Short reviews of known information relating to breeding biology and captive husbandry and any impacts, if relevant, of removal of founder stock from the wild for species selected by AC29*

Macaca fascicularis

Scientific name: *Macaca fascicularis* (Raffles, 1821)
Common names: Crab-eating Macaque, Long-tailed Macaque
IUCN Status: Least Concern (assessed in 2008)

Note: There are ten subspecies exposed to different levels of threat[1].

1.) Breeding biology

The species **breeds year-round**. In the wild, breeding shows a yearly **distinct birth peak** dependant on local conditions, which is not apparent in captivity[2,3]. Macaques are **highly social** and live in groups numbering up to 60 individuals, usually with fewer males than females[4]. Males **disperse** at the time of **sexual maturity**, while females stay in the group where they live in **female dominance hierarchies** that are inherited by mothers[5]. In captivity, males reach **sexual maturity** at 5.2 ± 1.2 years old on average (range: 2.8 - 11.9 years, n= 197 [6]) and females at 4.4 ± 1.2 years (n= 789 [7]). Mean **pregnancy duration** is 160 days (range: 134-184[8]). *M. fascicularis* give birth to a **single offspring**[8]. **Interbirth intervals** (time between birth events) are between 1-2 years[9,10]. **Weaning** (introduction of adult diet) of the young occurs progressively until 10-11 months of age[4]. Some breeding facilities separate young from their mothers at an earlier age between 5-6 months[4,11].

2.) Captive husbandry

Established husbandry protocols depend on the country, the facility and the purpose of breeding. In commercial breeding centers, animals are either **single-housed**[4,6,11] or **group housed**[7] and are kept **indoors**[4,6,11] or **outdoors**[7]. Single housed individuals are usually kept in **stainless steel cages** (approximate dimensions: L70 cm x W60 cm x H80 cm) with visual, olfactory and auditory contact to other monkeys[4,11]. Indoor rooms should be ventilated, controlled rooms under a 12:12 h light:dark **photoperiod**, **temperatures** of 19–25 °C, and 40–70% **humidity**[6,11]. When housed in **groups**, 1-3 males should be housed with a larger group of females[4,7]. Enclosures should include **structural enrichment** for improved welfare (hides, perches, etc.)[7,12]. **Diet** can consist mainly of commercially available pellet diets and should be supplemented with fresh fruit, vegetables, insects, or seeds for enrichment purposes, fed 2-3 times daily. **Water** should be provided at all times[4,6,11]. **Mating** in single housed individuals occurs by anesthetizing females 11 days after menstrual bleeding and co-housing her with the male for approximately 3 days. **Pregnancy** is diagnosed by ultrasonography under anaesthesia[11]. Young are **weaned** after 5-6 month in Asian facilities[4,11], sometimes longer, e.g. on Mauritius[7,12]. Thereafter juveniles are regrouped with peers of the same sex and similar age until 2-3 years old[4,11]. Before shipment to buyers, individuals are single-housed[4]. Large breeding facilities should have **health sur-**

* *The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CITES Secretariat (or the United Nations Environment Programme) concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.*

veillance systems in place, as macaques can transmit pathogens to humans[13]. This includes appropriate facility management (e.g. security, sanitation, waste handling), equipment (e.g. cage washer), staff management (operating procedures, training), and a veterinary care program. Individuals should be **individually identifiable**, some facilities use software to track kinship[12]. Large facilities should conduct **daily checks** on individuals by animal technicians or veterinarians and an annual or biannual veterinary examination under anaesthesia[7,11].

3.) Ease of breeding in captivity

The species is relatively **easy to keep, adaptable to new environments** and is **commonly bred** in zoos, research institutes and commercial breeding facilities[4,12,14,15]. Breeding from **F2 and following generations is possible**[15] and China, reportedly has several large breeding facilities with self-sustaining populations[17]. However, in 2009 the EU Scientific Committee on Health and Environmental Risk[18] reported that **95% of Old-World monkeys** (mostly *M. fascicularis*) used in research and testing in the EU **are F1 generation**, mostly imported from Asia. **Replacing breeding stock** with **wild-caught individuals** is standard practice, and **F2 generations can currently not meet the numbers needed** for research[18,19]. Breeders encounter **difficulties of breeding with F2**, not only related to **inbreeding**, but also related to **health** and **reproduction**, such as lower fertility, poor maternal care (due to early weaning and disruption of social structure), reduced birth weights, diabetes in the offspring, and earlier onset of ageing[12,18]. In 2008, the Mauritian Cyno Breeders Association and the breeding facility Noveprim believe that "very few breeding centres in the world have the experience of [breeding] F2 generation"[16] and that transitioning to F2 breeding would result in a substantial **cost increase** for the breeder[20].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

There are **numerous research centres** and **commercial breeding** operations across Southeast Asia[21], China[17], Japan[11], Mauritius[12], Brazil[14], and other parts of the world. **Zoo and aquarium members** of Species360's ZIMS currently hold 395 (211 females, 152 males, 32 unsexed) with 10 births recorded in the last year, across 40 zoological institutions in four continents[15]. **TRAFFIC Southeast Asia** reported in 2008 on six breeding operations in Cambodia ranging from several hundred to 10,000 animals registered in Cambodia, two large facilities in Viet Nam containing thousands of animals[21]. However, doubts have been expressed about how many specimens are being bred in some facilities[22].

5.) Marking systems applied to permit individual identification of captive bred specimens

Some facilities in Southeast Asia use neck tags, which can easily be removed[23]. China is implying a **microchip labelling** system for all primates bred in captivity[17].

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Vulpes zerda

Scientific name: *Vulpes zerda* (Zimmermann, 1780)
Common names: Fennec, Fennec fox
IUCN Status: Least Concern (assessed in 2015)

1.) Breeding biology

Limited records from the wild suggest that **mating** occurs in January-February and **birth** in March-April[1]. But the **breeding season** is probably variable upon latitude and local conditions[2]. In captivity, fennec foxes can reproduce **year-round**, but **birth** mostly occurs from March-August[3]. Fennec foxes live in **social units** that consist of parents and their offspring[4]. Age of **sexual maturity** is between 9 months[5] to one year[1] for both sexes. In the Association of Zoos and Aquariums (AZA; North America) population, the oldest male to breed was 13 years and the maturest female to produce offspring was 10 years old (ages at the time of conception)[6]. **Pregnancy** usually lasts 50-52 days[4], although in one case in captivity it has been of 62-63 days[7]. **Litter sizes** range in 1-4 kits[1,4,7]. Fennecs typically **give birth once per year**. However, more than one litter per year is possible. The AZA population has recorded **up to three litters** within 12 months[6], especially when a litter is lost[8]. If pups are lost or removed, females appear to be able to conceive again after 70-90 days[3]. In the United States in some private breeding facilities, **litters** are pulled for **hand-rearing** and 2-3 litters per year are common[9]. The **male** has a critical role in the rearing of the pups, protects the female after mating and provides food during pregnancy and lactation[2]. **Weaning** (introduction of adult diet) occurs at 61-70 days old for 8-10 weeks[1,2]. In the wild, **young** are born in dens that they initially leave after ~4 weeks and entirely by 3 months of age. They **grow entirely** in ~4 months[1,2].

2.) Captive husbandry

Fennec foxes are **omnivorous** but eat mostly animals. In captivity, **diet** usually consists 30-50% of commercially available dog or cat food (with at least half of that from dry food), 10-20% comprises fresh vegetables and fruit, 5-15% should be vertebrate prey (e.g., rats, mice, chicks), and 5-10% of invertebrate prey to provide additional sources of nutrients. They should be **fed 1-2 times daily** with a total quantity of diet of 5-10% of the bodyweight as a rule of thumb. Fresh **water** should be provided at all times. **Difficulties**, such as aggression or rejection by the mother may make **hand-rearing** of pups necessary. Hand-rearing is common in private facilities to produce offspring that are less nervous and aggressive towards humans. Hand-reared pups can be kept in a **crate supplied with a heat-pad** to maintain constant body temperatures. Hand-reared pups should, if possible, be allowed to **nurse** from the mother for the first 10 days to obtain immunity. Afterward, they can be fed with a nursing bottle or syringe with a commercial **milk substitute** for dogs (e.g., Esbilac). For the first 10 days, **pups** need **feeding** every 2-2.5 hours per 24 hours, then every 3-3.5 hours until approximately 26 days old. After that, small amounts of **solid food** can be carefully introduced (e.g., baby rice cereal) and weaning can begin at 28-30 days of age, slowly introducing nutritionally complete foods, such as soaked dry food. After each feeding, the pups must be stimulated to urinate and/or defecate by rubbing the anal region with a warm, damp towel. Each pup should be **marked**, weighed daily and information on weights, feeding amount, etc. should be tracked. **Veterinary care** is similar to domestic dogs and yearly examinations are recommended. All the above information was obtained from Reference 2.

