Giant Salamanders Husbandry Guidelines

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On behalf of the EAZA Amphibian and Reptile Taxon Advisory Group

The Japanese Giant Salamander (Andrias japonicus)
Photographer: Tim Johnson

HUSBANDRY GUIDELINES

for *Andrias* spp.

↑ **Fig.1 Andrias japonicus**
←**Fig.2 Andrias davidianus**/Courtesy of Caudata Culture www.caudata.org/

Preface

The husbandry guidelines for the Giant Salamanders are produced in the hope that this will contribute to saving these impressive amphibian species from dying out in the wild as well in the zoological gardens. There are many efforts made in the countries of origin **i**n order to establish a solid captive population. In the majority of European Zoos there are currently roughly 22 specimens kept mostly as separate single specimens. However, the European population in the zoological gardens seems to be in a very poor condition and additionally aging without any promising breeding prospects. It seems to be essential to consider purposefulness of importing new founders and starting to display the *Andrias* species in the proper breeding facilities. This could also become a great educational task, as *Andrias* which is a magnificent amphibian representative can play a role of a considerable flag species in the protection of amphibians in the wild.

Taxonomy

In the class of *Amphibia* the both *Andrias* species belong to the order of the *Caudata* (Salamanders) and the family of *Cryptobranchidae* (Giant Salamanders and Hellbenders), which next is divided into two genera, the Hellbenders *Cryptobranchus* and the Giant Salamanders *Andrias.* The genus *Andrias* includes two species: The Chinese Giant Salamander *(Andrias davidianus)* and *the* Japanese Giant Salamander *(Andrias japonicus)*.

Description of the species

The two permanently aquatic species of genus *Andrias* live in restricted mountain areas in China and Japan, both in cold streams and lakes in extremely clean water. Primarily nocturnal, in daylight they hide under rocks on in the holes close to the banks. Their flattened

bodies with streamlined shape facilitate motion at the bottom in the swift mountain streams. Giant Salamanders are the largest contemporarily living amphibian species, reaching a total length of more than 100 cm. According to information of ARKIVE (www.arkive.org), Chinese Giant Salamanders grow up to 1,8 m in length and Japanese Giant Salamanders up to 1,5 m. Both the Chinese and Japanese Giant Salamanders are the longest-lived amphibians, with one female of *Andrias japonicus* which lived 52 years. This specimen was born in Amsterdam Zoo 1903, dead in 1955. Body coloration in different shades of brown, greenish, olive green or black, but the shade of brown in *A. japonicus* is darker than the coloration of *A. davidianus.* Heavy shaped, large body with depressed head, small nostrils next to the upper lip, small lidless eyes positioned dorsolateral. Giant Salamanders have poor vision. On the trunk coastal grooves with a very strong vertebral groove. Big fleshy skin folds on both sides of the trunk, tail compressed. Giant salamanders absorb oxygen through its skin and the skin folds increase surface area to help it absorb even more oxygen.

The skin is rough and wrinkled, covered with spiracles playing a respiratory role as Giant Salamanders have no gills. No spiracles on head. After transformation gills slits atrophy. Lungs vestigial. The skin is covered in mucus, which protects their bodies from abrasions and parasites. When irritated or grasped, they produce a milky, sticky secretion. Legs short, five toes on the posterior legs and four fingers on the front legs. There are known also albino, red and golden coloration varieties in Giant Salamanders. Both species are very similar in their outward appearance; there are some main features differentiating one from another. *A. davidianus* has standing out eyes, blotches on the back and fewer tubercles on the head and throat than *A. japonicus*. The usually single tubercles in *A. japonicus* are irregularly scattered, while in *A. davidianus* the tubercles are paired, ordered in rows parallel with the lower jaw. The snout of *A. japonicus* is more rounded than that in the Chinese species. Furthermore the tail in *A. japonicus* is somewhat shorter and narrower. On the anterior fringe of vomer a row of teeth arranged arcuately, parallel with premaxillary and maxillary teeth, one row of mandibular teeth. Maxilla linked with nasal part, cartilaginous hyoid arches, and large but undeveloped tongue.

Ecology

The Giant Salamanders feed on fish and its spawn, amphibians and tadpoles, molluscs, crayfish, insects and larvae, aquatic reptiles and small mammals, they are also cannibals. Because of slow metabolism they can starve for weeks. The feeding behavior of Giant Salamanders is typical for these amphibians – they open their mouth in a flash and catch the prey. Observers have described the asymmetry and flexibility of the mandibles what allows them to depress quickly one side of the mandible as much as 40° and to suck the prey into mouth. As mentioned above, these amphibians are generally active at night. Along their bodies and on heads Giant Salamanders have sensory organs similar to such organs in sharks. Thanks to that in spite of tiny eyes and poor vision they can detect other animals in the water around them.

According to the Amphibia Web Site, the reproductive biology in both *A. davidianus* and *A. japonicus* is similar. In the descriptions of these species given below there is information regarding their mating behaviour.

Chinese Giant Salamander *Andrias davidianus*

Fig.3, 4 Chinese Giant Salamanders
/ Courtesy of Caudata Culture www.caudata.org/

It is the largest currently living salamander reaching body length over 1,8 m and weight over 20 kg. Remaining populations of *Andrias davidianus* inhabits large mountain streams in central China, mainly in forested areas, from 200 to 1500 meters above sea level. Chinese Giant Salamander occurs in 12 areas across 17 provinces in the mountainous areas of river basins of the Yangtze, Huang He (Yellow river) and Zhu Jiang (Pearl river) (Liu and Liu, 1998). This species has been also reported in Taiwan, where it was reintroduced.

