Testudo hermanni boettgeri and *Testudo marginata*

A sustainable breeding program

BERT EENDEBAK

This paper deals with the conditions necessary for a self-sustaining population of tortoises in captivity, illustrated by a breeding program of a group of *Testudo hermanni boettgeri* and *Testudo marginata* kept in outdoor terrariums in The Netherlands.

Schildpaddenstudiecentrum Oosterbeek
(Tortoise Study Centre Oosterbeek)

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ABSTRACT

During the International Turtle and Tortoise Symposium, January 17-20, 2002 in Vienna, a very large number of presentations on keeping and breeding turtles and tortoises provided evidence that breeding of the majority of species is now possible and has been successful in many cases. A second step is to demonstrate sustainable captive breeding programs, i.e. breeding results during long periods within a defined group of a given species. The goal of such a program is to achieve a genetically and physically healthy population in captivity.
In this paper, elements that are of vital importance in setting up self-supporting populations, like production of eggs, fertility and hatching rates of eggs, as well as survival of hatchlings, fertility and sex ratios are discussed. Examples given in this paper are based on experience with a group of *Testudo hermanni boettgeri* and *Testudo marginata* that have been kept for 20 years in outdoor terrariums at the Tortoise Study Centre in the Netherlands.

KEYWORDS

Tortoise, *Testudo hermanni boettgeri*, *Testudo marginata*, breeding program, eggs, hatchlings, conservation, long-term study

INTRODUCTION

Successful keeping and breeding of turtles and tortoises has been achieved for many species. During the "International Turtle and Tortoise Symposium**".** Vienna, Austria, January 17-2, 2002 reports of breeding of more than 20 species of tortoises and almost 60 species of turtles have been described. However, most of these results were achieved with parents originating from wild populations (often of unknown location) and the question that remains is what conditions should be fulfilled in order to speak with confidence of a self supporting, i.e. a healthy population without introduction of animals from outside that group. Many wild populations have been described, but very few reports include information on the population dynamics, like stability, age distributions, egg production and survival rates. It would be extremely interesting to know whether minimum requirements for such populations could be defined.
A small, self-sustaining population numbering 30 wild *T. graeca* in Greece was reported by Hailey (1988) but in general, populations that are believed stable consist of many more individuals. In Greece the size of 8 distinct *T.hermanni boettgeri* populations was assessed, based on mark-recapture method, and varied from 165 to 999 individuals (Willemsen & Hailey, 2001). Populations that are too small run an increased risk of extinction, in spite of the longevity of the individuals. Reports of groups of turtles or tortoises in captivity give hardly any information on the life cycle parameters involved and in the literature, hardly any assessment of the conditions, needed for a self-sustaining group, can be found.
This paper discusses the conditions that have to be fulfilled to raise and maintain a self-supporting group tortoises in captivity and the influence of parameters like egg production, survival of eggs and tortoises, fertility and sex ratio. This discussion and the examples given are based on experience with and measurements of population characteristics of a group of *Testudo hermanni boettgeri* and *Testudo marginata* kept at the Tortoise Study Centre Oosterbeek (SSC Oosterbeek) in the Netherlands.

MATERIALS & METHODS

A group consisting of ~ 70 *T.h.boettgeri* and 30 *T.marginata* was used to investigate life cycle characteristics. The tortoises are kept in outdoor terrariums that provide different areas to separate different species or individuals. Most of these areas contain a greenhouse or shelter to protect the tortoises from the Dutch climate during the early spring and autumn periods (see Figure 1). The total area available to the group takes up ca. 400 m². Half of it is covered with grasses, clover and low herbs with a variety of ground flora. The other part is covered with low bushes and shrubs, like brooms and brambles. Nesting takes place on the various sunny, sandy slopes that are available, or in the greenhouse. Hibernation takes place in the outdoor shelters from October up to April for the adults. For hatchlings the first hibernation is limited to 3 months.

Figure 1: One of the outdoor terrariums and outdoor shelter, including a small greenhouse

All tortoises are free to move in the open field and greenhouses, except for the hatchlings in their first or second year. These are kept in indoor terrariums or in a greenhouse for most of the year, mainly to protect them from birds, rats, hedgehogs etc. Thereafter, the juveniles are kept in the same outdoor terrarium as the colony of full-grown *T. hermanni boettgeri.*

All eggs are removed from the nests, marked with a pencil, weighed, inspected and placed in incubators, usually within 1 to 3 hours after nesting. In general the eggs of each clutch are equally distributed over three different incubators. Methods of incubation have been discussed in detail elsewhere (Eendebak, 1995).

