In the Cologne Zoo, the water levels in the terrariums are lowered from October onwards. The water part is gradually drained to a large extent except for small remnants for basic moisture supply in order to simulate the dry season. During this time the terrarium is also sprayed very little and only in some places (moss cushions). As soon as the males go into the water pool (probably triggered by air pressure fluctuations, in Cologne Zoo already from January), spraying is strong again and the water levels are raised again.

If gravel is used as substrate, it should be flushed regularly. Soil or soil-loam mixtures rarely need to be replaced. Recognizable contaminants (feces, food remains) are regularly collected from the terrarium.



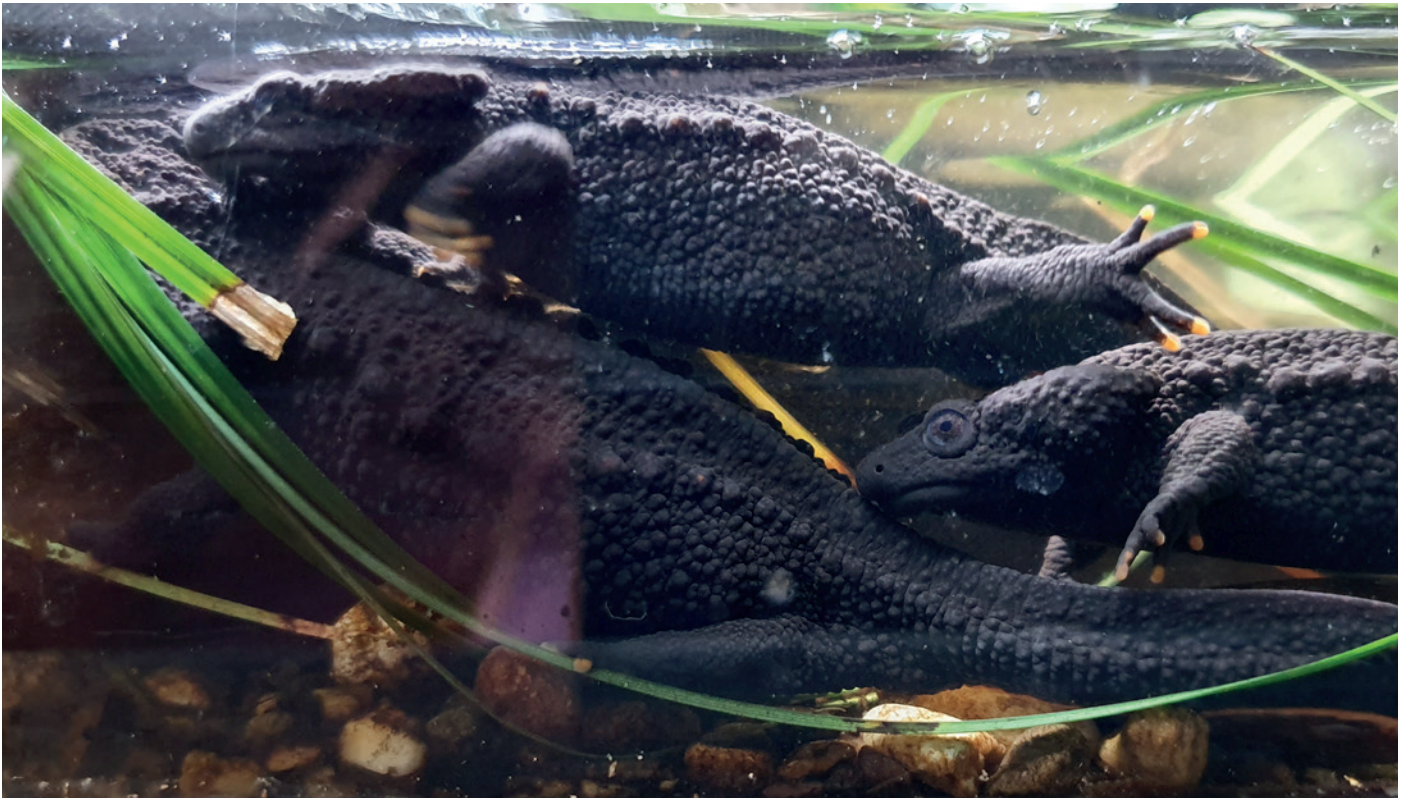
Anna Rauhaus during maintenance work on a crocodile newt terrarium | Benny Trapp/Frogs & Friends