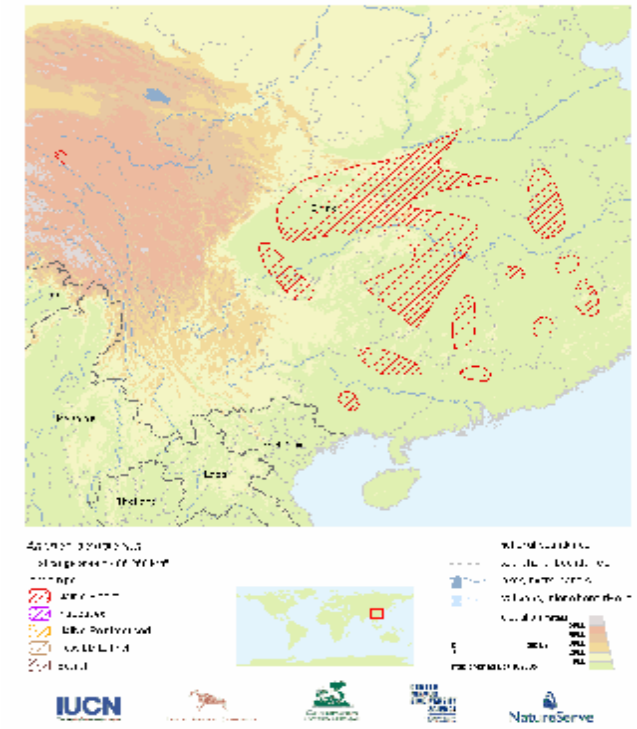


Fig.5 Distribution of *Andrias davidianus*

Conservation status of *Andrias davidianus*

IUCN Red List Category – CR /Critically Endangered/

IUCN Red List Criteria - A2ad

Chinese Red Book of Amphibians and Reptiles – CR /Critically Endangered/

CITES – Appendix I

Conservation measures

There are many conservation efforts undertaken in order to protect the natural habitat sites of Chinese Giant Salamander. Since 1980's a total area of ca. 335,000 ha including 14 nature reserves was approved as protected nature land for the conservation of Chinese Giant Salamander in China. In 1999 an area of Mount Wuyi of 99,975 ha in China, where the habitat of Giant Salamanders is located, was recognized as a World Heritage Site. According to the opinion of the Biology Department of the East China Normal University in Shanghai, in the wildlife reserves lack of funds and personnel are the main problems. In China each province has its own local protective wildlife catalogue. It is protected in the Fanjing Shan (Jiangkou, Yingjiang, and Songtao counties, Guizhou Province) and Dafengding (Ebian County, Sichuan Province) nature reserves (Zhao 1999). Nowadays Giant Salamanders occur in 17 provinces of China in the mountain region of Yangtze River. According to the Giant Salamander Protection International Website, Chinese Academy of Sciences cooperates together with other universities in China and some industrial enterprises in order to work out and improve technology of artificial breeding using modern science, means and resources. The main goal to achieve is protecting the natural environment of Chinese Giant Salamander and to breed this species on an industrial scale. One of the largest breeding farms, Guizhou Jinjang Breeding Farm in Yanxia Countryside (Guizhou Province) maintains more than 750 adult specimens of Chinese Giant Salamander and ca. 5500 young ones. This farm has reached the artificial fertilization rate 85%, the hatching rate 80% and the survival rate 95%. There were also some efficient reintroductions performed. There is also established an "aid-to-poor" programme in some mountain areas, which aims at peasants in order to encourage them to breed Chinese Giant Salamander. Moreover, China is currently working out the programme of Protection Aquatic Organism Diversity and Endangered Species.

Threats

Since the 1950 as a result of deforestation and deterioration of natural environment in general, hunting and catch for the food and pet trade the total population of Chinese Giant Salamander has dropped sharply. The flesh of the salamander is considered to be a delicacy and it is in a great demand on the market in the luxury food trade. The data of foreign trade shows, that in 1950's there was 50,000 kg Chinese Giant Salamanders sold per year for exporting in the counties of Cili, Dayong and Sangzhi. This has driven to a drastic decline of the reproductive ability of the species, so that already before 1988, when Wild Animal Protection Law came into force, the amount of sold animals lessened to 10,000 kg in these counties. In some places in Asia Giant Salamanders are used in traditional medicine and for religious purposes.

Reproduction

Courtship and spawning falls on late July to early September when the day length shortens. Hundreds of Giant Salamanders assemble at the nesting sites and males guard underwater breeding cavities, located near the river bank or inside it. One nest may be guarded by several males, which struggle viciously for the dominant role. The nesting ca- vities are burrows with one entrance, which are 100 to 150 cm long. Gravid female before producing eggs performs a nuptial dance with the male (Kuwabara, 1989). During the mating season, the Chinese Giant Salamander often cries, what sounds like that of a baby, therefore , it is often called "wawa fish" (baby fish) by common people in China. In the cavities females lay 400 to 500 eggs, measuring on average 22 mm by 19,2 mm. Eggs covered in chalazae resemble a string of beads. The diameter of the embryo is 8-9 mm. Fertilization is external. Eggs may be fertilized by several males. The breeding cavity is guarded aggressively by the male until eggs hatch, after 50-60 days at a length of 30 mm. Larvae resemble the adults in shape and start eating after 30 days i.e. when the yolk is absorbed. As opposed to *A. japonicus*, larvae of *A. davidianus* have longer gills, more pointed fingers and toes and the colour is darker. Reduction of the gills in larvae begins at the body length of 200-250 mm (Haker, 1997). Chinese Giant Salamanders reach sexual maturity at least at 5-6 years of age (ca. 30-40 cm body length).

