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2017 Formosan Pangolin PHVA Final Report

October 2019

IUCN SSC Species Survival Commission
CONSERVATION PLANNING SPECIALIST GROUP Changing the Future for Wildlife
IUCN SSC PANGOLIN SPECIALIST GROUP
臺北市立動物園 TAIPEI ZOO
行政院農業委員會林務局 FORESTRY BUREAU C.O.A

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Cover photo: Chinese Pangolin (Te-Chuan Chan / Taipei Zoo)

A collaboration between Taipei Zoo, Forestry Bureau of Council of Agriculture, Executive Yuan, Endemic Species Research Institute, and the IUCN SSC Pangolin and Conservation Planning Specialist Groups

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DIRECTOR'S PREFACE: TAIPEI ZOO

After relocating to the current residence in 1986, Taipei Zoo launched a wildlife rescue program. With medical care resources and experience, our zoo has been taking care of sick and injured animals ever since. For 30 years, the most frustrating rescue experiences lie with the Formosan pangolins. Recalling the pangolin rescue and research process during the first ten years, all of the salvaged Formosan pangolins, whether badly hurt or not, did not live longer than half a year. Among the most common causes of death were anorexia, gastrointestinal bleeding and severe anemia. Following compilation and examination of the information from each pangolin death, through necropsies by the NTU pathologists, most deaths are shown to have arisen from bleeding ulcers or hemorrhagic enteritis.

Compared to the paucity of research on pangolins worldwide, the above cases are widely reported in rescued pangolins maintained in captivity. By inference, their deaths originate from increased stress caused by bad feeding conditions or lack of vitamin K, which leads to coagulation disorders and triggers hemorrhagic diseases. However, none of the conservation centers around the globe have found a solution to the treatment of the bleeding disorders that pangolins may suffer after their rescue. Consequently, zoos have gradually given up raising salvaged pangolins in captivity. Based on advice from animal keepers and vets, officials in the zoo cannot help but release animals into the wild to decrease stress levels. However, due to the difficulty of tracking wildlife it is hard to document the condition of the animals post-release, which could help provide information to support improvements to management.

In 2004, to deal with the challenges of rescuing pangolins, we held a "Population and Habitat Viability Assessment" (PHVA) workshop at the Taipei Zoo, with the assistance of professionals from the Conservation Planning Specialist Group (formerly the Conservation Breeding Specialist Group) and pangolin specialists in Asia. As a result of this workshop, we revealed the lack of research on pangolins in the areas of biology, physiology, and pathology, as well as animal husbandry. After the workshop, in the hope of overcoming these obstacles, the Taipei Zoo, along with experts, carried out research on Formosan pangolin rearing and conservation biology, thereby making a big step in Formosan pangolin studies. Over time, we expect to learn more of their needs in the wild, to help improve captive food composition and feeding conditions, and as a result to lengthen their lifespan after rescue. The more information we collect on physiology, reproduction, endocrinology and medical imaging, the greater the possibility of successfully keeping and breeding pangolins.

In the meantime, all eight existing pangolin species are threatened by illicit trading. Despite support provided by rescue centers for confiscated pangolins, lack of experience continues to lead to high fatalities for pangolins. Additionally, although commercial trading of pangolin species is prohibited, illegal poaching is still occurring.

In December 2017, we again invited experts from around the world to attend a PHVA workshop at Taipei Zoo. Our aim was to examine potential threats to pangolins in the wild and to review the previously unsolved problems described above. After 13 years of effort, Taipei Zoo and experts at home and abroad had succeeded in greatly improving pangolin survival rates and health condition in captivity. As a result of key research on pangolin ecosystems, physiology and reproduction, as well as the invention of wireless tracking in the wild, we now understand more about pangolins and have more solutions to pangolin-

related challenges. Regretfully, pangolin habitat is still drastically declining. Hence, at the workshop, we worked hard to build consensus on what needs to be done to change this. By integrating *in situ* and *ex situ* research, sharing our pangolin rescue experiences, and promoting education, we are confident that everyone involved can contribute to the successful conservation of pangolins. By sharing our outcomes and experiences in Taiwan with the rest of the world we may also be able to help the conservation of pangolins throughout the globe.

Sincerely,

Jason, Shih-Chien Chin
Director
Taipei Zoo

DIRECTOR'S PREFACE: FORESTRY BUREAU

Pangolins comprise eight species, four in Asia and four in Africa. In Taiwan, due to *Compendium of Materia Medica* written by Li Shizhen during the Ming dynasty, pangolins were once famously known as "scaly carp" since their body resembles that of a carp and they inhabit burrows. Also, due to the scales covering their skin, they were classified as fish!

Usually gentle, solitary animals, when threatened they can curl up into a ball, with the overlapping scales as armor. "Scaly carp," pronounced "lâ-lí" in Taiwanese, are often found in the juncture between Shiding and Pinglin district. La Li Jian, for instance, is named as the place where pangolins are normally found. Nantun Village in Taichung is formerly called "lâ-lí," as, legend has it, during wasteland reclamation in the era of the Ching dynasty, there was a golden lâ-lí, who was believed to cause catastrophe for descendants if unawakened before the Dragon Boat Festival; hence, the locals exhausted their wits to awaken lâ-lí and let it till the soil. To this day, villagers still preserve this custom to wake up golden lâ-lí with the wooden clog parade. The Nantun Wooden Clog Festival, in turn, has become a unique holiday during the Dragon Boat Festival in Taichung City.

In response to growing habitat destruction and the poaching crisis, several strategies are mapped out by the government to protect pangolins. On August 4 in 1989, pangolins were listed as rare wild animals, according to the Wildlife Conservation Act. Meanwhile, a five-year plan for a Pangolin Breeding and Conservation Study was developed, aimed at conducting an ecological survey and study of pangolins. Shortly after, and since the year 2000, licenses are no longer issued to Chinese Medicine traders for any purchase or use of protected animals, such as pangolins. To further prevent and combat such trafficking in pangolins, the government developed identification technology for any medicine and products made by pangolins, including mitochondrial DNA sequencing. Together with experts from the Forestry Institute, Taipei Zoo operated a three-year "Taiwanese Pangolin Conservation Program" to research and conserve pangolins. The results included the successful development of feed formula for captive breeding, and the unraveling of feeding techniques for pangolins in captivity around the world.

In 2004, and again in 2017, the Taipei Zoo held Pangolin Population and Habitat Viability Assessment workshops. This was done in cooperation with international specialists to examine and recommend pangolin conservation strategies and to provide concrete ways of prolonging survival in pangolins, along with related conservation works.

Taipei Zoo will compile and publish these conference results in the hope of bringing attention to pangolin conservation worldwide.

Hwa-Ching Lin
Director General
Forest Bureau, Council of Agriculture, Executive Yuan

DIRECTOR'S PREFACE: ENDEMIC SPECIES RESEARCH INSTITUTE

Illegal trading of pangolins is currently one of the most severe conservation issues around the world. All eight existing pangolin species are now listed as threatened by the International Union for the Conservation of Nature (IUCN). In light of the continued threat posed by illicit trading, all commercial trade in pangolin species is prohibited under the Convention on International Trade in Endangered Species (CITES), which lists all eight pangolin species on Appendix I. Within Taiwan, Formosan pangolins are categorized as a "Rare and Valuable Species" according to the National Wildlife Conservation Act. Despite this, Formosan pangolins remain listed as Vulnerable on The Red List of Terrestrial Mammals of Taiwan, 2017, which is issued by the Taiwan Endemic Species Research Institute.

Although Formosan pangolins are not as endangered as pangolins living outside Taiwan, they are, according to researchers and experts, potentially at risk from habitat destruction, poaching, and the threat of stray dogs. If no further action is taken to conserve Formosan pangolins, they could be on the endangered species list in the future.

Our institute has for a long time engaged in research, conservation, and education focusing on the fauna and flora of Taiwan. In December 2017, we held a Population and Habitat Viability Assessment (PHVA) workshop at Taipei Zoo, aiming to assess pangolin biology, distribution and threats, and to discuss the conservation strategy for pangolins. As part of this, the first-aid station in our center, and the Taiwan Roadkill group, contributed data about pangolin rescue and roadkill observations. Following the workshop, and to ensure effective delivery of Formosan pangolin research, conservation, education, and rescue, rehabilitation and release, four working groups and one core team were established with an overarching goal of "understanding, and cherishing pangolins while creating a harmonious world."

For the sake of maintaining biodiversity and a healthy ecosystem, we hope that the wildlife in Taiwan, including pangolins, can be sustained in viable populations and habitats, while people become more accountable and responsible for their actions, towards a world where people and ecology prosper together.

Jia-Dong Yang
Director
Endemic Species Research Institute, Council of Agriculture, Executive Yuan

CONTENTS

EXECUTIVE SUMMARY

VISION: By 2042, everyone is aware of and values the Formosan pangolin and is willing to work together to properly protect its habitat and maintain its viable population based on adequate knowledge so that pangolins can live in harmony with human beings.

BACKGROUND

Taiwan is the home of the Formosan pangolin (*Manis p. pentadactyla*), a subspecies of the Chinese pangolin, and is the last remaining strong-hold of this Critically Endangered species. The viability of the Formosan pangolin is therefore important not just within Taiwan, but to global pangolin conservation efforts. Importantly, Taiwan now provides one of the few places where this species can still be studied under relatively natural conditions. As wildlife trade drives the disappearance of pangolins from other parts of the world, pressure on the Taiwanese population may increase and ongoing vigilance is essential.

2018 Priorities:

- *Convene a meeting of stakeholders to establish a **Formosan Pangolin Core Group,** with themed sub-groups.*
- *Confirm **research priorities** for pangolins in Taiwan.*
- *Establish a platform for collecting scientific evidence relating to the impact of **stray dogs** on pangolins.*
- *Add pangolin conservation information to **Taipei Zoo's Outreach Program**, especially for schools near pangolin habitat and places where roadkill occurs.*
- *Bring representatives from rescue centers and local governments together to progress key issues related to **rescue, rehabilitation and release.***
- *Publish a **children's book** about pangolins.*

THE 2017 PHVA

In December 2017, over 70 pangolin experts from 13 countries gathered in Taipei for four days of intensive planning discussion. This Population and Habitat Viability Assessment (PHVA) workshop was hosted by Taipei Zoo and was organized in collaboration with the Forestry Bureau of Council of Agriculture, Executive Yuan, the Endemic Species Research Institute (ESRI) and the IUCN SSC Pangolin and Conservation Planning Specialist Groups (PSG and CPSG respectively).

Participants worked together to agree a vision for the future of pangolins in Taiwan, to identify and prioritize current obstacles to achieving the vision, and to agree what could be done to overcome those obstacles. On the final day of the workshop, summaries of these discussions and recommendations were presented to a smaller gathering of key representatives and a way forward was agreed.

OUTCOMES

Population Viability Analysis

Population modelling based on the best available data for Formosan pangolin population size, biology and threats suggests that the wild population is not in decline and is projected to have good viability in the absence of significant threats. Adult female survival and reproduction are primary drivers of future viability. Important knowledge gaps in reproduction and survival, and especially information on the degree and impact of various threats to pangolins (e.g., dogs, roads, trapping) need to be investigated to

better assess the future of the Formosan pangolin and to develop effective management strategies for its conservation across Taiwan.

National Conservation Strategy

While there is no evidence that pangolin populations in Taiwan are declining, and may even be increasing in some areas, there are a number of challenges to ensuring long-term population health. A National Conservation Strategy and Action Plan was developed, formed around the major themes of increasing understanding of pangolin population biology, understanding and addressing threats to pangolins and their habitat, and maximising the conservation benefits of *ex situ* pangolin management.

A major outcome of the workshop is the proposed formation of a **Formosan Pangolin Core Group (FPCG)** whose purpose will be to coordinate information sharing and implementation of the National Conservation Strategy and Action Plan. It is proposed that the following themed sub-groups be established to drive activities:

> **A pangolin research group led by Endemic Species Research Institute:** to connect researchers working on pangolins, to encourage research aimed at filling important knowledge gaps and to ensure integration of *in situ* and *ex situ* research.
>
> **A pangolin conservation strategy group led by the Forestry Bureau of Council of Agriculture, Executive Yuan:** to lead on a review of existing information relating to the impact and distribution of threats such as stray dogs, changes in land-use, use of traps, hunting, roadkill and logging.
>
> **A pangolin education group led by Taipei Zoo:** to identify appropriate education targets and materials for pangolin conservation education, especially for people who live near lowland habitat, and to support education and awareness raising across all areas of the conservation strategy.
>
> **An integrated pangolin rescue group, led by Taipei Zoo:** to connect institutions working on pangolin rescue, rehabilitation and release in Taiwan, to develop standard operating procedures for key areas of work and to support first-response staff.

The National Conservation Strategy and Action Plan will be reviewed every five years.

PART I.

Population and Habitat Viability Assessment

INTRODUCTION

GLOBAL CONTEXT

Dan Challender, Chair, IUCN SSC Pangolin Specialist Group

Pangolins are among the world's most fascinating species, but also some of the most threatened. All eight pangolin species, four of which are native to Asia and four to Africa, are threatened with extinction globally. The IUCN Red List of Threatened Species™ categorizes each species as Critically Endangered, Endangered or Vulnerable due to historic, ongoing and future population declines attributed to overexploitation. Pangolins are principally threatened by overexploitation from local use and international wildlife trafficking, and estimates suggest that more than 1 million pangolins have been trafficked globally since the year 2000, making pangolins the most trafficked wild mammals in the world. These trends are driven by demand for pangolin meat, their scales, which are used for their alleged medicinal properties, and other body parts, primarily in Asia and Africa. Compounding this situation, pangolins have suffered from a lack of concerted research attention and conservation action historically.

However, this predicament has started to change. Within the last few years there has been a surge of activity and interest in pangolins and their conservation from governments, NGOs and civil society. This is reflected in the increasing number of conservation strategies that are being developed at the national, regional and global level to guide conservation investment and action most wisely. For example, TRAFFIC, the wildlife trade monitoring network, convened stakeholders in 2008 to develop conservation recommendations for South and Southeast Asia, the IUCN SSC Pangolin Specialist Group published the first ever global conservation action plan for pangolins in 2014, *Scaling Up Pangolin Conservation*, and the US and Vietnamese governments convened pangolin range States to develop key actions to combat wildlife trafficking in pangolin and their parts in 2015.

Recognizing that many conservation interventions will be implemented at the national and sub-national level, national actions plans are crucial to devising actions to deliver effective pangolin conservation. In this respect, Taiwan has demonstrated global leadership in pangolin conservation. Not only did Taiwan organize the first ever Population and Habitat Viability Assessment (PHVA) workshop for pangolins anywhere back in 2004, in order to instigate actions to, among other things, control feral dogs and prevent poaching, it has now developed this PHVA and Conservation Action Plan for the Formosan pangolin. Combining a number of essential research, conservation and coordination actions, let's hope it serves Taiwan's pangolin populations well over the next 25 years.

REVIEW OF OUTCOMES SINCE 2004 PHVA AND CURRENT CONSERVATION ACTION FOR PANGOLINS

Jung-Tai Chao, Senior Scientist (retired), Taiwan Forestry Research Institute

Threatened by habitat loss and poaching, the Formosan pangolin (*Manis p. pentadactyla*) has been listed as a protected species by the Wildlife Conservation Act of the ROC. A Formosan Pangolin Population and Habitat Viability Assessment (PHVA) workshop was held in 2004 to evaluate the conservation status of the species in Taiwan and provide recommendations on actions needed for the conservation of the species (Chao *et al*., 2005). Thirteen years later, we need to review the progress made on the conservation of the species, before further conservation recommendations can be made.

When reviewing progress in conservation of a species, one should ask if the species is better off now than it was before. In our case, we should ask, "Are the Formosan pangolins better off now than they were 13 years ago?" at the individual, population, and species level.

Different people may have different answers for this question. In this report, I will examine this question from two aspects. First, from late 1980s to 1990s, my colleagues and I at the Taiwan Forestry Research Institute (TFRI) were the first and the only team studying the Formosan pangolin. By contrast, in the last 13 years we saw a booming of research on the Formosan pangolin by quite a few research teams, including 11 Masters theses and one Ph.D. dissertation on the species from 2004 to 2016 (see Appendix II), and these generated a great deal of knowledge needed to save this endangered species. Second, public awareness on pangolin conservation has increased and many wildlife conservation actions have been taken since 2004. I will briefly review some of these actions and social/environmental changes relevant to the conservation of the Formosan pangolin, since the 2004 PHVA.

