

## Captive Breeding and Husbandry of The Golden Orb Weaver *Nephila inaurata madagascariensis* at Woodland Park Zoo

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Orb-weaving spiders have long been a desired addition to any insectarium, and the golden orb-weaving spider, *Nephila inaurata madagascariensis*, is an especially charismatic and showy species! It is one of the few spiders often kept in open exhibits, and it can serve as an ambassador for those who wish to teach the public important lessons about arachnid biology, the important ecological niche these predators play, and ways to avoid human/wildlife conflicts.

### Taxonomy

The genus of true spiders known as golden orb weavers, or *Nephila* (Leach 1815), has undergone many changes of name and classification and is still being revised. The ancient Greek words “nen” (to spin) and “philos” (to love) translate into the descriptive “one who is fond of spinning”. It is also interesting to note that the word *Nephila* is a synonym of the constellation Orion- important to Egyptian religion.

*Nephila* is often recognized as the oldest surviving genus of true spiders. Evidence of *Nephila jurassica*, which lived about 164 million years ago, was found in Mongolian volcanic ash in 2011.

The current accepted taxonomy for *Nephila* is: Family Nephilidae>Subfamily Nephilinae (Kuntner et al 2008) Genus: *Nephila* (Leach 1815). There are now at least 15 recognized species and many subspecies, some still undescribed.

### Natural History

The genus *Nephila* is found in warmer climates of Asia, Australia and the Americas. These large colorful spiders, also known as giant silk spiders, giant wood spiders, and golden silk spiders, are known to for their impressive beautiful orb webs. They are often found in moist woodland habitats, but can also be found near human habitation, with webs strung between fence rails, ornamental trees, or anchored to the eaves of houses.

*Nephila* spiders are most often reddish to yellow in color with distinctive silvery white cephalothorax. The striped legs are long and specialized for weaving. These are some of the largest web-spinning spiders, females averaging 4.5 to 6.0 cm without leg span. Males are markedly smaller, usually less than 2.5 cm. Reportedly, one of the largest *Nephila* spiders

photographed was found in 2012 in Queensland killing and consuming a half meter long brown tree snake. Some *Nephila* in the mountainous regions of Taiwan are reported to reach over 130 mm leg span.

In order to avoid overheating in warmer tropical and subtropical climates, it has been proposed that the silvery carapace reflects sunlight. The long cylindrical shaped body, when pointed directly at the sun, helps to decrease the amount of the body surface area exposed to the overheating effects of the sun. In warm habitats, active evaporative cooling may be employed in temperatures above 35° C by manipulating a drop of fluid with the chelicerae (Krakaven 1972).

Adult female *Nephila* often position themselves near or above the hub, or central area, of the web. There are often multiple webs found in the same location. Male courtship appears to be mainly opportunistic. There is some evidence that male *Nephila* many find females by detecting short distance pheromones produced by the female. It is also thought that females leave chemical signals on certain web strands. During courtship, males systematically pluck web strands, approaching the larger female if she shows receptiveness by remaining motionless. Males often approach a female after prey capture. As he approaches the female, he carefully touches her tarsi, the pedipalps, and, if receptive, she allows him to mate. If not, the female will attack and kill the male. The male inserts embolus of pedipalps individually into female genitals. Mating may take a few seconds to several minutes. Sometimes, males have been recorded depositing silk periodically over several days onto the dorsal opistosoma and pedicel of the female spider. This appears to affect the flexibility of the female, thus decreasing her ability to bend and pluck the male off during copulation. Often, multiple males are found near the hub of the female's web. Depending on the species, anywhere from several weeks to several months later, the gravid female, who has swollen in the girth up to twice her normal size, deposits a silk-wrapped case, 2-4 cm in length which contains 100 to 200 ova. It is attached either to the web, to surrounding leaves or other surfaces near the web, or in a pit in the soil underneath the web. Depending on species, humidity, and temperature, the spiderling's hatch 20 to 45 days later, leaving the egg case at first or second instar. Spiderlings often clump together for several days to two weeks before dispersing to build their own orb webs.

