# Galápagos pink land iguana (*Conolophus marthae*)

## Conservation and management plan 2022–2027

Edited by Danny Rueda, Paula A. Castaño, Karl J. Campbell, Giuliano Colosimo, Glenn P. Gerber, Patricia León, Washington Tapia, Gabriele Gentile

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

SSC Species Survival Commission

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**Back cover photos:** Galápagos pink land iguana males. © Giuliano Colosimo (top and bottom), Gabriele Gentile (center), Tor Vergata University of Rome

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# Table of contents

# Foreword

The conservation of the Galápagos Archipelago, a natural heritage of humanity, is a priority for the Government of the Republic of Ecuador. Proof of this, the Ministry of the Environment, Water and Ecological Transition, through the Galápagos National Park (GNP), convened a series of experts in reptile conservation to provide advice on the development of an action plan to prioritise and coordinate the efforts for the conservation and management of the pink land iguana of Galápagos.

This species is classified as Critically Endangered by The IUCN Red List of Threatened Species™ because its current distribution is restricted to a small area (approximately 25 $km^2$) on the slopes of an active volcano in northern Isabela Island. The most recent studies show few individuals from a mature population with very poor natural recruitment.

The plan for their conservation, prepared by the experts and the GNP park rangers, seeks to establish a comprehensive long-term programme for these reptiles, which facilitates their recovery and permanence in nature, prioritising a set of strategies that will be addressed between 2022 and 2027.

I am pleased that the Galápagos National Park can work together with scientific and conservation entities to have first-class advice and practical strategies implemented locally under the leadership of our park rangers. This powerful and effective combination is an example of how Ecuador and the world join efforts to protect the best-preserved archipelago in the world.

The Galápagos pink land iguana, particularly charismatic, as it could be described as a ‘pink dinosaur’, has become an icon of the efforts to restore and care for our Enchanted Islands.

From the Ministry of the Environment, Water and Ecological Transition, we are committed not only to the protection of species such as the pink land iguana, but also to restoring their habitat so that they can survive without human intervention. We have a great challenge: to restore the Wolf Volcano to leave it for the next generations in a better state than we received it! We believe it is possible; I invite you to join us in implementing this plan together.

Gustavo Manrique

Minister of Environment, Water and Ecological Transition of Ecuador

# Executive summary

The Galápagos pink land iguana (*Conolophus marthae*) is categorised as Critically Endangered by The IUCN Red List of Threatened Species™. The entire distribution of pink iguanas is within the protected area of the Galápagos National Park (GNP), which is managed by the Galápagos National Park Directorate (GNPD), the legal authority regulating and protecting the biological diversity of the Galápagos Islands. The geographic area where the Galápagos pink land iguanas persist is not easily accessible; only GNP park rangers and scientists with the appropriate permits have access.

A single, known wild population of Galápagos pink iguanas exists. The current estimated population size is approximately 300 individuals (95% CI 269.60–372.31). This extremely small population is prone to both demographic and genetic stochasticity, as well as environmental impacts (volcanic eruptions, drought, etc.) that could extirpate the entire population.

Predation, by invasive alien species (feral cats and rodents) may contribute to the current population's age distribution being skewed towards adults (i.e., there is a lack of natural recruitment). Feral cats (*Felis catus*) and black rats (*Rattus rattus*) are among the main threats to pink land iguanas; black rats can prey on hatchlings, while feral cats likely prey on hatchlings and juvenile iguanas. Feral cats are known to prey on other Galápagos land iguanas up to three or four years of age. Pink land iguanas of this age have not been found in the wild, suggesting that the impact of feral cats on pink iguana recruitment is extremely high (Gentile, 2012).

Volcanic eruptions are also an imminent threat for pink land iguanas, due to their restricted distribution. The latest eruptions of Wolf Volcano occurred in May 2015 and January 2022, with lava flows occurring on the eastern and south-eastern slopes of the volcano (NASA, 2017; https://www.nasa.gov/image-feature/eruption-of-wolf-volcano-Galápagos-islands). Fortunately, neither eruption significantly impacted the population of pink land iguanas, which occur on the northwest slopes of Wolf Volcano.

Droughts could also pose a threat for pink land iguanas and may contribute to the population's low recruitment if soil moisture, in some years, is insufficient for successful incubation of eggs and successful development of hatchlings. Breeding, in most terrestrial Galápagos species including land iguanas, is heavily associated with rain, and availability of food resources. Therefore, severe drought years, which could become more frequent due to climate change, can severely affect the size of such a small population of aging adults.

There are still some gaps in knowledge regarding the biology and ecology of the species. However, the information available is sufficient to develop an action plan that allows prioritising and defining the efforts necessary to conserve and manage the species. The GNPD and its partners are clear that this very vulnerable species, with no evidence of natural recruitment, requires urgent attention to prevent its aging population from becoming extinct. Hence, to develop the plan, the GNPD convened a multidisciplinary group of scientists, experts, and park rangers to a consultation process through

interviews and a workshop held in Puerto Ayora, Galápagos Islands, Ecuador, from 23 to 25 August 2021.

This conservation and management plan (2022–2027) has the vision to ensure the long-term survival of Galápagos pink land iguanas in the wild, and as a general objective to establish a comprehensive conservation programme for Galápagos pink land iguanas that facilitates their recovery and persistence in the wild. The plan prioritises a set of strategies that will be addressed in the time frame set for this. Section three includes an overview of each strategy. This plan is established in phases and presents key decision points in which the results of the previous phase are analysed prior to the implementation of the next phase.

Phase one has two priority strategies: invasive predator control and filling knowledge gaps. In years one and two, invasive predator control activities will be implemented and monitored. At the beginning of year three, results from monitoring will show if invasive predator control has been sufficient to restore the population of pink land iguanas. If not, priority two activities will begin, by establishing an initial headstart programme for pink land iguanas. Predator control and research to fill knowledge gaps will continue in years three to five, but priority two actions will begin, in order to complement efforts. Experiences from phase one will feed into decisions and management of phase two. After year five, depending on results obtained so far, other strategies will also be evaluated. These are captured here so they can be evaluated in the future. This phased approach aims to be cost effective by escalating in complexity and expense only if required.

Guardaparques del Parque Nacional Galápagos realizan actividades de monitoreo de la población de iguanas terrestres rosadas en el Volcán Wolf. Foto por © Dirección del Parque Nacional Galápagos

# Acknowledgements and credits

This plan is the product of a participatory process, which included: a review of the available literature, an exhaustive interview process, and a workshop that was held in Puerto Ayora in August 2021. The ideas raised in this plan were discussed and agreed to in the workshop and belong collectively to all those who participated in it. This plan would not have been possible without the ideas and expertise of all who participated in this process, and who are listed in alphabetical order below.

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A few workshop participants oversaw the capture and recording of all contents and discussions occurring during the workshop and organised the outcomes into this plan. The content of this plan has been edited and revised to ensure it complies with IUCN standards.

The Galápagos National Park Directorate wants to acknowledge and thank Re:wild, who provided funding for the workshop and publication of this document, for their support.