In the 2004 PHVA workshop, there were 3 working groups, namely the *Habitat Improvement Working Group,* the *Human-Caused Threats Working Group*, and the *Population Biology/Modeling Working Group.* This review is focused on priority actions recommended by the *Habitat Improvement Working Group* and on one action recommended by the *Human-Caused Threats Working Group.*

Table 1. Recommended actions to address priority issues and goals, by the *Habitat Improvement Working Group* of the 2004 PHVA workshop

ISSUE (activity)	**GOAL**		
	Reduce habitat loss	**Reduce habitat fragmentation**	**Reduce habitat degradation**
Road construction	*Promote critical review of new road construction.	*Connect habitat and improve road construction.	*Restrict road use in pangolin habitat.
Housing	*Decrease lowland hill development.	*Establish wildlife protected area.	*Enhance conservation awareness of residents through community awareness programs.
Agricultural abuse	*Improve law enforcement for land abuse.	*Encourage habitat restoration.	*Reduce use of pesticides and herbicides.

The *Habitat Improvement Working Group* identified 3 issues related to habitat improvement, i.e., road construction, housing, and agricultural abuse. To address the issue of **Road Construction**, the goal included: 1) to promote critical review of new road construction; 2) to connect habitat and improve road construction; and 3) to restrict road use in pangolin habitat.

In terms of reducing the negative impact of road construction, credit should be given to the Observer Ecological Consultant Co., Ltd. (OECC) established since 2004. The staff of this company successfully helped transform the Taiwan Area National Freeway Bureau into taking ecologically oriented construction. Originally the OECC worked for the Freeway Bureau by contracted projects. Moving towards mainstreaming biodiversity, the Freeway Bureau began to allocate annual budget a couple of years ago to mitigate the negative impact caused by road construction. The budget has been spent on connecting habitats which had been isolated by road construction to reduce the impact of habitat fragmentation, on controlling invasive alien species, and on preventing unnecessary road construction at the planning stage.

In addition, with the effort of the OECC and like-minded environment groups, NGOs, the Public Construction Commission, Executive Yuan sent an official document earlier this year to 21 central government agencies requesting the adoption and further development of the Ecological Checklist Mechanism for Public Construction for ALL public construction plans in the future. Although the Ecological Checklist Mechanism is still at an early stage, adoption of such a mechanism in all public construction processes will definitely benefit the biodiversity of Taiwan as a whole, including endangered species such as the Formosan pangolin.

Ms. Pei-Jung Wang, a master student of Professor Ling-Ling Lee of the National Taiwan University, designed and implemented a wildlife rescue system in 2006, for the Formosan pangolin (Wang 2007). Data and samples collected from this system were analyzed to evaluate its efficiency in providing information for pangolin conservation. The number of reported cases per year more than doubled following the initiation of the rescue system (based on 150 cases reported from 1997 – 2006 and 44 cases reported in the year following initiation). The study stressed the importance of enhancing accurate data recording and sample collection from the wildlife rescue system, to facilitate further research and planning of conservation strategies and actions for pangolins. However, an attempt to maintain this system in all counties of Taiwan was not successful due to the lack of a stable coordinating mechanism.

The report system was then replaced partially by the Taiwan Roadkill Observation Network (https://roadkill.tw/en) that has been actively keeping records of road-kills in Taiwan since August 2011. There are 14,071 members so far, indicating a tremendous increase of public awareness and concern about the negative impacts of roads on wildlife. Members of the Network take pictures of road-kills and send them to the Network by smartphone. Data are verified before inclusion in the database. Pangolins are one of 31 focal species that the Network has been keeping records of.

Forty pangolin road-kills have been recorded by the Network over a 6-year period. However, the number of records seems to be increasing over time and in 2017 alone, there were 19 pangolin road-kills, or 47.5% of the records. It is too early to draw any conclusions from these data but it will be of great help to the conservation of the Formosan pangolin if long-term records can be maintained and analyzed.

The second issue was **Housing** and the recommended actions included: 1) to decrease lowland hill development; 2) to establish wildlife protected area; and 3) to enhance conservation awareness of residents through community awareness programs.

House and real estate prices in Taiwan have almost doubled over the last decade. New buildings and construction projects all over the island indicate that lowland development has increased. However, Taiwan has been experiencing the lowest birth rate in the world. The shape of the population pyramid changed from a triangle in 1980 to a barrel-like shape in 2014. A falling birth rate and a rising life expectancy will likely lead to land use changes and probably some relief from lowland development in the future.

Regarding protected areas in Taiwan, there are nine national parks covering about 3,100 km^2 of land area, or nearly 8.6% of the entire land area of the country. Three national parks were established after 2004, although two of these were for marine areas. In addition, three more Nature Reserves with a total area of 1,017.2 ha, and three more Wildlife Protected Areas, with a total area of 1,611 ha, were established after 2004. Most of these are in lowland areas and should have a positive impact on the survival of pangolins.

In 2004, many participants at the PHVA workshop still considered establishing more protected areas as the main, if not the sole, solution to saving the Formosan pangolin. Our ideas have changed over the past decade. At most, protected areas account for only 20% of the total land area of any country in the world. If the majority of the land area, that is, the human-influenced landscape, could be sustainably used or subject to other effective conservation measures, we would feel more optimistic about the future of the Formosan pangolin.

The human-influenced landscape includes areas for agricultural production. Participants at the 2004 PHVA workshop agreed that curbing "**Agricultural abuse"** would make a significant contribution to the conservation of the Formosan pangolin. Recommended actions to confront this challenge included: 1) to improve law enforcement related to land abuse; 2) to encourage habitat restoration; and 3) to reduce use of pesticides and herbicides.

Eight years ago, the Council of Agriculture (COA) set a Rural Regeneration Policy that was endorsed by the Executive Yuan, or the Cabinet. The key points of the policy were to: 1) replace agricultural subsidies with investment in rural communities; 2) carbon "locking" (sequestration) in rural communities; and 3) environmentally friendly agricultural production. Recently, the Chair of the COA announced the expansion of organic agriculture to double its current size (~ 0.8%) within 3 years.

In addition, the *Satoyama* Initiative, recognized by COP10 of the CBD as a potentially useful tool to better understand and support human-influenced natural environments for the benefit of biodiversity and human well-being, has been well supported by government, private sectors, and NGOs in Taiwan. The *Satoyama* Initiative attempts to restore or rebuild Socio-ecological Production Landscape (SEPL) through eco-friendly farming practices. This means to significantly reduce, or in some cases totally ban, the use of agrochemicals such as pesticides, herbicides, and chemical fertilizers. The movement will see a return of cleaner environments that benefit many wildlife species, including pangolins.

Last but not least, the status on control of feral dogs, an action recommended by the *Human-Caused Threats Working Group in 2004,* needs to be examined. Two decades ago, many dogs in Taiwan were drowned, poisoned, eaten or abandoned on the streets or in the mountains when they became too expensive to care for or when owners got tired of them. Under the 1998 Animal Protection Act, Taiwan created animal shelters and an adoption system and began registering pets and tracking stray dog populations.

From 1999 to 2009, nearly 923,000 dogs were taken into shelters, according to the 2010 study. About 18% were adopted, and 72% were put down. A campaign by animal welfare activists to ban euthanasia received enormous publicity. Parliament succumbed to the public pressure and banned the practice of euthanizing stray dogs in shelters. The law came into effect on February 4, 2017, two years after it was first passed by parliament. The central government last year allocated NT$1.9 billion (US$58 million) to boost the standard of animal shelters. However, many fear that the ban on euthanizing stray dogs in shelters will lead to overcrowding and to more owners abandoning their pets.

The estimated number of stray dogs in Taiwan was 120,000 in 2015. A video taken in 2013 and released in 2015 by Mr. Weiting Liu of the OECC showed how a young pangolin tried to escape from an attack by a stray dog. So, stray dogs remain a threat to local wildlife including pangolins. The risks posed by the stray dogs need to be assessed and managed.

THE 2017 PHVA WORKSHOP

The PHVA workshop took place at Taipei Zoo from 5-8 December 2017 and was attended by more than 70 participants from 13 countries. The initiative was a collaboration between Taipei Zoo, the Forestry Bureau of Council of Agriculture, Executive Yuan, the Endemic Species Research Institute (ESRI) and the IUCN SSC Pangolin and Conservation Planning Specialist Groups (PSG and CPSG respectively).

Leading up to the PHVA, on 3 December, CPSG convened a one-day Population Viability Analysis development workshop, during which a smaller group of biologists and researchers met to finalize parameter values for a population simulation model, built using the software program *VORTEX* (Lacy & Pollack, 2017). The PVA identified primary drivers of Formosan pangolin population viability and important data gaps for viability assessment and conservation action. A full report on the modelling work is included on pages 36 – 44. In addition, a conference was held immediately preceding the PHVA on the "One Plan Approach to Conservation Planning". This included a mix of formal presentations and practical exercises, and used planning for *ex situ* pangolin rescue centers as a case study. Information and ideas from these sessions also contributed to the PHVA discussions. A summary of information presented by rescue centers is provided in the *Ex situ* Working Group Report (see pages 26 – 33).

The PHVA workshop opened with a welcome from Taipei Zoo and an introduction to CPSG's planning processes. Participants were invited to introduce themselves and to describe at least one priority issue that they would like to see discussed or addressed during the PHVA. This was followed by a series of scene-setting presentations pertinent to the challenge of planning for pangolins in Taiwan:

Scene-setting presentations:

- Status review of Chinese pangolins in Taiwan: biology, ecology, distribution, abundance and threats **(Flora, Hsuan-Yi Lo; Nick, Ching-Min Sun)**
- 2004 PHVA: review of outcomes and other current conservation action **(Jung-Tai Chao)**
- Chinese pangolin conservation and research on mainland China **(Shi-Bao Wu)**
- Involvement of Taipei Zoo with pangolins **(Jason, Shih-Chien Chin)**
- IUCN SSC Pangolin Specialist Group: Global Action Plan for pangolins **(Dan Challender)**
- IUCN SSC CPSG Conservation Planning Tools: *VORTEX* and Population Viability Analysis **(Kathy Traylor-Holzer)**

A visioning exercise involving all delegates followed. The purpose of this was to develop main themes for an inclusive VISION STATEMENT that would describe a desirable but also realistic future for pangolins in Taiwan. A small visioning group took these themes and built a statement that was unanimously adopted by participants on the second day.

Having completed the visioning exercise, participants worked to describe the threats or obstacles to achieving this vision, with consideration given both to existing and potential threats. Participants were encouraged to identify those threats directly impacting pangolins, their root causes, and the relationships among them. The full set of threats considered is illustrated in Figure 1.

Three working groups were formed around the main themes that emerged from this exercise: 1) Population biology, distribution and wild status; 2) Habitat improvement issues and direct threats from humans; and 3) *Ex situ* management. Groups were assigned a series of tasks and timelines but otherwise

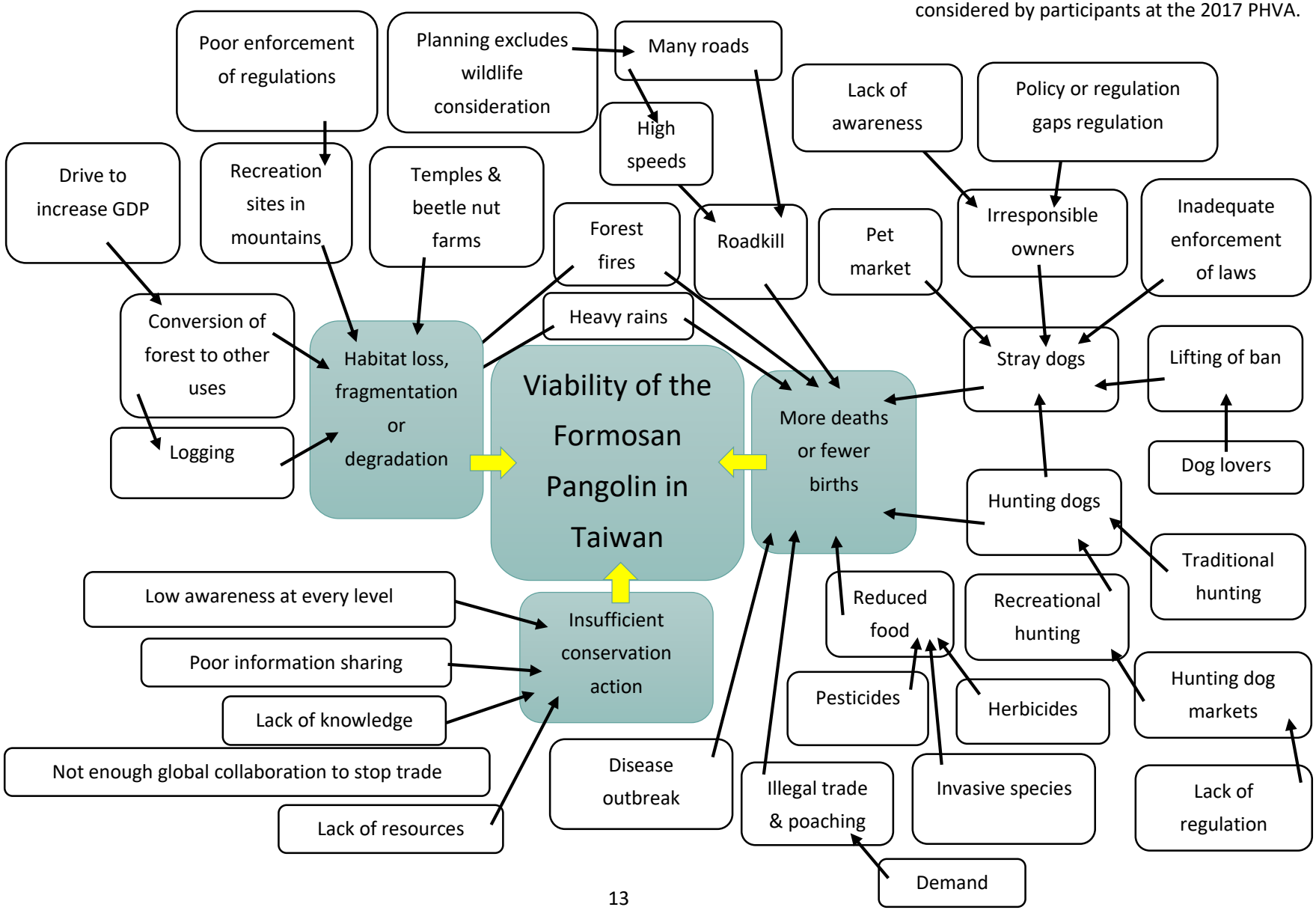
managed their own work, with the help of designated Taipei Zoo facilitators. The *Ex situ* group was tasked with working through the steps in the *IUCN SSC Guidelines on the Use of* Ex situ *Management for Species Conservation* (IUCN SSC 2014), which are to: 1) review the status and threats to the wild population; 2) identify the potential role(s) that *ex situ* management might play in Formosan pangolin conservation to reduce the impacts of these threats; 3) determine the characteristics of the *ex situ* population or program needed to fulfil the identified potential conservation role(s); 4) define the resources and expertise needed and appraise the feasibility and risks; and 5) decide which role(s) to pursue. The group then developed actions aimed at implementation of the recommended *ex situ* programs.

The other two working groups discussed, described and prioritized the issues that fell within their designated theme. For each issue, groups attempted to determine what is known, what is assumed, and what needs to be known for effective conservation to be undertaken. Objectives were agreed to address each of the issues defined and were prioritized by all PHVA participants using a simple prioritization scheme. Finally, actions were identified to achieve the agreed objectives.

On the final morning of the PHVA, participants discussed an implementation framework for the actions recommended, and an editing team was formed to develop the written workshop report and action plan.

Immediately following the workshop, the PHVA findings were presented and discussed at a smaller meeting of key representatives from the PHVA and from the main collaborating organizations: Taipei Zoo, Forestry Bureau of Council of Agriculture, Executive Yuan, and the Endemic Species Research Institute. This group used the PHVA recommendations to finalize a National Strategy and Action Plan for the Formosan Pangolin, which is described in Part II of this document (pages 46- 61.).

Figure 1: Existing and potential threats to the viability of pangolins in Taiwan considered by participants at the 2017 PHVA.



WORKING GROUP REPORTS

WORKING GROUP 1. POPULATION STATUS, BIOLOGY, DISTRIBUTION AND WILD STATUS

Participants:
Dan Challender; Jung-Tai Chao; Wei-Ren Cheng; Watabe Hirofumi; Nian-Hong Jang-Liaw; Chung-Hao Juan; Dung Le; Bei-Shan Lee; Ling-Ling Lee; Jin-Ting Liu; Sophia, Shu-Hsuan Shen; Nick, Ching-Min Sun; Tulshi Laxmi Suwal; Shan-Ta Tao; Cindy, Ming-Shan Tsai; Die-Hua Tsai; Wing Tsui; Shelly, Hsuan-Ya Yu

Facilitator: Nian-Hong Jang-Liaw; **Computer recorder:** Cindy, Ming-Shan Tsai; **Time keeper:** Ling-Ling Lee
Presenter: Wing Tsui

Complete list of brainstormed issues: Lack of sufficient knowledge or information about the following: population size, density, range; demographic parameters, meta-population structure and dynamics; species distribution; carrying capacity of the environment; genetic characteristics (subspecies/species status, gene diversity and its distribution in Taiwan); behavior (including dispersal patterns, breeding behavior, etc.); disease; physiology.