Immediately after laying, the eggs are inspected for the possible development of blood vessels, although these are normally visible only after 6-8 days of incubation. No sign of blood vessels has ever been detected the first day, so a hypothetical developmental process within the female is unlikely and will not influence the results. Eggs that do not show any development or that have stopped developing are opened and examined for any sign of fertilization. If there was even the slightest sign of blood vessels or the presence of an embryo, the eggs were defined as “fertilized”. Embryos with a length of 1 mm are already easily detected with the naked eye.

Most of the hatchlings produced have been distributed among members of the Dutch Tortoise Association.

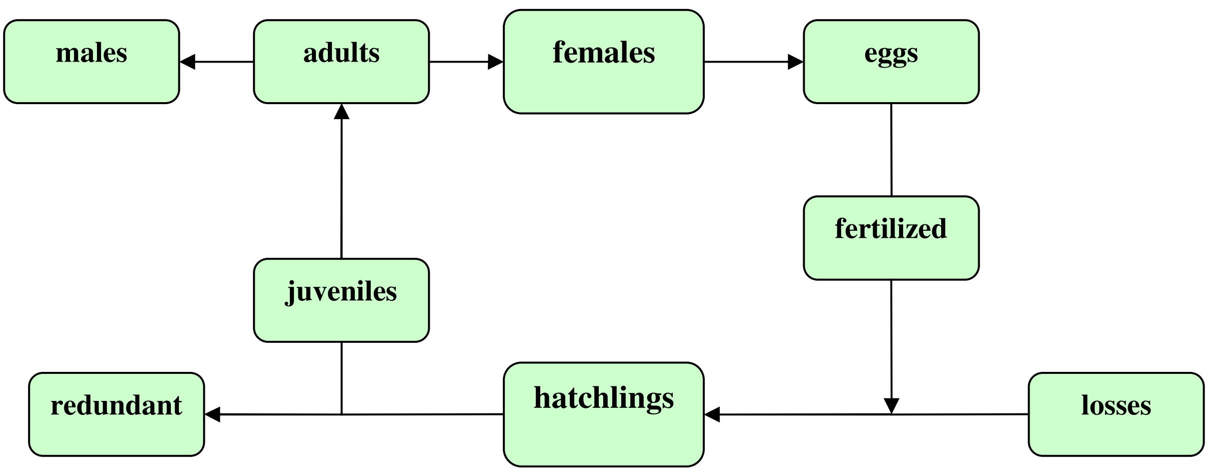
The sex of the juveniles can be determined by external characteristics, such as the shape of the tail, carapace, plastron or anal scutes. In most cases, this determination can take place at a carapace length of ~10 cm, typically at an age of 3-4 years. Juveniles were defined as male or female only when at least two different sex characteristics, usually the shape of the tail and anal scutes, were determined.

RESULTS & DISCUSSION

A group of full-grown fertile females is essential for a self-supporting tortoise population. Their egg production has to produce enough hatchlings to compensate for the annual mortality of that group. In Figure 2, a schematic view is given of the female tortoise life cycle, where we can distinguish the following important issues:

- Production of eggs
- Survival of eggs and hatchlings
- Fertilization and sex ratio
- Age distribution within the population