Male *Nephila*, depending on species, climate, and food availability, mature after in 2 to 3 months after eight instars, and typically live another 3 to 4 months. Female *Nephila*, again depending on species, usually mature in 4 to 6 months after 12 to 14 instars, and may live another 6 to 8 months.

*Nephila* spiders are renowned for the beautiful orb or wheel webs they produce. The golden orb weavers are named for the golden yellow color of their webs. The golden hue is derived from four compounds: xanthurenic acid, two quinones, and a fourth unknown compound. It appears the color of the silk not only attracts bees and other flying pollinators to sunlit webs, but also serves to camouflage the web in low light conditions. Spiders apparently can adjust the intensity of pigment according to light conditions.

An asymmetrical, complex, and fine-meshed orb is made by these spiders. These semi-permanent webs are repaired as needed, not destroyed and rebuilt daily as with many other orb

weavers. Occasionally, barrier web threads are made in front of the web often containing boluses, dead insects, or molts. It is thought these visual cues are left to prevent bird strikes on the main web. Some *Nephila* species are known to remove the lower parts of their web before stormy conditions to protect the main structure of the web.

*Nephila* silk is reported to be one of the strongest threads known to man. Due to its low density, it is reportedly five times stronger than steel per unit weight, stronger than Kevlar due to its strength and ductility, and has three times the flexibility of nylon. It can retain these properties at temperatures ranging from -40° to 220° centigrade.

The diet of *Nephila* spiders consist largely of arboreal and flying insects from the orders Odonata, Orthoptera, Hymenoptera, Lepidoptera, Diptera, and Coleoptera. However, it has been observed that large webs have snared small hummingbirds as well as tiny lizards and tree frogs. *Nephila* spiders are considered to have a more primitive method of capturing prey than *Argiope* orb weavers. These spiders make webs nearly as large as *Nephila* spiders but first immobilize their prey with silk wrapping, contrary to *Nephila* spiders which use their bite as a primary attack weapon (Robinson et al 1969). This allows *Argiope* spiders to safely attack larger prey than *Nephila*. This difference in behavior may be viewed as an evolutionary development to reduce competition for the same prey in shared habitats.

It is worth mentioning that *Nephila* spiders are often subjected to kleptoparasitism by small 3 to 4 mm *Argyrodes* spiders. *Nephila* often bring food back to the center of their web to reduce this problem or move to a new location.

There are three main attack methods used by *Nephila*:

1. Long Bite - for more active or heavily armored prey such as beetles.
2. Bite and Retreat - a series of short bites (in less than 5 seconds) before a long bite is delivered. Used mainly for large prey such as grasshoppers.
3. Seize and Pull - into chelicerae used for small light prey such as flies or mosquitoes.

The venom of *Nephila* spiders varies with species and, while potent, is not dangerous to humans. Its neurotoxic affect causes localized pain and redness, and occasionally blisters may form that disappear within 24 hours. Rarely, its bite can trigger allergic reactions resulting in asthma-like symptoms or involuntary muscle cramps. Due to relatively strong chelicerae, bites from adult females can leave scar tissue.

*Nephila* spiders are preyed upon by a variety of birds, lizards, and mammals. The warning coloration of a black, yellow, and red may provide some protection. Spiderlings, as well as adults, use vibrational motion or bouncing of the web not only to differentiate between prey or a predator touching the web, but also to disorient or alarm a potential predator, making it hard to focus on the spider itself as it's web oscillates in a blur of motion up to 40 Hz. *Nephila* spiders are also aided by this motion if they choose to drop to the ground and play dead, another common defense tactic.

## Importance to Humans

Due to its strength, resiliency, and beauty, *Nephila* spider silk has been tested in a variety of medical and commercial projects.

Two bed hangings made from *Nephila* silk were presented at the 1900 Paris Exhibition. In 2004, a 335 cm by 122 cm golden tapestry or shawl was spun entirely from the silk of over 1.2 million *Nephila* spiders in Madagascar by textile maker Simon Peters and fashion expert Nicholas Godley. It took four years to make and was exhibited in the American Museum of Natural History. In 2012, a cape was also produced by these two men.