3.) Ease of breeding in captivity

This species is **common** in captivity and moderately **challenging to breed** due to **difficulties on both husbandry and breeding**[10]. In captivity, there is **significant infant mortality** due to parents' sensitivity to disturbances[4]. Thus, continuity of staff with substantial husbandry knowledge and the ability to provide breeding areas in locations with little disruption are essential. The Association of Zoos and Aquariums (AZA) reported

a **24% reproductive success rate** during a 10 years period[11]. The study also demonstrated **that younger animals are more likely to breed successfully**, and they tend to continue to reproduce when a pair is experienced (i.e., had one litter together). Zoos find it challenging to get consistent reproduction with fennecs, mainly because populations are regionally managed to ensure a 90% genetic diversity in a 100 years horizon. Therefore, pairs are exchanged, but a less responsible commercial breeder could produce a fair number of cubs under the right circumstances. **Breeding over several generations has not been seen to be problematic.** Wild-caught animals are more difficult to breed. Accredited zoos invest considerable resources into managed species-based programs, but if breeding is the unique goal, it is relatively cheap since fennecs can be bred in modified dog runs[9]. **First-year mortality** is 36% for males and 40% for females in the AZA population, yet fennecs that survive to 2 years old have a median life expectancy of 11 years[6]. **Infant mortality** is likely lower in the European zoo population (EAZA) than in the AZA population, which is the subject of a current study by AZA[9]. **Hand raising** can reduce infanticide and produces kits that have a calmer temperament being frequently used by private breeders and selectively used in the AZA population[9]. As reported by a private breeder, hand raising is **labour-intensive and tedious** as pups aspirate easily (they breathe in milk into lungs which can cause them to die) and ensuring sufficient calcium for bone development can been challenging[12].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

There is a stable **zoo population** both genetically and demographically managed (Studbook management), **private collections in the Middle East** and **private breeders in the U**S, as well as some **commercial breeding facilities** for the pet trade[10]. **Zoo and aquarium members** of Species360's ZIMS currently hold 415 individuals (197 females, 213 males, 5 unsexed) with 29 births recorded in the last year, across 134 zoological institutions in five continents[13]. Members of the **Association of Zoos and Aquariums** (AZA; North America), the **European Zoos and Aquarium Association** (EAZA; Europe) and the **Zoo and Aquarium Association** (ZAA; Australia, New Zealand & South Pacific) **manage** this population[10].

5.) Marking systems applied to permit individual identification of captive bred specimens

Typically **micro chipped** in zoos; **tattoos** (inside of thigh) or small ear tags can also be used[9]. Unclear if this is used to emit permits for individuals.

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Lorius lory

Scientific name: *Lorius lory* (Linnaeus, 1758)
Common names: Black-capped Lory
IUCN Status: Least Concern (assessed in 2016)

Note: This species contains 7 subspecies.

1.) Breeding biology

Limited data from the wild suggest that the **breeding season** may occur from May to July[2]. In different parts of the range, breeding might occur at different times according to rainfall. They reach **sexual maturity** at 3-4 years[3]. **Clutch size** is usually two, sometimes three eggs[2,3]. **Incubation length** is on average 26 days in captivity[3]. Records of incubation lengths in the wild are lacking, but are likely to be similar to captivity[4]. Chicks **leave the nest** at 9-10 weeks old and continue to be fed by their parents for up to two weeks[4]. It is easy to wean them if hand-reared, and birds can become independent at a very early age, before the age of seven weeks[3].

2.) Captive husbandry

Birds can be **housed** in aviaries, equipped with perches, and sufficient space to fly around[3]. **Enclosures** should have minimum length of 3 m. The **floor** can be concrete (for easy cleaning) that slopes towards a drain while the walls can be made from tiles or formica[3]. **Roofs** can be constructed of welded mesh (suggested 14 ga.)[3]. Aviaries need regular **cleaning**, small cages require daily hand-cleaning, larger aviaries require daily change of floor surface or pressure-cleaning every couple of weeks[4].
Also, as they like to bathe, large **water** containers that are cleaned and renewed daily are recommended. Water for drinking should be provided in smaller containers near the food. For breeding, **nest boxes** should be supplied, either ordinary vertical or L-shaped boxes[3]. As they can exhibit strong aggression to other lories, the **introduction** of a new bird into the aviary is likely to be fatal. **Introductions** should happen in neutral territory. Therefore, double wiring between each aviary is recommended, to prohibit biting between the lories of different aviaries. **Diet** includes nectar, pollen, small seeds, flowers (such as dandelion), buds, fruits and insects[3]. Some of the most common **diseases** of captive lories are bacterial infections. As antibiotics may weaken the immune system, probiotics are recommended. Baytril (enrofloxacin) is widely used to treat bacterial infections[3].

3.) Ease of breeding in captivity

In general, lories are **relatively easy to breed** in captivity[3]. Black-capped lories are one of the easiest to breed among the larger lory species. Breeding pairs are especially compatible when **introduced at a young age** as they form strong bond and will attempt to reproduce over a long time. Little is known, however, about whether **breeding** can be sustained **over several generations** and very few zoos are committed to breed them. Most private breeders do not maintain lories over the long-term as they require a **large amount of cleaning**[4].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Zoo and aquarium members of Species360's ZIMS currently hold 141 individuals (34 females, 49 males, 58 unsexed) with 3 births recorded in the last year, across 31 zoological institutions in six continents[5]. According to one of the world's expert on lories[4], **captive breeding** of this species **has declined greatly** in recent years and only few private breeders breed this species, as there is currently **little demand**. There may be fairly extensive breeding in farms in Bali, but not many are bred elsewhere. Based on the opinion from Low[4], it is extremely unlikely that the large numbers originating from South Africa during the last ten years are captive-bred and are likely imported wild-caught individuals, as indicated by the very few advertisements for Black-capped lories in the South African avicultural magazine Avizandum in recent years[4].

5.) Marking systems applied to permit individual identification of captive-bred specimens

Chicks can be **ringed** with 8-8.5mm rings at ~16 days (from 14-17 days old), about or just before the time their eyes open[3].

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Cacatua alba

Scientific name: *Cacatua alba* (Statius Müller, 1776)
Common names: White Cockatoo, Umbrella Cockatoo
IUCN Status: Endangered (assessed in 2016)

1.) Breeding biology

The breeding biology in the wild is poorly known, the **breeding season** probably starts early in the year, with hatchlings in April-May[1]. **Sexual maturity** is reached at 3-5 years in captivity, probably similar in the wild[2]. Breeding pairs **nest** in hollows of large trees[3]. **Clutch size** is 2, occasionally 1[3]. In the wild, the larger chick will become dominant and the smaller one dies[3]. In captivity, both chicks may survive when hand-reared. The **incubation period** is 27-28 days in captivity and **eggs** are incubated by both male and female[3,4]. Chicks spend about 14 weeks in the **nest** before they become **fledglings**[3].

2.) Captive husbandry

Cockatoos should be **housed** in pairs in aviaries either indoors or outdoors[3]. New birds should be introduced very carefully into the aviary as males sometimes kill female partners[3,4]. Enclosures should be sturdy, as cockatoos tend to manipulate objects with their powerful beaks[3]. Large suspended cages or aviaries can be used (a minimum of 2.5-3m height and floor area of 15-20 m^2 per pair) including open and sheltered areas[3,4], and different perches, of natural wood, hemp rope or chain[4]. Primary **barriers** should be of 10-gauge wire mesh[4]. To prevent **aggression** between adjacent pairs, divisions between aviaries should be double-wired[4], leaving a minimum of 40mm to the next aviary[3]. The floor can be concrete or with a **substrate** such as bark chippings, sand or gravel[4]. Cockatoos need to gnaw, e.g. on fresh perches[3]. As they like to bathe in the rain, a **misting** system can be applied, especially in hot climates or when housed indoors[3]. In more temperate climates, controlled **heating** (10-15°C) during the colder months may be required[4]. Artificial **light** should be provided indoors[4]. For breeding, **nest sites** including appropriate nesting material (e.g. sawdust) are required, such as nest boxes or tree trunks[3,4]. Nest sites should have two entrances (so female can escape from the male) and be disturbed as little as possible[3]. Aviaries should be **cleaned** 1-2 times per week; uneaten food should be removed daily. Once a month, concrete floors should be disinfected. In dry climates, floor substrate can be sand, which needs to be raked every few days and exchanged approx. 4 times per year[3]. **Freshwater** should be provided at all times and they should be fed at least once if possible 2-3 times per day. A wide variety of **food** is essential to prevent dietary health issues but also as enrichment. Diet can include seeds, nuts, vegetables, fruits, animal protein (e.g. mealworms or cooked meat), wild berries, weeds, and commercially prepared foods such as pellets[3,5]. **Dietary supplementation** with cuttlefish bone or mineral blocks is recommended. Mineral/vitamin powder can be mixed in with certain foods[3]. Cockatoos have strong food preference, and some individuals may reject certain foods. In captivity parents often damage eggs; thus they may have to be artificially incubated at ~60% humidity. When shell starts cracking, **eggs** should be moved to a hatcher (80% humidity at ~34°C)[3]. Eggs need to be turned 4-5 times daily[3]. Hatching success of eggs that are immediately removed from the nest is much lower than in other parrots and they should be left to incubate for at least two weeks by the parents. Often difficulties arise that makes **hand-rearing** of young essential for them to survive. Hand-rearing is a demanding activity as chicks need to be fed from 7am-10pm for several months[3]. Young birds should be maintained in same-age groups[4]. Common health issues include metabolic bone **disease** due to calcium deficiency, Avian Polyoma Virus, bumble-foot, ectoparasites, intestinal problems, psittacosis, respiratory problems and stereotypies[4].

3.) Ease of breeding in captivity

This species requires **substantial experience** and effort to breed although they have been shown to reproduce well in captivity. **Breeding success** in private collections was measured at 47% (i.e. 47 fledged young

per 100 adult birds, measured in 1989, n=789 birds)[3]. Breeding in especially **F1 and following generations** is more difficult than for other parrot species, as they are significantly more nervous[3]. Their **reproductive capacity** is low due to their small clutch size, and several factors can prevent successful breeding[3]. They **are remarkably pair-bond,** so finding a **compatible breeding pair** is critical. When separating a couple, it is possible that the female will not show interest in another partner, a problem especially when individuals are wild-caught[3]. Also, some males can become very **aggressive** during the breeding season and kill female partners[4]. In such a case, the male needs to be removed immediately. **Eggs** are often damaged by the parents, which is one reason why young are often hand-reared[3]. Mass-bred nestlings aimed at the pet trade are often **hand-reared** to increase the female's productivity. However, hand-rearing can make them **unsuitable for breeding,** due long-term effects of **imprinting** with humans (birds need to visually imprint on their parents during critical period of development)[3]. Breeders must make an effort to produce some **parent-reared birds** to prevent them from losing interest in breeding in the long term, which is rarely the case in the production of birds for the pet trade. If the **right breeding pair** is found, and young are hand-reared in the right way they can **breed well** and will produce offspring that are less nervous and less susceptible to stress than parent-reared birds[3].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Zoo and aquarium members of Species360's ZIMS database currently hold 300 individuals (85 females, 131 males, 84 unsexed) with 3 births recorded in the last year, across 125 zoological institutions in six continents[6].