Figure 2: Tortoise life cycle

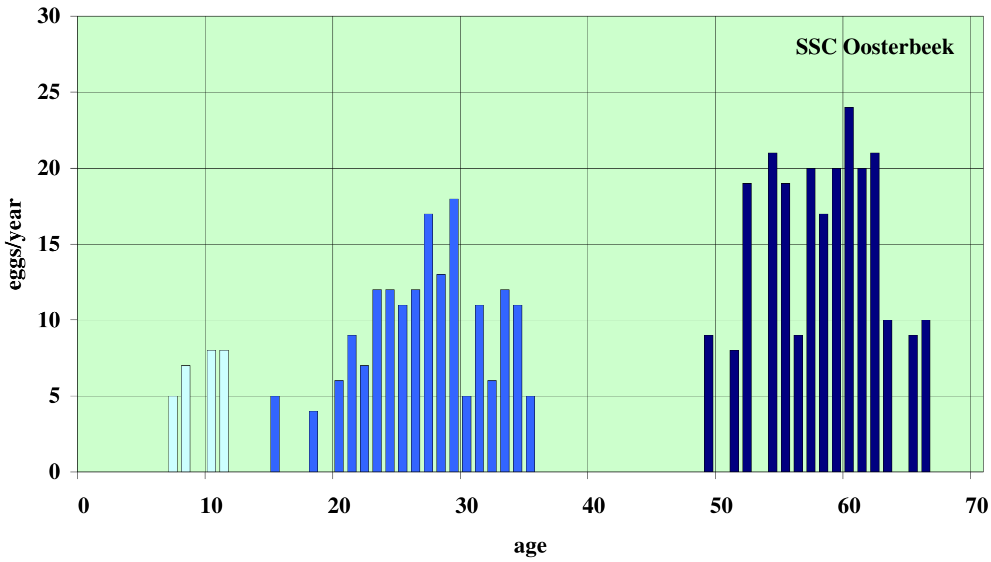


Production of eggs

Assessments of egg production in wild populations are rarely carried out. Hailey assessed the annual egg production in 3 populations *T. hermanni boettgeri* in Greece as 7, 10 and 14 eggs / female and for *T. marginata* as 14.4 eggs / female (Hailey, 1988). For a population of *T. graeca* in Spain, a number of 9.2 was given (Díaz-Paniagua, 2001). Much lower annual values have been reported for *T.h.hermanni*, e.g. 3.1 eggs/female (Bertolero, 2001) and 6 to 8 (Devaux, 1988), for *T.horsfieldi* 5.79 (Henen, 2001) and for *T.graeca.terrestris* 3.8 (Lapid, 2001).
In the discussion in the present paper a typical value of 10 eggs per year is used, which is close to the average egg production for T.h.boettgeri of 8.8 eggs / female/ year at the Centre over the period 1973-2001. More information on nesting and clutch size has been discussed elsewhere (Eendebak, 2001)

In Figure 3 the data for egg production of a number of *T.h.boettgeri* are presented, showing typical results for a young, first generation female, as well as a 40 and a 66 year old wild captured female.

Figure 3: Egg production of 3 *T.h.boettgeri*



Survival of eggs and hatchlings

The most important threat to the conservation of turtle and tortoise populations in Europe is formed by cultivation and habitat loss (Devaux, 2001; Willemsen & Hailey, 1989). For those populations that escape from these dangers, loss of both eggs and hatchlings mainly to predators like birds and foxes are the typical limiting factors for population growth or stability. These dangers may also play a role for captive held groups, but in this situation, eggs are normally protected in incubators and hatchlings are protected by keeping them indoors, during the first vulnerable year(s). The average embryo survival of the group of *T.h.boettgeri* over a period of 20 years was 58 %. This number is probably an underestimate of the real possible survival because of the many measurements at relatively low and high incubator temperatures, leading to higher mortality rates. Hatchling survival was relatively low during the first years of the studied period because of incidents or accidents, like losses from inappropriate hibernation or insufficient protection from birds. The average hatchling survival over the period of 20 years was about 30 %. Only a small number of hatchlings, enough to keep the group stable is retained. Surplus hatchlings are distributed among other breeders, preferably members of the Dutch Tortoise Association (ca. 90 % of all hatchlings).

Fertilization and sex ratios

Successful fertilization of eggs is dependant on many factors, such as parental condition and the environment where the population lives. Under normal conditions most eggs will be fertilized. This holds also for wild populations (Willemsen & Hailey, 1989). Incubation temperatures are the deciding factors for successful hatching, as well as for the sex of the hatchling. The average number of fertilized eggs in the group was 75 %. At the Tortoise Study Centre Oosterbeek (SSC Oosterbeek), many measurements of sex ratios resulting from different incubation temperatures have been performed (Eendebak, 2001). In Figure 4, these results are summarised as the percentage male hatchlings together with the total number of tortoises that were incubated at that temperature whose sex was irrefutably determined. This shows a sharp transition between 30°C and 33°C, with a sex ratio of 50% at a temperature of 31.5°C.

