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From troubles to solutions: conservation of Mediterranean tortoises under global change

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Chelonians are among the animal groups with the poorest conservation status. Since tortoises are long-lived species that need very long time to reach sexual maturity, they are extremely vulnerable

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to human pressure. Despite their endangered status, there are no common strategies for the development of conservation actions. At the "Mediterranean workshop to develop tortoise conservation strategies", scientists, conservation associations, environmental managers, IUCN advisers and CITES inspectors met in October 2019 in Alicante (Spain). The aims were to update the diagnosis of the conservation status of the Hermann's tortoise (*Testudo hermanni*) and the spur-thighed tortoise (*Testudo graeca*) and to suggest strategies that guarantee their preservation at the Mediterranean Region. The main conclusions are summarized by:

i) Mediterranean tortoises are wild endangered species that must be protected in, and together with, their natural habitat. Their main threats are habitat loss and fragmentation and pet trade, but we should also pay attention to wildfires, spread of diseases, the introduction of exotic species or lineages and climate change.

ii) Long-term efforts and stablished protocols are needed to accurately diagnose and monitor the conservation status of wild populations, as well as flows among captive and wild animals.

iii) Tortoise trade should be banned because it threatens the conservation of wild populations of tortoises. Illegal practices related to tortoises should be decidedly persecuted. People should consider tortoises as wild animals that are endangered and deserving of protection. It is possible to enjoy them by responsibly observing them in their habitat.

iv) Tortoises may carry pathogens or parasites and their sanitary status cannot be fully assessed. They should always be considered potential vectors of tortoise pathogens and of zoonotic agents. Hygiene protocols should be implemented when managing them.

v) The researchers attending this workshop aimed to develop a scientific network for the long-term monitoring of *T. graeca* and *T. hermanni* populations in the Mediterranean Region. They will need the support from public administrations.

Chelonians (comprising tortoises, freshwater and marine turtles) are among the most threatened groups of vertebrates with 187 out of the 360 currently recognized species being considered Threatened by IUCN Red List criteria (51.9% of the total; STANFORD *et al*., 2018, 2020). Within this group, terrestrial tortoises (family Testudinidae) are especially vulnerable. Of the 10 taxa of chelonians that have gone extinct in recent human history, eight were tortoises (*Chelonoidis abingdonii*, *C. niger*, *Aldabrachelys gigantea daudinii* and the five representatives of the *Cylindraspis* genus) (STANFORD *et al*., 2018). Moreover, 33 out of the 50 living species of tortoises are listed as Threatened by the IUCN (18 of them being either Critically Endangered or Endangered) (RHODIN *et al*., 2011, 2018). Behind these alarming numbers, at least three facts make the diagnosis even worse: (i) one out of the three major branches of the Testudininae subfamily became extinct with the loss of the five *Cylindraspis* species after the discovery of the Mascarene Islands (approximately 150-250 years before present) (KEHLMAIER *et al*., 2019). This constitutes a major loss of genetic diversity and of one of the most iconic and functional fauna (GRIFFITHS *et al*., 2010); (ii) the conservation status of 21 live species (18 of them listed as Threatened by the IUCN) was assessed more than ten years ago and it might have worsened since then (Fig. 1);

Figure 1: Temporal scheme of the current IUCN Red List assessments of the 58 recognized tortoises' species. Note that the assessments of 21 live species trace back to 2010 or before. DD: Data Deficient; LC: Least Concern; NT: Near Threatened; VU: Vulnerable; EN: Endangered; CR: Critically Endangered; EX: Extinct. Data downloaded from IUCN (2020).

and (iii) the collapse of tortoise populations has importantly diminished their ecological roles as key species (for example, as seed dispersers and germination enhancers, consumers, prey or soil miners), with negative impact for ecosystems at a global scale (LOVICH *et al*., 2018). Despite their worrying status, there are no common established strategies for the development of conservation actions for these iconic species.