Adult *Tylostotriton zieglerei* in the terrarium | Thomas Ziegler



4.7 Mating



Mating tumult in the water part of the terrarium | Thomas Ziegler

Already towards the end of the summer half-year, the females clearly increase in girth. Crucial for triggering the readiness to mate are the winter temperature drop described above in conjunction with drier husbandry and low feeding, as well as the subsequent simulated rainy season. Crocodile newts are sensitive to fluctuations in atmospheric pressure. It is therefore recommended to start the rainy season in the terrarium when a low-pressure area is approaching. For this purpose, the terrarium is sprayed intensively from now on (several times a day), and the water level in the water part of the terrarium is increased significantly. At the same time, the temperatures should also rise.

If they have not done so on their own due to fluctuations in atmospheric pressure, males should move into the water within 1-2 days of the onset of the „rainy season“ with increased spraying and water level rise, where they will wait for females. Males exhibit lighter coloration and a distinctly different skin texture during the weeks they spend in the water - a typical „aquatic mating“ for many newts. In *T. zieglerei*, reproductive behavior in captivity seems to be less dependent on the season than in *T. vietnamensis*. If mating behavior does not occur despite a simulated rainy season, it may be helpful to lower the water level again and raise it again after a dry period. Animals of both sexes develop a much larger appetite in the spring. Males also consume food in the water.



Egg laying takes place in sheltered, moist places on land near the water part. | Thomas Ziegler



Female laying eggs | Thomas Ziegler

The females also come into the water for one or more days to mate with the males. Air pressure probably plays a role in this as well. At the Cologne Zoo, mating was observed when low pressure areas or thunderstorms were occurring outside. Water temperatures during observed matings were 18-19 °C in the morning and 21-22 °C during the day.

As is common with crocodile newts, the pairs perform a circle dance during mating. The male repeatedly bumps the female with his head and wags his tail in the female's direction. Finally, it deposits several spermatophores (sperm capsules) and directs the female over them by means of the gyratory movements with the cloaca. The whole procedure can take several hours.

Egg-laying usually takes place the day after mating, but it can also extend over two days. For this purpose, the female prefers a moss-covered spot on the ground near the water. The clutch is often hidden under leaves or pieces of bark.

In the Cologne Zoo, egg-laying has so far been observed between January and September. Mostly 30-80 eggs were laid, a peak value was 134 eggs.



Larvae during development in the egg
| Thomas Ziegler



4.8 Breeding

The eggs can also develop successfully in the terrarium, but we recommend separate breeding to provide more controlled conditions on the one hand, and on the other hand because of the danger of spawn and larvae being eaten by the parents. In the Cologne Zoo a male of the closely related species *T. vietnamensis* has already been observed eating eggs, and a larva of this species hatched in the terrarium there disappeared from the water part without a trace. Various methods have been tried for breeding.

At the Cologne Zoo, the eggs are laid individually or in small balls next to each other on slightly damp cellulose paper (kitchen paper), which is then placed on a light grid plate from aquarium supplies. This light grid plate is then placed in a closed plastic box filled with some water, so that the eggs are well above the water level, but exposed to very high humidity. Alternatively, a plastic grid floating on the water can be used, with cellulose paper placed on top. Once or twice a day, the can is opened for inspection and ventilation. Dead eggs are removed. The paper must be replaced after a time; this is necessary once or twice during the incubation period.