Figure 4: Sex ratios for *T.h.boettgeri*

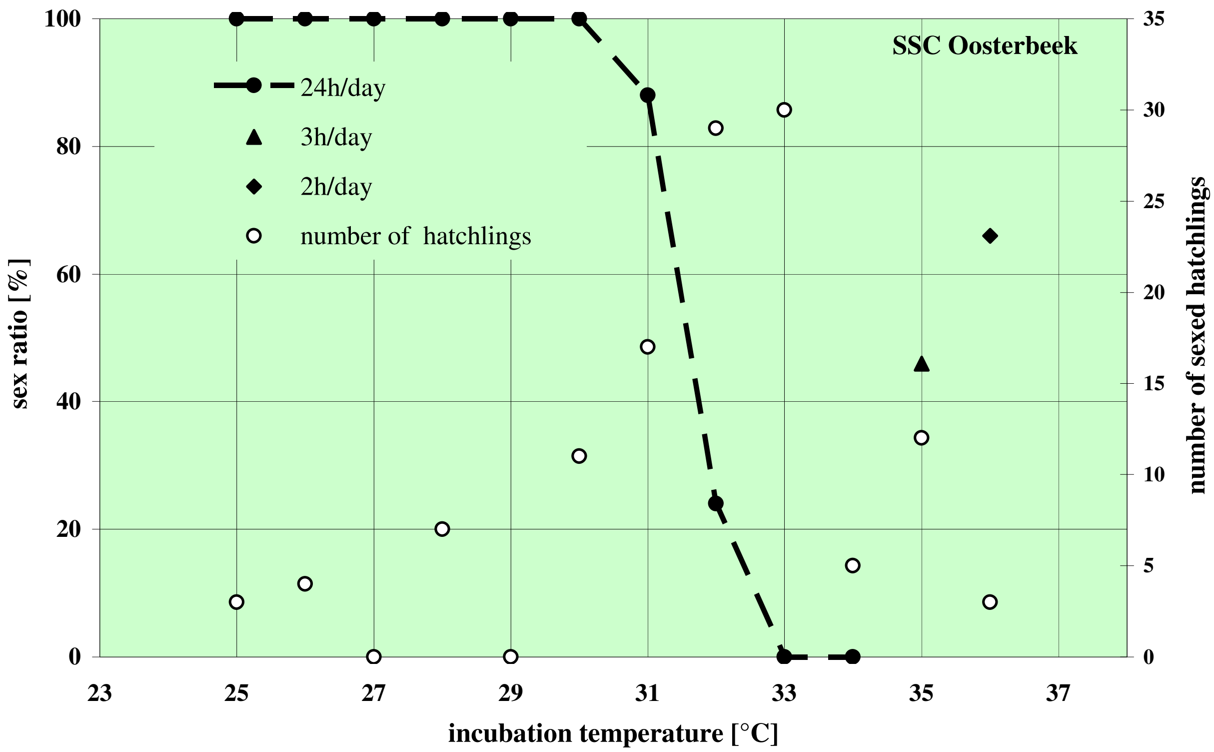


Figure 4 also shows the results of two experiments. Here the temperature was raised for a limited number of hours per day (either 35°C for 3 hours per day or 36°C for 2 hours per day). For the rest of the time, the incubation temperature was below 20°C.

Over the study period the average sex ratio was about 30 %, but this value is affected by choice of incubation conditions each year. For wild populations studies have been made of adult sex ratios. For 18 populations of *T.h.boettgeri* in Greece the observed adult sex ratios ranged from 0.5 up to 7.6 and were in general male biased (Hailey & Willemsen, 2000). Adult mortality was suggested as a possible reason for these findings. However there is no reason to assume a “juvenile” sex ratio significant different from 0.5.

Age distributions

The loss of individual tortoises, dependant on age and sex, can lead to a specific age distribution. In Figures 5 and 6, the age distribution of the groups of *T.h.boettgeri* and *T.marginata* at the SSC Oosterbeek at present is presented. In groups like these, a real equilibrium in age distribution can never be realized. All adult females have produced enough eggs, hatchlings and juveniles that lead, at the owner's preference, to one or two female daughters to stay within the group, but age-specific mortality may shift the age distribution easily.