The Hermann's tortoise *Testudo hermanni* (Gmelin, 1789; Near Threatened according to VAN DIJK *et al*., 2004) and the spur-thighed tortoise *Testudo graeca* (Linnaeus, 1758; Vulnerable according to TORTOISE & FRESHWATER TURTLE SPECIALIST GROUP, 1996) are widely distributed in the Mediterranean Region (Fig. 2). While *T. hermanni* occurs in southern Europe, from Turkey to Spain (BERTOLERO *et al*., 2011), the distribution range of *T. graeca* covers part of three continents: Africa, Europe and Asia (from easternmost Iran to the Moroccan Atlantic coast in an east-west direction, and from the Danube Delta to the Libyan Cyrenaica Peninsula in a north-south direction; ANADÓN *et al*., 2012; GRACIÁ *et al*., 2017a). Both species are restricted to natural and semi-natural habitats mainly characterized by open Mediterranean vegetation (or drier in the case of *T. graeca*) and to agricultural landscapes characterized by very low management pressures (ANADÓN *et al*., 2006; BERTOLERO *et al*., 2011).

Especially since the decades of 1970s and 1980s, the spread of urbanization and intensive crops and farming importantly diminished the suitable habitat for these species (BERTOLERO *et al*., 2011; RODRÍGUEZ-CARO, 2017). As a second major threat and since the same decades, poaching in large numbers for trafficking or to be maintained as pets by local people strongly declined tortoise populations (BERTOLERO *et al*., 2011; PÉREZ *et al*., 2011, 2012a; SEGURA *et al*., 2020) (Fig. 3). Other important threats are forest fires (e.g. CHEYLAN 2004; SANZ-

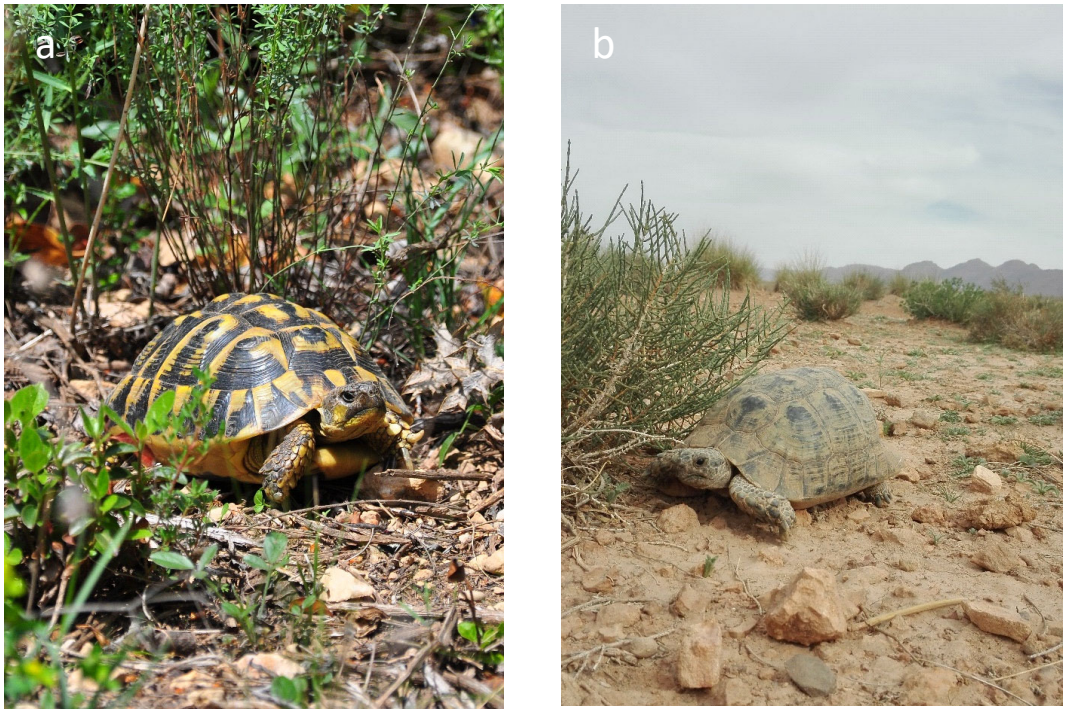

Figure 2: Mediterranean tortoises in the wild. (a) *Testudo hermanni* in Montsant Natural Park in Catalonia, Spain (Author: Joaquim Soler-Massana). (b) *Testudo graeca* near Missour, Morocco (Author: Eva Graciá).