Fig. 6, 7 Chinese Giant Salamanders
/Courtesy of Caudata Culture www.caudata.org/

Breeding

The first breeding took place in 1995 in Europe (Haker, 1997). A pair of Chinese Giant Salamanders, both of 1m total length was kept in a tank of the size 200 x 100 x 40 cm. Inside the tank there were prepared two cave systems – "A" for the female and "B" for the male with entrance tubes with a diameter slightly larger than the heads of the salamanders. Cave A was of the size 40x70 cm and had an entrance tube, cave B consisted of a pre-cave and a main-cave of the size 70x40 cm and both were accessible only through an entrance tube. In the cave B between pre- and main-cave there was a hole of 15 cm diameter. The entrance tubes were of 15 cm diameter as well. The width of heads of both animals was ca. 13 cm and

therefore the entrances could be blocked for intruders. In the center of the tank there was a clay tube of length 100 cm. The cave B was a breeding cave and was also the permanent place of the male. The water level was 30 cm; the tank was covered in half with wire mesh and also with boards in order to imitate a river bank environment. The layer of sand was 10 cm. A pump of efficiency 1200l/h ensured a good supply of oxygen and water was pumped from a filter system. Every day ca. 20 l of carbon-filtered tap water was added to the tank in place of old used water. The breeding cave was additionally ventilated. The salamanders were fed with live trout's and other fish, crayfish, worms and turkey hearts.

The first eggs laid (middle of August 1994) were unfertilized. The second egg laying (September 1995) was successful. Both layings happened when the water temperature has fallen by 16^{o} C. Hatching of the larvae began on 50^{th} day after egg laying and continued still two weeks. After 30 days, when the yolk sack was absorbed, the larvae started eating; their first food consisted of tubifex and red mosquito larvae. The temperature of water during the winter varied between 5^{o} to 10^{o} C.

Three months after hatching the larvae reached a length of ca. 6 cm.

The data concerning breeding of the Chinese Giant Salamander given above is based upon the reproduction biology and the one captive breeding case officially described. However, the breeding behavior and conditions of this species is very similar to the more known and better analyzed breeding of the Japanese Giant Salamander, which may set a good example.

Fig.8 A pink (or golden) form of *Andrias davidianus*

Japanese Giant Salamander *Andrias japonicus*

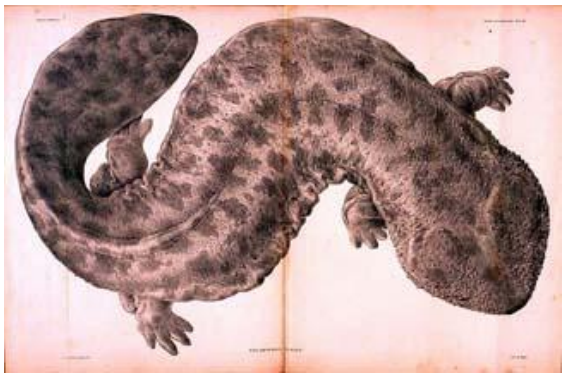


Fig. 9, 10 Japanese Giant Salamanders

/Courtesy of Caudata Culture www.caudata.org/

The Japanese Giant Salamander reaches 130 – 150 cm body length and 30 kg in weight. This species occurs in mountain streams of width ca. 20 m with stony bottoms providing for enough oxygen. The vertical distribution ranges from 300 to 1000 m above the sea level. This nocturnal species hides under rocks or in holes in river banks during the day. The Japanese Giant Salamander *Andrias japonicus* are known in Japan in the southwestern portion of the Island of Honshu northeast to the Prefecture of Gifu, Shikoku, and on the Island of Kyushu in the northern part in the Prefecture of Oita. The Japanese names of this species are „Osanshouuo", " Hanzaki" and "Hajikamiio". These are named for a mucus being produced from the skin, smelling like Japanese pepper (= sansho, hajikami).