*Nephila* silk has also been used in medical research in tissue engineering. It has been reported that due to its low occurrence of rejection and high tensile strength, *Nephila* silk may prove an ideal guiding material for peripheral nerve regrowth.

*Nephila* webs have long been used by New Guinea tribes to create both fishing nets for small fish or rolled to serve as fishing line for larger catches.

## Some Species Kept In Captivity

***Nephila clavipes*:** Also known as the golden silk spider, banana spider and calico spider. This is the only *Nephila* species found in the Western Hemisphere. *Nephila clavipes* occur is in the U.S. from North Carolina through Florida and the Gulf states, south through Central and South America through Argentina. Populations may be locally rare but often occur in open woods, dense forest, between wetland vegetation, and in trees near bodies of water. It is the most common orb weaver in citrus groves (Muma 1975). Young spiders are often found in soybeans and other crops.

The web is often 1 to 2 m wide, with the hub near the top of a semi-permanent, asymmetrical web. Often, stabilimenta (zigzag silk) are found in the webs of juveniles.

Female *Nephila clavipes* are among the largest true spiders in North America. Females are 24 to 40 mm long, with a silvery carapace and cylindrical body covered with yellow spots on a faded orange to tan background. Brown and orange-banded legs have dark brown to black “hair brushes” or “gaiters” on tibial segments of legs I, II, and IV. The dark brown male is much smaller- only about 6 mm in length. In temperate zones, this spider only produces one generation in the field. In warmer climates, males mature July through September. Females mature in August and live through late fall, usually producing two 2.5 -3 cm long egg cases each year. Several hundred babies emerge in three weeks to a month.

***Nephila pilipes*:** The giant golden orb weaver is found throughout Asia, including Japan, China, Vietnam, Cambodia, Taiwan, Singapore, Indonesia, Laos, the Philippines, Sri Lanka, India, and Papua New Guinea. Females are 30 to 55 mm leg span. Males are 5 to 6 mm leg span. Their vertically-oriented, asymmetrical webs are of irregular mesh with the hub near the top. Egg sacs

are deposited in shallow pits dug under the web and covered with debris or soil. Several subspecies exist.

***Nephila inaurata***: The red-legged golden orb weaver (Walckenaer, 1842) is found in Southern Africa and several Indian Ocean islands: the Seychelles, Reunion, Mauritius, Rodrigues, and Madagascar. There are two subspecies: *Nephila i. inaurata* and *Nephila i. madagascariensis* (Vinson 1863) found from Southern Africa to the Seychelles.

Webs are found in humid habitats, in or between large trees in undisturbed areas. Often, numerous webs strung together to form a huge home. A diet of flies, mosquitoes, wasps, beetles, and other flying insects sustains this species.

Egg sacs typically contain 100 to 200 eggs. Female spiders mature in 4 to 6 months and have up to 100 mm leg span. Two forms of males occur. A small percentage of a males mature in 1 to 2 months, have only an 8 to 10 mm leg span, and are dark brown to black in color, looking like small crab spiders. A larger percentage of males mature in 3 months, their color and shape resembling a smaller version of the female, but having 25 to 30 mm leg span.

#### Captive Husbandry at Woodland Park Zoo

The insectarium at Woodland Park Zoo (WPZ), known as “Bug World” is a freestanding exhibit housing crustaceans, arachnids, insects and many other terrestrial and freshwater invertebrates. A species of spider recorded as *Nephila madagascariensis* was acquired by WPZ in 2002, and occasional acquisitions have come from AZA zoos such as Cincinnati and Toledo Zoos. Currently, *Nephila inaurata madagascariensis* is being kept successfully at “Bug World”.