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Participants of the workshop “Galápagos Pink Land Iguana Conservation and Management Plan 2022–2027”, held 23–25 August 2021 in Puerto Ayora, Galápagos, Ecuador.
Photo © Galápagos National Park Directorate

# Introduction

### Taxonomy

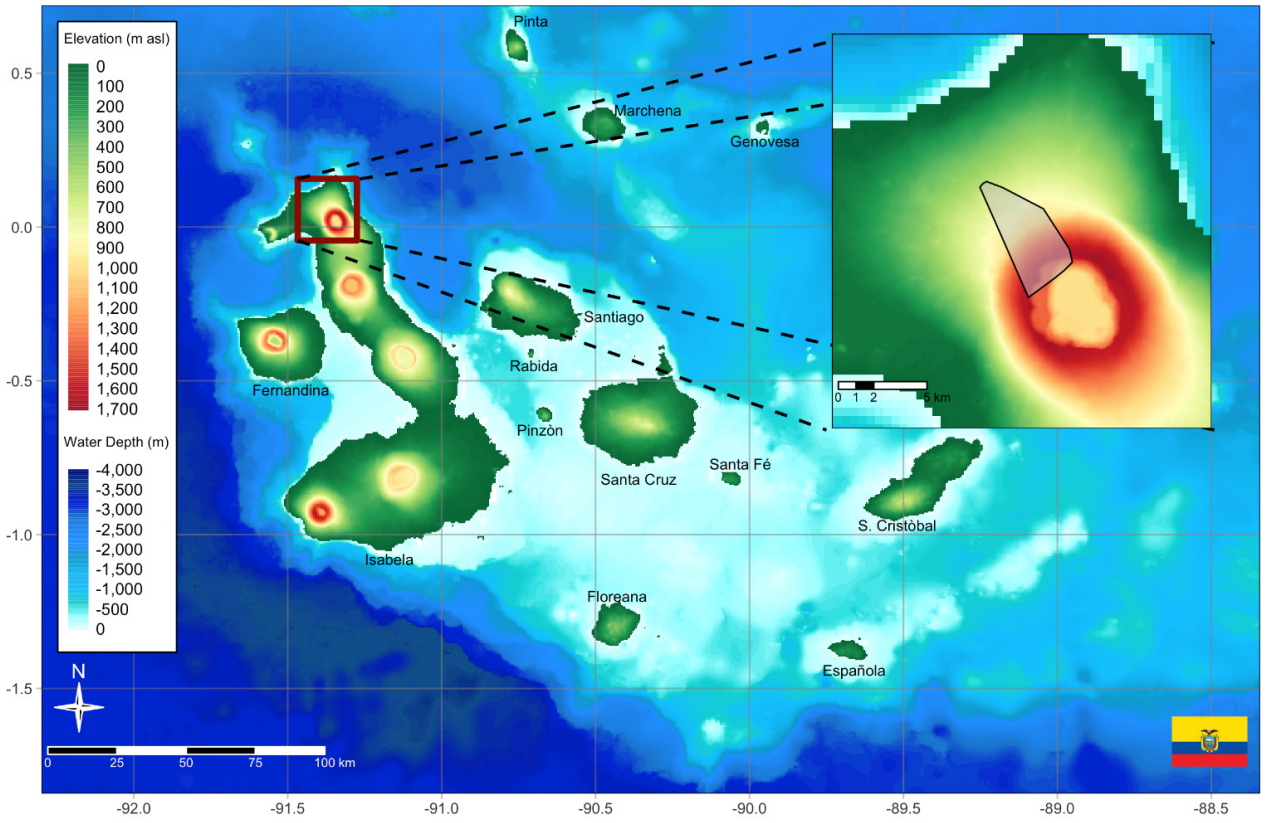
Land iguana individuals with an anomalous "pink" colouration ("rosada" in Spanish) were first observed in 1986 by GNPD rangers and Charles Darwin Research Station staff patrolling the remote west slope and summit of Wolf Volcano on Isabela Island (Pierson & Durham, 2009; Márquez et al., 2010). However, it was not until 2009 that the species was fully described as a separate Galápagos land iguana species and identified with the name of *Conolophus marthae* (Gentile & Snell, 2009). First molecular phylogenetic analysis suggested that pink land iguanas diverged from all other land iguana lineages (*C. pallidus* and *C. subcristatus*) approximately 5.7 million years ago. Such dates were later revisited and the split between the lineages was set at about 1.5 million years ago, a time that predates the emergence of Isabela Island (Geist et al., 2005; Geist et al., 2014; MacLeod et al., 2015). Additionally, more detailed taxonomy studies indicate that *C. marthae* has less gene richness and heterozygosity when compared to *C. subcristatus*. Preliminary genetic studies showed that although *C. marthae* and *C. subcristatus* are sympatric (sensu Rivas, 1964) on Wolf Volcano and share 26% of alleles, none of the pink individuals investigated incorporated genes from the congeneric yellow land iguanas, at least in the past two generations, and only one yellow individual was suspected of possible mixed ancestry with a pink land iguana (Gentile et al., 2009). Further genetic studies clarified that the two species do not currently hybridise, nor over the last two generations, although it may have occurred in the more distant past (Di Giambattista et al., 2018).

### Distribution

The current distribution of pink land iguanas covers approximately 16 $km^2$ on Wolf Volcano (G. Colosimo, pers. comm., 2021 estimate), Isabela Island in the Galápagos Archipelago, Ecuador (see map). Pink land iguanas occur along the north-west slopes of Wolf Volcano, in an area ranging from 600–1,700 m asl (Gentile et al., 2016). A more recent monitoring of individuals using remote tracking technology (Loreti et al., 2020), suggests that most iguanas seem to have a small range. Some migrate to lower altitudes (between 500–600 m asl), while some others also visit the area inside the caldera (Gentile, 2021) – a behaviour never recorded previously.

### Population information

A single known wild population of Galápagos pink land iguanas exists. The current estimated population size is approximately 300 individuals (95% CI 270–372). This estimate is based on a long-term capture-mark-recapture study encompassing a time frame of over 10 years (2006–2021; Colosimo et al., 2021). The population of pink land iguanas lacks natural recruitment, presumably due to predation by feral cats. The sex ratio appears biased towards males, a trait shared with other species of Galápagos land iguanas. Gentile and collaborators estimated an effective population size ($N_e$) from genetic analyses, using samples of different sizes, performed in 2005, 2006 (pooled), and 2009. These results showed an $N_e$ of 72.6 for 2005–2006, and for 2009 an $N_e$ of 98.5, representing only one-third to one-fifth of the effective population size of Wolf Volcano's yellow land iguana population ($N_e$ = 280 for 2005–2006 and $N_e$ = 347.4 for 2009; Gentile, 2021).




Galápagos pink land iguana (*Conolophus marthae*) distribution. **Main:** The Galápagos Islands, Ecuador. Water depth data is downloaded from the General Bathymetric Chart of the Oceans (GEBCO; https://download.gebco.net). Elevation data (30 meters, from the Shuttle Radar Topographic Mission-SRTM) is downloaded from the web application available at https://dwtkns.com/srtm30m/. The red square in the northern part of Isabela Island focuses on Wolf Volcano. **Inset:** Close up of Wolf Volcano's caldera (~1,700 m asl). The shaded area corresponds to the minimum convex polygon (16.22 km$^2$) obtained from available field observation of *Conolophus marthae*. Map © Giuliano Colosimo

### Species habitat and ecology

Galápagos pink land iguanas live in syntopy (sensu Rivas, 1964) with congeneric *C. subcristatus*. *Conolophus subcristatus* inhabit areas surrounding and within the habitat of *C. marthae*, and their population size is much larger. Preliminary habitat observations indicate that areas surrounding pink land iguana habitat are ecologically distinct from the core area inhabited by this species, suggesting the ecological requirements for pink land iguanas may not be met outside this core area (Gentile et al., 2016). Refined studies of the diet of the two species are currently ongoing. The use of stable isotope ratio analysis of carbon and nitrogen indicated that fractionation profiles are different for the two species, with yellow land iguanas showing larger variance in the $\delta^{13}C$ profile than pink land iguanas. This evidence is consistent with yellow iguanas having a more generalist diet than pink iguanas (Gentile, 2021).

Across the altitudinal distribution of *C. marthae*, there are different types of vegetation with tropical dry shrubland at the top of the volcano and tropical dry forest along the slopes (Rivas-Torres, 2018).