Figure 5: Age distribution of *T.h.boettgeri*

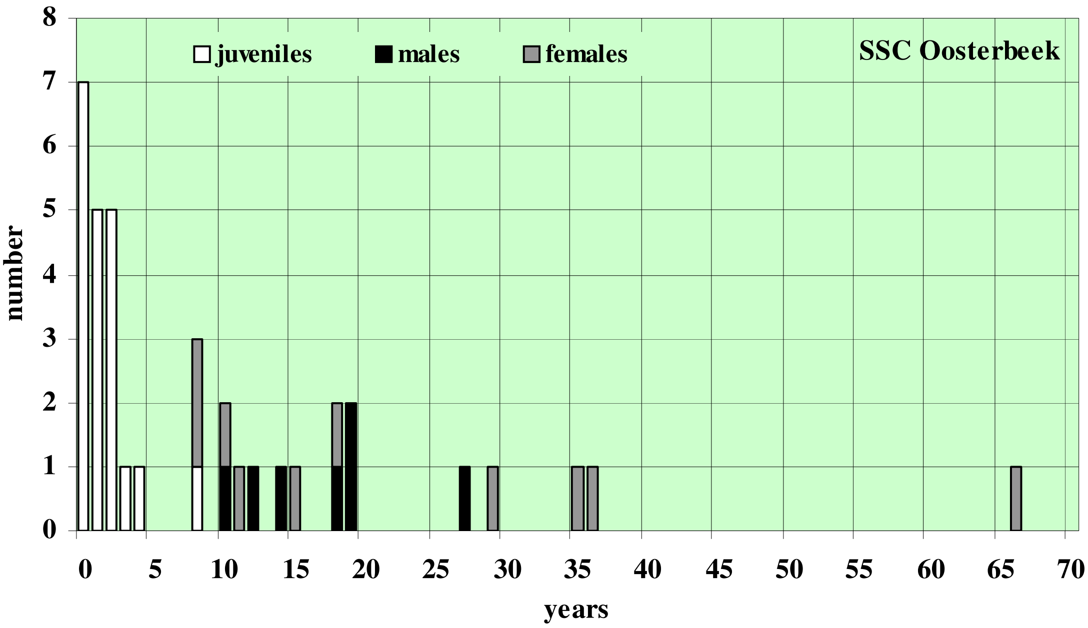
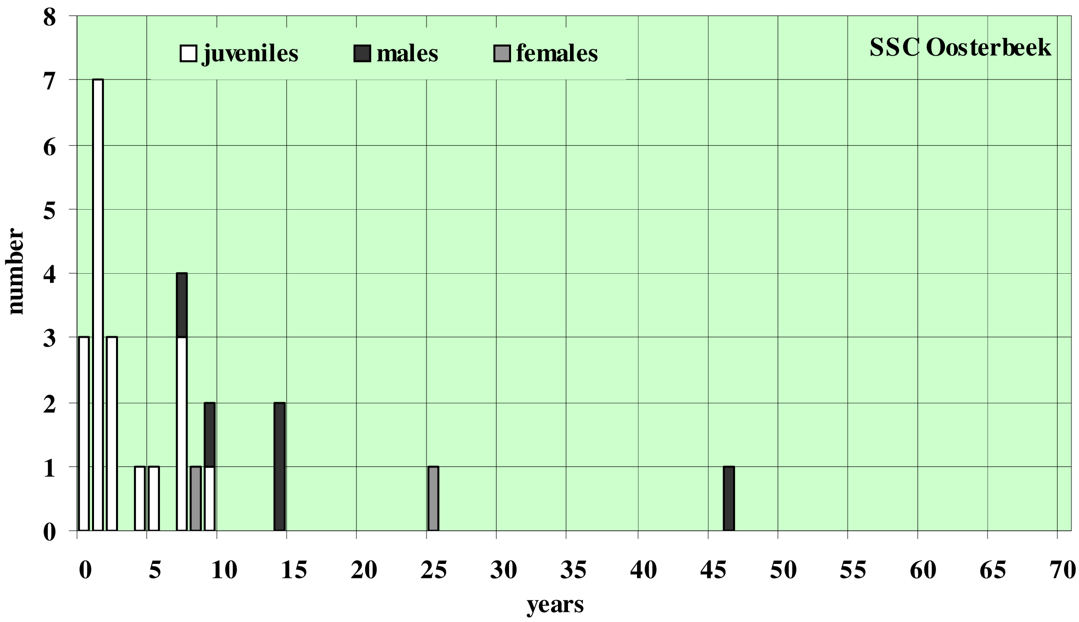


Figure 6: Age distribution of *T.marginata*



Life cycle

In Table 1 an overview is given of some typical life cycle values as mentioned above.