AGUILAR, 2011), the spread of diseases or parasites (BROWN, 2020), genetic exogamy (GRACIÁ *et al.*, 2013, 2017b; ZENBOUDJI *et al.*, 2016) and climate change (FERNÁNDEZ-CHACÓN *et al.*, 2011). However, there is a lack of global and updated studies evaluating the conservation status of these two species and there is no consensus about how to manage captive animals (i.e. different protocols have been developed, e.g. MATTM, 2019; PÉREZ *et al.*, 2012b).

With the aims to discuss about the conservation status of these tortoise species and their populations, and to agree conservation and management strategies, scientists, conservation associations, environmental managers, IUCN advisers and CITES inspectors met in October 2019 in Alicante (Spain). The "Mediterranean workshop to develop tortoise conservation strategies" was organized by the Ecology Area of the Miguel Hernández University, the Spanish Herpetological Association and the Network of Scientific Women of *Casa Mediterráneo*. A total of 64 participants from Portugal, Spain, Morocco, Algeria, Italy, Serbia, Armenia, Turkey and Germany contributed to the workshop with data, short talks and debates around three topics: (i) conservation of wildlife populations; (ii) species trade and management of tortoises in captivity; and (iii) emerging diseases and parasites. The organizing committee is aware that this

Figure 3: Threats to wild populations of *Testudo hermanni* (i.e. particular case of south-eastern Spain). (a) Habitat loss and fragmentation (Author: José Daniel Anadón). (b) Confiscated tortoises from local inhabitants in a single work morning of environmental rangers (Author: Eva Graciá). (c) Long-established custom of keeping and breeding tortoises in captivity (Author: Eva Graciá).

meeting constitutes a starting point. Further united efforts are needed to encompass the conservation of the two other *Testudo* species inhabiting the Mediterranean Region (*T. kleinmanni* and *T. marginata*). The conclusions of the workshop are shown below. Whereas the existing information has been considered when possible to elaborate these conclusions, we must highlight that no previously published information exists to support some of the asseverations below. In these latter cases, expert judgement coming up from discussion and agreement at the workshop was used to elaborate the conclusions.

AGREED TIPS AT THE MEDITERRANEAN WORKSHOP TO DEVELOP TORTOISE CONSERVATION STRATEGIES

Conservation of wildlife populations

1) Chelonians are one of the animal groups with the poorest conservation status worldwide. Within this group, tortoises (family Testudinidae) are especially vulnerable. Nearly 70% of all tortoise species are either extinct or close to extinction as a consequence of human impacts (STANFORD *et al.*, 2020; Fig. 1). Therefore, it is mandatory to take effective conservation

measures.

2) Conservation actions should focus on preventing situations of critic conservation status, not only on reverting them. International institutions, the European Union, circum-Mediterranean states and regional governments should invest efforts in making accurate diagnoses and monitoring the conservation status of tortoise populations. Particularly on the IUCN Red List of threatened species, *T. graeca* is considered "Vulnerable" and *T. hermanni* is considered "Near Threatened", as assessed in 1996 and 2004, respectively. However, the conservation status of these two species has worsened since then mainly because of habitat loss and fragmentation and poaching. We urgently call for the revaluation of the conservation status of these species, which may result in moving both species to a higher threat category.

3) As tortoises are long-lived species, long-term monitoring (over 10-15 years, according to the generation time of *T. graeca* and *T. hermanni*) is necessary to estimate population viability and to highly and accurately assess their conservation status. The researchers attending this workshop aim to develop agreed standard protocols and a scientific network for the long-term monitoring of *T. graeca* and *T. hermanni* populations in the Mediterranean Basin. This comparable framework will be extremely useful to design broader studies and to draw general conclusions about the species' conservation status. This network should encompass the conservation of the two other species inhabiting the Mediterranean Region (*T. kleinmanni* and *T. marginata*). The scientific network will aim to get support from the international community, and from national and regional governments.