Reproductive biology of *C. marthae* continues to be poorly understood. Up to 2021, no nesting areas have been identified for the species, but preliminary GPS tracking results from 2021 suggest gravid females nest inside the caldera (G. Colosimo et al., unpublished data). Studies of reproductive biology based on a combination of hormonal and ultrasound analyses, conducted in 2010 and 2014 (Gentile et al., 2016; Onorati et al., 2016), demonstrated that *C. subcristatus* and *C. marthae* show almost contemporaneous sexual activity at the end of the rainy season (April–June) on Wolf Volcano. Nonetheless, such activity does not result in high numbers of reproductive pink land iguana females. While these studies made it possible to determine a specific reproductive season for *C. subcristatus*, it was not possible to exclude that pink land iguanas may also reproduce opportunistically (Onorati et al., 2016). Ultrasonographic analyses performed on females of both species in subsequent field trips since 2015, showed quiescent ovaries with several anechoic spherical structures, suggesting that no reproductive activity exists from July through November. Onorati et al. (2016) showed a clutch size equal to 5.4 ± 1.5 eggs for *C. marthae*, smaller than the clutch size of *C. subcristatus* from Wolf Volcano (8.4 ± 3.4), and much smaller than the known size for *C. subcristatus* on Fernandina Island (7–23 eggs; Werner, 1982). Head bobbing behaviour in male *C. marthae* – important for mating – is very distinctive and completely different from the syntopic species *C. subcristatus*, potentially acting as a behavioural barrier to hybridisation.

Average snout-to-vent length (SVL) of captured pink land iguanas observed is 46.8 cm, with males being significantly larger than females. Pink land iguana males can reach an SVL of at least 57.5 cm and a mass of 8 kg, while females can reach an SVL of 49.4 cm and a mass of 5.8 kg (Marquez et al., 2010). The SVL of the smallest subadult male Galápagos pink land iguana captured was 37.3 cm, which is the average size of a seven-year-old yellow land iguana (Gentile, 2012). The species holotype (an adult male) weighed 5 kg and had an SVL of 47 cm (Gentile & Snell, 2009).

The only native predator for the species in their current habitat is the Galápagos hawk (*Buteo galapagoensis*; Gentile et al., 2016), which can feed on hatchling and juvenile iguanas. The diet of Galápagos pink land iguanas is made up of both native and introduced plant species, including shrubs (48%), herbs (~37%), and grasses and cacti (Arteaga & Guayasamin, 2019). However, a complete dietary analysis is still pending.

**Use and trade**

No current or historical human use is known for the species. Pink land iguanas, along with all three other species of iguanas in Galápagos, are included in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species™ and are protected under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Galápagos is not immune to illegal wildlife trafficking. In 2012, a German tourist was arrested at the Baltra airport in Galápagos for trying to illegally smuggle four yellow land iguanas out of the province. Molecular tools, with early genetic characterisation,

proved to be crucial for determining the provenance of those individuals in a timely manner, facilitating their repatriation to the wild. More recently, on 28 March 2021, a police officer was caught trying to smuggle 185 baby giant tortoises at the Baltra airport. Although no illegal trade issues have been observed in Galápagos with pink land iguana, Gabriele Gentile reported that in the CITES database there is evidence of an export permit issued for *C. marthae* in 2010 from Mali to Switzerland for two live individuals declared as obtained from captivity. The Galápagos National Park Directorate and the Ecuadorian Ministry of Environment have never issued CITES export permits for live pink land iguana specimens or eggs. It is clear that, in the absence of an original CITES export permit issued by Ecuadorian Authorities, any other such document has to be regarded as illegally produced.

**Threats**

The pink land iguana population is extremely small and prone to both demographic and genetic stochasticity, as well as environmental impacts (volcanic eruptions, drought, etc.) that could extirpate the entire population. Although no live F1 hybrids have been found during annual surveys conducted since 2005 (Gentile et al., 2016) and hybridisation is not ongoing at present, hybridisation is context dependent and the potential for hybridisation could change under different environmental or demographic conditions. Consequently, genetic monitoring of newly captured individuals of the two species on Wolf Volcano should not be interrupted. In fact, due to the pink land iguana's small population size, rare events of hybridisation could have a significant effect on the species.

The overlap with yellow land iguanas can also lead to competition for resources, including nesting locations, impacting the species' reproduction and long-term survival. This, coupled with predation by invasive alien species (feral cats and rodents), may contribute to the current population's age distribution being skewed towards adults (i.e., there is a lack of natural recruitment). Feral cats (*Felis catus*) and black rats (*Rattus rattus*) are among the main threats to pink land iguanas; black rats may prey on hatchlings, while feral cats likely prey on hatchlings and juvenile iguanas. Studies conducted on Wolf Volcano in 2022 have demonstrated the presence of pink land iguana remains in feral cats' stomach contents (V. Carrión, pers. comm., 2022). Feral cats prey on other Galápagos land iguanas up to three or four years of age. Pink land iguanas of this age have not been found in the wild, suggesting that the impact of feral cats on pink land iguana recruitment is extremely high (Gentile, 2012).

Volcanic eruptions are also an imminent threat for pink land iguanas, due to their restricted distribution. The latest eruptions of Wolf Volcano occurred in January 2022 and May 2015, with lava flows occurring on the eastern and south-eastern slopes of the volcano (NASA, 2017; https://www.nasa.gov/image-feature/eruption-of-wolf-volcano-Galápagos-islands). Fortunately, neither eruption significantly impacted the population of pink land iguanas, which occur on the northwest slopes of Wolf Volcano. Volcanic eruptions have been suggested as a potential cause of extinction for populations of *C. subcristatus* on Chico Volcano on the eastern side of Sierra Negra Volcano (Snell, 1984).

Droughts could also pose a threat for pink land iguanas and may contribute to the population's low recruitment if soil moisture in some years is insufficient for successful incubation and development of eggs. Breeding, in most terrestrial Galápagos species, including land iguanas, is heavily associated with rain and availability of food resources. Therefore, during severe drought years, breeding could cease completely, or hatchlings and juveniles may have poor survival.

Parasites (internal and external) could also pose a threat for a species whose population is highly reduced and with low genetic diversity. However, preliminary results from a health assessment conducted on 41 adult wild individuals, suggests that the population (or at least those individuals) is clinically healthy, despite high tick loads and levels of hemoparasite (hemogregarines) infection (Colosimo et al., 2022).

**Conservation status**

Galápagos pink land iguanas are categorised as Critically Endangered by The IUCN Red List of Threatened Species™. The entire distribution of pink land iguanas is located within the GNP protected area, administered by the GNPD. The GNPD is the legal authority governing the National Park and protecting biological diversity of the Galápagos Islands. All three land iguana species are included in the GNPD's Management of Native and Endemic Species Program. The GNPD undertakes major campaigns to control and remove invasive alien species in the Galápagos, including the major threats to this species (i.e., feral cats and rodents). GNPD management efforts have resulted in the successful removal of feral goats from northern Isabela, protecting pink land iguanas and their habitat. Similar efforts resulted in the removal of feral goats, donkeys, and pigs from Santiago Island, enabling yellow land iguanas (*C. subcristatus*) to be reintroduced in 2019, more than 200 years after their extirpation. Feral cat eradication was achieved on Baltra Island in 2004 (Phillips et al., 2005; Carrion et al., 2008), where the *C. subcristatus* population was almost wiped out by these introduced predators and other impacts such as the US military base (Woram, 1991; W. Tapia, pers. comm.). Yellow land iguanas eventually recovered, following the removal of feral cats, with population supplementation from a captive breeding and headstart programme. Additionally, rodent eradication has been achieved on 13 islands in the Archipelago, resulting in the first recorded survival of hatchling Pinzón giant tortoises (*Chelonoidis duncanensis*) in 150 years (Tapia-Aguilera et al., 2015). Eradication of feral cats and invasive rodents from Wolf Volcano is unfeasible at present; however, innovative tools (e.g., drones) are being trialled to determine their potential for supporting the control of these invasive alien species.