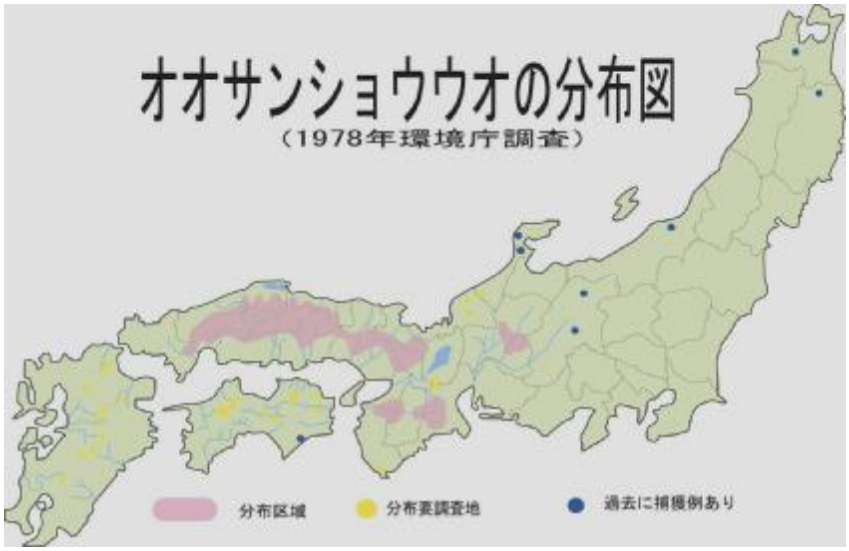


Fig.11 Distribution of *Andrias japonicus* /Courtesy of Prof. K. Kuwabara/

Conservation status of *Andrias japonicus*

IUCN Red List Category – VU /Vulnerable/

CITES – Appendix I

Conservation measures

Fig. 12. Stuffed *A. japonicus* / Courtesy of Caudata Culture www.caudata.org/

Recognized as a Japanese national treasure. One of the most threatened animals in Hiroshima. Due to river destruction artificial nesting sites are prepared in the bottom of the rivers. To this end are used pipes with diameters of 20 cm with nesting chambers with 60 cm diameter. However, the main problem consists in a little knowledge about development of the larvae. Therefore some generations of juvenile animals don't survive. Nowadays many researches of microhabitats, ecology and development process of Giant Salamander's larvae are being conducted in order to improve the conservation efforts. There are measures taken for restoring the spawning grounds in the Ichi river (Tochimoto,1995).

Threats

Fig. 13 Left foreleg of *A. japonicus*
/Courtesy of Caudata Culture www.caudata.org/

Fig. 14 Head of *A. japonicus*
/Courtesy of Caudata Culture www.caudata.org/

This species has no natural predators; however, it was recently the object of hunting for food and traditional medicine. The main threats are river dams and pollution, which exemplify a typical model of habitat destruction. River dams may dramatically change the natural habitat

of the Japanese Giant Salamanders by separating different populations and their migration ability. According to the IUCN World Conservation Monitoring Centre a continuing decline is observed in extent and quality of habitat and in the number of locations where the animals were found. In spite of different conservation measures, the devastation of natural habitat of Giant Salamander causes local decline to a greater extent than it happened in the past (Matsui & Hayashi 1992). A low genetic variation may cause another problem in Japanese Giant Salamander (Matsui & Hayashi 1992).

Fig. 15 The Japanese Giant Salamander in its habitat

/Courtesy of Prof. K. Kuwabara/

Reproduction

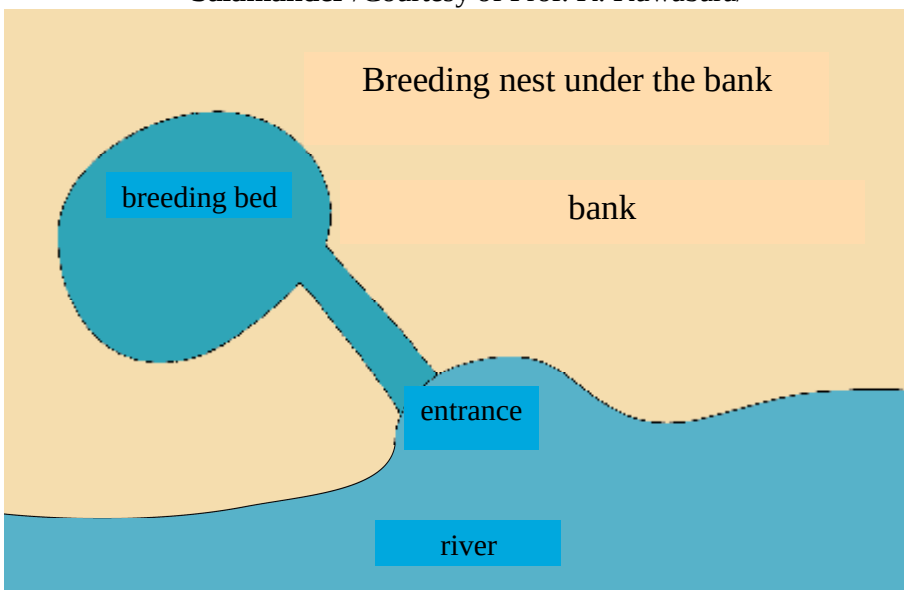
The Japanese Giant Salamanders show no external sexual dimorphism. In the breeding male cloacal lips are swollen during the mating season whereas in the female these are flat. The breeding season is in August and early September. At this time herds of males and females congregate nearby the nests, which are usually burrowed under water into or next to the bank of the river. The outlet of the nest is also open under water. Nests are patrolled around and guarded from inside by big males so-called "den-masters" and all other males trying to get into the nest are attacked. Females enter the nests where they approach males and start to whirl and to lay eggs. Females spawn several times in the nest, then the eggs are fertilized by the male, however other intruder males at the same time may also try to fertilize the laid spawn. In the same nest more females can spawn. The "den-masters" guard the eggs with a great aggressiveness mostly until the larvae hatch at the end of October.

The Asa zoological park's team observed the breeding behaviour of this species in Toyohira-cho, Hiroshima in 1978. This species began to breed after the water temperature had dropped to 20^{o}C degrees from the end of August through early September. There were 18 males and 9 females in the breeding group. The smallest male and female were respectively 30cm and 40cm in total length. They gathered in nests in the river bank as far as 30-600m from their own territories. The largest males occupied a nesting site and guarded a 2-3m radius around it. They then fought off other males awaiting potential mates. After a female came into the nest to breed, other males would then enter the same nest. Five females laid in the same nest for three days (Kobara, 1985).