4) Habitat loss and fragmentation, and pet trade, are the major threats for these tortoise species, but wildfires, climate change, the introduction of exotic lineages and diseases also play a major role on their population declines. Nevertheless, European, Asian and African tortoise populations are subject to differences in magnitudes and combinations of the aforementioned threats, and we should consider such differences when planning conservation schemes.

5) Landscape use intensification, and increased abandonment of traditional farming and grazing, have considerably reduced and fragmented *T. graeca* and *T. hermanni* habitats and populations. Conservation plans should include the protection of their habitat and restoring population connectivity as a priority objective. As tortoises are umbrella species, such restoration will support the preservation of ecological communities in valuable Mediterranean habitats (e.g. arid and semiarid landscapes). So, it is necessary to strengthen the effectiveness of networks of protected areas (e.g. the European Natura 2000 Network) by expanding declared areas, establishing ecological corridors between these spaces and reviewing conservation and management plans of tortoises (considering the climate change context).

6) The Mediterranean Basin is undergoing fire-regime shifts due to socio-economic trends (e.g. rural abandonment) and climate change, with the consequent increment of fire intensity, extension and frequency (e.g. CHERGUI *et al.*, 2018). Tortoises are especially vulnerable to high-

intensity and recurrent fires. The promotion of traditional grazing practice could help preserve tortoises' habitat. Although controlled burns can improve the quality of tortoises' habitat, potential negative effect on tortoise individuals or other wildlife such as small vertebrates and invertebrates arise. Then, the development of this measure needs further research and should only be developed under very cautious control and considering the recommendation of species' recovery plans.

7) Understanding the effect of global change on tortoise populations is essential to plan effective conservation measures. We highlight the use of some tools like ecological modelling, long-term demographic studies and genetic tools. It is necessary to consider both large-scale models (that offer an overview) and local / regional scale models (characterized by higher spatial resolution, including the role of local factors that are essential for tortoise population conservation).

8) To not compromise the conservation of wild populations, translocations, reinforcements, introductions and reintroductions should always be evaluated following standardized criteria as suggested by IUCN/SSC (2013) and other scientific works (e.g. PÉREZ *et al*., 2012b). Released animals should be marked to be trackable and monitored to assess their success. Management actions like these should be supervised by administrations and considered in species' conservation programmes. Transparency in species' management programmes based on scientific knowledge promotes trust in competent administrations.

9) Further research is needed to monitor the effects of accidental or illegal introductions of tortoises from captivity into wild populations (besides controlled breeding programmes). Genetic exogamy and the introduction of exotic diseases are undesired consequences of such introductions. Management actions should prevent and reverse such effects (e.g. recently introduced animals should be removed from wild populations).

10) The integration of conservation associations, citizen science, research and management provide a promising framework to raise awareness about the conservation of tortoise populations (e.g. volunteering programmes or crowdsourced data collection). In addition, coordination among administrations is necessary to ensure the proper management of tortoise populations according to scientific criteria.

Species trade and management of tortoises

11) Tortoises are wild endangered species and must be protected in, and together with, their natural habitat. Their consideration as pet species compromises their conservation.

12) The negative impact of traded tortoises on wild populations has been widely documented (STANFORD *et al*., 2020) and includes poaching and, when released in nature, genetic exogamy and the transmission of diseases or parasites from domestic environments to wild populations.

13) It is necessary to diagnose the current impact of poaching on *T. hermanni* and *T. graeca*, and the size of captive stocks. It is also necessary to stop the flow of tortoises from wild to captivity and reduce the captive stock by not allowing captive breeding (except when it is justi-

fied with conservation purposes). Public awareness and environmental education are fundamental for changing these behaviours.

14) Wildlife recovery centres are often crowded in space and personnel terms by large numbers of tortoises of the genus *Testudo* arriving each year. There are no single or universal solutions for managing these captive stocks, but increased economic investment by administrations is generally required. Each particular case should be specifically addressed on the basis of scientific criteria and in accordance with present conclusions. Regarding the management of pet trade animals, we highlight that:

- Reproduction should be avoided. Thus, the physical separation of males and females and the destruction of clutches, are necessary. These are the least invasive and cheapest methods.
- Captive individuals should remain isolated from wild populations and should not give rise to new populations in the wild. Therefore, if they are kept outdoors, they should be confined by fences in places far away from wild populations.
- Regardless of lack of conservation value, these animals are worthy of welfare and must be kept in good condition.