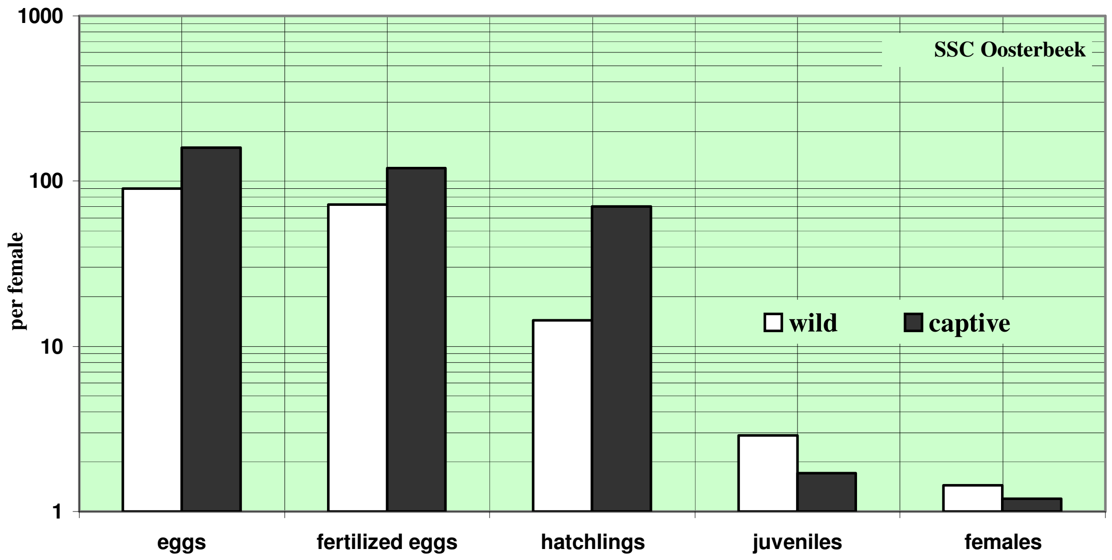
Table 1: Life cycle values

Parameter	Quantity	Typical numbers	
		Wild population	Captive population
Female survival rate	Per year	0.89 *	0.95 **
Nesting	Eggs/year	10 *	8.8 **
Max. nesting period	Years	~40	~50
Total egg production	Eggs per life time	90	160
Fertilization of eggs	%	80 *	75 **
Embryo survival	%	20	58 **
Retained	%	100	8 ***
Hatchling survival	%	20	30 **
Sex ratio	% (males)	50 *	30 ***
Total production rate		1 to 2	1 to 2

* Derived from literature (see text)
** Based on 20 years average for SSC Oosterbeek
*** At choice

The life cycle values mentioned as crucial for the tortoise life cycle are dependent on many variables, including the conditions of the tortoises and the quality of the specific environment. Therefore to attempt to calculate average values, not to mention reliability intervals, does not make much sense. Therefore in Table 1, only typical numbers are presented. Apart from strong human intervention from the values mentioned in Table 1, the embryo and hatchling survival rates are especially determining factors for the self-sustaining capabilities of a wild population. For tortoises kept in a healthy group in captivity, generally there are enough offspring to balance loss of individuals by disease and redundant hatchlings can be transferred to other tortoise keepers. In Figure 7 this difference is shown, starting from the typical values as presented in Table 1.

Figure 7: Death and survival of *Testudo h.boettgeri* – typical life cycle values for self-sustaining populations



The question of what a realistic minimum size for an individual self-supporting group in captivity could be cannot be simply answered. Whether risks from inbreeding in small tortoise populations are worth mentioning is questionable and will not be discussed in this paper. For the parameters in Table 1, one would expect that a group of ca. 7 individuals, consisting of 2 females, 2 males and 3 juveniles could be enough. Because of the lower hatchling survival in wild populations the minimum size for such a population may consist of ca. 12 individuals. However, these estimates are not realistic because of the danger imposed by the different losses from year to year. Such small groups are extremely vulnerable to risks and the minimum population sizes may easily be twice as much. For tortoises in captivity specific threats like insufficient protection against risks coming from, predators, food, hibernation, incubation and temperature control (turtles) may be minimized by keeping small sub-groups in different environments.

Some dangers however happen to the group or population as a whole. For wild populations this holds true of course especially for human intervention, forest fire and predators. For tortoises in captivity the main threats are insufficient care, leading to loss of production of fertilized eggs and diseases. These dangers, in general, are structural. Exchange of experience and active participation in the European Studbook Foundation may increase the viability of these groups.

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