The geographic area where pink land iguanas occur is not readily accessible; only GNPD rangers and scientists holding appropriate permits have access. Consequently, there are still some gaps in knowledge regarding the species' biology and ecology. However, the information available to date is sufficient to develop an action plan that allows prioritising and defining the efforts necessary to conserve and manage Galápagos pink land iguanas. For the development of the plan, the GNPD convened a multidisciplinary group of scientists, experts, and park rangers to a consultation process through interviews, and then to an in-person workshop held in Puerto Ayora, Galápagos Islands, Ecuador, from 23 to 25 August 2021.

# Vision and general objective

## Vision

Long-term survival of Galápagos pink land iguanas in the wild.

## General objective

Establish a comprehensive conservation programme for Galápagos pink land iguanas that facilitates their recovery and persistence in the wild.

A male and female Galápagos pink land iguana (*Conolophus marthae*) on Wolf Volcano.
Photo © Gabriele Gentile

# Priority conservation strategies and activities

To establish a comprehensive conservation programme for pink land iguanas that facilitates their recovery and persistence in the wild, a set of strategies were prioritised to be implemented during 2022–2027 (duration of this action plan). An overview of each strategy is included below.

It is important to highlight that this plan is established by priorities and presents key decision points in which the results of the previous priority are analysed prior to the implementation of the next priority or strategy. Further, it details the next priority to be implemented and allows for incorporation of lessons learned.

## Priority 1

**Invasive species control and filling in key knowledge gaps**

### Activity 1

**Establish basic infrastructure on Wolf Volcano facilitating field work related to all prioritised strategies.**

Field activities on Wolf Volcano are limited by several factors; it is a remote location that can be accessed only via strenuous hiking (15 hours or more) on steep, rocky terrain. Alternatively, the area of interest can be accessed via helicopter, however, transportation of provisions to the volcano, especially fresh water, is extremely expensive and there is no basic infrastructure that could provide support for any field activity. These factors are an important limitation for the time that park rangers and scientists can remain in the area, and therefore limit the observation, study, and management of the species. Therefore, in the first six months, basic infrastructure will be established on Wolf Volcano to collect water and for field crews to sleep on a raised platform that protects against the elements. This activity will require following the established biosecurity protocols of the Galápagos Biosecurity Agency and Galápagos National Park to prevent incursion of new invasive species to the area.

## Activity 2

**Identify and record the exact location of Galápagos pink land iguana nesting sites on Wolf Volcano using transmitters, camera traps, and field observation. Monitor throughout the year to determine the reproductive phenology of the species.**

One of the priorities identified to preserve the species is to locate the nesting ground(s) of female *C. marthae*. Once identified, these key areas will be protected against invasive species. Identification of the nesting ground(s) will also provide the opportunity to collect hatchlings and initiate a headstart programme. Moreover, data collected will help the implementation of additional management actions (such as a captive breeding and rearing programme – strategy 4).

As part of this strategy, basic infrastructure will be established on Wolf Volcano. This will allow the prolonged presence of GNPD personnel and collaborating scientists to fill priority information gaps about pink land iguana reproductive biology and ecology. Our approach will be initiated by marking observed Galápagos pink land iguana nests, and complemented by GPS transmitters and an established network of camera traps to register the reproductive parameters and timing of hatchling emergence and demonstrate any impact that feral cats and rodents may have on the species. Once nests are identified, data loggers to record incubation temperatures and other environmental conditions will be placed in nest chambers. This, coupled with the weather stations deployed at Wolf Volcano, will allow us to determine if environmental conditions such as drought are impacting the species' incubation and hatching success. Enclosures can be put up to protect hatchlings emerging from nests, and field personnel will excavate nests after emergence to determine hatching success rates and other parameters.

Habitat usage will also be investigated in the two syntopic species (*C. subcristatus* and *C. marthae*) to clarify for what resources the two species might be in competition. Census population size assessments will also be conducted according to an established and unified protocol.

The activities described here will be carried out at the same time as the invasive species control actions are implemented during the first, second, and third year of this plan.

## Strategy 1

**Manage invasive species (feral cats, rodents) at levels that allow the natural recruitment of Galápagos pink land iguanas on Wolf Volcano.**

Feral cats and invasive rodents are among the main threats for pink land iguanas on Wolf Volcano. Feral cats are known to prey on hatchlings and juvenile pink iguanas (up to the third year), while black rats could prey on eggs, hatchlings, and nibble adult pink land iguanas' tails.

Under this plan, the management of invasive species at Wolf Volcano will focus on the control of rodents and feral cats as eradication is currently unfeasible with available technologies due to the size of Isabela Island (4,588 $km^2$) where Wolf Volcano is located, and the complexity associated with non-target species. To increase the area protected for pink land iguanas and increase efficiency and minimise resources to control invasive predators, innovative tools (e.g., drones) are being trialled to determine their potential for supporting

the control of these invasive species. In the meantime, management will consist of identifying a core and buffer zone on Wolf Volcano where the control actions of the target species (for example, feral cats and rodents) will be implemented. Within this area, a network of camera traps and bait stations will be installed to monitor the results of control efforts on target species and non-target species, and based on this, implement adaptive management to comply with the control strategy and the needs of the species. For example, some ideas identified during the workshop included expanding control efforts to cover the entire Wolf Volcano to treat this as an island-within-an-island, using topographic barriers to keep Wolf Volcano free of invasive predators (e.g., feral cats).

During the first six months of implementation of this strategy, a risk analysis will be developed for non-target species that could be impacted as a result of the control actions for feral cats and invasive rodents.

Management of invasive species will be one of the primary conservation priorities for the first 18 months of the plan. It will be evaluated to determine what adaptive changes must be made to continue with this management strategy and if the next phase should initiate (e.g., establishing a headstart programme). Additionally, biosecurity protocols will be strictly enforced to reduce the possibility of new incursions into the core area where pink land iguanas are found.

## Strategy 2

**Fill knowledge gaps.**

During the first two years, identified knowledge gaps will be filled, including:

- **Ecology:**
  1) Habitat requirements
  2) Breeding seasonality, including environmental conditions required for successful breeding and hatching. Weather monitoring stations (up to 10) located at Wolf Volcano will be utilised. These weather monitoring stations collect the following variables: ultraviolet radiation index, temperature, humidity, and precipitation
  3) Use of other areas by the species in Wolf Volcano
- Baseline data on the health condition
- Disease screening and surveillance. This assessment will provide valuable data for determining the potential impact of those diseases or parasites on the species in case of an outbreak on Wolf Volcano or while in captivity
- Genetic characterisation for management purposes

In years three to five, activities to fill knowledge gaps will continue, and they will feed into the adaptive management decisions of this plan.

## *Indicator

**Indicators to evaluate success of priority 1 strategies.**

The following indicators were established to determine if priority 1 strategies have been successful in restoring the pink land iguana population on Wolf Volcano:

Galápagos pink land iguana restoration – conduct the actions and measure the resource (e.g., recruitment indicators should start to increase, such as new age classes being observed in the pink iguana population).

Invasive predator control – the index of abundance of invasive predators (rodents and feral cats) is at least 80% below baseline (i.e., prior to control actions being taken).

# Priority 2

**Establish a headstart programme**

## Strategy 3

**Establish an initial headstart programme of pink land iguanas that are in good health and present adequate behaviour to survive in the wild.**

Headstarting refers to raising hatchlings and/or eggs collected from the wild in captivity, and subsequently releasing them back to the wild once they have reached a size that makes them less susceptible to predation by invasive species (e.g., feral cats, rodents) and native predators in some circumstances (Ferguson et al., 1982). It is a widely used tool to protect endangered species by increasing survivorship and recruitment. Headstart programmes are very important in situations where invasive species are driving native and endemic species to extinction and eradication programmes cannot be implemented altogether or at the scale required. Headstart programmes can constitute an intermediate remedy to prevent further population declines and to promote population recovery (Pérez-Buitrago et al., 2008). These programmes have been implemented in several species of rock iguanas including the Jamaican rock iguana since 1991 and Anegada rock iguana since 1997 (Pérez-Buitrago et al., 2008).