"A female usually lays 500-600 eggs. Larvae hatch in 40-50 days, they stay immobile until about January and then leave the nest little by little. Larvae were found in and around the nest as far as 600m downstream. Larvae are 60-70mm TL in late June and then disappeared. Larger larvae have never been found"(Kobara, 1985).

The Asa zoo team succeeded breeding this species in captivity after wild breeding observations had been recorded. Dr Jiro Kobara describes captive breeding of A. japonicus in detail in his book (Kobara, 1985).

Fig.15 The Breeding Nest of the Japanese Giant Salamander /Courtesy of Prof. K. Kuwabara/



The spawn is deposited in strings which may contain 400 – 600 eggs of diameter ca. 8-15mm together with external transparent gelatinous capsule. The diameter of single egg without this capsule is 5,5 mm. Incubation period of the eggs at temperature 13^{o}- 20^{o} C lasts about two months (Thorn 1969). The length of larvae at hatching is ca. 30 mm. Large numbers of offspring are produced each season, so mortality early in life is probably high (Sleeper, 1997).

Fig. 16,17 The spawn of *Andrias japonicus* */Courtesy of Caudata Culture www.caudata.org/*

Fig.18 A string of eggs *A. japonicus* /Courtesy of Prof. K Kuwabara/

Fig.19 Young larvae developing inside the eggs /Courtesy of Prof. K. Kuwabara/

Fig.20 A larva inside the egg /Courtesy of Prof. K. Kuwabara/.

Fig.21 A larva of *A. japonicus* /Fot. Gerry Marantelli/

The larvae start feeding after the absorption of the yolk. The length of a larva at the age of one year is about 100 mm and ca. 200 mm in three year old animals when they lose their gills. The Japanese Giant Salamanders reach sexual maturity at the body length of 30 cm in males and 40 cm in females but the earliest at the age of five years (Matsui & Hayashi 1992). Metamorphosis in this species is incomplete. Adults do not develop eyelids, and retain a single pair of closed gill slits on the neck. *Andrias japonicus* retains its larval teeth for life and has lungs which are vestigial, performing no gas exchange. ("Arkive-Images of Life", 2004; Gadow, 1901; Parker, 2001; Pough et al., 2001; Sleeper, 1997; Zug, Vitt, and Caldwell, 2001). The substantiated longevity of this species is exceptional - according to the specimen report from Amsterdam ZOO one Japanese Giant Salamander born in the ZOO in 1903 died in 1955, reaching the age of 52 years.

Breeding

History

The first case of breeding of the Japanese Giant Salamander in captivity took place in the Amsterdam ZOO in 1903 (Kerbert 1904). The measurements of the aquarium were 3 x 3 x 2m, diameter of eggs was 7 mm, the only larva after 3 years reached over 20 cm body length and survived 52 years, died in 1955.

The Asa ZOO since its opening in 1971 has been running the breeding and conservation programme for the Japanese Giant Salamander. The second breeding case in captivity in Asa Zoological Park in Hiroshima 1979 was described by Kobara *et al.* in 1980.

Facilities and keeping conditions

The present description of the captive breeding techniques is based mostly on the experience and expertise of Prof. Kazushi Kuwabara and his team working on the breeding and conservation of the Japanese Giant Salamander.
The Asa Zoological Park used two types of breeding aquaria built especially for the Giant Salamanders. The first type was worked out and built in 1978 (Fig. 20), and was made up of four plastic tanks 90 x 70 x 45 cm connected in a quadrangle with pipes of a diameter 15,5 cm which enabled animals to move from one tank to another and also assured them a possibility to stay in constant moving. On the bottoms of the tanks there was 15 cm sand. The water was kept on the level of 20 cm thanks to the overflow slots. All the tanks were placed in the soil in order to ensure no daylight access and were covered with a wire mesh and three of them were half covered with hinged wooden lids, the fourth one was covered entirely.

Fig.22 The aquarium consisted of four tanks linked by pipes
/Courtesy of Prof. K. Kuwabara/