ISSUE: STATUS OF INFORMATION ABOUT FORMOSAN PANGOLINS

Relatively little is known about the Formosan pangolin. This lack of knowledge makes it difficult to establish the risk status and population trends of the species in Taiwan, to identify the causes and impacts of potentially threatening processes that exist in pangolin environments, and, therefore, to understand what kinds of conservation action might be needed, if any. Factors contributing to this lack of knowledge are: a lack of resources and capacity to do research; a lack of integration between existing research initiatives; the inherent difficulties involved in studying the species; the fact that the pangolin is not a high priority species in Taiwan; a disproportionate focus on *ex situ* research; and a lack of linkages between *in situ* and *ex situ* research.

Key knowledge gaps fall into four main areas. These are described below, along with the implications for pangolin conservation and objectives aimed at filling those gaps, all agreed by the group.

Sub-issue 1. Lack of knowledge of wild Formosan pangolin meta-population structure and characteristics

Greater knowledge of pangolin meta-population characteristics could help to identify vulnerable population fragments for conservation attention such as the placement of habitat corridors. It may also help the establishment of rescue and release protocols by helping to better identify the origins of specimens and to choose appropriate release sites.

Included within this are the following:

1. Meta-population size
2. Sub-population number and size (it is assumed that population sub-division for pangolins will follow a similar geographic pattern to that of other species in Taiwan. Genetic analyses show that differentiation in the north is consistent with this, but sampling elsewhere is not yet sufficient to confirm the boundaries of any sub-populations in the south, central and eastern regions.)
3. Population trends (i.e. increasing, stable or declining, and by how much, over time)
4. Connectivity (gene flow between sub-populations)
5. Key demographic parameters:
    a. fecundity measures: proportion of females breeding each year and inter-birth interval, and the extent to which these are influenced by age or nutrition
    b. mortality rates for adult females (under "normal" conditions in the wild) and, ideally, their main causes
6. Dispersal behavior

Sub-issue 2. Lack of understanding of habitat quality and quantity in the wild, for Formosan pangolins

Little is known about the habitat requirements of Formosan pangolins in the wild. As a result of this lack of knowledge it is difficult to predict where good habitat is distributed and how much of it exists. Further, it is difficult to know whether pangolins are currently living in their ideal habitat, or have been excluded from it and have moved instead to less favourable habitat types. In addition to other problems, these data gaps increase the difficulty of identifying suitable release sites with confidence.

In summary, there are key data gaps in the following areas:

1. Habitat requirements
2. Ideal versus actual habitat
3. Availability of suitable habitat
4. Distribution of suitable habitat
5. Methods for assessing quantity and quality of habitat
6. Suitable habitat for release programs

Sub-issue 3. Lack of understanding of wild pangolin health

Little is known about the health status of pangolins in the wild. Without a good understanding of the "normal" health status of pangolins (both individuals and populations), it is difficult to anticipate, identify and manage problems if or when they occur. More information is required in the following areas:

- Infectious disease (virus, bacteria, fungus, parasite)
- Non-infectious disease and other conditions (trauma, nutrition, endocrine, stress, toxic, genetic)
- Identification and prioritization of those diseases or conditions that have the most impact on survivorship
- Impact of environmental toxins
- Zoonoses

Sub-issue 4. Taxonomy and classification of Formosan pangolins

The Formosan pangolin is currently classified as a subspecies of the Chinese pangolin. Whether it is classified as a subspecies or as a species has implications for its conservation management. Molecular studies can help to understand the degree of difference between Formosan and Chinese pangolins, and to help determine whether subspecies or species status is more appropriate.

Table 1 summarizes what is known about Formosan pangolin populations, their biology, distribution and wild status, what is assumed about them, and where there are important information gaps of conservation relevance.

OBJECTIVES:

- To understand meta-population structure and characteristics in wild Formosan pangolins.
- To understand habitat quality and quantity for wild Formosan pangolins.
- To understand the general health condition of wild Formosan pangolins.
- To confirm the taxonomic status of the Formosan pangolin.

WORKING GROUP RECOMMENDATIONS

The working group recommended taking the following action to ensure the collection of priority information over the coming years:

Action: Form a Formosan pangolin working group to coordinate research and conservation.

Timeline: First meeting of this new Research Working Group to be held in April 2018

The working group would address the following areas:

- drafting research strategies to fill identified knowledge gaps (by 31 September, 2018)
- integration of *in situ* and *ex situ* conservation actions and information (by 31 December, 2018)
- standardization of research protocols and methods to make sure the information we need is collected from rescued animals (by 31 December, 2019)
- coordination of sample exchange between institutes, including Taipei zoo, museums and rescue centers (e.g. specimens, faeces, bloods) (by 31 December, 2019)
- establishing training courses/capacity building, especially in population monitoring (no specific timeline)

Recommended lead agencies: Endemic Species Research Institute (research); Forestry Bureau of Council of Agriculture, Executive Yuan (conservation)

Potential collaborators:

Rescue centers: 臺北市立動物園野生動物檢疫救傷中心 Wildlife Quarantine Rescue Center, Taipei Zoo; 特有生物研究保育中心野生動物急救站 Wildlife First Aid Station, Endemic Species Research Institute;

屏東保育類野生動物收容中心 Pingtung Rescue Center, National Pingtung University of Science and Technology

Government agencies: 行政院農業委員會林務局 Forestry Bureau, Council of Agriculture, Executive Yuan; 內政部消防署 National Fire Agency, Ministry of the Interior; 內政部警政署保安警察第七總隊 The Seventh Special Police Corps, National Police Agency, Ministry of the Interior; 臺灣國家公園 National Parks of Taiwan; 各縣市政府 County and City governments

NGOs: **路殺社** Taiwan Roadkill Observation Network; **野生動物追思會** Wildlife Concern of Taiwan; **台北動物園保育教育基金會** Taipei Zoological Foundation; **野灣野生動物保育協會** WildOne Conservation Association; **金門縣野生動物救**暨**保育協會** Kinmen Wildlife Rehabilitation and Conservation Association

Zoos: 臺北市立動物園 Taipei Zoo; 新竹市立動物園 Hsinchu Zoo; 六福村主題遊樂園 Leofoo Village Theme Park; 高雄市壽山動物園 Shou Shan Zoo

Academic institutes: 國立臺灣大學生命科學系 National Taiwan University, Department of Life Science; 國立臺灣大學動物科學技術學系 National Taiwan University, Department of Animal Science and Technology; 國立中興大學昆蟲學系 National Chung Hsing University, Department of Entomology; 國立中興大學生命學系 National Chung Hsing University, Department of Life Sciences; 國立彰化師範大學生物學系 National Changhua University of Education, Department of Biology; 國立屏東科技大學野生動物保育研究所 National Pingtung University of Science and Technology, Institute of Wildlife Conservation; 中國文化大學動物科學系 Chinese Culture University, Department of Animal Science

Ecological Consultant: 觀察家生態顧問有限公司 Observer Ecological Consultant Co., Ltd; 羽林生態股份有限公司 Feathered Forest Ecological Work Co. Ltd.

Table 1: Summary of the current status of knowledge of Formosan pangolins in Taiwan.

	Facts	**Assumptions**	**Knowledge gaps**
Demographic parameters	Sex ratio: 1:1 Life span: 12 yrs (wild), 20 yrs (captive) Initial reproductive age: 2 (wild female); 2.5 (captive female) Litter size: 1 Maternal dependency: 6 months (Sun, unpublished data from wild)	Mortality for juveniles: 42% (wild; n=7), (Sun, unpublished data); Breeding intervals: 1 year (wild), (Chang, 2014)	• Age or life-stage specific survival/mortality rates • Fecundity • Initial reproductive age: male • End of reproduction age: both genders
Molecular genetic information	There are three institutes (Taipei Zoo, Endemic Species Research Centre and Pingtung university) that preserve DNA or tissue samples of Formosan pangolin. Some museums, like the National Museum of Natural Science, might keep some samples as well.	Formosan pangolin is a subspecies of the Chinese pangolin species.	1) Formosan pangolin subspecies status – is it a species or a subspecies? 2) Gene diversity: seven MHC loci showed low genetic diversity (n=92) (Liu, 2017). However, recent studies in mitochondria DNA (n=88) (Wang, 2007) and microsatellite markers (n=92) (Wu, 2015; Liu, 2017) both showed that there may not be low genetic diversity of these samples. The reasons why these genetic markers show contradictory results needs further study.
Behavior	Diet/ feeding behavior Maternal care Home range Polygyny (have polyandry case rarely 一夫多妻為主，偶有一妻多夫) Activity patterns Burrowing behavior	Mating season is around spring. (from captive data, Zhang, 2016; from wild, Sun, unpublished data)	Territory: • Are pangolins territorial? • For both sexes? • Seasonality pattern? • Age to establish territory?
Population size	-	Factors from which population size might be inferred: • Geographic range • Density • Number of populations	• Total population size • Population sizes for any discrete populations/population fragments.

	Facts	Assumptions	Knowledge gaps
Carrying capacity/ distribution	Burrow site conditions: from 294 burrows around Taipei Feitsui Reservoir Mean slope: 32.5±15.4° Soil type: The percentage of slit and clay of soils in the study site was all over 80%, which was classified as clay or loam. (Fan, 2005)	-	Fundamental niche/ realized niche Microhabitat
Disease	• Check list of parasite and bacteria • Hematology • Serum biochemistry • Basic clinical findings (Khatri-Chhetri, Sun, Wu, &Pei, 2015; Mohapatra, Panda, Nair, &Acharjyo, 2016)	Respiratory and gastrointestinal infection found over 50% cases (pathological reports in Taipei Zoo)	• Disease priorities • Impact (mortality, morbidity) • Epidemiology (transmission modes) • Diagnosis • Treatment • List of viruses (coronavirus, avian influenza virus)
Physiology	Growth rates: From studies on juveniles (less than 1 year old): • For body mass, captive data only (n=1) (Wang et al., 2012). • For body length, from wild (n=1) (Sun, 2017) and from captive (n=1) (Wang et al., 2012) • Study on sub-adult and adult individuals of wild pangolin (n=35) (Pei et al., 2015 conference proceeding)	-	• Nutrition requirement (in captivity) • Impact of climate change • Pesticide impact • Hormones (endocrinology)
Metapopulation	-	There is a northern sub-population	• Presence and rates of gene flow • Boundaries between sub-populations (actual area of populations)

WORKING GROUP 2. HABITAT IMPROVEMENT ISSUES AND DIRECT THREATS FROM HUMANS

Participants:
Bharti Arora; Joann Chang; Ying-Yu Chen; Chun-Jen Hsiao; Jim Kao; Leo, Chih-Shang Lee; I-Lung Lee; June, Ngo-Hei Leung; Hou-Feng Li; Ching-Lung Lin; Pei-Chen Lin; Wei Ting Liu; Hsien Keng Peng; Joyce Voon; Shao-Yi Weng; Yi-Shuang Yu

Facilitator: Jim Kao; **Computer recorder:** Bharti Arora, Joyce Voon; **Time keeper:** Joyce Voon, Hsien Keng Peng; **Presenter:** June Leung

Complete list of brainstormed issues: stray dogs, hunting dogs, roadkill, human development (conversion of land for human use), traps, lack of food, illegal trade (potential threat), heavy rain, forest fire (potential threat), logging (potential threat)

ISSUE 1. CONVERSION OF LAND FOR HUMAN USE

The conversion of land for human use in areas where pangolins live reduces overall pangolin abundance by removing, fragmenting, disturbing or degrading pangolin habitat and, in some cases, by directly killing pangolins.

Examples of potentially harmful land uses considered by the working group were: urbanization, conventional farming with pesticides and herbicides, transport construction (e.g. roads), water body management, and recreation (e.g. Taiwan has 1700 camping sites mainly located in Central and Northern Taiwan). In addition to their impact on habitat: road development leads directly to roadkill; there are recorded instances of pangolins in urban areas becoming trapped in items of human rubbish; and encroachment by humans is known to be accompanied by an increase in the number of stray dogs, which are known to attack and injure pangolins. It is assumed that some land use changes may be accompanied by an increase in the number of pangolins caught in traps or hunted as “by-catch” (for example agriculture-related wildlife damage control).

For the Formosan pangolin, the two biggest challenges were considered to be conventional agriculture and transportation construction (e.g. roads).

Priority information gaps:

1. Formosan pangolin habitat requirements and distribution
2. Impacts of different types of human activities in pangolin habitat, on pangolin presence and density
3. Impacts of different types of land use conversion for human use, on pangolin presence and density

ISSUE 2. STRAY DOGS

Taiwan has a large stray dog population (128,473 stray dogs in 2015 estimation; (https://animal.coa.gov.tw/html/index_06_0621_dog.html). Stray dogs are known to kill and injure pangolins in Taiwan. It is assumed that the actual number of cases is much larger than the number

reported (e.g. by rescue centers). It is assumed that stray dogs may carry diseases (e.g. canine distemper) and parasites (e.g. ticks) that are harmful to wildlife (including pangolins), and that pangolins may pass diseases to stray dogs as a result of close contact. At present not enough is known about these potential risks. It is not known to what extent the distribution of stray dogs overlaps with the distribution of pangolins.

The reasons why Taiwan has such a large population of stray dogs include: irresponsible breeding by pet store managers; poor enforcement of existing laws; irresponsible owners; problems with the Animal Protection Act, including lack of comprehensiveness of the law, poor law enforcement, and lack of co-ordination among related policies (for example, a ban on euthanasia of stray dogs has not been accompanied by an increase in resources for housing them); animal lovers who think that dogs should be free to roam Taiwan's forests; and a general lack of public education and awareness about this issue. It is assumed that movies such as "Pet" may also influence those who are against stray dog control.

Priority issues were agreed to be irresponsible dog owners, stray dog lovers and the lack of public education.

Priority information gaps:

1. Effect of stray dogs on the wild pangolin population
2. Extent to which the distribution of stray dogs overlaps with the distribution of pangolins
3. Whether rabies affects pangolins, and whether they are a potential carrier

ISSUE 3. ROADKILL

There are many roads in areas where pangolins live, and pangolins are killed and injured by road traffic. It is assumed that the numbers reported (62 individuals from 2011 to 2018 Sept, Taiwan Roadkill Observation Network) underestimate the total number of pangolins affected. According to the roadkill statistics, there is a slight bias towards young males. We assume that males of dispersing age are most affected and this could disturb the age structure and sex ratio in areas where roadkill is high, but the likelihood of this is not known. Roads cut through pangolin habitat, fragmenting and isolating populations. It is assumed that this exposes these populations to additional risks.

Conditions that lead to roadkill include: the high density of roads and lack of integrated road planning; failure to include consideration of wildlife in road and city planning; and speeding in forest areas. Of these, failure to include consideration of wildlife in road planning was agreed to be the most important factor.

Priority information gaps:

1. Frequency of pangolin roadkill and where it occurs
2. How to prevent pangolin roadkill

ISSUE 4. TRAPS AND HUNTING DOGS

Pangolins are not a primary focus of hunting in Taiwan; however, they are killed and injured as "by-catch" by traps and hunting dogs. There are thought to be differences in hunting pressure in the North and South of Taiwan, but there is no concrete evidence for this.

Hunting using traps or dogs is known to take place in Taiwan for the purpose of agricultural wildlife damage control and for recreation. It is also assumed to take place as part of traditional hunting culture. There are thought to be a large number of hunting dogs in Taiwan associated with hunting dog training businesses. Though the Wildlife Protection Act should protect wildlife from these threats, it is poorly enforced and contains loop-holes that can be exploited (for example, it is legal to use hunting dogs to hunt wild pigs to protect crops, but in the process of this other species may be killed or injured).

Priority information gap:

1. Frequency with which pangolins are killed by traps or hunting dogs, and where it occurs

ISSUE 5. LACK OF FOOD RESOURCES

Termites and ants are the primary source of food for pangolins. It is assumed that when these are in short supply mortality will increase as pangolins travel further to find food and are more likely to encounter roads, hunters, predators and other threats.

Food supply is reduced by clearing forest beds and changes in the landscape that affect the composition of ants and termites. It is assumed that the introduction of invasive ant species and the use of pesticides and herbicides could also affect the composition or abundance of termites and ants.

Changes in the landscape were considered the most important issue affecting food availability for pangolins.

Priority information gaps:

1. Which ant and termite species are mainly used by pangolins
2. How pangolins are affected by their food resources (mortality, home range, reproduction, etc.)