Success of headstart programmes can be increased by careful design of captive conditions and release strategies (Alberts, 2007). Programmes can use eggs or hatchlings collected in the wild. For pink land iguanas, it was determined that headstarting would begin with the collection of hatchlings emerging from nests, and later if necessary, with the collection of eggs. The implementation of this strategy requires the establishment of appropriate infrastructure on Santa Cruz Island as it is operationally much easier than establishing a facility on Wolf Volcano. The identification of nesting areas, individual nests, and nesting phenology are all essential to implement a successful headstart programme. Weather monitoring stations deployed at Wolf Volcano will provide weather data necessary to determine the requirements for increased

hatchling/juvenile survivorship in the wild and during the captive holding period. In addition, if eggs are to be harvested, knowledge of the time it would take for eggs to hatch and when they can be successfully recovered for transport to an incubation facility is needed.

Some considerations raised for the implementation of this strategy are the need to develop a protocol for the collection and transport of hatchlings and eggs, as well as a captive management protocol that clinically evaluates the individuals and allows for the implementation of treatment, if necessary, as well as responding to a possible epidemic within the captive facility. Finally, the implementation of adequate security to prevent illegal trafficking of the species is needed, since access to the facility would be less restricted than to Wolf Volcano.

Individuals resulting from the headstart programme will be released first at Wolf Volcano, to bolster recruitment of the only natural wild population of pink land iguanas, and secondarily in a suitable location other than Wolf Volcano to establish a second viable wild population of pink land iguanas.

Implementation of this strategy and its nuances will occur if the management of invasive species on Wolf Volcano is insufficient to allow an adequate increase in natural recruitment of the population that ensures the long-term persistence of the Galápagos pink land iguana in the wild. That is, from the second year onwards of implementation of this plan.

# Priority 3

**Strategies and activities to consider implementing (not necessarily in the order presented below) beyond year 5 of this plan if priority 1 and 2 activities do not yield expected results**

## Strategy 4

**Establish a captive breeding and rearing programme for pink land iguanas to supplement the populations of pink land iguanas in the wild.**

Previous experience with captive breeding of land iguanas exists in Galápagos. A captive breeding programme was established back in the 1970s to prevent the disappearance of land iguana populations impacted by feral dogs (Cayot, 2008) in Cerro Cartago on Isabela Island and Conway Bay on Santa Cruz Island, and to re-establish the locally-extirpated population on Baltra Island in 1991. A population of Baltra iguanas had survived on Seymour Norte, since researchers in the 1930s had introduced ~70 land iguanas from Baltra to Seymour Norte to prevent their extinction due to the impacts of goats, feral cats, and human impacts experienced on Baltra.

Iguanas brought into captivity proved to be more difficult to hold and breed than giant tortoises. This required field research and experiments to make the programme a success. Primary concerns were related to captive holding cages for breeding individuals, incubation techniques including temperature and substrate humidity, and diet (Cayot, 2008).

Considering that for Galápagos pink land iguana the entire distribution is on Wolf Volcano and occurs in an area ranging from 600–1700 m asl (Gentile et al., 2016), it needs to be determined if the species can adapt to being in captivity at sea level, where the infrastructure for the captive breeding centre will be established. As

the species is Critically Endangered, and therefore each individual (especially females) is valuable, a pilot study will be implemented using two to three adult males. If successful, for the establishment of a captive breeding programme, construction of appropriate infrastructure with reproduction and rearing pens is required. Additionally, the establishment of a captive holding management plan detailing security measures to prevent access for illegal traffickers, quarantine, disease screening processes, and management is necessary.

Similar to headstarting, individuals resulting from the captive breeding programme will be released first in Wolf Volcano assuming the invasive species can be controlled, and later in a place outside of Wolf Volcano (e.g., to establish a second population).

The implementation of this strategy and its different nuances will only occur if the management of invasive species in Wolf Volcano and the headstart programme with hatchlings or eggs are not enough to allow natural recruitment of the pink land iguana population that ensures the long-term conservation of the Galápagos pink land iguanas in the wild. Therefore, activities related to this (e.g., information collection, filling knowledge gaps that feed this strategy) if they were to be implemented, would begin around year three of this plan.

## Strategy 5

**Establish at least one additional healthy and self-sustaining population of Galápagos pink land iguanas in the wild on the Galápagos Islands outside of Wolf Volcano.**

Assisted colonisation is the intentional movement and release of an organism outside of its natural geographic distribution with the aim of preventing the extinction of a species' population or the whole species (IUCN, 2013). This effort is often implemented where protection from current and future threats can be managed more appropriately at an alternative site rather than within the species' current distribution.

Currently, the pink land iguana range is restricted to a small area (16 $km^2$) on an active volcano (Wolf Volcano) for which the last eruptions occurred in 2022 and 2015 (NASA, 2017). Within the current pink land iguana range, there are also invasive mammals (e.g., feral cats and rodents) that likely prey heavily on juveniles, impacting natural population recruitment. Therefore, establishing an additional population on an island where the main threats (e.g., invasive predators and volcanic activity) are not present could prevent the pink land iguana's extinction in the long term. In the Galápagos, there are locations that may fit these criteria (no invasive predators: e.g., Rabida Island with no invasive feral cats and rodents, and Santiago Island with no feral cats; both are volcanically inactive). Rabida Island could be a suitable place for establishing a second population of pink land iguanas, as invasive rodents were successfully removed from the island in 2011 (Campbell et al., 2013; Rueda et al., 2019) and land iguanas have been detected in subfossil records on the island (Steadman, 1991). However, this island is arid and easily accessible to illegal species trafficking. Santiago's highlands could also be a suitable place for reintroduction, although invasive rodents are present. However, feral cats, the main threat to pink iguanas, are not present. Yellow land iguanas were present in high numbers on Santiago when Darwin visited the Galápagos Islands and more than 3,000 land iguanas (*Conolophus subcristatus*) were reintroduced during 2019–2021. However, Santiago has invasive blackberry (*Rubus niveus*) that could make it difficult for the species to access certain areas and, although less than Rabida, it could be accessible to illegal traffickers. Santiago also has the largest number of Galápagos hawks in the Archipelago, which are the main native predators of yellow and pink land iguanas on Wolf Volcano.

Although pink land iguanas are currently restricted only to Wolf Volcano, their genetics indicate that the species has been present in the Archipelago much longer than the age of Isabela Island (Gentile et al., 2009), which could suggest that the species potentially lived at lower altitudes prior to being restricted to Wolf Volcano. This should be validated by implementing a more detailed analysis of the diet and environmental requirements for the pink land iguanas. Additionally, it was decided that results from the pilot study conducted with adult males brought to captive holding, will identify whether the establishment of this species is possible on other islands of lower altitude (e.g., Rabida, Santiago).

Individuals that could be used for establishing one or more additional populations are individuals that would result from the headstart and (if needed) captive breeding programmes.

## Strategy 6

**Use of cryogenics (preservation of fibroblast cell lines for future cloning or stem cell technology).**

Establishment of cell lines (including fibroblasts) have been widely used to preserve the genetic material of many rare and endangered species, including the Bengal tiger (Guan et al., 2010), the jaguar (Mestre-Citrinovitz et al., 2016), and the Sumatran rhinoceros (Jenuit et al., 2021) although not yet for iguanas. These cells can be used in the future for cloning or stem cell technology. An example of this is the result of the black-footed ferret project, where cell lines cryopreserved from a highly genetically diverse wild black-footed ferret in 1988 led to the birth of the first cloned black-footed ferret in 2020 (Revive & Restore, 2020; https://reviverestore.org/projects/black-footed-ferret/).