5.) Marking systems applied to permit individual identification of captive-bred specimens

The most common marking system is closed **rings** of stainless steel for young birds[2], until the 5th day after hatching[4]. Otherwise, open rings can be used[2].

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Centrochelys sulcata

Scientific name: *Centrochelys sulcata* (Miller, 1779)
Common names: African Spurred Tortoise, Grooved Tortoise
IUCN Status: Vulnerable (assessed in 1996, needs updating)

1.) Breeding biology

Copulation of *C. sulcata* occurs during the rainy season in the wild[1] and during summer and fall in captivity (for North America, depending on local conditions[2]). **Egg-laying** occurs ~1 month later in a **clutch** of 15-33 eggs[2,3]. Up to four **nestings** per breeding season can occur under captive conditions[2,4]. **Incubation** length depends on temperature and can be highly variable between 118-212 days[3,4,5]. Tortoises are generally **slow to mature**, with relatively **few hatchlings surviving** to sexual maturity in the wild. **Sexual maturity** depends on size, not on age. Captive specimens that grow faster reach sexual maturity earlier than their wild counterparts[6,7]. In captivity, absolute minimum of sexual maturity has been recorded between 4-5 years old (n=3, Ref.7) at ~ 35cm in carapace length for males (n=1, Ref.8) and at ~ 45cm for females, but these animals have been reared at the maximum rate possible and it is uncertain whether they would be physiologically, anatomically or reproductively healthy[2]. Sexual maturity probably occurs much later in the wild, estimated at ~15 years[7]. Once mature, *C. sulcata* have a long reproductive **lifespan** and can live more than 50 years[9].

2.) Captive husbandry

Tortoises in general should be kept **outdoors**, at least part of the year, to allow for natural grazing activity and sunlight exposure important for vitamin D synthesis[3]. Approximately 70% of the **enclosure** should be in full sun; **shaded areas and shelters** should be provided to allow temperature regulation. In colder climates, shelters may need additional **heating**. The enclosure should be dry and planted with shrubs and grasses[3]. Tortoises can be kept in **groups** but sexually mature males should be housed separately, or in large enough enclosures to limit aggression[2]. **Toxic plants** and small non-food items should be removed, as tortoises tend to ingest those. **Nesting areas** for females can be enhanced by providing ~30cm deep mixture of sand, dirt and gravel. To prevent **escape**, solid walls, such as wood or concrete buried in the ground should surround the enclosure[3]. **Predator-proof** fencing may be necessary to protect young tortoises. **Indoor housing** is mandatory in colder regions for most of the year. The area of all combined shell sizes of all turtles should not exceed one quarter of the floor area of the enclosure[3]. **Temperature** gradients should be provided between 24-32°C for thermoregulation, wide-spectrum fluorescent including UV **light** as well as a **basking spot** between 40-45°C. Clean drinking **water**, as well as hiding boxes or visual barriers, should be provided[3]. The enclosure should be **cleaned** from fecal matter several times per week. Large enclosures can consist of smooth cement, covered with hay. Fine sand, gravel, and cat litter are inappropriate as they can be ingested and be **potentially harmful**[3]. **Eggs** can be incubated between 27-32°C in humid vermiculite substrate, whereas temperature determines sex ratios[2]. **Hibernation** does not occur in this species. Adults should be **fed 2-3 times per week**, juveniles daily or every other day. Tortoises should be best allowed to forage on **natural grasses**, supplemented with hay, rarely vegetables. Fruit or protein-rich foods can lead to **diet-related health problems**. Two common **health issues** that occur in captivity include shell-softening due to lack of sunlight, calcium deficiency or excessive phosphorus and **pyramidal shell growth**, due to excess protein, diet deficiencies and rapid growth rates in captivity. Careful **supplementation** with calcium-mineral supplements can prevent some of these imbalances[10]. Other **common diseases** include respiratory infections, reproductive problems, bacterial and fungal infections, rock and substrate ingestion[4].

3.) Ease of breeding in captivity

Breeding of *C. sulcata* has been reported by zoological institutions and private breeders many times and is especially **easy** within its natural range[5,7,11]. Captive breeding for conservation purposes of this species has been proposed the IUCN Conservation action plan[11] and there are **captive breeding and reintroduction programs** in Senegal[13]. According to some of the best turtle specialists in the world, captive breeding **can meet domestic demand** for the pet trade for hatchlings in the US[13, 14], but there is no pet trade demand for larger animals[,14]..

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Zoo and aquarium members of Species360's ZIMS database currently hold 1865 individuals (369 females, 461 males, 1035 unsexed) with 71 births recorded in the last year, across 315 zoological institutions in six continents[15].

5.) Marking systems applied to permit individual identification of captive-bred specimens

Micro-chipping is possible in small tortoises, but the preferred minimum size to implant PIT tags is 500 grams, well past the 50-110 gram hatchling size. The reliability of Photo-documentation[16] has not been verified for this species but is likely to be applicable[14].

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Geochelone elegans

Scientific name: *Geochelone elegans,* Schoepff, 1795
Common names: Star Tortoise, Indian Star Tortoise
IUCN Status: Vulnerable (assessed in 2015)

1.) Breeding biology

The **breeding season** starts with the monsoon which varies across location[1,2]. Courtship and mating occur during monsoon until the colder months. Nesting occurs during winter and hatchlings emerge during the onset of the first heavy rains[1]. Females reach **sexual maturity** at 6-7 years[2]. In captivity, tortoises grow faster, and maturity largely depends on size, which may be attained by the age of 3 years[2]. Mean **age of maturity** recorded in Species360' zoo and aquarium members is 5.3 years, but most zoos are not actively breeding the species (n=15)[3]. *G. elegans* can lay multiple **clutches per year**; usually, 2 with up to 5 clutches in captivity[1]. Clutch size is 1-10 eggs, with an average of ~5 eggs[1,2]. In captivity, **incubation length** ranges from 47-257 days with an average of 198 days[1]. Incubation length, egg and hatchling size tend to decrease with each clutch when multiple clutches are laid per season[1]. The interval between successive clutches is on average 177 days in captivity (25-385 days, n=3)[1]. **Hatching success** has been of 65% on average per year in captivity (range: 30%- 97%, n=39). Generation time is ~10 years[2].

2.) Captive husbandry

In warmer climates, tortoises can be kept in predator-proof outdoor **enclosures**, which allows for natural grazing activity and sunlight exposure necessary for vitamin D synthesis[4]. Shaded areas and **shelters** should be provided for temperature regulation[4]. The species does not hibernate; **temperatures** should range between 24-35°C during the day and ~20°C at night[5]. When housed outdoors heated shelters may be necessary[5,6]. For indoor enclosures, humidity should be <40%, and provide a wide-spectrum fluorescent including UV **light** and a **basking** spot of 40-45°C[4,6]. Tortoises can be kept in **groups** of males and females. Male aggression during breeding season is lower in this species than in other tortoises[5,6]. Females dig in the dirt to lay eggs, so bare ground or potting soil should be available[6]. **Eggs** can be incubated at approximately 30°C in humid vermiculite substrate[4]. **Diet** should be high in fiber. Therefore, is best if they forage on natural grasses, weeds, *Opuntia cacti*, and wildflowers. When housed indoors dandelion greens, Bermuda grass hay, and cactus pads should be preferred over grocery store vegetables[5]. A clean shallow water dish is essential for tortoises to drink and soak in. When kept in suboptimal conditions, this species is very susceptible to respiratory **disease** and infections, such as through *Mycoplasma* infection[7] and should not be mix with other species[5,6]. Runny Nose Syndrome is also observed regularly[8].

3.) Ease of breeding in captivity

The species **can successfully reproduce** in captivity, but is one the **most difficult tortoises** to keep and breed, as they tend to get **stressed** when handled[6,9], are **sensitive** to cold and long periods of humidity, and prone to **respiratory disease** and **pathogens** carried by other species of tortoises[10,11]. This is especially the case for breeding in colder climates[10,11,12]. Wild-caught animals **adapt generally very slowly** if at all to captive conditions, as these may become sick during transport and are often exposed to suboptimal conditions, and exposure to other tortoises and reptiles[10,11]. A **decrease in reproductive performance** has been observed to occur with successive generations[1]. However, given the right care they can be captive bred, mostly by **dedicated private breeders**[13].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

The species is **commonly kept and bred** by private collectors, hobbyists and zoos across the world[14]. **Zoo and aquarium members** of Species360's ZIMS database currently hold 1122 individuals (218 females, 225 males, 679 unsexed) with 10 births recorded in the last year, across 94 zoological institutions in four continents[3]. A survey of Indian zoos in 2002-2003 shows that of the 26 institutions that hold the species, none of them reported to breed them during that year[14]. Overall, the species is not bred anywhere in the world in the quantities needed to supply the commercial demand[13].

5.) Marking systems applied to permit individual identification of captive-bred specimens

Micro-chipping can be used to mark individuals, it unkown whether it is used to emit permits for individuals.