ISSUE 6. ILLEGAL TRADE (DOMESTIC AND INTERNATIONAL)

Outside Taiwan, poaching for illegal trade is the most pressing threat to the survival of pangolin species in the wild. Within Taiwan, illegal trade is not a current threat to pangolin populations, though this could change as pangolin species become increasingly scarce in other parts of their range.

Trade is driven by demand for meat, and for scales and parts that are used in Traditional Chinese Medicine and in ornamentation. There is a market for Traditional Chinese Medicine in Taiwan. Wildlife Conservation Act prohibits selling conservation wildlife products. It is hard to find pangolin and scales in Traditional Chinese Medicine stores. But there was a case in 2017 that one Traditional Chinese Medicine store was fined by the government due to displaying an old pangolin specimen in stock without reporting it to authorities. At present, global conservation collaboration is not sufficient to mitigate risks to wild

pangolins outside Taiwan. Within Taiwan, lack of public awareness of the situation for pangolins coupled with lack of law enforcement are considered to pose a risk.

Priority information gap:

1. Number and frequency of pangolins caught due to illegal trade

ISSUE 7. HEAVY RAIN

Heavy rain is known to have washed away both animals and habitat causing death and displacement of pangolins. In one case a pangolin was found in the ocean. In the aftermath of heavy rains food source composition may be sufficiently changed for pangolins to have to forage further afield, exposing them to additional risks. It is assumed that climate change will increase the frequency and severity of heavy rains. It is assumed that the impact will be experienced across the whole of Taiwan but evidence is available only for Taiwan's Northern Coast.

Priority information gap:

1. Effect of heavy rain on pangolins and their habitat

ISSUE 8. LOGGING

At present, logging is not a threat in Taiwan as 99% of timber is imported from other countries. The Government intends to open up Taiwan to sustainable harvesting of timber. It is assumed that this will result in habitat loss, fragmentation due to access roads, changes on pangolin food quality and composition, and some direct killing of pangolins due to increased access to forest by humans.

Priority information gaps:

1. How pangolins are distributed in logging areas
2. How logging affects pangolin habitat in terms of food resources and burrows

ISSUE 9. FOREST FIRE

Forest fires are not a major issue in Taiwan but they do occur. It is assumed that they are caused by people during camping or mountain climbing trips, during the Sky Lantern Festival, during tomb sweeping or during other religious activities (e.g. paper burning). Where fires occur it may affect pangolins through loss of habitat, impacts on food source composition and quality, and direct death or injury.

Priority information gap:

1. Frequency of forest fire and where it occurs

WORKING GROUP RECOMMENDATIONS

Objective 1. To understand and quantify how each of the threats identified affects pangolin populations and their conservation in Taiwan.

Ranking: Urgent 2

Actions:

1. Review existing information on impact and distribution, for each threat identified (land use, stray dogs, roadkill, traps, lack of food, hunting dogs, illegal trade, heavy rain, forest fire and logging).
2. Map the distribution of these threats and compare it to the known distribution of pangolin populations.
3. Initiate research to fill the knowledge gaps identified in Actions 1 & 2.

Objective 2. Ensure that laws governing the welfare of individual animals and those governing the conservation of wildlife are sufficiently comprehensive and well-enforced, and that related policies work in support of each other.

Ranking: Urgent 1

Actions

1. Review the relevant laws, identify problem areas and list stakeholders at each level (Animal Protection Act, Wild Animal Protection Law, Environmental Impact Assessment Act).
2. Petition for change where needed.

List of stakeholders that are concerned about the issues of animal welfare and wildlife conservation-relevant laws in Taiwan:

1. Environmental Jurists Association
2. Wild at Heart Legal Defense Association, Taiwan
3. Taiwan Society for the Prevention of Cruelty to Animals
4. Environment and Animal Society of Taiwan (EAST)台灣動物社會研究社
5. Legislators who involve in wildlife conservation
6. 台灣狩獵研究會(about the rights of hunters)
7. Faith for Animals 台灣懷生相信動物協會

Objective 3. To enhance public awareness, direct targeted behavior change campaigns at priority audiences, and ensure that public education is carried out in the right way, by the right people.

Ranking: Important 2

Actions

1. Add pangolin conservation information to Taipei Zoo's Outreach Programme (especially for schools near pangolin habitat and places where roadkill occurs).
2. Publish a children's book about pangolins
3. Produce a suitable educational channel (such as a YouTube Channel or Facebook Fan Page) for local committees and Taipei zoo (to study the audience composition and feedback to conservation education planning.)
4. Create a network for local educators operating near roadkill hotspots and near pangolin habitat.

Objective 4. To identify and implement measures to protect pangolins and encourage co-existence with humans, both in natural and in human modified habitats.

Ranking: Important 1

Note: Working Group 2 prioritized the need to improve understanding of habitat suitability and distribution with regard to pangolins. This objective will rely on that information gap being filled in the first instance.

1. Find and implement tools or methods to reduce the effect of each threat (based on the priority assigned).
    a. Create more specific trap or methods to control wildlife damage in farmlands.
    b. Create proper guidelines of animal-friendly crossroads or paths.
2. Establish a network for conservation of pangolins and other lowland endangered species, such as leopard cat and box turtle.

WORKING GROUP 3: *EX SITU* MANAGEMENT

Participants:

Laura Benedict; Ya-Ting Chan; Chloe, Yu-Chia Chang; Tina, Ting-Yu Chen; Brandon, Po-Han Chou; Alex Grioni; Jimmy Lee; Jocy, Yu-Wen Lee; Chu-Hong Liao; Flora, Hsuan-Yi Lo; Thai Van Nguyen; Craig, Jian-Bo Wang; Shi-Bao Wu; Bencharong Sangkharak; Boripat Siriaroonrat; Warisara Thomas

Facilitator: Tina Chen; **Computer recorder:** Craig Wang ; **Time keeper:** Chole Chang ; **Presenter:** Warisara Thomas

INTRODUCTION

The 2017 Formosan Pangolin PHVA workshop was preceded by a one-day conference on the "One Plan Approach" to conservation planning. During the afternoon, presentations were given by representatives from centers dealing with rescued pangolins in Hong Kong, Nepal, Sabah (Malaysia), Thailand, and Vietnam, as well as from rescue centers in Taiwan (see Table 2 for a summary of information provided). Following these presentations, those present discussed in more detail the routes through which pangolins arrive at rescue centers, what happens to them afterwards, and what the major challenges are to rescuing, rehabilitating and releasing pangolins. They also discussed the role that this plays, or could play, in the conservation of pangolins. Information from this session was used by the *Ex Situ* Management Working Group during the PHVA workshop to discuss and agree the conservation role of *ex situ* management in Taiwan, the challenges to doing this effectively, and a plan for what needs to be done.

The working group followed the decision process outlined in the IUCN SSC *Guidelines for the Use of* Ex Situ *Management for Species Conservation* (IUCN 2014). This included examining the threats developed in plenary; identifying potential conservation roles; identifying what those programs should look like (components); examining the costs, risks and feasibility of each program; and deciding on which roles/programs to recommend, specifying further actions as time allowed.

Three potential conservation roles were identified for *ex situ* management of Formosan pangolins in Taiwan: rescue, rehabilitation and release; *ex situ* research; and *ex situ* conservation insurance.

RESCUE, REHABILITATION & RELEASE

While rescue, rehabilitation and release is not *ex situ* conservation role in itself, it is an *ex situ* management activity that may help reduce the loss of pangolins from the wild by returning rehabilitated injured or confiscated pangolins to the wild (when appropriate).

Definitions:

Rescue: in this context means the active (e.g. confiscated) or passive (e.g. donated by members of the public) acquisition of healthy or injured Formosan pangolins by authorities responsible for the care or management of wildlife. This is the rescue of individuals and is not the same as a "rescue population" as defined in the IUCN ex situ guidelines (IUCN 2014).

Rehabilitation: the process of restoring the health and condition of unfit rescued pangolins for potential future conservation purposes.

Release: the process of returning fit rescued Formosan pangolins back into suitable habitats in Taiwan, which may benefit the wild Formosan pangolin population. If the animal is confiscated from other countries, the release also includes the possibility of population reinforcement for Chinese pangolin populations outside of Taiwan with very cautious assessment. The animals that are not suitable for release may be used for other conservation purposes (such as research, education or insurance)

Program scope: The institutions of Wildlife Rescue Program in Taiwan

Potential conservation benefit: HIGH

Ideal program components:

- One professionally managed rehabilitation program, comprising a network of rescue centers with dedicated capacity for pangolins, used efficiently (new program)
- Maximum capacity to hold 30 pangolins at a time/ 50 per year
- Continuous government support, secure funding and collaboration, both with government and among centers
- A clear mandate from the Government
- Veterinary treatment protocols and guidelines
- Advanced knowledge of husbandry and medical treatment
- Trained personnel
- A first response team for fast rescu.
- Post-release monitoring programs to assess survival
- One additional new rescue center established in the eastern coastal area
- Continuous government support for a first response team/facility
- A dedicated wildlife hot line!
- Release training: fill knowledge gaps relating to the impact loss of a limb has on an individual's ability to survive in the wild.
- Disease assessment
- Supportive policies and action from government.
- Fill knowledge gaps about habitat requirements to help in identifying suitable habitat for release.
- International cooperation

Risks:

- Institutional conflict (institutions may compete with each other for resources)
- An increase in the number of confiscated pangolins (that would exceed available capacity)
- Lack of long-term government funding to allow longer-term planning
- High staff turnover, which makes investment in training hard to justify
- Lack of integration of rescue and research activities. Each county or city currently has its own system and can cause difficulties
- Increase in the need to house non-native pangolin species (which may introduce disease)
- Disease transmission among resident rescued or confiscated animals and the risk of transmitting this to other wild populations

Current challenges:

- Limited willingness to collaborate
- Limited manpower

- Lack of knowledge (husbandry, medical treatment, nature and details of pangolin trade in Taiwan, release site location and suitability)
- Unstable government funding, support and awareness
- Lack of equipment and resources
- No first response team.

Likelihood of Success: MEDIUM to HIGH (if the value of the program can be communicated to the Government)

EX SITU RESEARCH

Definition:

To conduct studies on the *ex situ* population to better understand the Formosan pangolin in every aspect, in order to benefit both *ex situ* and wild populations.

Program scope:

- Nutrition and husbandry
- Biology, physiology and behavior
- Disease and health
- Genetics
- Welfare
- Reintroduction/release and monitoring
- Human dimensions
- Good research management

Potential conservation benefit: HIGH

Ideal program components:

- Good academic partners
- Dedicated full time research staff
- Equipment and funding
- A long-term program
- A network of experts
- Guidelines on welfare and ethics

Risks:

- Pangolin abuse
- Disease outbreak
- Purpose of research is unclear
- Discontinuity of support and funding
- Objections from animal rights groups

Challenges:

- Funding, equipment and human resources
- Lack of communication and data sharing
- Willingness to collaborate
- Unclear research goals

Likelihood of Success: MEDIUM (if there is good collaboration and good data quality)

Table 2: Summary of information provided by rescue centers in Hong Kong, Nepal, Sabah (Malaysia), Thailand, Vietnam and Taiwan, prior to the PHVA workshop.

	Pangolin Species	**Local threats**	**Conservation Activities**	**Number rescued**	**Outcomes**	**How do they arrive in centers**	**Challenges**
Nepal	Chinese & Indian	• Poaching for meat & traditional medicine • Dog attacks • Habitat loss • Forest fires • Cattle grazing • Road development	• Awareness programs in schools and in communities • Conferences • Radio program. • Outreach materials	34 since 2000, 24 were Chinese pangolins	Some are maintained in captivity, some are released.	Confiscated from outside protected areas and brought to a local facility where transferred to final destination?	• Handling techniques • Rescue techniques • Lack of rescue and long-term *ex situ* capacity • Release techniques • Lack of post-release monitoring • Lack of trained manpower
Vietnam	Chinese & Sunda	Mainly poaching for trade in meat & Chinese Traditional Medicine but also for wine.	• Holistic approach • Habitat protection • Conservation Research • Wildlife rescue • Education & outreach • Advocacy – training enforcement staff	Increased from 8 in 2006 to 291 in 2017.	Released after treatment where possible.	Confiscations of poached specimens ranging in size from a few individuals to hundreds.	
Sabah, Malaysia	Sunda	• Trade • Dog attacks • Note trend in tourists coming to Sabah to eat pangolin there (this may reduce the number trafficked out?)	• Public awareness • Research • Aiming to upgrade pangolin to Schedule 1 of Wildlife Conservation Enactment 1997 to increase punishment from a fine to a larger fine plus mandatory incarceration of 5-6 months. • Undercover work to expose and prosecute traders.	58 in total over the last 3 years – most confiscated rather than surrendered.	If they survive they are generally released but for confiscated specimens this requires a court order as they are sometimes needed as evidence.	Confiscation (e.g. at road blocks) or surrender. Not the same all year round. In the dry season animals wander into built-up areas, people pick them up and report them to the agency. Often they are picked up and immediately released. Also dog attacks.	• No dedicated facilities for rescued pangolins. • Penalties currently too small. • Carrying capacity only 20-30 (can hold up to 100 if really needed). • Feeding difficulties • Background information about the animal (when and how it was captured, when it last ate etc.) • Treatment

	Pangolin Species	Local threats	Conservation Activities	Number rescued	Outcomes	How do they arrive in centers	Challenges
Thailand	Chinese Sunda	Trafficked into Thailand for meat and scales.	Classified as "Protected Wild Animals"	2617 confiscated over last 3 years		Trafficking seizures are sent to the wildlife breeding division – 25 breeding centers (3 keep pangolins) and 1 quarantine center.	No dedicated facilities
Taiwan	Chinese pangolin	• Poaching for meat & traditional medicine • Dog attacks • Habitat loss	• Public awareness • Research • Enforcement Rules of the Wildlife Conservation set up in 1989, pangolin is listed in Schedule 2.	523 in total over the last 10 years –mostly are trauma, some orphans, and confiscate are very few.		People pick them up and report them to the agency by rescue report system.	• Feeding difficulties • Lack of suitable habitat to release • Rescue report system and SOP depends on Counties and cities • Lack of post-release monitoring
Hong Kong	Chinese pangolin	Stray dogs	Public awareness Outreach	12	9 were released 1 was radio tracked	Delivered by SPCA	• Radio-tracking • Unknown population size • Feeding difficulties

EX SITU CONSERVATION BREEDING PROGRAM

Program definition and scope:

A viable *ex situ* Formosan pangolin breeding population, maintained for the purpose of insurance against severe decline or extinction in the wild, and founded using retained individuals from rescue operations.

Potential conservation benefit: HIGH

Ideal program components:

- Gene bank of retained individuals
- Sufficient space and housing for living animals
- Includes ONLY rescued pangolins that cannot be released
- Well-established long-term population management
- Strong relationship with the research program, mainly reproductive research
- Awareness of the importance of conservation breeding in the retained population
- Strong welfare policy/guidelines

Risks:

- Disease outbreak due to increased density of animals.
- Promotion of pangolin farming (the knowledge gathered and success of this *ex situ* program could be misused by someone intending to set up a pangolin farm. It is happening in China now. We do not want to help these initiatives).
- Inbreeding depression if the population is not genetically managed, or if access to wild-caught animal stops, and breeding continues

Challenges:

- Lack of capacity (space, money, manpower)
- Funding
- Knowledge of reproductive biology
- Lack of new genetic lines
- Lack of detailed knowledge about how to provide for good welfare

Likelihood of Success: MEDIUM

RECOMMENDATIONS

Rescue, Rehabilitation and Release

Action 1. Hold a workshop to bring the three rescue centers together: 1) to develop long-term communication; 2) to share and agree Standard Operating Procedures (SOPs); 3) to discuss the necessity of a 4th rescue center in the East; and 4) to agree on how the post-release monitoring program will be done.

Action 2. Produce first draft of Rescue, Rehabilitation and Release Guidelines within one year: to include husbandry, welfare, and SOPs. Review periodically (every three years).

Action 3. Fund-raise to secure NGO and government support.

Action 4. Redistribute or reassign capacity. Maximize funding, manpower, space, and knowledge.

Action 5. Circulate a questionnaire to communities to help identify suitable release habitat (in collaboration with members of the research forum).

Action 6. Promote community and public awareness to prevent inappropriate capture and sending of pangolins to rescue centers.

Action 7. For the three rescue centers, launch ongoing in-house and off-site capacity building programs, training courses, site visits, and staff exchanges.

Action 8. Improve Government-operated wildlife hotline through better SOPs and, if sufficient response capacity can be established, make it operational 24-hours a day. (Note: existing hotline 0800000930)

Action 9. Write a report on the PHVA outcomes to the Government, together with the rescued animal data from the existing 3 rescue centers, to help with fundraising.