15) Herpetological associations are key actors helping the conservation of wild tortoise populations and the management of captive populations. Herpetological experts may participate in research, dissemination or conservation programmes. Such dissemination and conservation programmes should be focused on changing the social representations of tortoises as captive animals towards wild and endangered species, promoting conservation awareness, and the enjoyment associated with responsible tortoise observations in the wild (teaching that tortoises should not be manipulated, caught or translocated). Dissemination campaigns at schools are necessary to involve schoolchildren in species conservation throughout their distribution range, particularly in places where trade and collection have been documented as a historic and recent major threat. The international community, and national and regional governments, should be involved and support these actions.

16) International, national and regional legislation on tortoise trade and captive maintenance matters is complex. International and national legislative frameworks should serve to develop common coherent management schemes in which species conservation should be a priority. The development of specific manuals and protocols (e.g. the one known as "The Kiten Protocol"; KORNILEV *et al.*, 2017), and informative campaigns would be useful for conservation managers and citizens.

17) Given the poor conservation status of the majority of tortoise species and the issues deriving from their consideration as pet species, we request to the Council of the European Union, the EU Parliament and other international institutions involved in wildlife trade and conservation (e.g. CITES), as well as to the national and regional governments throughout the species' distribution range, to ban both commerce and captive breeding of all tortoise species beyond recovery or conservation plans. To avoid the release of captive tor-

toises on wild populations, we claim for the strong implication of public administrations that should, among others, invest efforts in conservation awareness campaigns. At the same time, poaching, illegal trade and illegal breeding or keeping should by decidedly persecuted.

Emerging diseases and parasites

18) Due to the complexity of interactions among hosts, potentially pathogenic or parasitic agents and the environment, increased research efforts are needed to understand their ecological relations in the current global change context (e.g. some endosymbionts may be parasites or mutualists depending on environmental conditions). Therefore, we should consider the potential synergic effect of environmental disturbances (i.e. habitat loss) and an impaired physiological, endocrinological and / or immunological status.

19) Some infectious diseases have negatively impacted the conservation status of wild tortoise populations (e.g. upper respiratory tract disease in *Gopherus* sp.; JACOBSON *et al*., 2014) and the morbidity associated with tortoise pathogens, especially Herpesvirus and *Mycoplasma*, in *Testudo* tortoises in captivity is high. Therefore, recovery or conservation programmes for *T. hermanni* and *T. graeca* should consider and monitor some agents of concern both in wild and captive animals. In particular:

- Bacteria: *Mycobacterium*, *Mycoplasma* and *Chlamydia*.
- Protozoa: Eimeriidae family.
- Gut nematodes: mainly the Oxyuridae and Ascarididae families.
- Viruses: Herpesvirus, Ranavirus and Picornavirus.
- Ectoparasites: ticks (*Hyalomma aegyptium* is the most frequent and carrier of other pathogens).

20) Researchers and managers working with tortoises should implement agreed hygiene protocols to avoid zoonosis and pathogen spreading among animals in both the wild and recovery centres. Adequate hygiene training is needed, especially for working with wild populations. The scientific network constituted by the researchers attending this workshop may develop such a protocol and disseminate it. Competent administrations should request the implementation of hygiene protocols to approve research and manipulation permits.

21) Control of the sanitary status of traded animals is non-existent. To prevent zoonosis and the spread of diseases among wild populations, monitoring them during appropriate quarantine periods and veterinary checks are necessary. In particular for tortoises, knowledge about the time during which tortoises are eliminators or carriers of pathogens is lacking. Further research is needed to develop appropriate protocols.

22) In spite of veterinary checks and analyses, the sanitary status of tortoises cannot be fully assessed. Therefore, captive animals should always be considered potential vectors of pathogens for wild populations. Tortoise translocations must be carried out with extreme caution and long-term monitoring. As previously stated, these translocations are justified only by conservation and scientific criteria.

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