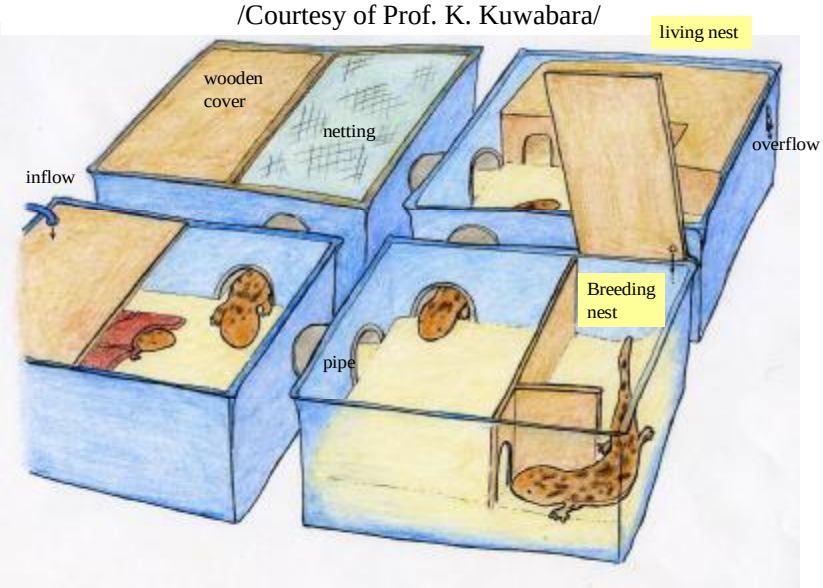
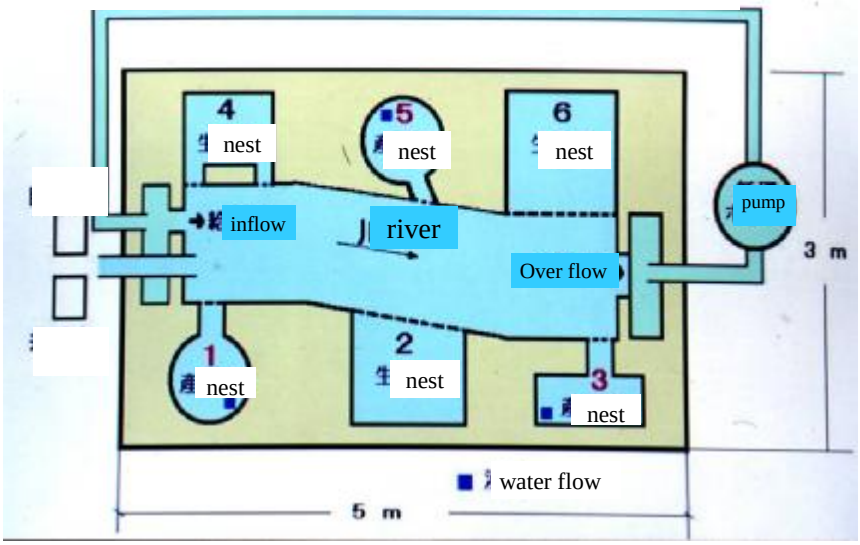


Fig.23 A breeding aquarium in the ASA Zoo
/Courtesy of Prof. K. Kuwabara/

Fig. 24 An artificial nest
/Courtesy of Prof. K. Kuwabara/

In the two tanks there was a rocky shelter box made of tiles and in one tank there was a separate breeding nest with an entrance room, divided by a wooden partition from the rest of the tank which could be used by other salamanders for moving between the tanks. This kind of artificial breeding facilities imitated natural habitat of the Giant Salamanders with streams and nesting burrows hidden in the bank of the river.
The water was supplied from a natural stream via plastic hoses and this system assured impact of outside temperatures which varied in 1979 from 4°C in March to 20°C in September. The rate of water flow was ca. 13 l/min. Water pH level varied between 5.7 – 6.0. The dissolved oxygen /D.O./ level was 8.5 ppm at the temperature 13.8°C. The biological oxygen demand /B.O.D/ was 0.1 ppm, as the water contained little organic matter.
After the first experiments the various arrangements of aquaria were constructed. The new arrangements consisted of three or four tanks connected in triangles or quadrangles or in a straight line. The tanks were covered fifty-fifty by wooden lids and a wire mesh.
Below is an outline of the new type aquarium. There is a river in the center and various types of nests put into the bank. According to Prof. Kuwabara's information there were five salamanders kept in this aquarium and they successfully bred in 1999. An owner male usually lived in the nest nr 4. During the breeding season he came and moved between the nest nr 1

Fig. 25 The new type Aquarium
/Courtesy of Prof.. K. Kuwabara/



and the nest nr 5. At last this male chose the nest nr 5 as a breeding nest. This nest was used by this male every year. The nest nr 5 has one entrance, short slant tunnel leading to the middle part which imitates river, breeding space and a small water flow out from the inside. The new type aquarium confirmed the condition of the breeding nest.

Fig. 26 The Asa zoo made an artificial breeding nest.
/ Courtesy of Prof. K. Kuwabara/

Nutrition

Nutrition and feeding methods in the Asa Zoo were changed every year. First, in 1976 Giant Salamanders were fed on Japanese jack mackerel ***Trachurus japonicus***, then in 1977 on Rainbow trout ***Salmo gairdneri*** /***Oncorhynchus mykiss/*** served with the help of tweezers. Since 1978 amphibians were offered a constant supply of live Rainbow trout, which were successively eaten, however, the Giant Salamanders had difficulties with preying on agile, fast moving fishes. For this reason in the next year Oriental weatherfish or weather loach /***Misgurnus anguillicaudatus/*** were used as easily accessible food for the amphibians. According to the data given by Prof. Kuwabara the varied diet in the three years 1977 – 1979 bore fruit of increasing body weight in the salamanders and greater swelling of the cloacal glands, what was a sign of sexual activity.

Animals

In 1979 the first breeding group was made of seven specimens /4.3/, caught in a degraded habitat area. The sizes of animals varied from 54-80 cm of body length and 2200-4300 g body weight. They were put together and no fights between amphibians were observed.
The second breeding group was formed in 1982 from one male (recognized as a proven breeder in captivity), two females and two other males.
In 1983 the third breeding group consisting of two males, two females and one unsexed specimen was established.

Egg laying and reproductive behaviour

In the first breeding year there were no signs of typical reproductive behaviour. The first spawn was deposited in the tank containing the artificial breeding nest /see Fig. 20-22/ on 28th

September 1979. Two females were spawning and finally 1224 eggs with the embryos inside were found. One of the males, the "dens-master" Ushiroyama guarded the eggs poking his head out of the entrance slot and other animals remained separately in the three other tanks /Fig. 23/. This male was very aggressive when the lid of the tank was raised and he also tried to attack the keepers.