Ex Situ Research

Action 9. Form a specific Formosa pangolin working group, including research /advisory/international groups.

Action 10. Form an ethics committee, including a chair, investigation officers, scientists, non-scientists, veterinarians, members of the public, and ensure compliance with Institutional Animal Care and Use Committee (IACUC) policies and guidelines.

Action 11. Hold an internal meeting to identify and prioritize research topics.

Action 12. Ensure guaranteed funding for pangolin research.

Action 13. Ensure a continuous stream of research.

Action 14. Develop and sign an MOU to ensure data sharing and maintenance of a professional relationship between NGOs and universities.

Action 15. Encourage researchers to do research on pangolins

Action 16. Perform and publish research.

Additional notes:

There are different ways to get funds and to have proposals approved. The Ministry of Science and Technology covers a broad range of topics. The Forestry Bureau of Council of Agriculture, Executive Yuan has more specific topics.

The three rescue centers need to identify a clear goal and practical, viable projects (e.g. related to pangolin health) and propose this to the Forestry Bureau of Council of Agriculture, Executive Yuan. The individual or organization that runs the project needs to be responsible for finding the money. A group should be formed to focus specifically on Formosan pangolin research.

***Ex situ* conservation breeding program**

Action 17. Follow the guidelines (once discussed and approved by 3 rescue centers and pangolin specialists) on the circumstances that should lead to an animal being retained in captivity.

Action 18. Get the three main rescue centers together to allocate the resource: decide who have or is able to obtain the sufficient space and housing for this program.

Action 19. Reference the husbandry guidelines by the Pangolin Specialist Group and welfare committee to establish the enclosure.

Action 20. Start the pangolin gene bank project from animals of three rescue centers' animals(Taipei, ESRI, Pington)

NATIONAL CONSERVATION STRATEGY PLANNING MEETING

8 December 2017, Taipei Zoo

Participants:

Dan Challender; Ya-Ting Chan; Lin-Wen Chang-Chien; Jung-Tai Chao; Hui-Lun Chen; Szu-Lung Chen; Ying-Yu Chen; Yu-Yen Chen; Hsi-Chi Cheng; Wei-Ren Cheng; Jason, Shih-Chien Chin; Jung-Sheng Hsia; Hsin-I Hsieh; Hsiao-Hua Hsu; Wei-En Hsu; Nian-Hung Jang-Liao; Chung-Hao Juan; Jim Kao; Bei-Shan Lee; I-Lung Lee; Ling-Ling Lee; Caroline Lees; Hou-Feng Li; Syun-Huang Li; Jocy, Yu-Wen Lee; Lily Lin; Pei-Chen Lin; Sih-Chen Lin, Chin-ting Liu; Shih-Fen Liu; Flora, Hsuan-Yi Lo; Sophia, Shu-Hsuan Shen; Chih-Chin Shih; Nick, Ching-Min Sun; Wei-Yu Tai; Shan-Ta Tao; Kathy Traylor-Holzer; Die-Hua Tsai; Cindy, Ming-Shan Tsai; Yu-Lin Tsai; Eric, Hsien-Shao Tsao; Shelly, Hsuan-Ya Yu; Craig, Jian-Po Wang; Pao-Jung Wang; Pei-Jung Wang; Shou-Min Wang; Chien-Chu Wu

Chairman: Jason, Shih-Chien Chin; **Computer recorder:** Jim Kao; **Presenter:** Dan Challender; Flora, Hsuan-Yi Lo; Jim Kao

Dan Challender presented the pangolin global action plan. Flora, Hsuan-Yi Lo presented the situation of the Formosan pangolin in Taiwan. Jim reported the action plans of Formosan Pangolin PHVA.

Topics

1. To establish a Formosan pangolin working group to coordinate research and conservation, include population density, habitat, physiology, poaching, etc.
2. Review existing information on impact and distribution, for each threat identified, include stray dogs, land use, traps, hunting, roadkill, logging, etc.
3. Review the relevant laws, include Animal Protection Act, Wild Animal Protection Law, Environmental Impact Assessment Act). Identify problem areas and list stakeholders at each level (the law, coordination and enforcement) to help government to improve the process.
4. To review the wildlife rescue principles and establish a national pangolin rescue standard operating procedure.
5. Look for appropriate routes and materials for pangolin conservation education, especially for people who live near lowland habitat.

CONCLUSION:

1. Establish a Formosan pangolin core group and four working groups to coordinate information and the conservation action plan. Members are mainly PHVA attendees.
    a. Pangolin research group: Coordinated by Endemic Species Research Institute (ESRI).
    b. Pangolin conservation strategy group: Coordinated by Forestry Bureau of Council of Agriculture, Executive Yuan.
    c. Pangolin education group. Coordinated by Taipei Zoo.
    d. Pangolin rescue integration group. Coordinated by Taipei Zoo.
2. Integrate and improve rescue network.
    a. Link rescue institutions such as Taipei Zoo, ESRI, Pingtung Rescue Center, NGOs, and local governments to establish national animal rescue and release SOPs, including rescue

and release criteria, first aid, inspection classification, refuge, transportation, carcass disposal and data collection, to help front-line staff to do rescue work correctly and accumulate data that can help population, disease, threats, animal welfare and research.

b. Taipei Zoo will prepare information and invite the institutions such as local governments to hold a meeting for discussion in April 2018.

c. To establish 24-hr rescue group and hotline.

3. Research

   a. Pursue PHVA-recommended focus on basic biology and habitat. Include population, meta-population, density, threats, hunting, impact of logging, etc.

   b. Develop husbandry, nutrition, physiology, and reproduction research on the *ex situ* population and feed information back to the *in situ* work. Taipei Zoo will follow-up on this.

   c. Pursue PHVA recommendation to establish a working group and network. Submit research priorities before September 2018.

4. Stray dogs

   a. Establish a platform to collect scientific evidence about the impact of stray dogs. Include passive information collection, such as photos and video from rescue centers, and animal resource survey research data and data from NGOs; or initiate information collection for example through monitoring studies.

   b. Invite government administrations such as Forestry Bureau, ESRI, Department of Animal Industry, national parks, and zoos to discuss how to improve the management of stray dogs. Include consideration of the impacts, relevant laws, enforcement, coordination, and resourcing. Forestry Bureau will be the contact point for the meeting.

   c. Promote educational information about the impact of stray dogs and cats. Taipei Zoo will be the contact point for promoting information.

5. Poaching

   a. Invite stakeholders to review the problems on relevant laws, enforcement, coordination, and resource. Discuss how to improve the management of wildlife utilization, traps, or habitat. Help government developing strategies or modifying the law.

   b. There are a lot of Chinese box turtle poaching cases. Pangolins also have potential risk from poaching. Investigation and monitor systems on poaching are already executed. Separated prosecution and telephone monitor are still under amending process.

   c. Design a training course for Judges. Add environment, biodiversity, poaching, and trap issues into logging training course. Education group will follow this and Dr. Jung-tai Chao will help.

   d. Working group edit the information to make it easier for the public to understand. Announce the information through social media or other bulletin board such as PanSci, natural education centers, wuo.bow, etc.

6. All action plans will be evaluated every 5-10 years.

POPULATION VIABILITY ANALYSIS

PVA Modeler: Kathy Traylor-Holzer, IUCN SSC Conservation Planning Specialist Group

The purpose of this Population Viability Analysis (PVA) was to develop a *VORTEX* population model for the Formosan pangolin that could be used to identify those factors that are most critical to population viability, identify important data gaps, and provide a general estimate of future population viability to inform discussions by the PHVA working groups.

The simulation software program *VORTEX* (v10.2.14) was used to conduct the Formosan pangolin PVA. *VORTEX* is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild or captive small populations. *VORTEX* models population dynamics as discrete sequential events that occur according to defined probabilities. The program begins by either creating individuals to form the starting population or importing individuals from a studbook database and then stepping through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, litter size, sex at birth, and survival are determined based upon designated probabilities that incorporate both demographic stochasticity and annual environmental variation. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities. For a more detailed explanation of *VORTEX* and its use in population viability analysis, see Lacy (1993, 2000) and Lacy *et al.* (2017).

Computer modelling is a valuable and versatile tool for quantitatively assessing risk of decline and extinction of wildlife populations, both free ranging and managed. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to evaluate the effects of alternative management strategies to identify the most effective conservation actions for a population or species and to identify research needs. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA). The usefulness of a PVA is dependent upon the quantity and quality of data available on the biology of the species, its current population status, and current and future threats. Limited data mean limited applicability of the results; however, PVA often can provide useful information even with a modest amount of data.

Pangolin model development

Thirteen years ago, a PVA using the *VORTEX* program was conducted as part of the 2004 Formosan Pangolin PHVA. At that time little demographic or census data existed for pangolins in Taiwan. Basic analyses were run using existing data as well as expert opinion on pangolins and general mammalian life history traits. This early model suggested potential future slow decline in the pangolin population but with significant uncertainty around this trend. Several priority research needs were identified,

including investigation of: 1) reproductive and mortality rates; 2) population size, trend and carrying capacity estimation; and 3) genetic structure and degree of connectivity/isolation across Taipei (Chao *et al*. 2005). In the intervening 13 years, some of these data gaps have been addressed while others remain. The 2017 PVA model was developed using data from the 2004 PVA supplemented by additional or more current information from both *in situ* and *ex situ* pangolin populations.

A preliminary *VORTEX* model for wild Formosan pangolin populations on Taiwan was developed prior to the PHVA workshop based on detailed demographic and population data compiled by Taipei Zoo staff in collaboration with the Endemic Species Research Institute (ESRI). Key references included Lin (2010), Chang (2014), Lai (2014) and Zhang *et al*. (2016) as well as unpublished field data (Sun, pers. comm.) and zoo data (Taipei Zoo databases). This preliminary model was reviewed, discussed and revised during the one-day PVA development workshop held immediately prior to the PHVA. Input from this group of pangolin experts led to the final base model that was used during the PHVA as a basis for sensitivity testing and population projections. The model operates on a one-year time step, with projections running for 100 years into the future (200-500 iterations per scenario). The final values used in the baseline model are described below.

Population size and distribution estimates

Due to the difficulty in censusing pangolins, there are no reliable population estimates of wild pangolins on Taiwan. Population size and structure can greatly influence the viability of wildlife populations. Small isolated populations are more vulnerable to stochastic process such as random fluctuation in demographic rates, variation in environmental conditions, and genetic drift (Shaffer 1981). Understanding the approximate size and degree of connectivity of Formosan pangolin populations across Taiwan will help to estimate the vulnerability of this taxon to stochastic processes and its risk of severe decline or extinction.

The 2004 PVA noted that studies suggest four sub-populations on Taiwan. Connectivity among these sub-populations is restricted in some areas by the Coastal Mountain Range (CMR) and by roads and human development (Chao *et al*. 2005). Total population size in 2004 was roughly estimated at 10,200 pangolins, with a habitat carrying capacity of 30,000 (33-40% occupancy of potential habitat).

Lai (2014) used information on preferred pangolin habitat from the CMR in eastern Taiwan to identify environmental predictors of pangolin distribution (elevation, slope, aspect and whole sky light space). Habitat suitability modelling was conducted by Hsiu (National University of Tainan) using MaxEnt based on environmental predictors from Lai and also ESRI occurrence and non-occurrence data to develop a spatial distribution model of potential pangolin habitat across Taiwan (Hsiu, unpublished data).

At the PVA development workshop, Shan-Ta Tao (Wildlife Concern of Taiwan) used occurrence index estimates from Observer Ecological Consultant Co. Ltd. and information from other workshop participants to develop pangolin density estimates for each area (e.g., county, provincial city municipality) in Taiwan. These areas were grouped into four pangolin sub-populations based on molecular data work by Wang (2007), as follows (see map in Figure 1):

NORTH:	Yilan, Keelung, Taipei, Taoyuan, Hsinchu, Miaoli
CENTRAL:	Taichung, Changhua, Nantou, Yunlin, Chiayi, Tainan
SOUTH:	Kaohsiung, Pingtung
EAST:	Hualien, Taitung

The Coastal Mountain Range on the eastern side of Taiwan restricts pangolin movement between the west and east sides of Taiwan, while development especially in the north may provide other obstacles such as roads.

Lai (2014) suggests that pangolins occupy about 30-45% of their potential habitat. The combined data for predicted coverage and density estimates, and assuming 40% occupancy, resulted in rough population estimates for the four proposed sub-populations (Table 1). These estimates are similar to, but are larger than, the 2004 PVA estimates. *These estimates are for PVA purposes only* and should not be considered as reliable Formosan pangolin population estimates.

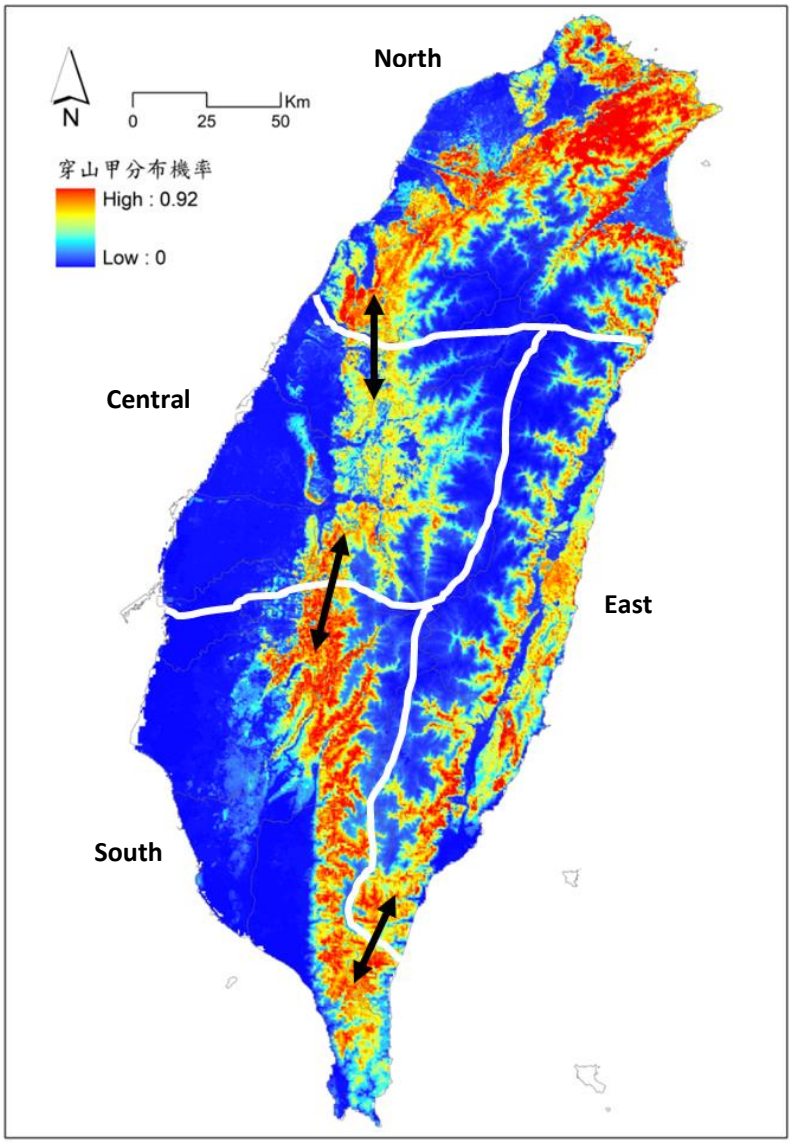


Fig. 1. Map of potential pangolin habitat on Taiwan. White lines indicate the boundaries of the four core population areas, while black arrows indicate estimated connectivity between these areas.

Table 1. Data used to estimate Formosan pangolin populations in the four areas of Taiwan.

Sub-population	Predicted coverage (km^2)	Density (pangolins/km^2)	Population size (100% occupied)	Population size (40% occupied)
North	4023	1.99	8004	3202
Central	2030	3.66	7423	2969
South	1653	0.99	1637	655
East	2572	7.73	19890	7956
Meta-population			36955	14782

Species biology model inputs

Breeding structure and reproductive rates

Pangolins may inhabit the same area for several years, with the home range of males bordering or overlapping the range of several females (Lin 2010; Chang 2014). This social structure was simulated as follows. The mating system was modelled as long-term polygyny such that one male has the potential to mate with more than one female per year. A maximum of 5 female mates per year was set for each adult breeding male; in the model this would only occur with highly female-biased sex ratios. Each year 80% of the adult males are potential breeders while 20% were modelled as excluded from breeding opportunities for that year. Each breeding female was given a 50% chance of mating with the same male as she did the year before and 50% chance of mating with a different male.

While sexual maturity has been observed under a year of age (Zhang *et al.* 2016), the average age of first reproduction was set in the model at age 2 years for females and age 3 years for males (age 3 years was used for both sexes in the 2004 PVA). Not all pangolins begin reproducing at the average age of reproduction set in the model.