Establishment of cell lines is coupled with cryopreservation techniques that extend the storage of the established cell lines (Jenuit et al., 2021). Advancements in cryopreservation will ensure the cell line's indefinite supply and distribution, prevent genetic and phenotypic instability, delay cell senescence and transformation, and reduce the risk of contamination. Several considerations must be contemplated before developing a cell bank, including provenance of the primary culture, quality, characterisation, and authentication of the cell line (Freshney, 2015).

Cryopreservation of animal cell lines with the highest genetic diversity among pink land iguanas could support the long-term survival of a healthy population of pink land iguanas.

Due to the current requirements for the shipment of genetic material outside Ecuador, it was determined that this activity would not fall within the priority conservation actions for the species. However, at least two sites that may have the necessary infrastructure for the preservation of these cell lines, both within Ecuador (e.g., Galápagos Science Center, San Cristobal – BioBank facility) and outside the country, will be identified and evaluated. Once this information is available, the possibility of acceding to a Framework Contract for Access to Genetic Resources will be coordinated with the Ministry of the Environment, Water and Ecological Transition of Ecuador, to take the samples and send them to the identified and selected laboratories.

# Priority conservation strategies and activities – overview

| **Priority 1: Invasive species control and filling in key knowledge gaps** | | | | | | |
|---|---|---|---|---|---|---|
| **Strategies & activities** | **Programmed actions (by year)** | | | | | **GNPD in collaboration with[1]:** |
| | **1** | **2** | **3** | **4** | **5** | |
| Immediate actions that support all strategies prioritised below | | | | | | |
| Activity 1: Establish basic infrastructure on Wolf Volcano facilitating field work related to all prioritised strategies. | Establish infrastructure. | | | | | GC |
| Activity 2: Identify and record the exact location of Galápagos pink land iguana nesting sites on Wolf Volcano using transmitters, camera traps, and field observations. Monitor throughout the year to determine the reproductive phenology of the species. | Identify and register nesting sites.<br><br>Determine the species reproductive phenology. | | | | | FJ, GC, NCSU, SDZ, URTV |

[1] GNPD will coordinate with partners listed here, which are reflected in alphabetical order.
List of acronyms: FJ: Jocotoco Conservation Foundation; GC: Galápagos Conservancy; HZ: Houston Zoo; IC: Island Conservation; LO: Luis Ortiz-Catedral; NCSU: North Carolina State University; SDZ: San Diego Zoo Wildlife Alliance; URTV: Tor Vergata University of Rome

| Strategies & activities | Programmed actions (by year) | | | | | GNPD in collaboration with[1]: |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Strategy 1: Manage invasive species (feral cats, rodents) at levels that allow the natural recruitment of Galápagos pink land iguanas on Wolf Volcano. | Identify the core and buffer area for invasive species control.<br><br>Develop a non-target species risk assessment for the use of toxicants to control invasive species at Wolf Volcano and develop a plan based on this information.<br><br>Establish a camera trap network throughout the core area and a buffer area.<br><br>Use the camera trap network to monitor effectiveness of control on feral cat abundance (continues at regular intervals).<br><br>Implement control efforts for feral cats and invasive rodents. | Monitor the impact of invasive species control on the pink land iguana survival (continues at regular intervals).<br><br>Use the camera trap network to monitor effectiveness of control on feral cat abundance (continues at regular intervals).<br><br>Continue control efforts for feral cats and invasive rodents. | In years 3 to 5 the following activities will continue at regular intervals:<br>(i) Monitoring the impact of invasive species control on the survival of pink land iguanas, and feral cat abundance.<br>(ii) Based on results, adjust core and buffer area for invasive species control and continue control activities. | | | FJ, IC |
| Strategy 2: Fill knowledge gaps:<br><br>• Ecology: habitat requirements, breeding season, hiding places, environmental conditions, and use of other areas on Wolf Volcano<br>• Baseline data on health condition, disease surveillance, and their potential impact in captivity<br>• Genetic characterisation for management purposes | Collate information on yellow land iguana captive breeding management efforts.<br><br>Include in research permits the request to search for pink land iguanas in other sites on Isabela Island. | Ecology and health studies include: coordinated actions aimed at habitat modelling, population monitoring, investigating reproductive ecology, and presence and prevalence of diseases or infective agents potentially causing diseases. | In years 3 to 5, activities to fill knowledge gaps' activities will continue and they will feed into adaptive management decisions of this plan. | | | FJ, GC, HZ, LO, NCSU, SDZ, URTV |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Decision point:** | | | In early months of year 3, the GNPD and partners will evaluate priority 1 actions to determine if strategies used were sufficient to restore the pink land iguana population. If not, priority 2 activities will begin. Adapt priority 2 activities based on lessons from priority 1 activities. | | | |
| **Priority 2: Establish a headstart programme** | | | | | | |
| **Strategies & activities** | **Programmed actions (by year)** | | | | | **GNPD in collaboration with[1]:** |
| | **1** | **2** | **3** | **4** | **5** | |
| Strategy 3: Establish an initial headstart programme of pink land iguanas that are in good health and present adequate behaviour to survive in the wild. | | Establish a protocol for collecting neonates and eggs to transfer to head-start centre.<br><br>Design basic infrastructure for maintaining pink land iguanas in captivity. | Establish basic infrastruc-ture for maintaining pink land iguanas in captivity.<br><br>Design a protocol for health evaluation, initial treatment, and response to diseases.<br><br>Collect neonates and eggs (if needed) for the headstart programme.<br><br>Implement and manage the headstart programme. | Collect neonates and eggs (if needed) for the headstart programme.<br><br>Manage the headstart programme. | Monitor programme results.<br><br>Repatriation or release on Wolf Volcano of headstart individuals if ready. (Note: repatriation may initiate later than Year 5, potentially 3 to 4 years from collection of neonates or eggs). | FJ, GC, HZ, LO, NCSU, SDZ, URTV |
| **Decision point: Evaluate if the headstart programme, plus the invasive predator control, works and is sufficient. Determine if it is necessary to start with phase 3.** | | | | Determine if strategies used were sufficient to restore the pink land iguana population. If not, identify if priority 3 activities should start. Adapt priority 3 activities, based on lessons learned so far. | | |

| **Priority 3: Strategies and activities to consider implementing (not necessarily in the order presented below) beyond year 5 of this plan if priority 1 and 2 activities do not yield expected results** | | | |
|---|---|---|---|
| **Strategies & activities** | **Year 1 to 5** | **Beyond Year 5** | **GNPD in collaboration with[1]:** |
| Strategy 4: Establish a captive breeding and rearing programme for pink land iguanas to supplement the populations of pink land iguanas in the wild. | Collect information and fill knowledge gaps that could inform this strategy, if required, as a last resort to support pink land iguana survival. | Develop a plan for the management and quarantine process.<br><br>Establish required infrastructure.<br><br>Adult extraction (2–3 adult males) for pilot trial.<br><br>Implement captive breeding programme.<br><br>Collect information, fill knowledge gaps, and feed the future captive breeding management plan.<br><br>If implemented, monitor and release individuals at Wolf Volcano. | TBD based on results in previous years |
| Strategy 5: Establish at least one second healthy and self-sustaining population of Galápagos pink land iguanas in the wild on the Galápagos Islands outside of Wolf Volcano. | Assess available resources and feasibility for translocation of the species to lower elevations (e.g., Rabida and Santiago Islands).<br><br>If feasible, coordinate with GNPD for approval and develop translocation plan. | If feasible and approved by GNPD, implement the translocation plan to selected release site.<br><br>Monitor the released population. | TBD based on results in previous years |
| Strategy 6: Use of cryogenics (preservation of fibroblast cell lines for future cloning or stem cell technology). | Identify two facilities (one in-country and one outside of Ecuador) with infrastructure to preserve genetic material through cryogenics. | If no national site is available, obtain required permits for genetic material to be preserved outside of Ecuador.<br><br>Train staff and collect samples of pink land iguanas' fibroblasts and send to selected preservation facilities to preserve genetic material.<br><br>Generate agreements and necessary legal documentation according to what is established in Ecuador for access to genetic resources. | IC, LO, SDZ |

# Communication strategy

The Galápagos National Park Directorate has a pre-established communication strategy and protocol for communicating research and management actions undertaken in the Galápagos National Park protected areas. As such, all partners and parties involved in implementing this plan will follow this strategy and protocol to ensure they are coordinated, and the information gathered is disseminated appropriately to inform management actions in a timely manner and to maintain support from decision-makers and funders.