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Testudo hermanni

Scientific name: *Testudo hermanni* (Gmelin, 1789)
Common names: Hermann's Tortoise
IUCN Status: Near Threatened (assessed in 2004, needs updating)

Note: includes the two subspecies *T. h. hermanni* in Western Europe and *T. h. boettgeri* in Eastern Europe

1.) Breeding biology

T. hermanni grows at ~10mm carapace length per year until they reach **sexual maturity** at 8-12 years in the wild. As reported by an experienced conservation breeder, animals can reach maturity faster in captivity (~5 years), but it is not promoted as it can lead to health problems related to rushed growth[2]. Moreover, reproductive output is related to body size, thus larger females tend to have a higher number of offspring. According to a commercial breeder full productivity is only reached at 13-14 years[3]. The **breeding season** starts after winter-hibernation. **Egg-laying** usually occurs between mid-May and the end of June. **Hatchlings** are born from late August to October. The **length of the breeding season** (time between ovulation of first clutch and laying of the last clutch) varies from ~30 to 48 days with a **mean clutch retention time** of ~21 days for the first and ~13 days for the third clutch. **Mean inter-clutch interval** ranges from 10-28 days (mean = 18-20 days) depending on location. **Clutch size** ranges from 1-7 eggs (mean = 3.3) for *T. hermanni* and 1-9 eggs for *T. boettgeri* (mean = 4.3). They can lay up to 3 **clutches per year** but most frequently are 1-2 clutches per year. **Incubation time** and sex determination depend on temperatures. Incubation time ranges from 90-124 days in the wild and from 56-102 days in captivity incubated at temperatures between 22-35C. All information on the breeding biology was extracted from the compilation paper of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group review paper[1] unless indicated otherwise.

2.) Captive husbandry

Within their natural range, Hermann's tortoises can easily be kept in outdoor **enclosures** that allow for natural grazing activities and sunlight exposure. In colder climates free access to a greenhouse is recommended (e.g References 1 & 4). The enclosure should provide different temperature zones to allow for thermoregulation, as well as hiding places, especially when tortoises are housed in groups. Groups with a sex-ratio of 2 males to 2-8 females have been reported successful by a breeder, and male combat may be necessary for long-term breeding success[2]. **Nesting areas** of loose, moderately deep substrate in different temperature zones will give the female the ability to choose an appropriate egg-laying site[5]. **Eggs** can be artificially incubated on damp vermiculite substrate in a standard reptile incubator (Humidity 50-80%). Temperatures below 30°C will produce mainly males, between 30-31°C mixed sexes, and between 31.5-34°C mainly females[5]. When housed indoors, a broad spectrum **light source** (including UVB) directed onto an overhead **basking spot** is essential[5]. Over winter, healthy tortoises can be **hibernated** e.g. in wooden, ventilated boxes filled with shredded newspapers of polystyrene at temperatures between 5-10°C[6]. A clean shallow **water** dish is important for tortoises to drink and soak in. **Diet** should as close as possible to their natural diet and be high in fibre, vitamins, and minerals and low in fat and proteins[6]. Suitable diets consist mainly of pesticide-free herbaceous plants. Vegetables and fruits should be fed to a lesser extent. Juveniles are fed more frequently than adults. Toxic plants and small non-food items should be removed, as tortoises tend to ingest those[5]. Two common husbandry-related **health issues** include shell-softening and pyramidal shell growth[5,7]. Careful supplementation with calcium-mineral supplements can prevent some of these imbalances[8]. Herpesvirus imported by *T. graeca* and exotic parasites may cause high mortality in captivity[1].

3.) Ease of breeding in captivity

Breeding this species in captivity is **easy** and has been reported many times (e.g. References 1, 2 & 9). Due to their sturdiness, animals taken from the wild will quickly adapt to captive conditions[2]. Whereas *T. h. boettgeri* is very common in the breeding community, *T. h. hermanni* is very rare. Most keepers fail to acknowledge these differences and will produce hybrids, which is one reason why *T. h. hermanni* is becoming a rarity and can be sold at much higher prices. The very long maturation time of 8-12 years makes breeding **not economically feasible** in most cases[2]. Some breeders reported that other sellers would buy wild-caught individuals to bypass long maturation times[3].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Zoo and aquarium members of Species360's ZIMS database currently hold 1505 individuals (329 females, 341 males, 835 unsexed) at 158 zoological institutions in five continents. In the last 12 months, 24 recruits have been recorded[9]. Moreover, various **conservation-breeding centres** exist, for example in the US (GardenStateTortoise & the TurtleRoom), Spain (El centre de reproduccio de tortugues de l'Albera, C.R.T), France (Station d'observation et de protection des Tortues des Maures (SOPTOM)) and the Netherlands (Tortoise Advice Oosterbeek). There are two **private studbooks** maintained for this species (by the EU Studbook foundation, and one North American Regional Studbook by Leone, C.). Animals are also frequently bred by private breeders in the **hobbyist community** and produced in some breeding centres for **commercial** purposes, for example in Italy (TestudoAlbino, produces 500-600 hatchlings of *T. h. hermanni* per year).

5.) Marking systems applied to permit individual identification of captive bred specimens

Micro-chipping is successfully being used for individual identification for permitting in some countries (e.g. Italy). Miniaturization of microchips allows insertion of microchips (1,25mm x 7mm) at 4-5cm carapace length[3]. Photodocumentation is also possible[10].

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Ptyas mucosus

Scientific name: *Ptyas mucosus* (Linnaeus, 1758)
Common names: Oriental Rat Snake
IUCN Status: Not evaluated - NE

Note: The scientific name as used by CITES (*Ptyas mucosus*) differs from the official nomenclature in accordance with the International Code of Zoological Nomenclature (ICZN), *Ptyas mucosa.*

1.) Breeding biology

The **breeding season** varies considerably with geographical location and climate. Eggs are being laid mid- to late July on Zhoushan and associated islands of China with sub-tropical monsoonal climate, and all year round on Java[1]. **Sex ratio** in the wild is unknown. In captivity, sex ratios were reported 1:7[2] and 1:6[3] females versus males. On farms, sexes are kept at a mean ratio of 2:3 females per male[4]. Females reach **maturity** at about 110-140 cm (mean=120 cm) in about 9 months (survey of 15 snake traders[1]). Snake farmers (n=17) reported an average age of 10.7 months (SD = 2.6) and an average weight of 1.3 kg (SD=0.2)[4]. **The percentage of reproductive females** in the wild has been reported as 48% (20/42) and 53% (17/32) in Central Java during the periods, Dec. 1994 to Jan. 1995 and Oct to Nov. 1996, respectively[1]. The **period of internal gestation** has been reported to last 35[4] and 59 days[2] under captive conditions. **Clutch size** is 7 - 25 eggs in the wild (averaged at 13.0; SD = 4.0) (n=37, Ref.1). In captivity clutch size has been measured as 8-17 eggs (mean=13.3, SD=0.6) (n=15 females[3]). Farms reported an average of 16 eggs (SD=3). Females lay 1-2 **clutches per year** in the wild[1], sometimes up to 3 clutches per year in farm conditions[4]. Average annual egg production in farms has been reported as a total of 37 eggs per female (SD=12.6)[4]. **Incubation length** depends on temperature and can last between 51-105 days[2,3,5]. Farms report an average incubation period of 75 days[4]. **Egg and hatchling mortality rates** were reported 17% and 21% respectively by farmers[4]. Hatching success has been observed to be 55% (n=9 clutches)[2] and between 70-100%, depending on temperature[3].

2.) Captive husbandry

The following information is summarized from the CITES report on commercial breeding farms in Vietnam and China, for a detailed description see Ref.4. **Enclosures** range from traditional mud-walled pits to modern climate controlled cages constructed from synthetic materials and include snake pits, individual stacked cages, communal cages and communal snake rooms. Ideal breeding **temperature** lies between 28 C° and 31 C°, additional heating and/or insulation may be required. **Humidity** is important for molding and can be provided, e.g., through use of natural building material, mounds of damp sand within rooms, artificial sprinklers, or polyethylene covers over a portion of the cage. Enclosures usually need **cleaning** once per week to remove bulk waste, a substrate (sand or clay) can be replaced less frequently. Clean drinking **water** is required at all times. **Diet** can consist of wild-harvested natural food (rodents, toads, frogs), waste protein from existing industries and formulated diets. Long-term overfeeding and underfeeding both lead to increased mortality and/or decreased fecundity. In meat production snakes are fed to satiation or 10% more than snakes raised for breeding purposes. When snakes are not distinguished between breeders and growers feed rates average 10% of body weight per feeding event for adult snakes. Hatchlings and juveniles are fed more frequently, usually daily. Breeder snakes are allowed to **hibernate** (on average 2.3 months) while growers are retained at optimal temperature and are fed throughout the year. Fine sand or soil serves as an **incubation** medium for eggs, usually contained in the insulated container (e.g. clay pot, polystyrene box, etc.). Covering eggs with a layer of moist sand or covering the container retains humidity. Hatchlings and juveniles are often kept with adults or housed communally (~100 individuals per cage) for the first few months after hatching. Anecdotal evidence by snake farmers reports a low prevalence of disease and high juvenile mortality that can be negated by high turnover of adults. In China, no medicine is used, in Vietnam a farmer reported the use of

antibiotics, minerals, vitamins, and parasiticide. There are a number of diseases among snakes held in captivity, such as viral, bacterial, fungal and parasitic infections[6]. Most common veterinary issues include respiratory infections; nose-rub is present in some snakes housed in wire mesh-cages. **Inbreeding** can be avoided by exchanging animals between farms.

3.) Ease of breeding in captivity

Rat snakes can be bred **easily** and are compatible with the intensive demands of livestock production due to early maturation, rapid growth, high reproductive output, efficient food assimilation and undemanding space requirement. Closed- cycle farming is possible and profitable[7].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Rat snakes are bred in **snake farms** in Vietnam and China. In Vietnam, 1,461 farms with 210,685 individuals were reported by the CITES Management Authority in 2014[4]. There is no information available on breeding operations for commercial purposes in Indonesia, Malaysia and Thailand[8]. Given the high volumes of meat from wild-caught individuals imported from Indonesia to China, Chinese farms can currently not meet demand. This species is rarely kept and bred as a pet or in zoos. **Zoo and aquarium members** of Species360's ZIMS database currently hold 164 individuals (2 females, 4 males, 158 unsexed) at 20 zoological institutions in Asia. In the last 12 months, no recruits have been recorded[9].