If egg cases of still living larvae are damaged, they are placed in the water of the incubator at Cologne Zoo, where they usually hatch (see item 4.12, „Husbandry problems“).

Of course, other incubation methods are possible, but this breeding variation has proven to be successful at the Cologne Zoo with a very high hatching rate.

Alternatively, other breeding methods have been tested for *T. vietnamensis* (for details see ZIEGLER & RAUHAUS 2019a, RAUHAUS & ZIEGLER 2021).



The eggs should be removed from the terrarium and hatched separately. | Thomas Ziegler



The growth of the larvae in the eggs can be easily observed from the outside. | Thomas Ziegler



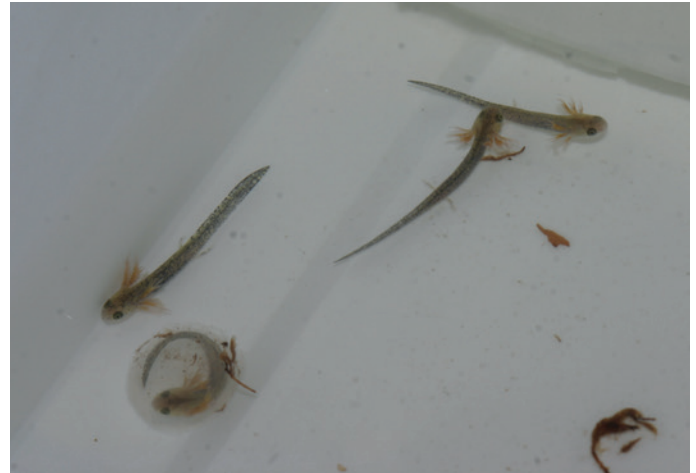
4.9 Larval Development

The duration of larval development in the egg depends on the temperature. At Cologne Zoo, the larvae hatched under the above-described temperatures of 22-24 °C during the day and 20-22 °C at night after 20-36 days.

At hatching the larvae are up to 22 mm long. They can jump into the water on their own - in the Cologne Zoo jumps of up to 12 cm have been documented in *T. vietnamensis*!

With the hatching of the first larvae the water level in the incubation vessel should be increased, which also induces the other larvae to hatch. Presumably, this behavior corresponds to the response to precipitation in the natural habitat and ensures that the temporary water bodies actually carry water.

For a detailed description of larval development, see BERNARDES et al. (2017).



Young Larvae | Thomas Ziegler



Older Larva | Anna Rauhaus



Larva shortly before metamorphosis | Anna Rauhaus



4.10 Rearing the Larvae

In practice, different rearing methods for the larvae of crocodile newts have now been tested, mainly through the work of the Cologne Zoo (RAUHAUS & ZIEGLER 2021). The larvae of *Tylototriton zieglerei* have proven to be significantly more incompatible than those of *T. vietnamensis*. Therefore, the rule of thumb for rearing is: the fewer larvae, the better, the higher the successful rearing rate. When rearing in small groups, care should be taken to provide plenty of plants and hiding places due to the high aggressiveness of the larvae, and the larvae must also be constantly sorted according to size so that only animals of the same size are kept together. Cannibalism is quite common in this species; if there is a surplus of larvae, keeping them together, especially larvae of different sizes, can be used for population regulation.

Breeding individually or in small groups promises the greatest success but requires a high level of care. Alternatively, the much more time-efficient breeding in large groups in spacious aquariums with many hiding places is possible. The survival rate of the larvae is significantly lower, but you get strong, large young animals.

T. zieglerei can be reared in groups of up to 5 larvae in plastic boxes with 10 liters of water each. Among the larvae kept together, faster-growing dominant individuals soon emerge. Smaller, suppressed larvae are bitten, often there is loss of tail tips, tail fin hems or even limbs (which in principle can be regenerated, in the case of toes and fingers this is possible even after they have gone ashore; but usually such injuries lead to death). If the rearing boxes offer enough hiding places, the smaller larvae will retreat.