Collaborators celebrate the installation of the satellite gateway for remote monitoring of the iguanas on Wolf Volcano, 20 September 2019. Photo © Gregory Lewbart

# Estimated budget

The plan was considered in priorities and its budget reflects this. These costs are an estimate for the implementation of each priority.

| Activity | Estimated Value (USD) |
|---|---|
| **Priority 1: Invasive species control* and resolving key information gaps (0–18 months)** | |
| Logistics (aerial, sea, land) | $560,000 |
| Infrastructure (caseta, tracks) | $110,000 |
| Equipment | $70,000 |
| Communication system | $5,000 |
| Personnel training | $50,000 |
| Personnel labour (fill knowledge gaps and invasive species control) | $220,000 |
| Safety and evacuation plan from Wolf Volcano | $20,000 |
| Genetic characterisation for management purposes | $25,000 |
| **Total priority 1:** | **$1,060,000** |
| **Cost estimates considered here for invasive species control is for the first two years of the Plan* | |
| **Priority 2: Establish a headstart programme (18 months onward)**** | |
| Logistics (aerial, sea, land) for transfer of hatchlings or eggs from Wolf Volcano to headstart centre | $45,000 |
| Infrastructure for headstart programme | $300,000 |
| Infrastructure annual maintenance | $5,000 |
| Personnel labour (collect hatchlings or eggs and captive care) | $120,000 |
| Equipment and supplies | $20,000 |
| Development of a health assessment protocol | $5,000 |
| Implementation of health protocol | $300/animal*** |
| Logistics (aerial, sea, land) for repatriation of iguanas to Wolf Volcano upon reaching a suitable size and age | $30,000**** |
| **Total priority 2:** | **$525,000 (initial investment), then ~$225,000 annually + health assessment cost** |
| ***Cost estimates are annual, while infrastructure is a one-time investment with annual maintenance* | |
| ****Total cost will depend on number of animals assessed* | |
| *****This cost estimate will apply from year six onwards when hatchlings are 5 years old* | |

| Activity | Estimated Value (USD) |
|---|---|
| **Priority 3. Strategies/activities to consider implementing beyond year five of this plan, if priority 1 and 2 activities do not yield expected results** | |
| Establishment of captive breeding and rearing programme | $410,000 (initial investment), then ~$215,000 annually + health assessment cost |
| Establishment of a second population outside of Wolf Volcano | $120,000 |
| Second population establishment monitoring (annually) | $50,000 |
| Use of cryogenics to preserve fibroblasts of the species | $20,000 |
| **Total strategies to consider beyond year five:** | **$550,000 (initial investment), then ~$265,000 annually** |


Galápagos National Park rangers perform population monitoring activities for the pink land iguanas on Wolf Volcano. Photo © Galápagos National Park Directorate

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# Appendices

## Appendix 1. Full current assessment from the IUCN Red List of Threatened Species™

Gentile, G. (2012). *Conolophus marthae*. The IUCN Red List of Threatened Species 2012, Article e.T174472A1414375. https://dx.doi.org/10.2305/IUCN. UK.2012-1.RLTS.T174472A1414375.en

### Taxonomy

*Conolophus marthae* was recently described. No prior reference exists in the taxonomic literature as the species was not known before its description (Gentile & Snell, 2009). The description was based on morphological, genetic, and behavioural diagnostic traits. The holotype is a free-living adult male tagged with a subcutaneous electronic marker, branded, and released. Further genetic evidence supporting separate taxonomic status of the Galápagos pink land iguana prior to the species' description is found in Gentile et al., 2009, and Tzika et al., 2008. Gentile et al. (2009) disclaims the name 'rosada' for nomenclatural purposes (Articles 8.2 and 8.3; International Code of Zoological Nomenclature, 1999).

### Distribution

The Galápagos pink land iguana is a recently described species endemic to Volcán Wolf, a single location on Isla Isabela. Based on direct observations (G. Gentile, pers. comm., 2011) and reports of the Galápagos National Park surveys, this iguana has never been observed outside an area larger than 25 $km^2$. The maximum area surrounding the geographic capture points of all individuals observed to date is 10.9 $km^2$, with more than 95% of observations clustering in a much smaller area (G. Gentile, pers. comm., 2011). The iguana occurs along the northern slopes of the volcano, in an area ranging from 600–1,700 m asl. There may be a seasonal shift in altitude, with pink iguanas concentrating at the crater rim at 1,700 m during the months of May–July and descending to 600 m when vegetation starts drying out. This iguana has not been seen inside the caldera.

### Population information

A single wild population of Galápagos pink land iguana exists, and it is not found ex situ. Recently, the effective population size ($N_e$) has been estimated at as large as 41.21 individuals (95% CI = 30.71–67.97) by using microsatellite data (nine loci) (Fulvo, 2010). Mark-recapture data, by applying the Lincoln-Petersen method from two contiguous temporal samples in 2009 and 2010 (percentage of recapture = 53%), would indicate 192 adult individuals (95% CI = 155–260). Sex ratio estimated from samples collected in May 2009 was one male to 0.59 females and one male to 0.51 females in July 2010 (Gentile & Fulvo, 2011). Past and future population trends are impossible to assess due to the lack of a sufficiently long series of estimates of population size. Monomorphism for a single mitochondrial DNA haplotype in a sample of 102 iguanas strongly suggests that the Galápagos pink land iguana might have suffered severe demographic contractions in the past (G. Gentile, pers. comm., 2011). From 2005 to 2011, 133 adult individuals were

captured and permanently marked with brands and Passive Integrated Transponders, representing nearly all observed pink iguanas (G. Gentile, pers. comm., 2011). During these surveys, no juveniles were observed, suggesting population recruitment appears to be noneffective.

### Habitat and ecology

The Galápagos pink land iguana (*Conolophus marthae*) is found coexisting with a subpopulation of Galápagos land iguana (*Conolophus subcristatus*) on Volcán Wolf. Altitudinal shifts along the slopes of the volcano imply different environmental conditions, which ultimately are reflected by different types of vegetation. The habitat includes tropical dry shrubland at the top of the volcano and tropical dry forest along the slopes. Vegetation at the highest altitudes may be impacted by droughts. The head nodding behaviour of *C. marthae* is very distinctive and completely different from *C. subcristatus* and may be a barrier to hybridisation. Basic reproductive biology of this iguana is unknown. In late spring 2010, a few *C. marthae* females were observed carrying 4–7 eggs in their follicles, investigated by a portable ultrasound machine (G. Gentile, pers. comm., 2011). These data would indicate a much smaller clutch size than for the geographically closest population of *C. subcristatus* on Fernandina Island (7–23 eggs; Werner, 1982). It is still unclear whether *C. marthae* and *C. subcristatus* have overlapping reproductive seasons and if the two species may compete for nesting sites on Volcán Wolf; the location of these nests is unknown. Average snout-to-vent length (SVL) of animals observed is 46.8 cm, males being significantly larger than females. The SVL of the smallest male Galápagos pink land iguana captured was 37.3 cm, a size that broadly corresponds to the SVL in seven-year-old Galápagos land iguana individuals (37.5 cm ± 6.0 SD) from Santa Cruz, and even older individuals from Plaza Sur.

### Use and trade

There is no current or known historic human use or trade of this species.