5.) Marking systems applied to permit individual identification of captive-bred specimens

No known marking systems are used to permit individuals.

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Varanus exanthematicus

Scientific name: *Varanus exanthematicus* (Bosc, 1792)
Common names: Savannah Monitor, Bosc's monitor
IUCN Red List: Least Concern (assessed in 2009)

1.) Breeding biology

Breeding season occurs towards the end of wet season. Animals have been observed to breed in November and December on a study in Ghana[1]. **Egg-laying** occurs September-October in Senegal[2]. **Eggs hatch** in March and April in Ghana, probably June-July in Senegal[1]. **In captivity, egg-laying** periods seem more flexible and have been observed between November- April[3,4]. **In the wild, age at maturity** depends on size; females reach maturity at 0.5 kg with a total length of ~27cm[5]. **In captivity, age at maturity** is at about 10 months of age[5]. **Clutch size** in captivity is 15-50 eggs (mean=24, SD=12, n=7)[3], similar to observed clutch size in the wild of up to 49 eggs[2]. In the wild, the number of **clutches size per year** is unknown, but occurrence in captivity suggests two clutches could be produced over the short egg-laying season[6]. In captivity a proportion of the eggs have been shown to be infertile 6%-94% (mean=36%, SD=39%, n=7)[3]. Limited records suggest that **hatchling success** of fertilized eggs is high ~80% (19-100, SD=30%, mean=80%, n=7)[3]. In captivity, **incubation days** are 152-200 days conditional on temperature (n=7)[3]. **Hatchling weight** may depend on humidity[1] with 6-7g in the wild, which is lower than in captivity with 9-11g[1] and 10-15g[3].

2.) Captive husbandry

The **enclosure** should be spacious with a floor area no less than $1m^2$ (Ref. 1). **Basking spots** of no less than 45°C[7] (report of 57°C in Ref.4) and large **thermal gradients** including cooler **hiding spots** are essential at 22-24°C[1,7]. **Humidity** should be provided and can be controlled, i.e., by sprinklers or by wetting the floor substrate. For egg-laying females a thick **substrate** on a floor or in nesting boxes is critical. Animals can be kept in small groups (especially when raised together) or in pairs[1]. **Reproduction** can be induced by a cooling period followed by a simulated rain-cycle[4]. After mating the male should be removed, due to **aggressive behavior**[4]. After **egg-laying**, eggs are transferred to an incubator, filled with humid vermiculite medium garden mold or sand/peat mix[3,4]. Successful **incubation temperatures** are reported between 27-30.3°C[3,4]. **Diet** in captivity should consist of a diverse range of invertebrates and vertebrates (i.e., small rodents) as well as supplemented minerals and vitamin[1,3]. Females may need additional **dietary calcium** before breeding[4]. Clean **drinking water** should be provided at all times. **Common problems** of captive varanids are obesity, reproductive disorders and conspecific aggression which interfere with their reproductive success and long-term keeping[6,7]. Major sources of mortality, reported by veterinarians of zoo-held varanids include bacterial infections, neoplasia, gout, and endoparasitism[8].

3.) Ease of breeding in captivity:

The species is **difficult** to keep in captivity and requires **a good understanding** of the species biology; the vast majority held as pets frequently dies[5]. An estimated 50% of purchasers of Savannah monitors will no longer have the animals after 12 months[6]. Whereas there are **few occurrences on the successful reproduction** of *V. exanthematicus* in captivity (e.g., a 7-cases review in Ref.3). **Captive breeding over several generations has not been achieved consistently**[5]. According to one of the worlds leading experts on V. exanthematicus[6], **no successful strategy for maintaining this animal** in captivity has ever been demonstrated. Most females **never cycle** and those that do die or stop cycling within two years. Longevity of this species is lower than in other *Varanus* species and almost all adult captive specimens are obese and contain much larger abdominal fat bodies than wild animals (up to 20% vs. 4% in wild animals)[9].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Trade increasingly involves animals that originate in Benin and Togo exported to Ghana prior to re-export for the wildlife trade. This includes many animals with ranched (R) or captive-bred (CB) declarations. There is, however, **no information on the ranching or breeding** of this species available since the investigation of de Buffrenil (1993)[10], who found the operations to be unsustainable. Private breeders or research studies report some breeding activities[3]. Possibilities are currently explored for the potential for captive breeding of *Varanus* in West Africa, which has not been demonstrated previously[6]. **Zoo and aquarium members** of Species360's ZIMS database currently hold 72 individuals (11 females, 20 males, 39 unsexed) at 53 zoological institutions in four continents. In the last 12 months, no births have been recorded[11].

5.) Marking systems applied to permit individual identification of captive bred specimens:

Micro-chipping is a possibility but there is no evidence that this has been used for permitting

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Varanus timorensis

Scientific name: *Varanus timorensis* Gray, 1831
Common names: Spotted Tree Monitor, Timor monitor
IUCN Status: Least Concern ("*Varanus glauerti*", assessed in 2009)

Note: This species represents a (sub-)species complex and might include several undescribed taxa[1].

1.) Breeding biology

This species is a **seasonal breeder**. In the wild, they breed **early in the dry season** (May-July)[2]. **Egg deposition** occurs roughly in August-March[3]. In captivity females become **sexually mature** after approximately three years, are **pregnant** for 35-49 days[4] and **incubate** one clutch per year between 93-186 days[2,3,5]. **Clutch sizes** range from 3-18 eggs[3,6]. At hatching, young are 55-70mm in snout-vent length, weighing 4.5 to 6g[2,5,7].

2.) Captive husbandry

The species are **tree dwellers**. **Enclosures** should be higher than the individual's snout-vent-length by a measure 5 x 2 x 4 (length x width x height)[8] and contain plenty of **vertical structures** and **hiding places**. A **temperature** between 30- 35°C in summer and 25-28°C in winter and a **humidity** level of 60-80% during the wet season, UV lighting and a **basking spot** of at least 40°C should be provided[6,9]. During the **dry season** (November-January) humidity can be decreased. A **nest box** filled with sand/soil is important for breeding females. **Diet in the wild** includes reptiles, insects and other invertebrates[7]. **Diet in captivity** has been reported to include a variety of invertebrates dusted with vitamins and minerals, supplemented with pinky mice, smelt and mussel meat and additional calcium for gravid females. At all times water should be provided. After **egg-laying,** eggs need to be **incubated** at 29-30°C in moist vermiculite[6]. For captive varanids **social conditions** need to be monitored as aggressive behavior[10] and **cannibalism** for juveniles of *V. timorensis* has been reported[11]. Husbandry factors that influence **healthy rearing** include insufficient UV light and related calcium deficiencies, overfeeding, chronic dehydration, conspecific aggression, and deficient maternal diet, and reproductive disorders[10,12]. Parasitic infections in captive animals require immediate intervention[8].

3.) Ease of breeding in captivity:

The species can be housed and reproduced in captivity, but at present private individuals carry out almost all breeding. Only **few occurrences of successful F1** reproduction have been documented (e.g. References 3, 5, 6 and 11) and it is **unlikely** that breeding over several generations is **successful** let alone **economically feasible** given the species husbandry related health issues that interfere with long-term reproductive success[10], the cost of feeding and maintaining the species and its life-history, such as its late age at first reproduction[4].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

The largest exporter for captive-bred individuals is Indonesia[13]. According to a TRAFFIC report (see Ref. 4), four facilities in Indonesia held the species in 2008, of which two claim production and export of F2. Based on the discrepancies of numbers of individual claimed to be bred (518) and numbers actually observed (39) at these facilities, as well as their maximum possible production based on breeding biology, TRAFFIC concluded that that all specimens of this species exported as captive-bred are **in fact wild-caught**. **Zoo and aquarium members** of Species360's ZIMS database currently hold 14 individuals (4 females, 3 males, 7 unsexed), of which 9 are recorded as captive bred. Only one of them was actually born at a zoo, whereas the other 8 were acquisitioned from private breeders or have unknown birth locations. No births have occurred in the last 12 months[14].

5.) Marking systems applied to permit individual identification of captive bred specimens

Microchip implants can be used for individual identification, but is not currently used.

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Oophaga pumilio

Scientific name: *Oophaga pumilio* (Schmidt, 1857)
Common names: Strawberry Poison Frog, Flaming Poison-arrow Frog, Flaming Poison Frog, Red-and-blue Poison Frog
IUCN Status: Least Concern (assessed in 2014)

Note: This species shows high diversity in coloration between isolated subpopulations, which can make it difficult to identify by custom authorities.

1.) Breeding biology

O. pumilio can **breed year-round** as long as humidity is sufficiently high[1]. The **minimum size of sexual maturity** depends on the population as they occur in different habitats and altitudes and vary largely in size. In Nicaragua and Costa Rica frogs are larger and they mature at approximately 19 mm in snout-vent length. In Panama adults only reach 15 mm from snout to vent length (SVL)[2,3]. **Sexual maturity** is reached at approximately 10 months[4]. In the wild, males defend territories from which they court females. Females lay a **clutch** of ~5 eggs in the leaf litter on the forest floor, which is **guarded and hydrated by fathers** for 7-12 days[5,6,7]. In captivity, **clutch size** has been reported higher than in the wild, with 5-9, occasionally up to 20 eggs (mean = 10.9, n = 10, Ref.5). There appears to be no data on the number of clutches laid annually[4]. Once the eggs hatch, mothers deposit each of the tadpoles in its own water body, usually leaf axils and revisit sites to regularly feed tadpoles on unfertilized eggs[5,9]. In captivity, no more than four tadpoles are usually recruited from egg to tadpole[10]. **Mean brood size** is ~2 tadpoles (mean = 1.9± 1, Ref.10). The **metamorphosis** from tadpole to juvenile takes an average of 45 days (range 41–56) in the wild[7]. A complete **reproductive cycle** (from egg production until tadpoles reach metamorphosis) takes between 6 - 11 weeks[6,7,8]. Adult **sex ratios** in the population can range from unbiased, to slightly female biased to strongly female biased[11].