It is likely that pangolins do not live as long in the wild as when they are managed *ex situ* with veterinary care, good food availability, and no predators. Taipei Zoo documented two pangolins living to almost 20 years of age, and reported reproduction in a 9-year-old female and 16-year-old male. Two wild pangolins have been report to live to 15 years (Sun, unpublished data). For modelling purposes the maximum age in the wild was set at 12 years, with no reproductive senescence (i.e., they can breed up until their death). Maximum age of 15 years was used in the 2004 PVA, but there was considerable variation in experts' estimates of this value. Other values were explored in sensitivity testing.

Females produce only single young (Zhang *et al*. 2016), which is dependent on its dam for less than a year. Field data on six adult females found three to be pregnant (50%), but this sample size is too small to estimate female reproductive rate. Gestation length is unclear in this species, with a wide range of reported values. Zhang *et al*. (2016) compiled data reported for 20 Chinese pangolin birth records (primarily in captivity) and concluded that gestation to be typically 6-7 months, although estimates vary up to over 300 days (Chin *et al*. 2012). Taken together, this suggests that pangolin produce a maximum of one offspring per year, and may skip a year between births.

In the model, reproductive rate was set to an average of 75% of adult females reproducing each year. This translates into an inter-birth interval of 1.5 years (average time between consecutive births for a female). It is probably that this IBI value may be between 1 and 2 years. Reproduction was not modelled as density-dependent. Birth sex ratio was assumed to be equal (Taipei Zoo captive data).

Mortality rates

Rates were estimated based on consideration of zoo data for juvenile mortality as well as expert opinion informed by pangolin life history traits and natural mortality rates from other mammals of similar size or life history. Males are thought to have higher early mortality than females, leading to a female-biased adult sex ratio. As with many species, first-year mortality was estimated to be high (50% for males, 40% for females), followed by moderate sub-adult mortality (10% for females, 25% for males), and relatively low adult mortality (5% per year for both sexes). This mortality schedule results in an adult sex ratio of 0.58 male:1 female and with ~2% of the population being comprised of 12 year olds. When combined with the above reproductive rates, this leads to an annual intrinsic growth rate of ~8% and a generation time of ~6 years. These attributes are reasonable for a mammal species with this general life history with a population that is not under excessive threat. These mortal rates are lower than those used in the 2004 PVA, which were extrapolated from other mammal species in the absence of any data on pangolins.

Variation in demographic rates

Actual reproductive and mortality rates vary from year to year in the real world and can impact population viability especially for small populations. The *VORTEX* model incorporates stochastic (chance) variation in four ways that represent the sources of stochasticity outlined by Shaffer (1981). First, the actual proportion of pangolins surviving and reproducing each year varies due to chance based on population size, although the populations modelled are large enough to show little deviation from the mean rates given above. Secondly, annual variation in environmental conditions (EV) can lead to good or poor survival and/or reproduction from year to year. This was incorporated into the model by adding EV as a standard deviation of 20% of the mean rate (e.g., first year male mortality: mean = 50%, SD = 10%).

A third source of variation are catastrophic events, which could be natural (e.g., typhoon, fire, disease) or anthropogenic (e.g., toxin contamination). A non-specific catastrophic was added to the model that represents the loss of 50% of the population at a very low frequency (~once in 50 years, or 2% risk per year). This is the default setting for the model and is based on an assessment of 88 vertebrate populations that found the risk of severe population decline ($\geq$ 50%) to be approximately 14% per generation (Reed *et al.* 2003).

Genetic processes are also incorporated into the model, both as the random loss of genetic variation (genetic drift) and as inbreeding depression (lower viability of inbred individuals). *VORTEX* models inbreeding depression as reduced survival in inbred juveniles; the severity of the effect is determined by the number of lethal equivalents (LE) in the model. O'Grady *et al*. (2006) concluded that 12 lethal equivalents spread across survival and reproduction is a realistic estimate of inbreeding depression for wild populations. The pangolin model incorporated the default setting of 6.29 LEs as the recommended conservation estimate of inbreeding impacts.

Base model and sensitivity testing

The base model represents the best estimate of the current situation for the Formosan pangolin based on available data and expert opinion of the participants at the PVA and PHVA workshops. Essentially the base model represents the best estimation of a large population under natural conditions and in the absence of significant threat. Given the uncertainty in demographic rates, population size and structure, and anthropogenic threats, precise projections of Formosan pangolin population viability are not feasible. If the population is not under additional threat, then the base model may be a reasonable estimate of probable trend.

Base model results reflect pangolin populations that, on average, are relatively stable in size, retain high levels of genetic variation with little inbreeding, have the ability to recover from severe short-term decline, and show no risk of extinction over 100 years. Mean stochastic growth (r) is about 8%. Pangolin populations with these vital rates and relative size are projected to be viable and persistent in the absence of future habitat loss, fragmentation, poaching or other threats.

Data are scarce for wild pangolin populations, and there is some uncertainty in the model inputs for demography and genetics. Sensitivity analyses were performed on the primary rates in the base model to determine which parameters most affect population viability. These analyses also suggest the most important data gaps for assessing population viability as well as those parameters that might be targeted through management to promote viability. Table 2 gives the parameters and values that were tested along with the relative results.

While several parameters have some impact on growth rate (e.g., age of first reproduction for females), growth remains positive and leads to similar population viability for populations at or near carrying capacity as modelled here. Two factors stand out as having the greatest effect on population growth and population size: reproductive rate and adult survival.

Table 2. Input parameters explored in model sensitivity testing and their relevant impact.

PARAMETER	VALUES TESTED	IMPACT ON RESULTS
Reproduction		
Average inter-birth interval	1, 1.5, 2 yrs	**Significant impact on growth**
Age of first reproduction (female)	2, 3 yrs	Slightly lower growth at 3 yrs
Age of first reproduction (male)	2, 3, 4 yrs	No effect
Survival (± 10%, ±20% of mean)		
Adult survival	72-99.9% (both)	**Significant impact on growth, extinction risk**
Sub-adult survival	72-100% (females); 60-90% (males)	Lower (positive) growth and population size
Juvenile survival	48-72% (females); 40-60% (males)	Lower (positive) growth and population size
Maximum age	12, 15, 18 years	Slightly higher gene diversity with longer lifespan (longer generation time)
Genetic relatedness		
Initial kinships	0, 0.08	No effect

Impacts of female reproductive rate

Given the average observed gestation and length of dependency, adult females may have the ability to produce an offspring each year; however, factors such as food availability and environmental conditions may mean that not all females reproduce annually. Given other demographic rates in the model, growth may be very high (~13%) with a mean inter-birth interval (IBI) of one year (i.e., 100% adult females reproducing each year), but this would be higher growth than typically observed for mammals with pangolin lifespan. The base value of IBI=1.5 years (75% of females reproducing) leads to lower but still strong growth of ~8%, still strong enough allow population to recover from short-term declines and grow to capacity. Dropping IBI to 2 years (50% of females reproducing each year) slows growth to ~1 to 1.5% and slow recovery or lead to populations often below carrying capacity. While the actual IBI is not known for wild Formosan pangolin populations, it is reasonable to conclude that it would naturally be within this range given the period of dependency of offspring.

The importance of female reproductive rate has two main implications. First, this is a potentially important knowledge gap for wild Formosan pangolin populations. Improved estimates of IBI or the percent of adult females producing young each year will lead to better understanding of the viability of wild pangolin populations. While IBI from *ex situ* populations may provide some biological benchmarks, it is important to assess IBI for pangolins living under *in situ* conditions. Second, any management actions that can improve the reproductive rate will improve pangolin population growth and viability. Examples are actions that reduce human disturbance to female pangolins or improve food and burrow availability to promote reproduction.

Impacts of adult survival

In polygynous species it is female survival that is most important, as females are the limiting sex on reproduction and population growth. The survival rates of juveniles, sub-adults and adults all influence population growth rates in the pangolin model. However, the same proportional change in adult survival has the greatest impact and, if large enough, can lead to population decline. In the base pangolin model, a 10% in decrease in adult survival reduced population growth to ~1%, while higher reductions can lead to population decline, loss of genetic variation, and risk of eventual extinction.

As outlined for reproductive rate, there are two important implications of these model results. Understanding pangolin mortality rates, both natural and anthropogenic, is key to understanding the probable future and viability of these populations. A better understanding of causes of mortality will allow for more effective conservation actions that can target the primary threats. In the absence of this specific knowledge, expert opinion and a proactive approach may help to identify probable threats and potential actions to reduce those potential threats. High priority would be threats that might be especially applicable to adult breeding females.

Potential impacts of harvest

Without accurate knowledge both of pangolin demographic rates and threat impacts to pangolins, it is difficult to provide precise estimates of future population viability and the level of poaching/harvest (or other threats) that the Formosan pangolin population can withstand. A small exploration of the impact of harvest on pangolins was conducted using the base model values. Annual harvest rates of 1% to 10% was modelled and applied across all age-sex classes. Given the base stochastic growth rate of ~8%, it is not surprising that modelled populations can withstand low levels of harvest. Population effects become noticeable at about 4% annual harvest, and lead to population decline at about 6-7% annual harvest (Fig. 2). Although referred to here as 'harvest', this could include the loss of pangolins due to other non-natural threats, such as roadkill or predation by stray dogs. Lower rates of loss would reduce viability if adult females are more susceptible. Of the 125 rescued pangolins in the Taipei Zoo rescue database, 70% were male; this suggests the possibility that males may be at greater risk for some threats, perhaps as a consequence of non-breeding males looking for available habitat. The actual number of pangolin losses that wild populations can withstand is dependent about actual population size and other sources of mortality (as well as other demographic rates).

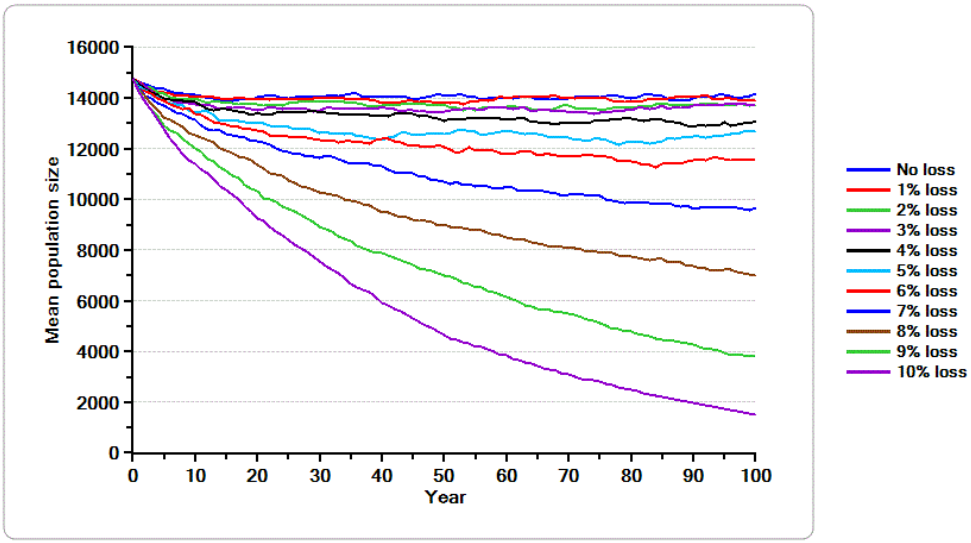


Fig. 2. Project mean size of Formosan pangolin population used base model values, under varying degrees of annual loss (0-10%) of pangolins across all age and sex classes.

Important knowledge gaps

Given the results of this PVA and small population biology principles, the following factors were identified as the most important knowledge gaps for assessing the viability of wild Formosan pangolin populations and to guide effective management strategies for conservation of this taxon.

Population size and degree of fragmentation: Model results were based on large regional populations with some connectivity to other populations. Populations of this size are buffered from many stochastic effects that make play a significant role in viability if pangolin density is actually significantly lower and/or pangolin distribution is highly fragmented.

Population trend: Information on population trends and/or distribution will help construct and validate a more accurate model that can be used to estimate future viability if these trends were to continue.

Reproductive rate: Information on the average inter-birth interval and/or the average number of females producing young per year can be used to more precisely estimate reproductive rates and environmental variation in these rates from year to year. This information will improve future viability estimates and inform how much harvest pressure the pangolin population can withstand.

Cause and rate of loss: Understanding how, and how fast, pangolins are lost from the population is critical to assess population viability. Ultimately it is valuable to understand all sources or mortality or other losses to the population (e.g., harvest/capture), both natural and otherwise; however, most critical is to estimate the loss of adults (especially females) due to anthropogenic-related threats such as direct harvest, stray dogs and roadkill.

Regional differences in threats: Threats such as harvest, predation by dogs, and roadkill may differ across different areas of Taiwan. It is important, both for viability projections but especially for management actions, to understand the type and level of threat for each region.

Conclusions

Despite the uncertainty in demographic rates, population size and distribution, and anthropogenic threats of wild Formosan pangolins, there is sufficient information available for PVA methods to provide useful information to help guide future research and potential management. There is no direct evidence either from the field or from modelling that suggests pangolin populations are in decline at this time. As knowledge of the reproductive biology and natural mortality of wild pangolins improves, intrinsic growth rate can be estimated more precisely. Concurrently, investigation into other sources of mortality and their rates across different age and sex classes will provide essential input to estimate future pangolin population viability and guide effective management actions to conserve the subspecies. Differences in threat factors and rates across Taiwan, along with better estimates of population size and spatial distribution, may be important to target high priority areas and actions, and can inform if there may be a need for meta-population management. Future monitoring and research activities should address these important data gaps as feasible. Until more information is available, management actions that promote successful reproduction and minimize the loss of adult female pangolins is recommended.

PART II.

National Conservation Strategy and Action Plan

NATIONAL STRATEGY AND ACTION PLAN

INTRODUCTION

The following pages summarize the 2017-2027 National Conservation Strategy and Action Plan for Formosan Pangolins, *Manis p. pentadactyla*. The purpose of this plan is to support efforts to combine and coordinate pangolin conservation resources behind commonly agreed priorities. These priorities are aimed at ensuring the ongoing protection and conservation of the species in Taiwan.

PLANNING PROCESS

The planning process through which these recommendations were generated followed a science-based, participatory and stakeholder-inclusive model, the details of which are provided in Part I of this document.

The 2017-2027 National Strategy and Action Plan, which summarizes the work of more than 70 stakeholders from 13 countries, includes:

- A STATUS REVIEW: summarizing the current state of knowledge of the species.
- A VISION STATEMENT: a desirable future state for the species in Taiwan.
- GOALS: long-term directions for conservation work.
- OBJECTIVES: shorter term directions and strategies.
- ACTIONS: specific activities aimed towards achieving the objectives.

The analysis of threats that underpinned these recommendations is described in more detail in PART I.

AUDIENCE

Pangolins are disappearing from other parts of the world due to wildlife trade and trafficking. The viability of the Formosan pangolin is therefore important not just within Taiwan, but to global pangolin conservation efforts. This plan is written for multiple audiences, including:

- Participants of the 2017 PHVA workshop
- The wider pangolin conservation community
- Government and non-government wildlife conservation agencies in Taiwan
- Universities and other research institutions
- Those working with rescued pangolins, both within Taiwan and elsewhere
- Education and outreach organizations
- Donors interested in supporting pangolin conservation

IMPLEMENTATION

A **Formosan Pangolin Core Group (FPCG)** will coordinate information sharing and implementation of the National Conservation Strategy and Action Plan. Four themed sub-groups will be established, to drive activities (see Figure 2.):

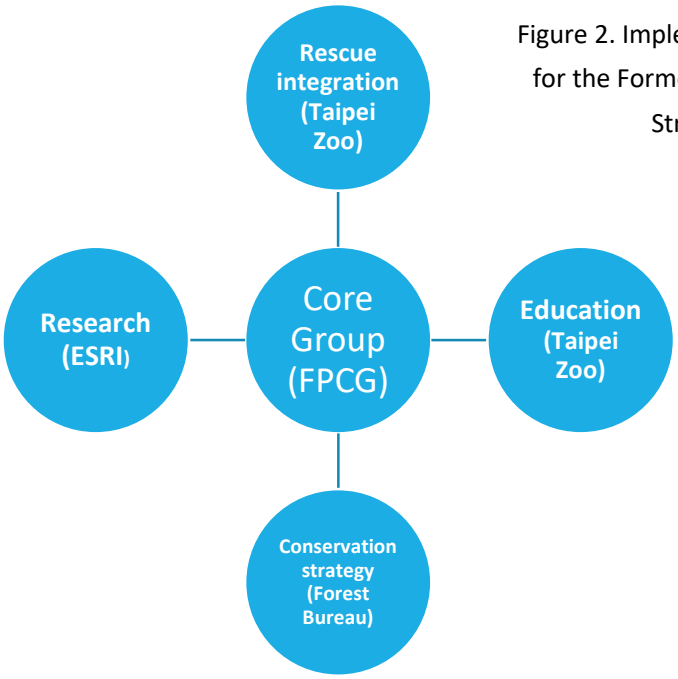


Figure 2. Implementation framework for the Formosan Pangolin National Strategy and Action Plan.