Adult *Nephila* spiders are kept in three primary types of habitat, with a fourth type being used dependent upon population numbers. Adult females are kept in two main types of enclosure for breeding and egg case care:

1. 44 cm H x 30 cm W x 30 cm L vertically-oriented tank with two opposing glass sides and the remaining two screen sides, with a top opening screen lid. The lid allows easy access during feeding crickets (held with forceps) as well as houseflies. The other advantages are excellent visibility of the spider and good ventilation. Males may be added as desired. Substrate is a layer of ~ 2 cm. vermiculite. A clean, dry branch is added for web attachment. One disadvantage to this tank is that, despite the aid of vermiculite to hold moisture, these enclosures due tend to promote desiccation when heating/cooling systems are in use. This problem may be addressed by taping plastic film (Saran Wrap®) across the top and one screened side of the tank. Another consideration is that this species of *Nephila* often hangs its egg case near the lid, though if care is taken, it can easily be separated from the screen.

A more recent enclosure being used for *Nephila* is a hard plastic and plastic screen 30 cm cube called a “Bug Dorm”. With the addition of a layer of vermiculite, and a thin, branched twig,

these cubes make excellent breeding and brood enclosures if two sides are covered with plastic film. A third type of enclosure is utilized for holding non-breeding adult females or suitably-sized juvenile females. A 173 cm tall mesh cylindrical tower comprised of six stacked compartments (originally made as a storage unit for children's toys or clothes) can be fitted with mesh sleeves sewn around the openings to ensure containment. The advantages of this tower is that it saves space, has easy access for feeding, and is easy to clean and store when not in use. Its disadvantage is that houseflies can easily escape through the open mesh, and it can collapse if not hung with care.

Juvenile spiders are housed through fifth instar in tall 1.2 liter clear deli cups with a paper insect lid partially taped to retain humidity. Mesh under the lid aids in containment. From here, they are moved to one of two types of enclosure for rearing to adulthood. One of the previously described tall vertical tanks has an additional layer of terry cloth added to one side and finer mesh sides and lid. This tank, with a substrate of vermiculite and multiple small thin twigs, makes a perfect home for young spiders. The second container for rearing is a "20-gallon long" tank with a fine mesh sliding end opening, as well as a sliding top lid. Both containers allow for good humidity (which is extremely important for ecdysis), good ventilation to reduce mold and fungus growth, and easy access for feeding. Due to the diversity of species needing habitats ranging from desert to temperate to tropical, the holding room of "Bug World" contains a variety of a microhabitats within one room. Relative humidity ranges from 50% to 80%, and many tanks are misted twice daily. Temperature ranges from the low 20's C near the floor to the low 30's C near the ceiling. Egg cases and early instars are kept in the mid-high 20's. Older juveniles and breeding pairs are kept in the mid 20's to high 20's, and other females are kept in the mid 20's. All *Nephila* are misted twice daily in the morning and afternoon, and brood tanks containing egg cases maybe misted a third time as needed.

As male spiders mature, they are placed with adult females. As many as five males may be added to any female's tank. Each female spider has its own label with information about its hatch date and dam enclosure. Courtship usually follows within several hours, and males from several different egg cases are added as available during each female's life. As females reach about 10 months of age, they are rotated out of the breeding tanks with newly mature females if available. The older spiders are placed in non-breeding tanks or in the mesh tower.

Usually within two weeks to one month, a mated female's girth increases, and she may refuse consecutive feedings. Humidity is increased at this time, and the spider is left as undisturbed as possible. Usually at night (but occasionally during the morning hours), an egg case wrapped in white-cream colored silk is produced and hung usually near the top of the enclosure. It has been noted that females are often found near the egg cases when the lights are turned on at 7:30 AM but quickly move near the hub of their web afterwards. It has also been observed that many female *Nephila* are seen to cover their egg case with a variety of boluses, substrate, and old exoskeletons - perhaps in an attempt to hide or camouflage the vulnerable egg case. On two different occasions where two breeding females cohabited in a single tank, it was seen that one female spider cut down the egg case of her conspecific, dropping it to the ground. It was thought that this was to prevent the presumed infertile or compromised egg case from

endangering the rival's nearby eggs; however, on both occasions, the rescued egg case later hatched successfully. It could be that this was an example of a female spider decreasing future competition to her own brood.