2.) Captive husbandry

O. pumilio can be housed in **pairs** in plastic enclosures (at least 37 x 22 x 25cm – length-width-height).[9] Housing in **groups** is possible, but males can be very aggressive. **Tanks** should be lined with **leaf-litter**. **Bromeliads** and/or several **PVC tubes/rearing cups** should be provided for tadpole deposition. In **range countries**, enclosures can be maintained in ambient light, temperature and humidity conditions similar to outside conditions[9]. **Diet in range states** can consist of wild invertebrates (such as *Drosophila spp*. or springtails) attracted to fruit placed in enclosures, supplemented with vitamin-dusted termites[9]. Under laboratory conditions, pairs can be housed in plastic containers placed in an environmental chamber held at 22–27 °C **temperature** and ≥40% relative **humidity** under a 12:12 light/dark **photoperiod**[9]. Tanks should be **misted** 2-3 times daily. **Diet in captivity** can include springtails and ~50 adult vitamin-dusted fruit flies (*D. melanogaster*), fed approximately three times a week[9]. **Dietary supplementation** of fruit flies with carotenoids is recommended for successful reproduction[12].

3.) Ease of breeding in captivity

The species has been shown to **successfully reproduce** in captivity, **without any negative influence** on the **reproductive success** when breeding different subpopulations or F1 backcross pairs[9]. *O. pumilio* is becoming a **model species** for evolutionary biologists to answer a number of questions that require captive breeding. **High mortality** during development have, however, limited theses attempts in some cases, but recent efforts in breeding them have improved due to better knowledge of dietary supplementation[12]. Breeding over several generations using this diet has been successful in at least one known case under laboratory conditions[13]. In outside enclosures in range states, breeding is likely much easier than indoor terrariums outside their natural habitat. A breeder from Costa Rica reports that the breeding of this species can be **profitable** and he

was easily able to breed hundreds of individuals per year, but that he had to close his facility because of **competition** with cheaply sold wild-caught specimens from Panama[14].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

The Amphibian Specialist Group Regional Chair for Panama Roberto Ibáñez reports of **one commercial frog farming facility in Panama**, which was closed down recently, as it went out of business. The Ministry of Environment (MiAmbiente) had to participate in its closure. MiAmbiente distributed the frogs of the shut-down operation among exhibits and other organizations. One of them was the Smithsonian's Punta Culebra Nature Center. MiAmbiente may be able provide information on how many other commercial frog farming are still operating in Panama[15].

Zoo and aquarium members of Species360's ZIMS database currently hold 301 individuals (21 females, 14 males, 266 unsexed) in two continents. In the last 12 months, 26 births have been recorded[16]. Moreover, **private breeders and hobbyists** around the world commonly breed this species.

5.) Marking systems applied to permit individual identification of captive bred specimens

No marking systems currently apply. Color patterns can be used for individual identification but patterns might change and this method would not be feasible in larger breeding operations[14,17].

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Agalychnis callidryas

Scientific name: *Agalychnis callidryas,* Cope, 1862
Common names: Red-eyed Treefrog, Red-eyed Leaf frog
IUCN Status: Least Concern (assessed in 2008)

1.) Breeding biology

Nocturnal **mass spawning** events occur during the rainy season (late May to November) at quiet water pools where males attract females by calling and defend calling sites with territories[1]. Attracted by calls, females will descend from the canopy and the male will hold on to the female[1]. The pair will dive into the pond for the female to absorb water, which is needed to produce the gelatinous egg masses. **Eggs** are usually deposited in multiple clutches (up to five) in masses of ~40 eggs on vegetation over ponds[2], immediately fertilized by the male. **Fertilization rate** is usually high (~100 %)[3]. Females may **ovulate** several times per breeding season[4]. Undisturbed embryos usually **hatch** after 6-7 days after egg-laying[6], but developing embryos can adaptively alter their time of hatching in response to environmental cues[6]. Upon hatching, tadpoles fall into the water below, where they complete **development**[3]. In captivity, **metamorphosis** (complete development) is achieved in about 6-8 weeks but can vary substantially[7,8]. Animals reach **sexual maturity** in captivity at about one year (especially males), but first egg clutches from young females may have **viability issues**. By two years old they are capable of being **fully mature** given optimal husbandry. **Age at maturity** in the wild is not known, but it is likely to be similar[8]. In the wild clutches and tadpoles are highly predated being critical to the recruitment rate from egg to metamorphosis. In captivity, most tadpoles will complete metamorphosis, given optimal husbandry[8]. They can **breed twice** a year if well fed in captivity[8].

2.) Captive husbandry

In range states or climate conditions similar to the species habitat, frogs can be **commercially bred** in **large plastic-fenced mesh cages** exposed to **sunlight and rain**[9]. The inside of the cages can include a **walking path**, to avoid disturbance of frogs, a **leaf-litter substrate** and a row of **large leafed plants**, as well as a few **water tanks** placed beneath large leafs. **Clutches** can be collected from leafs and incubated over water containers in a separate incubation area. Tadpoles are transferred to tadpole containers and froglets (small frogs) are grown in mesh covered plastic tanks (See ref. 9 for photographic documentation of the set-up up of such a farm)[9]. Breeding indoors is also possible, but more costly. For that, several frogs can be kept in a standard vivarium[8] planted with a large **broadleaf potted plant** (e.g. *Monstera*, *Spathiphyllum*)[10]. Frogs require **high ventilation** and **humidity** (60-80%) through daily misting and can be kept at a 12/12 h light:dark photoperiod using a UVA/UVB **fluorescent lamp**[3] at 24-26°C daytime **temperature** and 19-22°C at night. **Substrates** include damp paper towels (changed daily), and natural substrates (changed less frequently)[7,10]. Natural substrates should include a layer of leaf litter to prevent soil sticking to frogs[8] and a shallow water dish. Frogs are **fed to satiation** late in the day, approx. **3 times a week** with crickets, locusts etc. of appropriate size dusted with a mineral/vitamin dietary supplement[3,10]. To induce breeding, **rain** can be simulated through increased misting (e.g. in a rain chamber). **Spawn** can be left to hatch *in situ*, raised in Petri dishes or a separate tank[8]. Developing embryos must be **disturbed as little as possible**, so the embryos don't hatch early[6]. **Infertile eggs** with fungus should be removed. Tadpoles should be raised in **soft, slightly acidic water** with excellent but gentle **filtration** at 24-26°C and fed e.g. on fish food and spirulina algae. When front limbs emerge, tadpoles should be moved to a tank with shallow water on an **incline**. Juveniles that climb out the water need high humidity and excellent ventilation; too wet and they will rapidly die from **bacterial and fungal infections**, too dry and they will stick to surfaces and then desiccate completely[8]. Once the tail is completely absorbed, they will start to feed on fruit flies and small crickets. Almost all **health issues** in this species are environmentally caused and linked to poor husbandry. Some **common issues** include: skin infections due to insufficient ventilation, metabolic bone disease (MBD) due to insufficient calcium/UVB/vitamin D3 supplementation, prolapses of the rectum associated with intestinal helminthes, low temperatures,

and/or hypocalcaemia/MBD, as well as hypovitaminosis A due to insufficient vitamin A[8,11,12]. Keeping them at high temperatures will rapidly be lethal. Likewise, too low temperatures (< ~14°C) lead to immune suppression and infections[8]. Chytridiomycosis and contraction of ranavirus are possible in this species[13,14].

3.) Ease of breeding in captivity:

Breeding this species is **easy, especially in range countries** and a large number of frogs can be produced at **relatively low costs**. A private breeder reported being able to produce thousands of individuals in the first year after setting up his breeding facility in Costa Rica[15]. Breeding this species indoors is more difficult, as it requires experience with terrarium systems, lighting, and manipulation of environmental parameters. Frogs will die quite quickly if kept incorrectly. However, all necessary husbandry protocols are well established, and they are frequently maintained and have been bred successfully in the laboratory for several generations[3,10,16]. No deleterious effects of inbreeding have been observed and animals inbred to 5 generations did not show any apparent problems. Wild inbred populations show decreased survival, but captive populations remain viable for several generations[8].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Hundreds or thousands of frogs are produced by **private breeders and hobbyists**[8]. Main exporting country of captive-bred specimens is Nicaragua[17]. No information is available on **large-scale captive breeding** facilities and there is concern that animals are in fact wild-caught, ranched, or farmed[18]. In 2013, 600 frogs declared as captive-bred were **seized** due to concerns over the origin of specimens and were suspected as having been taken from the wild[19]. **Zoo and aquarium members** of Species360's ZIMS database currently hold 789 individuals (5 females, 2 males, 782 unsexed) at 79 zoological institutions in four continents. In the last 12 months, 143 recruits have been recorded[20].

5.) Marking systems applied to permit individual identification of captive bred specimens

No marking systems apply. Techniques such as **microchips**, photo IDs of lateral patterns, and Visible Implant Telomeres are possible but unsuitable for the pet trade, as they may change over time, can be falsified, are expensive, can cause infections or are too big for juveniles[8,15].