When rearing *T. vietnamensis*, a rule of thumb has been found: The smaller the group size during rearing, the larger the larvae will grow, the longer they will stay in the water and the larger the landers will eventually be. Therefore, especially when gaining first experience with this species, we recommend rearing in small group sizes of no more than 5 larvae; the safest way is to keep them singly.

The water used should be well stagnant. Stagnant rainwater with leaf decoction has proven to be good.

Sand from already acclimated aquariums is used as substrate, boiled oak leaves and hiding places in the form of PVC tubes are used as furnishings. The tank is planted with aquatic plants such as Java fern (*Microsorium pteropus*), Hygrophilia species (*Hygrophila difformis*, *H. siamensis*, *H. polysperma*) and Java moss (*Taxiphyllum barbieri*). Some inserted great ramshorns help to remove food remains. It is best to let the rearing boxes „run in“ a few days before the larvae move in.



Plant for the breeding of *Tylototriton* larvae at Cologne Zoo
| Thomas Ziegler



Larval rearing tank | Thomas Ziegler

The larvae hatch with a small yolk sac remnant or without any yolk sac at all and start feeding immediately after hatching. They practically have to swim in the food - even one day without food they can hardly cope with.

Artemia, very small water fleas and copepods serve as starter food. Initially they are fed two to three times a day, when the larvae grow up to six to eight times, depending on what the newt larvae eat. All feeding animals are well watered before feeding.

When the larvae have reached a length of 25 mm, the diet is expanded to include Tubifex pieces, and from about 35 mm, leaf worm pieces, whole Tubifex and Enchytraeidae are added. Even larger larvae also eat red mosquito larvae and sometimes young shrimp or the snails living with them in the rearing boxes.

The larvae become quite trusting when fed. Larger, more dominant animals quickly learn that the keeper's appearance is related to food. They then swim up and look up expectantly. This gives them an advantage over their smaller, shyer and hidden siblings in the same rearing tank. Basically, such dominant larvae grow larger but also stay in the water longer, while smaller, suppressed animals metamorphose earlier and with smaller body size and go ashore.



Partial water changes are carried out one to three times a day, depending on feeding. At Cologne Zoo, feces and food residues as well as a maximum of 1.5 liters of water are siphoned off. Stale water is used for refilling. This should be done very carefully, as the larvae have little resistance to the water flow and are washed away.

The metamorphosis of *T. zieglerei* takes place under the given temperatures in the Cologne Zoo 81-130 days (11-18 weeks) after egg laying. They are then about 5-6 cm long. The gill branches and caudal fin seams regress, and the skin becomes increasingly rough.

It is now of great importance that the animals can leave the water at any time without problems. For this purpose, the rearing boxes are redesigned or the animals are placed in a „terrestrial tank“. Easily accessible shore transition zones are crucial, which can be created by a rising gravel layer, but also by pieces of cork, roots, stones or similar.

In the case of *T. vietnamensis*, rearing in large common groups of up to 150 larvae in a 75-liter aquarium was also tested at Cologne Zoo. In contrast to the rearing conditions described above, water changes were omitted in this husbandry, and feeding was sporadic. The survival rate of the larvae was significantly lower in this aquarium husbandry, but the successful juveniles were significantly larger when walking on land, in some cases exceeding 7 cm.



Tylotriton vietnamensis going on land: The „gradual“ transition between water and land, made possible by sloping or obliquely introduced substrate, is important so that the juveniles can easily switch between the elements during the critical transition phase. | Thomas Ziegler



Freshly landed *Tylotriton zieglerei*
| Thomas Ziegler



4.11 Raising the Juvelines

The landers of *T. zieglerei* are smaller than those of *T. vietnamensis* and, according to the experience of the Cologne Zoo, also more sensitive. While there are only a few losses during metamorphosis of *T. vietnamensis*, the mortality rate of *T. zieglerei* during this time is about 35-40%.