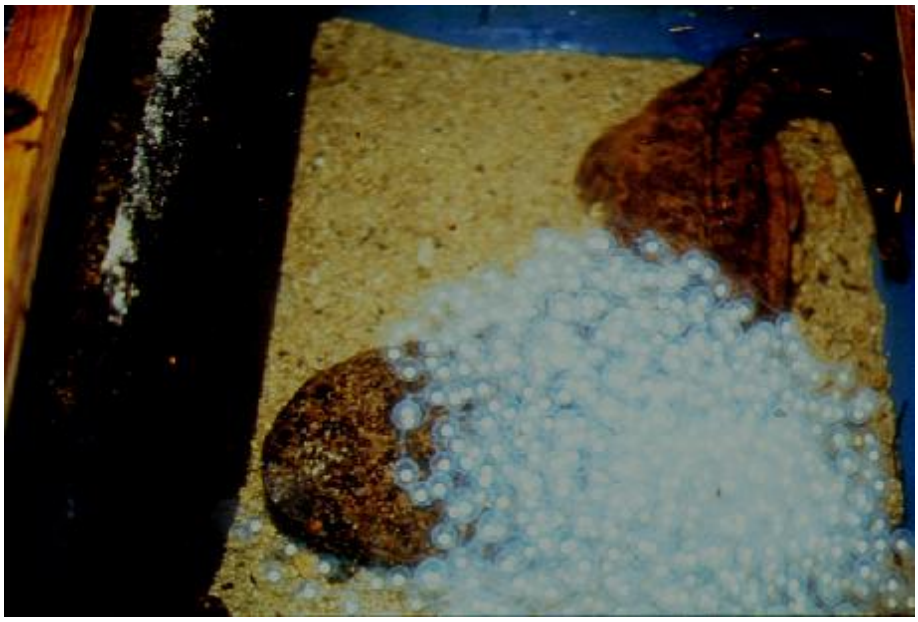
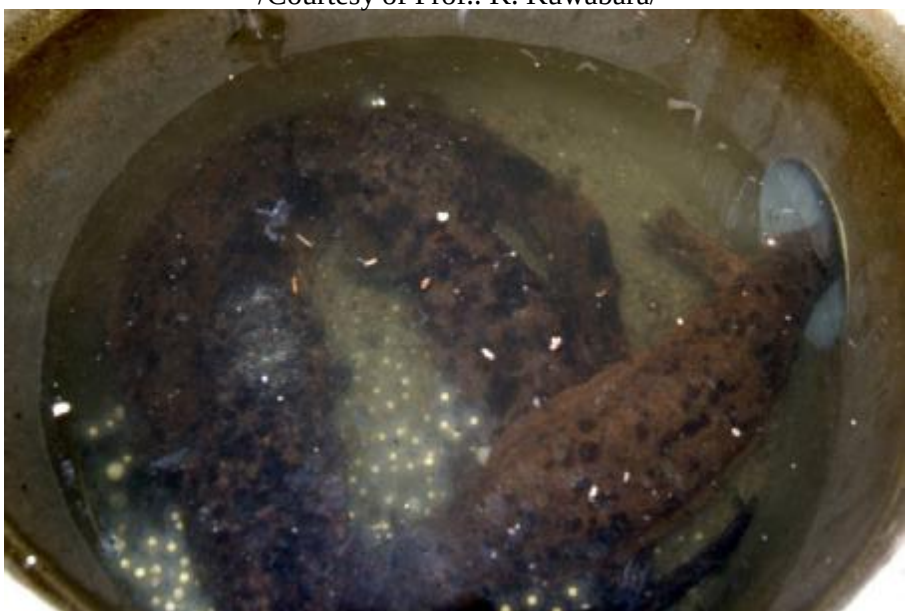


Fig. 27 The first egg-laying in 1979. "Ushiroyama" became the owner male (the "den-master") /Courtesy of Prof. K. Kuwabara/

The next described case of breeding took place in 1982. The spawn was deposited in the evening on 6th September in the tank with the artificial breeding nest. The male "Ushiroyama" as the owner male remained in the breeding nest. First one female entered this room and 22 minutes later she began laying eggs. The time when the first egg was laid was appointed "zero". 15 minutes before "zero" another male entered the breeding nest without any demur of "Ushiroyama". The same behaviour appears in the wild, i.e. the owner male accepts other males in the nest in the presence of a gravid female. For a moment three animals remained quiet, and then the owner male "Ushiroyama" bit the upper jaw of the female and ten minutes before "zero" both animals started turning and spinning together. Another male joined the dancing pair after three minutes. Two minutes before „zero" the dance was accelerated and the female arching her back laid ca. 100 eggs on the both males. Then the dance slowed down and two minutes after "zero" time a third male was allowed to enter the nest and to join the spin dance; within three minutes another 100 eggs was laid. Then five and again six minutes after "zero" males sprayed its semen into water which became cloudy. In the twelfth minute one of the males left the nest and the female kept her back arched. In the 31 and 34 minutes after "zero" the animals began dancing again and the female laid the next portion of eggs. In the 44th minute the salamanders started dancing again and the next part of spawn was deposited. In this time water was so cloudy that further observations were given up. This was the first observation of the breeding behaviour which was recorded. In all the breeding cases

the spawn was deposited in September, in the time limit from 2nd to 30th September. All the hatchings took place between October and November, the longest incubation period was 60 days, the shortest 40 days. The largest number of eggs in one group was 2434 from three females; the smallest number of eggs was 336 from one female in 1982.
In all the described above arrangements of aquaria normal mating behaviour was observed and also the spawn was deposited in the normal way. However, in the aquarium consisting of two or three tanks, (and for this reason more crowded, as well) the owner male "dens-master" didn't defend the eggs and two males were observed while eating the eggs, what never happened in a four-tank aquarium arrangement.