### Threats

The population of Galápagos pink land iguana is extremely small and prone to both demographic and genetic stochasticity, as well as environmental stochasticity (volcanic eruptions, droughts). Because of the overlapping range with Galápagos land iguana, hybridisation may occur, generating introgression between *C. marthae* and *C. subcristatus* on Volcán Wolf. Although there is no evidence of living F1 hybrids at present, DNA evidence shows that rare events of hybridisation have occurred, though the severity of subsequent introgression has not been fully evaluated yet (Gentile et al., 2009; Fulvo, 2010). Because the population is so small, rare events of hybridisation may have a significant effect on the species. In addition to the Galápagos Hawk (*Buteo galapagoensis*), the only native predator of Galápagos pink land iguanas on Volcán Wolf, invasive alien black rats (*Rattus rattus*) and feral cats (*Felis catus*) are potential predators of eggs and hatchlings. It is known that

feral cats prey on Galápagos land iguanas up to three and four years old. Animals in this age class represent a size that has not been found among pink iguanas. Therefore, it is suspected that feral cats pose a significant threat to population recruitment in Galápagos pink land iguanas. Volcán Wolf is an active volcano, with several eruptions recorded in the last century, most recently in 1982. Most recent lava is found on the eastern and southern sides of the volcano and in the caldera (Geist et al., 2005). Eruptions may have caused local extinctions of populations of *C. subcristatus* in the past, for example, Volcán Chico (on the eastern side of Volcán Sierra Negra) in 1979 (Snell et al., 1984). Droughts may be severe on the top of Volcán Wolf. Although adults are expected to cope fairly well with drought since they obtain water from consumed plants, the resultant scarcity of food may potentially cause aborted reproduction for the year due to a combination of lack of egg laying, a higher number of infertile eggs laid, and poor juvenile survival.

Ectoparasite load is high in both Galápagos land iguanas and pink iguanas on Volcán Wolf. In fact, the location is characterised by a massive occurrence of ticks, which are much more abundant in Volcán Wolf than elsewhere in the archipelago. Both *C. marthae* and the *C. subcristatus* populations from Volcán Wolf show an unbalanced leukocyte formula compared to other populations of land iguanas from the whole archipelago. This could be related to the presence of ticks but could also indicate a possible endoparasite infection affecting most individuals (Fulvo, 2010). This issue and how it might affect the fitness of the two populations is under investigation. There is no current or known historic human use or trade of this species.

**Conservation**

All species of Galápagos land iguanas (*Conolophus* spp.) are included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The known geographic range of Galápagos pink land iguana is within the Galápagos National Park, the legal authority governing and protecting biological diversity of the Galápagos Islands. The land iguanas are included in the Management of Native and Endemic Species Program, as part of the Galápagos National Park's management plan. The Galápagos National Park undertakes major campaigns to control and eradicate invasive alien species in the Galápagos, including on Volcán Wolf. Such actions have so far successfully prevented habitat disturbance by feral goats in northern Isabela and promoted habitat restoration of southern Isabela. In the early 2000s, a three-year programme to eradicate feral cats from the island of Baltra (where *C. subcristatus* was repatriated from 1991 onwards) was effective by initially poisoning with sodium monofluoroacetate (compound 1080), then trapping or shooting the remaining cats (Phillips et al., 2005). However, the applicability of this protocol on Volcán Wolf is questionable due to the difficult terrain and is likely impossible for an island as large as Isla Isabela, an area of 4,588 km$^2$ (Nogales et al., 2004). Further evaluation of the feral cat population on Volcán Wolf is needed for the purpose of implementing a programme for their control.

Based on successful programmes for the populations of *C. subcristatus* from Bahía Cartago (Isabela), Santa Cruz, and Baltra Islands (Snell et al., 1984), the National Park is also considering a captive-breeding programme for *C. marthae*. The University Tor Vergata (Rome, Italy) is actively assisting the Park in this regard.

The Galápagos pink land iguana is not in contact with humans in Galápagos except for the purpose of scientific investigation and management. The Galápagos National Park does not envision a plan to include Volcán Wolf in the list of touristic sites nor other possible intrusions to the population. Nevertheless, as the species is endemic and has a very limited distribution, the National Park has added a specific educational module focused on this species in the courses aimed at training and updating nature guides. This training ensures proper information is conveyed to visiting tourists.

Information on the population biology and ecology of pink iguanas is very limited and research has begun. Research needs include monitoring of population and habitat trends, diet analysis, and in-depth study of the reproductive biology of this species. Clarifying the frequency of hybridisation and level of genetic introgression between *C. marthae* and *C. subcristatus* is urgently needed. Additionally, the health status of the population should be monitored and the possible impact of a high parasite load on the fitness of the population should be investigated.

Additionally, in the event a captive breeding programme is started, the Galápagos National Park, in collaboration with the University Tor Vergata, will develop an education programme for local people and tourists. It is extremely difficult and expensive to access the study area. The need to transport equipment to and from the site limits the duration of research trips and consequently the extent of research that can be conducted on any one trip. The construction of a small low-impact, temporary field structure near the top of volcano would greatly help by allowing longer field trips and more effective research work and monitoring.

# Appendix 2: Workshop participants 23–25 August 2021

| | | |
|---|---|---|
| Wilson Cabrera | Ecosystems park ranger | Galápagos National Park Directorate |
| Karl Campbell | Director of Latin American islands initiative | Re:wild |
| Víctor Carrión | Island restoration coordinator | Jocotoco Conservation Foundation |
| Jorge Carrión | Conservation manager | Galápagos Conservancy |
| Paula A. Castaño | Native species manager | Island Conservation |
| Giuliano Colosimo | Postdoctoral research fellow | San Diego Zoo Wildlife Alliance & Tor Vergata University of Rome |
| Samuel Dubouis | Translator | |
| Joe Flanagan | Senior veterinarian | Houston Zoo |
| Gerardo Garcia | Curator of lower vertebrates & invertebrates | Chester Zoo |
| Gabriele Gentile | Professor | Tor Vergata University of Rome |
| Glenn P. Gerber | Scientist, population sustainability | San Diego Zoo Wildlife Alliance |
| James Gibbs | Vice president of science and conservation | Galápagos Conservancy & State University of New York, Syracuse |
| Diana Gil | Head of the native species conservation subprocess, workshop note taker | Galápagos National Park Directorate |
| Christopher Jordan | Director for Latin America | Re:wild |
| Patricia León | Programme officer, workshop facilitator | Re:wild |
| Gregory Lewbart | Professor of zoological medicine | North Carolina State University |
| Andrea Loyola | Veterinarian | Galápagos National Park Directorate |
| Cruz Márquez | Former Galápagos National Park ranger | |
| Manuel Masaquiza | Ecosystems park ranger | Galápagos National Park Directorate |
| Máximo Mendoza | Ecosystems park ranger | Galápagos National Park Directorate |
| Russell Mittermeier | Chief conservation officer | Re:wild |
| Johannes Ramírez | Ecosystems park ranger | Galápagos National Park Directorate |
| Harry Reyes | Ecosystems director | Galápagos National Park Directorate |
| Danny Rueda | Director of Galápagos National Park | Galápagos National Park Directorate |
| Christian Sevilla | Responsible for conservation and restoration of island ecosystems (CREI) | Galápagos National Park Directorate |
| Washington Tapia | Director of conservation | Galápagos Conservancy |
| Lina Valencia | Coordinator of the Andean countries | Re:wild |
| Freddy Villalva | Responsible Fausto Llerena breeding centre | Galápagos National Park Directorate |
| Gabriela Vivas | Former: Island restoration specialist, Current: Operations manager, workshop logistics coordinator | Former: Island Conservation, Current: Galápagos Conservancy |

Galápagos pink land iguana male (*Conolophus marthae*) on Wolf Volcano, Isabela Island.
Photo © Joshua Vela, Galápagos Conservancy


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