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Hippocampus comes

Scientific name: *Hippocampus comes,* Cantor, 1849
Common names: Tiger tail seahorse
IUCN Status: Vulnerable (assessed in 2013)

1.) Breeding biology

This species breeds **year-round**, with a peak in pregnant individuals during the rainy season in the wild (Jul.-Dec.)[1,2] leading to increased recruitment when water temperatures rise following colder weather periods[3]. Culturists in Viet Nam reported pregnancy peaks in April-September[4]. Females deposit their **eggs** into the male's brood pouch, where they are fertilized and develop[1]. Male and female form a **pair bond** throughout the breeding season[1]. Mate switching may occur in cultured individuals[4]. **Age at maturity** has been measured at 4 month in the wild[3] and estimated 6-12 month in captivity[2]; but **size** tends to be a better predictor of maturity than age. In the wild, the size at which 50% of males are physiologically mature is at a standard length (SL) of 9.3 cm (head+trunk+tail length)[3]. **Actual onset of reproductive** activity, however, does not occur before 11.6 cm SL[3]. The delay is probably due to time spent on establishing pair bonds. Smallest size at which males bear young is ~10.5 cm SL in the wild[3]. Females tend to mature at smaller sizes, at ~10.2 cm SL[3]. **Pregnancy** lasts 14-21 days in the wild[5], depending on water temperature (shorter at higher temperatures)[2]. Breeding operations in Viet Nam reported about two pregnancies per month[4]. The male gives birth for several hours and expels the young through muscular contractions into the water, where they require no further parental care[2]. **Brood size** in the wild is 388±172 (n=18) and the **reproductive output** tends to increase with the size of the animal[3]. Estimated generation time is 1.0-1.2 years[5] and lifespan is 2.7-3.6 years in the wild[5].

2.) Captive husbandry

Broodstock is mostly wild harvested (pregnant males brought into captivity)[6] or from F1 generation[7,8]. In Vietnam, **F1 breeding** for commercial operations takes place in **concrete outdoor tanks** (4-7m^3)[4]. Other sources also report **outdoor cages** in calm bay waters with high transparency in climate conditions similar to range countries[7]. **Closure of the life cycle** requires more **controlled conditions** in **indoor tanks**[4]. Successful **rearing of young** has been reported several times with slightly varying protocols[6]. The Institute of Oceanography in Vietnam reported 90% **survival of young** to 9 weeks[6]. In these protocols, broodstock is kept in **indoor tanks** linked to a flow-through system with sand-filtered seawater and mild aeration[6,8]. **Diet** includes *Artemia*, *Acetes*, and Mysid shrimp[8]. Young are reared under a 12:12 h light/dark **photoperiod** in bare **nursery tanks** (3.5 m^3) for the first 3-4 weeks, and then transferred to **grow-out tanks** equipped with holdfasts. Tanks are linked to a **recirculating system filtered continuously** through a trickle filter and slow rate sand filter with weekly water exchange. Water is maintained at 30°C **temperature**, 32ppt **salinity** and an 8.3 **pH level** with ammonia, nitrite, and nitrate concentrations below 0.1 mg/L. Daily **cleaning** by siphoning debris from the bottom of the tank is required. **Diet** for the first week includes wild-caught live prey (*Acetes*) after which young are gradually **weaned** (introduced to adult diet) onto frozen brine shrimp (*Acetes*), with two-day-old brine shrimp fed until satiation twice daily from day 7-28 and 3-4 day old brine shrimp until week 9. Uneaten shrimp are removed in the morning. Brine shrimp are **decapsulated** before hatching using standard techniques to avoid bacterial contamination, fed with *Chaetoceros* diatoms and enriched with blended *Acetes.* one hour before feeding. Seahorses reach **full size** (17cm) after approximately one year[3]. Other sources report similar protocols for rearing seahorse[8,9]. **Diseases** reported by one aquarium keeping *H. comes* include buoyancy problems from birth, bacterial and protozoan infection, and gas bubble disease[10.] A **husbandry manual** of *H. comes* is currently being developed to be included in Koldewey (2005)[11,12].

3.) Ease of breeding in captivity:

Among seahorses, which are in general among the more challenging marine aquarium fish to breed, *H. comes* is **not the most challenging** species, **at least to F1** generation[4]. **Closure of the life cycle to produce F2 is possible** and has been managed mostly by **smaller operations** for which conditions can be **carefully controlled**[8,4]. Whereas F1 generation can be produced in large outdoor tanks (as it is common in Viet Nam), the production of F2 relies on more controlled conditions[4]. Among Vietnamese culturists there is consensus that **wild broodstock** is better than F1, as **reproductive output** and **survival** of young **declines in F1**[4]. Average **broodsize** of *H. comes* **from wild is higher** (350) than in F1 broodstock (200-300 young) when >1 year in age[4]. Open air, low tech facilities in Viet Nam depend on regularly removing individuals from the wild, but it is not known how often wild broodstock needs to be replaced. One Vietnamese culturist reported that it is a **challenge** to produce ***H. comes*** as it is **hard to find broodstock** and the species does not change color like *H. kuda* and is thus **less desired** by customers. In general, culturist in Viet Nam reported a 80-90% decline in the availability of seahorse broodstock. Despite some traits that make *H. comes* a suitable candidate for seahorse culture (rapid growth and a large number of offspring) **more research** in cost-effective protocols is needed[6].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

Culturists in Vietnam reported only **small-scale production** in the past (5-10% of total volume), while only **one facility** in Cam Ranh was still breeding seahorses for export with a reported production of **5,000 individuals** of *H. comes* in 2016. They did not have *H. comes* on site at time of visit (Nov. 2016 - Jan. 2017)[4]. The **Institute of Oceanology** in Vietnam has been breeding *H. comes* for research and export (Reported annual production of 20,000-30,000, mostly *H. comes* and *H. histrix* from 2008-2013). However, culturists claim to be unable to sell seahorses recently due to the lack of necessary permits[4]. Individuals are hatched at the laboratory of SEAFDEC/AQD in the Philippines[8]. Sri Lanka is a major exporter, but at least as of 2000, all marine fish in Sri Lanka were wild caught[14] and we were not able to find evidence of a breeding facility for *H. comes*. Species360 's zoo and aquarium members only keep a small number of individuals (24), and no births have been recorded in the last year[15].

5.) Marking systems applied to permit individual identification of captive bred specimens

No marking systems currently apply. **Chemical marking** using **tetracycline** may be useful as part of the certification of captive breeding facilities but is not recommended for routine identification of captive-bred specimens. Other marking systems are probably not useful[16].

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Ornithoptera croesus

Scientific name: *Ornithoptera croesus,* Wallace, 1859
Common names: Wallace's Golden Birdwing Butterfly
IUCN Status: Endangered (assessed in 1996, needs updating)

1.) Breeding biology

This species is one of the least known birdwing butterflies. They develop, as other butterflies, in **four distinct stages**. Adult birdwing butterflies lay **eggs** on the underside of the leaves of climbing **vines** that serve as food plants for the larvae (*Aristolochia*)[1]. *Ornithoptera* species have a smaller **clutch size** as compared to other butterflies and will generally lay no more than 30 eggs per brood[2]. **Clutch size** in dissected females of closely related species has been counted as 5-7 eggs (*O. meridionalis*), 8-10 (*O. paradisea*), and 6-10 (*O. chimaera*). The largest birdwing, *O. alexandrae* lays 15-20 eggs, and it has been estimated that, if ovaries are continuously productive, a female can only reproduce about 240 eggs in their entire lifespan[2]. **Caterpillars** hatch from eggs and will feed on the plants passing through five moults until they are fully developed. Caterpillars then pupate, where they undergo complete **metamorphosis**, which can take several weeks[2]. **Egg stages** in closely related species last about 2 weeks (*O. chimaera* and *O. paradisea).* **Caterpillar stage** is 2 months in *O. chimaera* and 36-40 days in *O. paradisea*[2]. **Pupa stage** in *O. paradisea* is 37 days and 49-70 days in *O. chimaera* the wild[2]. After emerging from the pupal case butterflies are fully mature. **Adult birdwing butterflies** can probably survive up to three months, depending on the species[2]. In an example from **captivity**, one female of *0. priunzus* was caged with a plant of *A. ragala* and fed a mixture of honey, sugar, and water. She deposited nine eggs that hatched after one week, and two larvae completed development satisfactorily and pupated 24-25 days after hatching. After another 23 days, two adult males emerged[3]. In another example, three captive *O. richmondia* females began depositing eggs on the second day from the introduction into the cage whereas the last egg was deposited 22 days after introduction. 92% of the eggs hatched and 83% of them survived from egg to late 3rd instar larvae[4]. Males of the closely related *O. richmondia* usually **mate only once**, after 2-3 days after emerging from the pupa. In **captivity**, there are reports of individuals mating twice. Males might combat other male competitors or chase moderate-size birds when they enter their territories[4]. **Egg mortality** is probably high in the wild due to parasites and predator, as suggested from observations in related species[2].

2.) Captive husbandry

Birdwing butterflies can be farmed or ranched. When ranched, ranchers plant habitat patches with **food plants** (*Aristolochia*)[1] in village gardens or secondary growth forest[5] to attract the **egg-laying females** and provide food for caterpillars[5]. Although host vines are harmless to caterpillars and birdwings, they are toxic to humans and should be handled carefully[1]. **Pupae** can then be collected from the food plants. Ideally, 50% of pupae should be left on the vines to repopulate the wild stock[5]. Pupae are then either exported live or more commonly **reared** to adult stage in a **controlled environment that protects them from predators** (cages, large nets, hatching boxes, glass or shade houses). To maintain a healthy wild population, a portion of the adults should be released back into the wild, while the rest is used for the trade[5]. When farmed, enclosures are used to protect butterflies during all stages of their life[5]. In the Philippines, ranchers collect birdwing individuals (mainly *Troides rhadamantus, Trogonoptera trojana and Troides magellanus*) from the wild every 3-4 months. The wild-caught butterflies are placed into cages with food and host plants. After rearing, 10% are returned to the wild[5]. **Cage facilities** for the related *O. richmondia* butterfly measure 15 × 4 × 2.5 m (high) and are supported by a rigid tubular plastic frame with a curved roof and covered with black shade cloth[4]. A plastic sheet covers the 5cm deep hoop pine mulch substrate on the floor of the cage. **Water** is provided from an external tank for misting and watering the food plants. Additionally to the natural rainfall, plants are watered every second day. **Smaller cages** can be used to rear larvae to the pupa stage. **Feeding** occurs via bouquets of cut flowers until adults are accustomed to the cage. Afterwards, **adults are fed** via artificial feeders made from red plastic saucers (approximately 12 cm diameter) which contained white plastic beads, that are half-filled with diluted honey-water, replenished every second day[4].