A pangolin research group led by Endemic Species Research Institute, ESRI: to connect researchers working on pangolins, to encourage research aimed at filling important knowledge gaps, and to ensure integration of *in situ* and *ex situ* research.

A pangolin conservation strategy group led by the Forestry Bureau of Council of Agriculture, Executive Yuan: to lead on a review of existing information relating to the impact and distribution of threats such as stray dogs, changes in land-use, use of traps, hunting, roadkill and logging.

A pangolin education group led by Taipei Zoo: to identify appropriate education targets and materials for pangolin conservation education, especially for people who live near lowland habitat, and to support education and awareness raising across all areas of the conservation strategy.

An integrated pangolin rescue group led by Taipei Zoo: to connect institutions working on pangolin rescue, rehabilitation and release in Taiwan to develop standard operating procedures for key areas of work and to support first-response staff.

The National Conservation Strategy and Action Plan will be reviewed every five years.

STATUS REVIEW

Based on morphological characteristics, the "Formosan pangolin" (*Manis pentadactyla pentadactyla*) has been described by many authors (e.g., Allen, 1938; Chao, 1989) as a sub-species of the Chinese pangolin (*Manis pentadactyla*), endemic to Taiwan. They are mainly found in about 500 meters altitudes in mountain regions (Chao, 1989). From 1950s to 1960s, at least 60,000 Formosan pangolins were butchered annually in Taiwan to meet demands for pangolin leather. This resulted in population declines, and the leather industries turned to buy pangolin skins from other Southeast Asia country during late 1970s (Anon, 1992; Chao, 1989). Despite the evident population declines, hunting for local use of meat and scales (for medicinal purposes) continued. A survey performed by asking local hunters in 1988 and 1989, revealed that monthly collection of pangolins had declined compared to previous years, to the point that it was rare to find wild pangolins (Chao, 1989; Wang, 1986; 1988).

Research on the biology and ecology of the Formosan pangolin began in the late 1980s, when Dr. Jung-Tai Chao and the Taiwan Forestry Research Institute (TFRI) initiated projects on the biology, reproduction and conservation of the species. By 1990s, Taipei Zoo initiated the rescue program "Operation Project for Wildlife Sanctuary and Rescue Center" and began accumulating information on pangolin veterinary care and husbandry. With little knowledge in pangolin diets or nutritional needs, rescued pangolins often died of digestive problems (Chin *et al*., 2012). Veterinarians usually misjudged the condition of animals due to a lack of knowledge on their physiology and biology. Pangolin keepers also had not much experience in Pangolin microhabitats, which may have resulted in sub-optimal captive environments.

The use of *ex situ* management, observing animals and their interaction with their controlled and monitored environment over time, resulted in valuable data on pangolin reproductive physiology, husbandry and veterinary care allowing for suitable diets to be developed (Chin, 2006; 2007; 2008; Taipei Zoo, unpubl. data; Yang *et al*., 2001; Yang 2006). Unfortunately, between 1995 and 2004, there was a 67% mortality of rescued pangolins at Taipei Zoo as a result of digestive problems (Chin *et al*., 2012). However, the high mortalities declined to 13% between 2008 and 2017 (Taipei Zoo, unpubl. data).

Advances in captive care are also reflected in breeding success. The first successful breeding (i.e. conception and parturition in captivity) of the Chinese pangolin at Taipei Zoo was the birth of a male, "Chuan Pan" in December 1997; his parents were rescued around 1995. This animal is still alive and is more than 20 years old. It has also bred successfully producing a female offspring, which also produced two second-generation captive bred Formosan pangolins.

Despite decreasing mortality rates of rescued animals, wild pangolins were still under threat from poaching, trapping and attacks from feral dogs (Wang *et al.,* 2011). In order to accelerate the process of sharing information on wild pangolins general biology, perform targeted research, and promote pangolin conservation, Taipei Zoo, TFRI, the IUCN SSC Pangolin Specialist Group (PSG), and the Taiwan Council of Agriculture (COA) collaborated to conduct a Population Viability Analysis (PVA) and developed a conservation strategy for the Chinese pangolin in Taiwan. By 2004, thanks to the financial support from the Council of Agriculture, Taipei Zoo invited the IUCN SSC Conservation Planning Specialist Group (CPSG) to conduct the first Pangolin Population and Habitat Viability Assessment (PHVA) workshop for the Chinese pangolin in Taiwan.

The first Formosan pangolin PHVA workshop aided pangolin conservation strategies by increasing communication and cooperation among the participants and stakeholders as well as identifying focused research needs. With the knowledge and expertise available, workshop participants were able to develop priority goals and recommended actions useful in Pangolin conservation management strategies.

After 2004 PHVA workshop, several actions led by government and local organizations benefited pangolin conservation by establishing new protect areas, promoted eco-friendly agriculture practices such as the *Satoyama* Initiative and Taiwan Roadkill Observation Network. More research and important considerations followed the 2004 PHVA. Between 2004 and 2016, eleven Master Theses and one Ph.D. Dissertation focused their research on the Formosan pangolin life history, diseases and population genetics, establishing best practice rescue protocols (see Appendix II).

In light of new data collected since 2004, major stakeholders including Taipei Zoo, the COA, the Forest Bureau, and the Endemic Species Research Institute (ESRI), decided to re-convene experts to review the status of the Formosan pangolin and re-evaluate the conservation action plan and associated strategies in 2017 Formosan pangolin PHVA workshop.

Today there are still many threats to wild pangolin in Taiwan such as feral dogs, habitat lost, traps, and illegal hunting. Compared to other countries, wild Chinese pangolins in Taiwan represent one of the few populations existing in their natural conditions, and populations are potentially stable. Conservation and research activities have contributed to this success and offer unique opportunities to expand knowledge and understanding of pangolins and their conservation.

VISION AND GOALS

Vision

By 2042, everyone is aware of and values the Formosan pangolin and is willing to work together to properly protect its habitat and maintain its viable population, based on adequate knowledge, so that pangolins can live in harmony with human beings.

Goals

GOAL 1: To gather key information about pangolin population status, biology, distribution, habitat and threats.

GOAL 2: To ensure adequate protection for pangolins and their habitat.

GOAL 3: To maximize the contribution to conservation of* ex situ *pangolins.

Immediate priorities

- *Convene a meeting of stakeholders to establish a **Formosan Pangolin Core Group,** with themed sub-groups.*
- *Confirm **research priorities** for pangolins in Taiwan.*
- *Establish a platform for collecting scientific evidence relating to the impact of **stray dogs** on pangolins.*
- *Add pangolin conservation information to **Taipei Zoo's Outreach Program**, especially for schools near pangolin habitat and places where roadkill occurs.*
- *Bring representatives from rescue centers and local governments together to progress key issues related to **rescue, rehabilitation and release.***
- *Publish a **children's book** about pangolins.*

OBJECTIVES AND ACTIONS

GOAL 1: TO GATHER KEY INFORMATION ABOUT PANGOLIN POPULATION STATUS, BIOLOGY, DISTRIBUTION, HABITAT AND THREATS.

1.1	**Objective.** Form a research working group and network to coordinate and set priorities for pangolin research, including the following: • pangolin meta-population structure and characteristics • pangolin habitat quality and quantity • the general health condition of wild Formosan pangolins • the taxonomic status of the Formosan pangolin Note: this group is to be led by ESRI and is to sit under the Formosan Pangolin Core Group.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
1.1.1	Hold a meeting to discuss research coordinator candidates, stakeholders, resources and financial provider.	• Endemic Species Research Institute, ESRI • Forestry Bureau of Council of Agriculture, Executive Yuan • Department of Animal Industry, Council of Agriculture, Executive Yuan	PHVA participants; Rescue Centers; Government agencies; NGOs	By February 2018
1.1.2	Confirm research priorities and draft research strategies.	Research Working Group	As above	By September 2018
1.1.3	Standardize research protocols to support integration of *in situ* and *ex situ* information.	Research Working Group	Taipei Zoo; Rescue Centers; Research institutes (universities)	By December 2018
1.1.4	Coordinate sample exchange between institutes, including Taipei Zoo, museums and rescue centers (e.g. specimens, faeces, bloods).	Research Working Group	Taipei Zoo, museums and rescue centers.	By December 2019
1.1.5	Establish training courses/capacity building, especially in population monitoring.	Research Working Group	Forestry Bureau of Council of Agriculture, Executive Yuan; Taipei Zoo; Rescue Centers; Research institutes (universities); Observer Ecological Consultant Co,. Ltd.	To be determined

GOAL 2: TO ENSURE ADEQUATE PROTECTION FOR PANGOLINS AND THEIR HABITAT.

2.1	**Objective.** Form a conservation strategy working group. Note: this group is to be led by the Forest Bureau and is to sit under the Formosan Pangolin Core Group.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
2.1.1	Hold a meeting to discuss, stakeholders, resources and financial provider (as for 1.1.1).	Forestry Bureau of Council of Agriculture, Executive Yuan	Endemic Species Research Institute, Taipei Zoo, PHVA participants, Department of Animal Industry, national parks	TBC
2.2	**Objective.** Form a pangolin education group led by Taipei Zoo Note: this group is to be led by Taipei Zoo and is to sit under the Formosan Pangolin Core Group.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
2.2.1	Hold a meeting to discuss, stakeholders, resources and financial provider (as for 1.1.1).	Taipei Zoo	Endemic Species Research Institute; Forestry Bureau of Council of Agriculture, Executive Yuan	TBC
2.3	**Objective.** Understand and quantify how each of the threats identified affects pangolin populations and their conservation in Taiwan.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
2.3.1	Review existing information on impact and distribution, for each threat identified and produce a report:	See below	See below	TBC
	Land-use	Shan-Ta Tao 陶善達 (野生動物追思會 Wildlife Concern of Taiwan)	Endemic Species Research Institute	By Dec, 2018
	Stray dogs	Wildfact I-Lung Lee 李宜龍 (野生動物追思會 Wildlife Concern of Taiwan)	Animal Protection Office	By Dec, 2018
	Roadkill	Te-En Lin 林德恩 (Endemic Species Research Institute, ESRI)	3 Wildlife Rescue centers, Taiwan Roadkill Observation Network	By Dec, 2018
	Traps	Bharti Arora	Jai-Chyi Pei 裴家騏 (College of Environmental	By Dec, 2018

		(National Dong Hwa University)	Studies & Department of Natural Resources and Environmental Studies, National Dong Hwa University), Local community, Rescue Centers.	
	Lack of food	Hou-Feng Li 李後鋒 (National Chung Hsing University, Department of Entomology)	Tsung-Chi, Lin 林宗岐(National Changhua University of Education, Department of Biology)	By Dec, 2018
	Others (hunting dogs, illegal trade, heavy rain, forest fire and logging)	Jim Kao 高雋(Taipei Zoo)	Forestry Bureau of Council of Agriculture, Executive Yuan	By Dec, 2018
2.3.2	Establish a platform to collect scientific evidence about the impact of stray dogs. Include passive information collection such as photos and video from rescue centers; animal resource survey research data and data from NGOs; or initiate information collection for example through monitoring studies.	Endemic Species Research Institute, ESRI is the contact point on information integration.	• Taipei Zoo • Pingtung Rescue Center • 野生動物追思會 Wildlife Concern of Taiwan • 路殺社 Taiwan Roadkill Observation Network	TBC
2.3.3	Map the distribution of threats (from 2.3.1) and compare it to the known distribution of pangolin populations	Shan-Ta, Tao 陶善達 (野生動物追思會 Wildlife Concern of Taiwan)	The team collaborating on the data review (see above)	2019-2020 (2 years)
2.3.4	Initiate research to fill the knowledge gaps identified in Action 2.3.1 relating to other threats.	Research working group	Members of the Research working group	
	Land-use	行政院農業委員會林務局 Forestry Bureau of Council of Agriculture, Executive Yuan	• Endemic Species Research Institute; • Chi-Ming Sun (國立屏東科技大學野生動物保育研究所 National Pingtung University of Science and Technology, Institute of Wildlife Conservation); • Shan-Ta Tao 陶善達 (野生動物追思會 Wildlife Concern of Taiwan).	Follow the results of Actions 1&2

	Stray dogs	行政院農業委員會特有生物研究保育中心 Endemic Species Research Institute	• Forestry Bureau • Taipei Zoo • National Parks • Department of Animal Industry, Council of Agriculture, Executive Yuan • **野生動物追思會** Wildlife Concern of Taiwan	Follow the results of Actions 1&2
	Roadkill	行政院農業委員會特有生物研究保育中心 Endemic Species Research Institute	• 路殺社 Taiwan Roadkill Observation Network • 臺北市立動物園 Taipei Zoo • **屏東保育類野生動物收容中心** Pingtung Rescue Center	Follow the results of Actions 1&2
	Traps	行政院農業委員會特有生物研究保育中心 Endemic Species Research Institute	• 路殺社 Taiwan Roadkill Observation Network • Taipei Zoo • Pingtung Rescue Center • 野生動物追思會 Wildlife Concern of Taiwan • Bharti Arora (National Dong Hwa University)	Follow the results of Actions 1&2
	Lack of food (produce a report defining the major termite and ant species that make up the natural diet of Formosan Pangolins, and the distribution of these species)	Hou-Feng Li **李後鋒** (National Chung Hsing University, Department of Entomology) (National Chung Hsing University, Department of Entomology)	Tsung-Chi, Lin **林宗岐**(National Changhua University of Education, Department of Biology)	10 years
	Others (hunting dogs, illegal trade, heavy rain, forest fire and logging)	行政院農業委員會特有生物研究保育中心 Endemic Species Research Institute	行政院農業委員會林務局 Forestry Bureau of Council of Agriculture, Executive Yuan	Follow the results of Actions 1&2

2.4	Objective 2. Ensure that laws governing the welfare of individual animals and those governing the conservation of wildlife are sufficiently comprehensive and well-enforced, and that related policies work in support of each other.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
2.4.1	Review the relevant laws, identify problem areas and list stakeholders at each level (Animal Protection Act, Wild Animal Protection Law, Environmental Impact Assessment Act).			
	Wild Animal Protection Act: traps & penalties	I-Lung Lee 李宜龍 (野生動物追思會 Wildlife Concern of Taiwan)	• Department of Agriculture, Institute of Wildlife Conservation (Central Region Branch) • Animal Protection Office • Agricultural Bureau • Seventh Special Police Corps National Police Agency, Ministry of the Interior, R.O.C.	By Dec, 2018
	1) Animal protection act 2) No euthanasia of animals	Hui-Lun Chen 陳慧倫 (Taipei Zoo)	• Council of Agriculture, Department of Animal Industry (Central Region Branch) • Animal Protection Office • Agricultural Bureau	By Dec, 2018
	Land use (camping site, farmland, low land, woodland)	Wei-Ting Liu 劉威廷 （Observer Ecological Consultant Co., Ltd.)	• Environmental Protection Administration, Executive Yuan; • Forestry Bureau, Council of Agriculture, Executive Yuan; • Soil and Water Conservation Bureau, Council of Agriculture, Executive Yuan; • Water Resources Agency, MOEA; • Construction and Planning Agency, Ministry of the Interior, R.O.C.; • Citizen of the Earth, Taiwan	Until Dec, 2018
2.4.2	Petition for change where needed (ex. 公共政策網路參與平台)	I-Lung Lee 李宜龍 (野生動物追思會 Wildlife Concern of Taiwan)	As for action 1.3.1	Start Dec, 2019

2.4.3	Design a training course for judges. Add environment, biodiversity, poaching and trap issues into the logging training course.	Education group and Dr. Jung-Tai Chao	• Taipei Zoo; • Endemic Species Research Center.	TBC
2.5	Objective 3. Enhance public awareness, direct targeted behavior change campaigns at priority audiences, and ensure that public education is carried out in the right way, by the right people.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
2.5.1	Add pangolin conservation information to Taipei Zoo's Outreach Programme (especially for schools near pangolin habitat and places where roadkill occurs). Success = numbers of schools take the program.	Taipei Zoo	Taipei Zoo	Start from 2018
2.5.2	Publish pangolin books for kids.	Taipei Zoo	Joann Chang 張東君 Chu-Hong Liao 廖珠宏	Until 2018
2.5.3	Produce a suitable educational channel (e.g. YouTube Channel or Facebook Fan Page) for local committees and Taipei zoo (to study the audience).	Taipei Zoo	Joann Chang 張東君 Chu-Hong Liao 廖珠宏	2018-2023
2.5.4	Create a platform / network for local educators near roadkill hotspots and near pangolin habitat.	Taipei Zoo	路殺社 Taiwan Roadkill Observation Network	2018-2023
2.5.5	Promote educational information about the impact of stray dogs and cats.	Taipei Zoo	(野生動物追思會 Wildlife Concern of Taiwan)	TBC
2.6	Objective 4. Identify and implement measures to protect pangolins and encourage co-existence with humans, both in natural and in human modified habitats. **Note:** Actions under GOAL 1 address the need to improve understanding of habitat suitability and distribution with regard to pangolins. This objective will rely on that information gap being filled in the first instance.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
2.6.1	Find and implement tools or methods to reduce the effect of each threat (based on priority).			
	a) Create more specific equipment or methods to prevent wildlife damage in farmlands.	Forestry Bureau, Council of Agriculture, Executive Yuan	• Endemic Species Research Institute; • Department of Animal Industry, Council of Agriculture, Executive Yuan; • National Parks.	Begin 2018

	b) Create proper animal-friendly crossroads or paths.	Endemic Species Research Institute	• Transportation departments; • Freeway Bureau; • Public Construction Commission, Executive Yuan; • Forestry Bureau, Council of Agriculture, Executive Yuan; • Ecological Engineering Foundation (EEF).	Begin 2018
2.6.2	Establish a Network for conservation of pangolins and other lowland endangered species, such as leopard cat and box turtle.	• Nick, Ching-Min Sun 孫敬閔 National Pingtung University of Science and Technology, Institute of Wildlife Conservation • Jim Kao 高雋 (Taipei Zoo) • Jung-Tai Chao 趙榮台	• National Pingtung University of Science and Technology • Sheng-Hai Wu 吳聲海 NCHU 中興大學 • Endemic species Research Institute, COA • Soil and Water Conservation Bureau	Start from 2018
2.6.3	Invite government agencies to a meeting to discuss how to improve the management of stray dogs.	Forestry Bureau	ESRI, Department of Animal Industry, national parks, and zoos.	TBC

GOAL 3: TO MAXIMIZE THE CONTRIBUTION TO CONSERVATION OF *EX SITU* PANGOLINS.