Fig. 28 The egg-laying of the giant salamander in captivity
/Courtesy of Prof.. K. Kuwabara/



Egg development

As mentioned, the diameter of the single egg covered with the jelly capsule is 8-15 mm, mostly ca. 10 mm. This diameter over the next several hours increases to 20-25 mm as a result of water absorption. The spawn looks like a string of beads as eggs are connected with each other with a jelly thread (Fig. 18, 29).
The 1224 eggs laid in 1979 were protected by the owner male. During the incubation period the temperature of the water varied between 11.5° and 20° C. After 42-49 incubation days 349 larvae hatched.
The egg development process was recorded in 1981.On the next day after spawning the eggs were in the one-cell stage and on the third day in the four-cell stage. The blastula was formed on the fifth day after spawning, on 10th day gastrula, on 11th day neurula. The bud of the tail appeared on 16th day, the buds of the forelimbs on 27th and of the hind limbs on 38th day. The hatching took place between 52nd and 56th incubation day. During the incubation period water

Fig. 29 A string of eggs of *Andrias japonicus*
/Courtesy of Prof. K. Kuwabara/

temperature varied from 8 to 18° C. The detailed data concerning the development process of the spawn taken from the wild but artificially incubated was described by Iwama (1968) in a private publication in Japanese.

Neonate husbandry

The larvae from the first hatching were kept indoor and were fed on live food – earthworms, tadpoles and aquatic insects, but due to lack of this kind of food many larvae died. In 1981 the larvae were kept outdoor in the running water system which facilitated them access to the live food. The larvae were placed in a 65 x 38 x 15 cm plastic tank at water flow rate 500 ml/min. Water level of 10 cm was kept by the overflow slots. Inside the aquarium boxes built from pieces of wood, tiles and withered leaves were placed. Water temperature varied from 2° to 22°C depending on the season of the year.
As mentioned above, the larvae start feeding after the absorption of the yolk, when the yolk sac disappears and this abdominal part of the skin /ca. 3-7 mm/ becomes black.
The larvae in the water temperature varied from 3° to 13° C /more similar to natural conditions/ start feeding about 80 days after hatching, but in the temperature 16.5° C they start to take food already after 30 days since hatching.
The first food is larvae of Chironomids. Throughout the first year the larvae of the Giant Salamanders are offered frozen chironomid larvae with small live earthworms and aquatic insects; sometimes also tadpoles. After one year they are fed on sliced squids, krill and live oriental weather fishes once or twice a week.

Fig. 30 Young specimens hatched in the Asa Breeding Farm /Courtesy of Prof. K. Kuwabara/

Development of the larvae

The larvae after hatching measure ca. 3 cm of body length and have three pairs of external gills. Their body is black with the exception of a yellowish part of an abdomen covering the yolk sac. The limbs are thin and the fingers are not diverse yet. At the age of 1 year the larvae are ca. 10 cm long. The body colour becomes lighter and some dark spots are visible on the back. After three years the larvae reach 20 cm in body length and external gills disappear, however the branchial slits remain open. The branchial slits close at the age of four when the larvae reach the length of ca. 26 cm. One specimen born in the Asa Zoo at the age of nine reached 42 cm of body length.
One female named "Igaguri" gave the first information about maturing. She was born in the Asa Zoo in 1980 and laid eggs being 17 years and 9 months old.
The life-cycle of the Japanese Giant Salamander resembles the life-cycle of a human, maturing at the age of 17 sand the life span may reach 100 years.

Final observations

- The Japanese Giant Salamanders do not breed in pairs but form breeding groups and on this ground the Asa Zoo conducts its breeding and conservation programme.
- It seems to be crucial to establish groups consisting of more males in order to enable the best male to become the owner male "dens-master". According to the experience of the Asa Zoo team a group of minimum 4.2 Japanese Giant Salamanders kept in an adequately large aquarium should be the most successful.
- The largest aquarium consisting of four tanks produced the best breeding results, however animals also bred in all the arrangements of aquaria, with two or three tanks.

- Water should be constantly kept in a proper quality level by a current of water flowing through the breeding chamber, likewise in the wild habitat of the Japanese Giant Salamanders.
- The best diet, developed in the Asa ZOO, for the adult specimens was live Oriental weather fish /Weather loach/ *Misgurnus anguillicaudatus*, species living on the bottom of the river like the Giant Salamanders do. The Salamanders were forced to prey on the fish but the important fact is that they accepted it and the human interference is strongly minimized.
- The two important breeding factors are temperature changes typical for the wild habitat of the Giant Salamanders and the photoperiod, as the Giants deposit their eggs in autumn which is unusual in amphibians. This indicates a significance of the outside breeding enclosures.

Fig. 31 The New Farm of the Giant Salamanders in the Asa Zoo
/Courtesy of Prof. K. Kuwabara/

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