The Golden Frogs of Panama (*Atelopus zeteki, A. varius*): A Conservation Planning Workshop

19-22 November 2013
El Valle, Panama

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FINAL REPORT

Workshop Conveners:
Project Golden Frog
Association of Zoos and Aquariums Golden Frog Species Survival Plan
Panama Amphibian Rescue and Conservation Project

Workshop Hosts:
El Valle Amphibian Conservation Center
Smithsonian Conservation Biology Institute

Workshop Design and Facilitation:
IUCN / SSC Conservation Breeding Specialist Group

Workshop Support:
The Shared Earth Foundation
An Anonymous Frog-Friendly Foundation

Photos courtesy of Brian Gratwicke (SCBI) and Phil Miller (CBSG).

A contribution of the IUCN/SSC Conservation Breeding Specialist Group, in collaboration with Project Golden Frog, the Association of Zoos and Aquariums Golden Frog Species Survival Plan, the Panama Amphibian Rescue and Conservation Project, the Smithsonian Conservation Biology Institute, and workshop participants.

This workshop was conceived and designed by the workshop organization committee: Kevin Barrett (Maryland Zoo), Brian Gratwicke (SCBI), Roberto Ibañez (STRI), Phil Miller (CBSG), Vicky Poole (Ft. Worth Zoo), Heidi Ross (EVACC), Cori Richards-Zawacki (Tulane University), and Kevin Zippel (Amphibian Ark).

Workshop support provided by The Shared Earth Foundation and an anonymous frog-friendly foundation.

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The Golden Frogs of Panama (*Atelopus zeteki, A. varius*): A Conservation Planning Workshop

Executive Summary

Introduction

There are two closely related species of golden frogs that live in Panama. The Panamanian golden frog *Atelopus zeteki* is a species historically found in the region around El Valle de Anton and Cerro Campana. In 2001, the Maryland Zoo in Baltimore established an assurance population of this species and by 2013 the entire US captive population managed by the SSP exceeded 1,500 adult individuals. Wild populations of the frog declined precipitously when the frog-killing fungus *Batrachochytrium dendrobatidis* arrived in El Valle in 2006 and the last time this frog was seen in the wild was in 2009. The variable harlequin frog *Atelopus varius* also comes in a golden color form, but ranges much more widely through central Panama and Costa Rica. It has declined precipitously through-out its range but persists in low numbers at a few sites throughout its former range. A small captive population of both golden frog species is maintained and bred in Panama at the El Valle Amphibian Conservation Center. The main threat to these frogs is the amphibian chytrid fungus, although habitat modification and over-collection for the pet-trade have also been detrimental to golden frogs, even though *Atelopus zeteki* is listed under Cites Appendix I.

In order to create an action plan for conservation of these two iconic amphibian species in Panama, key individual stakeholders and experts from amphibian conservation research groups, NGOs and relevant government ministries and departments were invited to participate in a conservation planning workshop. The overarching goal was to identify and address critical issues necessary to conserve golden frogs in Panama, to foster collaboration and information-sharing, and to develop a roadmap for a broad forward-looking collaborative conservation effort.

The Workshop Process

The conservation planning workshop was held 19-23 November 2013 at the Hotel Campestre in El Valle, Panama with approximately 40 people in attendance. Each participant was asked to specify their individual goal for the workshop and their own view on the primary challenges facing management of the golden frogs in Panama. Many people were interested in gaining a greater understanding of the biology of the species, the disease-based threats to their long-term persistence, and identifying the essential elements of a successful reintroduction strategy for both species in suitable habitat in Panama. Additionally, many participants identified the devastating impact of chytrid infection as a primary cause of population decline and local extinction, although other important threats – both biological and social in nature – came to light in the early stages of presentation and discussion among participants. A portion of the day was devoted to presentations by species experts and management authorities, giving updates on the status of the species both in the wild and captivity as well as ongoing management efforts. There was also a presentation on the potential for application of population viability analysis tools and process to the broad questions around optimal reintroduction program design.

Later in the afternoon, participants created a draft Vision Statement to describe the ideal future for golden frog conservation in Panama. The final version of the Statement was presented the next morning and was posted on a wall for all to see throughout the course of the workshop:

We are saving a national treasure, returning the Panamanian Golden Frog to nature

Following this activity was another plenary activity designed to surface additional information on the threats and challenges influencing conservation of golden frogs in Panama. The resulting "mind map" was used to identify five different working groups that would carry on detailed discussions around the relevant specific threats and challenges previously identified:

1. Captive population management
2. Disease management
3. Habitat management
4. Population viability analysis
5. Communication and collaboration

All workshop participants were invited to choose which group they wanted to join. Through this process of self-selection, workshop participants were provided with the opportunity to contribute their expertise and perspective in the most effective and productive way. Participants were also invited to move between groups for shorter periods of time, thereby providing their insight and knowledge to the appropriate group at the right time.

Following this plenary exercise, the working groups began moving through a set of structured tasks introduced by the workshop facilitator. First, each group was asked to amplify those relevant issues / challenge statements identified earlier, to identify new challenges of importance to their specific topic, and to prioritize them according to an agreed criterion. The groups were then brought together in a plenary session where each working group shared their information and provided commentary and perspective with their peers. This process of working group sessions, followed by plenary reports and discussion, continued throughout the workshop.