3.1	**Objective.** Best practices for pangolin rescue, rehabilitation and release in Taiwan.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
3.1.1	Establish a pangolin rescue integration working group under the under the Formosan Pangolin Core Group.	Taipei Zoo	Other rescue centers	2018
3.1.2	Hold a workshop to bring the 3 rescue centers together: 1) to develop long-term communication; 2) to share and agree Standard Operating Procedures (SOPs); 3) to discuss the necessity of a 4th rescue center in the East; 4) to agree on how post-release monitoring programs will be done.	Taipei Zoo (Tina Chen and Flora Lo)	• Forestry Bureau; 3 rescue centers: • Taipei Zoo • Endemic Species Research Center • Pingtung Rescue Center	April 2018
3.1.3	Produce first draft of Rescue, Rehabilitation and Release Guidelines within one year: to include husbandry, welfare, and SOPs. Review periodically (every three years).	Taipei Zoo	All 3 rescue centers • Taipei Zoo • Endemic Species Research Center • Pingtung Rescue Center	1 year for first draft then ongoing
3.1.4	Fund-raise to secure NGO and government support.	Forest Bureau of Council of Agriculture, Executive Yuan	• Endemic Species Center • Taipei Zoo • Local Government	TBC
3.1.5	Redistribute or reassign capacity. Maximize funding, manpower, space, and knowledge.	Forest Bureau of Council of Agriculture, Executive Yuan	• Endemic Species Research Institute • Taipei Zoo	March 2018 and ongoing
3.1.6	Circulate a questionnaire to communities to help identify suitable release habitat (in collaboration with members of the research working group).	Forest Bureau of Council of Agriculture, Executive Yuan	• Endemic Species Research Institute; • Taipei Zoo	TBC

3.1.7	Promote community and public awareness to prevent inappropriate capture and sending of pangolins to rescue centers.	Forest Bureau of Council of Agriculture, Executive Yuan	• Endemic Species Research Institute • Taipei Zoo • Universities • Observer Ecological Consultant Co., Ltd.	Ongoing
3.1.8	For the 3 rescue centers, launch ongoing in-house and off-site capacity building programs, training courses, site visits, staff exchanges (include hot-line and other government-related topics).	Endemic Species Research Institute	3 rescue centers • Taipei Zoo • Endemic Species Research Center • Pingtung Rescue Center	2019 and ongoing
3.1.9	Improve Government operated wildlife hotline through better SOPs and, if sufficient response capacity can be established, make it operational 24-hours a day. (Note: existing hotline 0800000930) 可以實際運作的配套措施	Taipei Zoo	• Forest Bureau of Council of Agriculture, Executive Yuan • Endemic Species Research Institute • Pingtung Rescue Center	Ongoing
3.1.10	Write a report on the PHVA outcomes to the Government, together with the rescued animal data from the existing 3 rescue centers, to help with fund-raising.	Taipei Zoo	• Forest Bureau of Council of Agriculture, Executive Yuan • Endemic Species Research Institute • Pingtung Rescue Center	Ongoing

3.2	**Objective.** *Ex situ* research: to conduct studies on the *ex situ* population to better understand the Formosan pangolin in every aspect, in order to benefit both captive and wild populations.			
	Action	**Who leads?**	**Potential collaborators**	**Timeline**
3.2.1	Form a specific Formosa pangolin working group, including research /advisory/international groups.	Taipei Zoo	Taipei Zoo and all involved parties	Jan. 2018
3.2.2	Form an ethics committee, including a chair, investigation officers, scientists, non-scientists, veterinarians, members of the public, and ensure compliance with Institutional Animal Care and Use Committee (IACUC) policies and guidelines.	Taipei Zoo	• Taipei Zoo • Government • Universities; • NGOs • Private institutions	1 year
3.2.3	Hold an internal meeting to identify and prioritize research topics.	Taipei Zoo.	Taipei Zoo and all involved parties	Decide after workshop in March, 2018
3.2.4	Ensure guaranteed funding for pangolin research.	Forest Bureau of Council of Agriculture, Executive Yuan.	• Taipei Zoo • Endemic Species Research Institute • Ministry of Science and Technology	Ongoing
3.2.5	Ensure a continuous stream of research.	Endemic Species Research Institute.	• Taipei Zoo • Forest Bureau of Council of Agriculture, Executive Yuan	Ongoing
3.2.6	Develop and sign an MOU to ensure data sharing and maintenance of a professional relationship between NGOs and universities.	Forest Bureau of Council of Agriculture, Executive Yuan.	• Dr. Jung-Tai Chao • Taipei Zoo • Endemic Species Research Institute • Universities	TBC
3.2.7	Perform and publish research (annual report of pangolin related research. Minimum of 1 publication of each form (case report, technical report, paper) annually.	Research group	• Endemic Species Research Institute • Taipei Zoo • Forest Bureau of Council of Agriculture, Executive Yuan	Ongoing

			• Universities	
3.2.8	Develop husbandry, nutrition, physiology, and reproduction research on the *ex situ* population and feed information back to the *in situ* work.	Taipei Zoo (Flora, Hsuan-Yi Lo)	TBC	TBC

Additional actions proposed for *ex situ* pangolins management:

- Follow the guidelines (once discussed and approved by 3 rescue centers and pangolin specialists) on the circumstances that should lead to an animal being retained in captivity.
- Get the 3 main rescue centers together to allocate the resources: decide who is able to obtain the sufficient space and facilities for this program.
- Reference the husbandry guidelines by the Pangolin Specialist Group and welfare committee to establish the enclosure.
- Start the pangolin gene bank project from animals of three rescue centers (Taipei, ESRI, Pington)

REFERENCES

Allen, G.M. 1938. The Mammals of China and Mongolia. Natural History of Central Asia Vol. XI, Part 1. The American Museum of Natural History, New York.

Anon, 1992. Review of Significant Trade in Animal Species included in CITES Appendix II, Detailed Review of 24 priority species, Indian, Malayan and Chinese pangolin. CITES, Geneva, Switzerland.

Bharti, A., K. J.-C. Pei, C.-M. Sun, M. J. Chi. 2017. Morbidity analysis of wild pangolin (*Manis pentadactyla pentadactyla*) rescued by Pingtung rescue center, Taiwan. South Asian Conference on Small Mammals abstract. p.24

Chang, S.-P. 2014. The kinship and social structure of the Formosan pangolin (*Manis pentadactyla pentadactyla*) in Luanshan, Taitung, based on microsatellite variations.

Chao, J.T. 1989. Studies on the Conservation of the Formosan Pangolin (*Manis pentadactyla pentadactyla*) I. General Biology and Current Status. Council of Agriculture, Executive Yuan, Taipei, Taiwan.

Chao, J.T., E.H. Tsao, K. Traylor-Holzer, D. Reed and K. Leus (eds). 2005. Formosan Pangolin Population and Habitat Viability Assessment: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN, US.

Chin, S.C. 2006. Conservation Medicine Research on Chinese Pangolin (*Manis pentadactyla*). Research Programs of Taipei Zoo 2006. Taipei, Taiwan.

Chin, S.C. 2007. Physiology, Ecology, Pathology, and Husbandry Research on Chinese Pangolin (*Manis pentadactyla*). Research Programs of Taipei Zoo 2007. Taipei, Taiwan.

Chin, S.C. 2008. Physiology, Ecology, Pathology, and Husbandry Research on Chinese Pangolin (Manis pentadactyla). Research Programs of Taipei Zoo 2008. Taipei, Taiwan.Chin, S.C., C.Y. Lien, Y.T. Chan, C.L. Chen, Y.C. Yang, and L.S. Yeh. 2012. Monitoring the gestation period of rescued Formosan pangolin (*Manis pentadactyla pentadactyla*) with progesterone radioimmunoassay. *Zoo Biology* 31: 479-489.

Fan, C.Y. 2005. Burrow Habitat of Formosan Pangolins (*Manis pentadactyla pentadactyla*) at Feitsui Reservoir. Master Thesis, National Taiwan University.

Hsiu, Hau-Jie. 2016. A GIS-based environmental database of Taiwan and Penghu islands. available at: http://mountain-ecology.blogspot.tw/2016/06/gis.html.

IUCN/SSC. 2014. Guidelines on the Use of *Ex Situ* Management for Species Conservation. Version 2.0. Gland, Switzerland: IUCN Species Survival Commission.

Khatri-Chhetri, R., Sun, C. M., Wu, H. Y., and Pei, K. J. C. 2015. Reference intervals for hematology, serum biochemistry, and basic clinical findings in free-ranging Chinese Pangolin (*Manis pentadactyla*) from

Taiwan. *Veterinary Clinical Pathology*, *44*(3), 380–390. https://doi.org/10.1111/vcp.12273

Khatri-Chhetri, R., Wang, H.S., Chen, C.C., Shih, H.C., Liao, H.C., Sun, C.M., Khatri-Chhetri, N., Wu, H.Y., Pei, K.J.C. 2016. Surveillance of ticks and associated pathogens in free-ranging Formosan pangolin (*Manis pentadactyla pentadactyla*). Ticks and Tick-borne Diseases 7 (6), 1238-1244.

Lacy, R.C. 1993. Vortex: A computer simulation model for population viability analysis. *Wildlife Research* 20:45-65.

Lacy, R.C. 2000. Structure of the Vortex simulation model for population viability analysis. *Ecological Bulletins* 48:191-203.

Lacy, R.C., P.S. Miller and K. Traylor-Holzer. 2017. *Vortex 10 User's Manual*. 6 September 2017 update. IUCN SSC Conservation Breeding Specialist Group, and Chicago Zoological Society, Apple Valley, Minnesota, USA.

Lacy, R.C., and J.P. Pollak. 2017. Vortex: A stochastic simulation of the extinction process. Version 10.2.9. Chicago Zoological Society, Brookfield, Illinois, USA.

Lai, C.-Y. 2014. Using Species Distribution Models to predict habitat distribution for pangolins (*Manis pentadactyla pentadactyla*) on the Coastal Mountain Range. Master Thesis. Institute of Wildlife Conservation, National Pingtung University of Science and Technology, Pingtung, Taiwan. 61pp. (Chinese)

Lin, J.-S. 2010. Home range and burrow utilization in Formosan pangolins (*Manis pentadactyla pentadactyla*) at Luanshan, Taitung.

Liu, J.T. 2017. Genetic Diversity and Genetic Structure of Formosan Pangolin in Taiwan Based on MHC gene and Microsatellite Markers. Master Thesis, National Taiwan University.

Mohapatra, R. K., Panda, S., Nair, M.V., and Acharjyo, L. N. 2016. Check list of parasites and bacteria recorded from pangolins (Manis sp.). *Journal of Parasitic Diseases*, *40*(4), 1109–1115. https://doi.org/10.1007/s12639-015-0653-5

O'Grady, J.J., B.W. Brook, D.H. Reed, J.D. Ballou, D.W. Tonkyn, and R. Frankham. 2006. Realistic levels of inbreeding depression strongly affect extinction risk in wild populations. *Biological Conservation* 133:42-51.

Reed, D.H., J.J. O'Grady, B.W. Brook, J.D. Ballou, and R.Frankham. 2003. Estimates of minimum viably population sizes for vertebrates and factors influencing estimates. *Biological Conservation* 113:23-34.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. *Bioscience* 31:131-4.

Wang, P-J. 2007. Application of wildlife rescue system in conservation of the Formosan pangolin (*Manis pentadactyla pentadactyla*). Master's Thesis. Institute of Ecology and Evolution Biology, National Taiwan University, Taipei, Taiwan. 45pp. (Chinese) Wang, L.M., Lin, Y.J., Chan, F.T. 2011. Retrospective analysis of the causes of morbidity of wild Formosan pangolins (*Manis pentadactyla pentadactyla*). Taiwan Journal of Biodiversity 13 (3), 245-255.

Wu, Y.H. 2015. Genetic Diversity and Genetic Structure of Formosan Pangolins in Taiwan Based on Microsatellite Markers and Mitochondrial DNA. Master Thesis, National Taiwan University.

Yang, C.W., Guo, J.C., Li, C.W., Yuan, H.W., Ttai, Y. L., Fan, C.Y. 2001. The Research on Chinese Pangolin (*Manis pentadactyla*) in Taiwan. Research Programs of Taipei Zoo 2001. Taipei, Taiwan.

Yang, C.W. 2006. The Research on Gastrointestinal Tract Microbiota and Diet Requirements of Chinese Pangolin (*Manis pentadactyla*). Research Programs of Taipei Zoo 2006. Taipei, Taiwan.

Zhang, F., S. Wu, C. Zou, Q. Wang, S. Li and R. Sun. 2016. A note on captive breeding and reproductive parameters of the Chinese pangolin, *Manis pentadactyla* Linnaeus, 1758. *ZooKeys* 618: 129-144.

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APPENDIX II.THESES AND DISSERTATIONS

List of Master Theses and Ph.D. Dissertations on Formosan Pangolins, 2004-2016

Chang, Chi-Yen. 2004. Study on the Apparent Digestibility of Diet on Formosan Pangolin. Master Thesis, National Taiwan University.

Fan, Chung-Yen. 2005. Burrow Habitat of Formosan Pangolins (*Manis pentadactyla pentadactyla*) at Feitsui Reservoir. Master Thesis, National Taiwan University.

Wang, Pei-Jung. 2007. Application of Wildlife Rescue System in Conservation of the Formosan Pangolins (*Manis pentadactyla pentadactyla*). Master Thesis, National Taiwan University.

Wu, Jane-Hung. 2008. Method of pangolin identification from scale DNA and Analysis of pangolin Mitochondrial DNA D-loop Sequences (in Chinese) Master Thesis, Central Police University.

Chan, Ya-Ting. 2008. The Breeding Behavior Study and Mother-Young Relationship of Captive Formosan Pangolins (*Manis pentadactyla pentadactyla*). Master Thesis, National Pingtung University of Science and Technology.

Lin, Jing-Shiun. 2010. Home Range and Burrow Utilization in Formosan Pangolins (*Manis pentadactyla pentadactyla*) at Luanshan, Taitung. Master Thesis, National Pingtung University of Science and Technology.

Chen, Chao-An. 2011. The study of mitochondrial D-loop region on pangolin product identification. Master Thesis, Central Police University.

Lu, Ya-Wen. 2013. Investigation of Intestinal Parasite in Formosan Pangolins (*Manis pentadactyla pentadactyla*) at Luanshan, Taitung. Master Thesis, National Pingtung University of Science and Technology.

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Chang, Shu-Ping. 2014. The Kinship and Social Structure of the Formosan Pangolin (*Manis pentadactyla pentadactyla*) in Luanshan, Taitung, Based on Microsatellite Variations. Master Thesis, National Pingtung University of Science and Technology.

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