Freshly metamorphosed animals on land still show remnants of the gill branches, which disappear completely after a few days. Around the time of going ashore, the animals molt; if they have already gone ashore before, they return to the water once more for this purpose. Only after this first moult - if the skin is still very smooth, it has not yet taken place - should the young animals leave the transition tank and be placed in the rearing terrarium.

After metamorphosis, the small crocodile newts are uniformly black in color, apart from the now bright orange red finger and toe tips and the equally bright tail stripe.

After the first moult following metamorphosis, the animals are kept at Cologne Zoo in boxes with a floor area of 40 x 30 cm. The breeding takes place in groups of 5-12 animals. As with the larvae, the smaller the group size, the better the control possibilities.

Temperatures and lighting correspond to the conditions of the adult animals.

Gravel placed at an angle is used as the substrate. Water is poured in high enough to create a small „pond“ in the lowest gravel area, while the rest of the area serves as a land area. Mosses, stones, (previously baked) oak leaves and pieces of cork bark provide structure, hiding places and areas of varying moisture.

Hygiene is especially important when raising *T. zieglerei*. Juveniles are checked daily; foliage is replaced once a week and gravel is flushed.

As an alternative to a „natural“ husbandry, rearing is also possible on slightly moist pulp. Then, however, daily cleaning with paper change is necessary.

The young animals have a large appetite after transformation. They eat micro house crickets, small earthworms, firebrats, *Drosophila* as well as red mosquito larvae and *Tubifex*, which are offered in a bowl or on a small plate. Again, make sure the feeding animals are well supplied and powdered with vitamin-mineral supplements. Juveniles that are in poor nutritional condition can sometimes be encouraged to eat by holding live food animals (e.g., red mosquito larvae) in front of them with tweezers. Feeding of the landed animals is done daily and then gradually reduced as they grow. A slightly cooler base temperature of 19-21 °C is well tolerated by the young and seems to be possibly advantageous for rearing.



Freshly metamorphosed *Tylotriton zieglerei* in the rearing terrarium | Thomas Ziegler



Young Ziegler's crocodile newt in the rearing terrarium | Thomas Ziegler



Breeding facility for crocodile newts at Cologne Zoo | Thomas Ziegler



Offspring from *Tylotriton zieglerei* | Thomas Ziegler



4.12 Husbandry Challenges



Tylotriton zieglerei in the terrarium | Thomas Ziegler

The following problems have occurred in the keeping of *T. vietnamensis* at Cologne Zoo. It can be assumed that analogous difficulties may occur with *T. zieglerei*.

Occasionally egg cases are damaged before the larvae are ready to hatch. In the Cologne Zoo, such eggs were then placed in the water of the incubation tank, where the eggs often developed well. However, they then usually hatch at an earlier stage of development and cannot yet move independently. Such „preemies“ can be transferred to a Petri dish filled with water, where they grow for a few days, even without feeding, by resorbing their yolk sac. They remain in the Petri dish until they can no longer lie on their side but can „stand“ upright and swim.

During larvae rearing, some attention should be paid to the correct water condition. If too much fresh water is used, the larvae quickly develop gas accumulation in the abdomen, so only a partial water change of no more than about 15% should ever be performed. If the water has too high a hardness level, degeneration of the gill branches may occur. This can be remedied by replacing the water with water of lower hardness as soon as possible.

In Cologne Zoo, problems have frequently occurred because introduced freshwater polyps of the genus *Hydra* have injured the small crocodile newt larvae with their cnidocysts, which then no longer liked to stay on the ground. In contrast, great pond snails (*Lymnaea stagnalis*) were inserted into the rearing tanks.

When the larvae start to eat snails at the age of more than one month, snail remains in the shells can cause a problematic deterioration of the water quality. This must therefore be kept an eye on, especially if there is an accumulation of empty snail shells in the rearing tanks.



5. Further Reading

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