Woodland Park Zoo has experimented with a variety of incubation methods for *Nephila* egg cases. If the humidity is watched carefully, egg cases in the Bug Dorm cubes hatched well, with over 80% success rate. Egg cases left in the tall vertical tanks have less than 10% hatch rate, probably due to desiccation. Two methods have been investigated for pulled egg cases. Some were hung by their silk from opened paper clips pushed through the insect lids of deli cups holding ~2 cm moist vermiculite. A more recent method, now proving highly successful with pulled egg cases, has been investigated. A 5.5 cm filter paper is placed in a shallow 5.5 cm plastic Petri lid and moistened with reverse osmosis water. The egg case, with most of the silk removed or stretched to allow less coverage of the actual egg cluster, is placed on moist vermiculite or coir fiber in a 1.2 liter deli cup covered with an insect lid (partially taped to decrease desiccation). The substrate is a misted once daily, care being taken to prevent wetting the egg case itself. Using this method, over 80% of egg cases from mated spiders have hatched. Incubation usually takes 20 to 30 days on average. Once hatched, a small plastic plant twig is added to the cup to allow the spiderlings to climb up. Mesh is added under the lid. After 2 to 10 days, during which time the spiderling's have clumped together above the egg case, they will begin to disperse within the deli cup. A small number of fruit flies are added around day four. Fruit flies are offered every second day thereafter. Once the spiderlings have molted twice, they may be divided as needed. At around fifth instar, they are moved to the large juvenile tanks mentioned above. As the spiderlings mature, their diet begins to include pinhead crickets, houseflies, and later, pre-killed crickets fed by forceps. Juvenile spiders, by necessity for population control, are currently being allowed to cannibalize during rearing with the goal of saving all the males and 2 to 5 females per egg case as needed to continue the colony.

The Woodland Park Zoo golden orb weaver exhibit has been a steady favorite, and its spider one of the most photographed animals at our zoo. The large, open exhibit space 203 cm H x 92 cm W x 71 L has a dark interior cloth covering, soil substrate and plastic ferns at its base. Several tall, woody branches containing clumps of Spanish moss are available for web attachments for the adult female spiders kept on display. A metal guardrail extends out from the sturdy plush-covered exterior rim of the exhibit, and a clear plexiglass panel prevents small children from entering the exhibit space while not restricting vision. One monofilament thread connects the two main branches allowing a new inhabitant a starting place for her web. An explorer's clipboard graphic shows a photo and species information for the public. Across the front of the guardrail a graphic explains "Cool! No glass!" and explains why the *Nephila* can be viewed safely in an open exhibit. A second, small sign at the top of that inner frame reminds the public: "Yes, the spider is alive, the web is real- do not touch!"

When a new female spider is added to the exhibit, the open side is covered with a custom-made dark vinyl tarp for until the next morning. The spider on display is misted at least twice daily or three times if she is heavily gravid. She is fed a pre-killed crickets by forceps 3 to 5 times per week. When a spider occasionally dies on exhibit, it is usually found in typical "hanging from

one leg” pose of deceased orb weavers, or occasionally in the ferns inside the exhibit. More typically, as older spiders are noticed having difficulty maintaining the web or in hanging on due to worn tarsi, they are retired to the mesh tower where injury from a fall is less likely.

Keeper talks for the public are often held during feedings. The opportunity is taken to explain to the public that many wild animals prefer to avoid humans as long as food, water, and shelter can be found elsewhere. Human/wildlife conflict is often discussed and tied into such important conservation actions as bear awareness, pest vs. beneficial insects, and outdoor garden safety. Often, the public is amazed to hear of the wonderful maternal habits of many species of arachnid. In addition, the public is amazed at the seemingly polite manner in which the spider accepts her food offering from the keepers.

## Summary

The intriguing and beautiful genus *Nephila* offers many opportunities for zoological institutions to amaze and educate the public about the importance of these much maligned, yet beneficial, creatures. By understanding the captive husbandry and breeding of these wonderful spiders, it is hoped their future can be assured in AZA zoos as well as in the wild.

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