3.) Ease of breeding in captivity

Ranching and farming of birdwing butterflies in general **is easy**, and requires very little capital. Ranched or farmed butterflies are of higher quality than wild-caught individuals as they are undamaged and, once a farm is established, can be easily collected[5]. It is unknown whether that also applies to *O. Croesus.* **True captive breeding** of this species **has rarely been attempted**[1]. There currently is a research project in the UK that investigates its potential for captive breeding [1].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

This species occurs in the Northern Maluku islands in Indonesia. Online stores selling *O. croesus* report the origin as Halmaheira[7,8]. A 3-week privately financed research expedition in 2015, **found no butterfly farms in Halmahera**, where they did find the species to occur in the wild in low numbers[1]. The **high price** of 50-200 USD[1] could indicate that no mass farming occurs for this species. None of the *Ornithoptera* species is kept or bred in any zoological institution member of Species360 worldwide[9].

5.) Marking systems applied to permit individual identification of captive-bred specimens

No marking systems currently apply.

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Tridacna crocea

Scientific name: *Tridacna crocea,* Lamarck, 1819
Common names: Crocus giant clam, Boring Clam, Saffron-coloured Clam
IUCN Status: Least Concern (assessed in 1996, needs updating)

1.) Breeding biology

Giant clams are **hermaphrodites**, which means they produce both, eggs and sperm. Sperm release precedes egg release during spawning, presumably to prevent self-fertilization[1]. Natural spawning of giant clams has rarely been documented in the wild and time of spawning probably varies with geographic location[1]. Their lifecycle is typical of bivalves. Eggs (~100µm) hatch within 12 hours of fertilization into a free-swimming **trochophore larva**. About two days after fertilization, the trochophore develops into a filter-feeding bivalve **veliger larva** (160 µm)[1]. The veliger later develops a foot to become a **pediveliger** that alternately swims and rests on the substrate, eventually **metamorphosing** into a juvenile **clam** (200µm) at day 8-10 post-fertilization. Metamorphosis marks the beginning of the **symbiotic relationship** (where both species can benefit) with photosynthetic algae - the zooxanthellae[1]. **Growth** rates in giant clams are slow, with reproduction occurring at around 5-7 years old[2].

2.) Captive husbandry

T. crocea require **clear tropical seawater** for optimum growth and survival[1,3], 25-30°C water temperature, 32-35ppt **salinity** and an 8.1-8.5 **pH** level. **Sunlight** (<50% light) is important for **photosynthesis** of symbiotic algae (zooxanthellae) and clam survival[1]. Captive husbandry techniques typically vary between the hatchery operations, but usually consist of **three basic stages:** adult broodstock husbandry, larval rearing, and grow-out nursery[4]. Most successful aquaculture systems include **five different tanks**, each for a particular purpose[5]. The **broodstock tank** is usually shallow and keeps the mature individuals. Broodstock can also be kept in **ocean holding areas** (5-10 m deep mesh cages in areas of coral growth)[1]. **Broodstock** (6-8 years old)[6] can be collected from the wild or grown from locally reared seed[1]. Spawning broodstock is then transferred to a smaller easy-to-handle **spawning tank** for egg and sperm collection and transportation. Spawning can be induced by various methods, including serotonin injection, hydrogen peroxide, macerated gonads or thermal stress[5]. Eggs are then **fertilized** in a 1:200 sperm:egg ratio[7] in **hatching tanks**, which are usually round tanks made of plastic or fiberglass[5]. When most larvae have reached the veliger stage, they are transferred to shallow, flow-through **raceways** that provide the necessary substrate for larvae to settle and complete metamorphosis. **On day 4** and **day 6 post fertilization**, extracted **zooxanthellae** must be offered to larvae so they can form their symbiotic relationship[5]. Zooxanthellae can be extracted from the tissue of other clams. At approx. 14 days post fertilization metamorphosis is complete. Juveniles are then transferred **to grow-out tanks**, which are shallow and light to promote zooxanthellae growth[5]. Giant clams grown for aquarium trade of food require a 1-2 year grow-out time[1]. **Common diseases** include parasitic snails, and boring sponges and algae. Regular washing of the clams with freshwater or scrubbing with a formalin solution can treat sponge and algae. Offshore cages should be cleaned and checked for predatory snail eggs once a month. Water filtering to 25 µm can prevent snails from entering the land-based broodstock tanks[1].

3.) Ease of breeding in captivity:

Giant clams can be **easy and profitable** to cultivate, as they mostly only require good water quality and light for growth. Once reached the juvenile state, they require **relatively little maintenance**[2]. Aquaculture operations of *T. crocea*, however do **rely on wild-caught broodstock**. Current **production** is still relatively low[8]. A recent survey of managers of the **20 largest clam farms** reports a number of **challenges** in culturing giant clams, including *T. crocea*[8]. Problems include the **lack of access to healthy and large broodstock** (many farms operate with less than 30 broodstock clams, as large individuals are rare and protected from collection), **slow**

growth rates, **problems with culturing**, and **parasites**. Also mentioned were a **lack of funding** and **competition** with **lower-priced wild caught** individuals (Vietnamese *T. crocea* are lower in price and bigger in size than cultured ones), **infrastructural issue** (some producers had to close as distance from markets made them no longer cost-effective), and **environmental problems**, such as low water quality[8].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

The ***ex situ* breeding programmes** for giant clams were first established in the 1980s to repopulate or supplement depleted populations of giant clams[9]. **Captive breeding** of the Crocus clam, *T. crocea* **has been limited**, and reported to have taken place in Japan (Okinawa), New Caledonia, Palau, Papua New Guinea, and Vanuatu[9]. It is not known if all these localities still produce *T. crocea*, but the Okinawa Prefectural Fisheries Center is active and produces *T. crocea* spats for local restocking efforts. Mies et al. (2017) conducted a comprehensive review to understand the status quo of trade in giant clams and reported **20 active giant clam aquaculture farms** in the **Indo-Pacific** (as of 2016). Of these, **seven hatchery facilities** breed *T. crocea*. Reported production in 2016 according to Secretariat of the Pacific Community was 18,300 individuals (Australia: 200; Fed. States of Micronesia: 1,500; Indonesia: 500; Malaysia: 1,500; Palau: 6,500; Phillipines: 1,100, Vanuatu: 7,000)[8]. **One grow-out facility** was reported with a production of 2,000 individuals in Palau. These numbers do not include small- and medium-sized aquaculture farms such as e.g. the farm Acro Al (Perth, Australia)[10].

5.) Marking systems applied to permit individual identification of captive-bred specimens

No marking systems apply.

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Trachyphyllia geoffroyi

Scientific name: *Trachyphyllia geoffroyi,* Audouin, 1826
Common names: Banana coral
IUCN Status: Near Threatened (assessed in 2008)

1.) Breeding biology

This species can breed through **asexual** or **sexual** reproduction. Asexual reproduction can happen through **fragmentation**, where a section of the coral detaches and forms a new colony. Sexual reproduction occurs when mature gametes are spawned through the mouth of the corals and are mixed to form a planula larva, which will settle and initiate a new colony[1]. The species sexual **breeding season** may occur from November to December[1]. According to the IUCN Red List, individuals of this species are assumed to only reach **sexual maturity** at about 3 - 8 years[2].

2.) Captive husbandry

This species usually needs medium to low **lighting** and medium to low **water flow**[1]. Besides being easily kept in captivity, there are **no records of captive breeding** for this species[1]. There are, however, studies that show the potential for public aquariums to reproduce *T. geoffroyi* under controlled conditions, and some experiments achieved breeding corals in aquariums[3]. In the **wild**, this free-living coral is found at the soft sandy bottom of the reefs[4] in **solitary colonies** and permanent biotopes[5]. They occur in **tropical** and inter-reef habitats and are usually found with other species of corals[6]. For this species, it is important to keep a moderate water flow in order to remove detritus from its tissues. This is a **photosynthetic** coral that might benefit from the input of small chopped pieces of shrimps or clams[7]. Information from the world of aquariums indicates that corals also feed on zooplankton or small fishes, mainly during the night, by extending their tentacles to capture food[8].

3.) Ease of breeding in captivity

This species **grows slowly**, is **difficult to propagate** and there has been **limited success** in its mariculture[9]. Notwithstanding, the production of some individuals by **asexual vegetative** methods is possible and might be used for the aquarium trade[10]. The **investment** of building a breeding farm is very high and the investment return late, which makes it a **high-risk business**. Asexual reproduction is usually carried out through single polyps that **grow slowly** and easily succumb to **infection**. It takes between two to three years for fragments to successfully attach and heal. Moreover, one fragment can only be split in two, which makes its reproduction not commercially viable for the aquariums trade. Little is known about **sexual reproduction** for commercial trade, but some advances on captive husbandry have been made[11].

4.) Extent of breeding in captivity (quantity of specimens bred and number of breeders in different parts of the world)

No records of captive breeding in this species exist.

5.) Marking systems applied to permit individual identification of captive bred specimens

Some individuals of this species are taken from the wild and glued to a pedestal that might be marked[3]. Maricultured corals are smaller and have more uniform sizes and shapes than wild caught corals[12]. Coral experts can easily identify corals that were bred in captivity.

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