Once issues were identified and prioritized, the working groups met to review the collective body of knowledge around the primary activities that may impact the future of the Panamanian golden frogs. Throughout this process, the group placed an emphasis on separating known facts from assumptions, identifying the important justifications around each assumption, and (perhaps most importantly) flagging areas where potentially important information was missing. Through this process, the subsequent identification of management and / or research priorities was greatly enhanced.

When information assembly was complete, each working group was asked to brainstorm, refine and prioritize goals specifically designed to address the issues identified previously. Each group brought their prioritized goals to a plenary session on the afternoon of workshop Day 3, and the entire group was then asked to provide an overall sense of priority for these goals based on the importance of achieving them for successful management of golden frogs in Panama. This task was accomplished by giving each participant five colored adhesive dots and asking them to distribute those dots amongst those goals they viewed as most important to resolve. Since these goals are directly tied to the issues identified in the early stages of the workshop, the workshop design facilitates the resolution of the diverse needs of the various stakeholder groups in attendance.

With goals in hand, each working group then began the task of identifying specific actions that would achieve those goals. These actions are intended to include important details such as the individual responsible for moving the action forward, a timeline for completing the action, important collaborators, and specific obstacles to be overcome if the action is to be completed. With this level of detail, those agencies responsible for managing and recovering the species have a valuable set of comprehensive recommendations that can be used to guide future management activity.

Summary of Working Group Tasks and Workshop Findings

Each of the four working groups followed the same basic process, working through the specific tasks outlined below:

TASK 1. **Brainstorm Problems/Issues** for your group's topic, based on the "mind map" generated in plenary.
Consolidate the ideas and problems generated in the first step into a smaller number of topics. Write a one or two sentence 'problem statement' for each problem.
Prioritize the problem statements. This process promotes careful examination of each statement and possible further consolidation or better definition. It also assists making choices for the next step if time is limited.

TASK 2. **Data assembly and analysis.** Begin a systematic process to determine the facts and assumptions that are pertinent to your group's issues. What do we *know*? What do we *assume* we know? How do we justify our assumptions? What do we *need* to know?

TASK 3. **Prepare short-term (1 year) and long-term (5 years) goals** (minimum and maximum for each problem. Goals are intended to guide actions to help solve the problem. Prioritize your goals across each problem you have identified.
High-priority working group goals are brought to plenary and the entire set of goals is prioritized by the full body of workshop participants under a single set of criteria.

TASK 4. **Develop and prioritize Action Steps** for each of the high priority goals identified by the full body of workshop participants. These priority actions will form the body of the recommendations from the workshop.

The Captive Population Management Working Group reiterated the vital importance of ex situ colonies of *Atelopus* in Panama as insurance population against species extinction. Both wild and captive golden frog populations have provided opportunities for research (husbandry, disease/health, and conservation) and education by yielding important information, support, and awareness for the long-term conservation of amphibians globally. The working group acknowledged that captive populations will continue to be valuable in both of these roles going forward. Ideally, the long-term goals are that offspring of *ex situ* golden frogs will be reintroduced into the wild when the researchers feel that the proper habitat, environmental parameters, and disease risks have been mitigated to ensure the best possible outcomes at release.

However, while recognizing this need, the working group also acknowledged that current facilities in Panama are not sufficient to house long-term viable *ex situ* populations of *Atelopus zeteki* and *A. varius*, while at the same time noting that specific recommendations for the size of those populations have not yet been clarified. To address these needs, the group recommended that facility space within Panama should be expanded so that 200 individuals of each of the Lowland and Highland forms of each of the two species – 800 individuals in total – can be maintained to secure long-term viable populations in-country. Additionally, the group recognized the need for specific recommendations regarding the number of animals required to satisfy research and education needs, over and above the number designated above for genetic and demographic viability.

The Disease Management Working Group focused much of their attention on the need to learn more about the epidemiology of the fungus responsible for chytridiomycosis: Bd, known scientifically as *Batrachochytrium dendrobatidis*. The group outlined a variety of studies and research efforts to better understand the ecology of the pathogen in order to design more effective reintroduction programs in Panama. In addition, the group recognized that successful reintroduction of golden frogs to the wild will require large numbers of healthy captive-reared animals. Addressing disease problems that affect the captive populations will help to maximize captive breeding, ensure maximal possible genetic diversity over the long-term and produce animals with suitable fitness for reintroduction. Many disease issues in captive populations may be husbandry related; successful *ex situ* management of golden frogs will therefore require advances in husbandry, nutrition and disease management.

There are potential health risks of introducing novel infectious disease by returning captive golden frog populations in United States to Panama and by releasing captive animals in Panama to the wild (there are risks of disease transmission both from captive animals to wild animals AND wild animals to reintroduced captive animals). Therefore, the working group recommends establishing a disease screening protocol for repatriation of golden frogs held in the United States to Panama to minimize risk for existing Panamanian captive populations. This would be followed by a second disease screening protocol for reintroduction of golden frogs to the wild.

The Habitat Management Working Group identified that habitat loss and anthropogenic changes are affecting the sustainability of the golden frog populations in the wild. Furthermore, and perhaps more troubling, the group noted that there is a general lack of suitable reintroduction sites for golden frogs in Panama. To address these concerns, it will be important to develop short- and long-term GIS projections to estimate forest cover loss or recovery using remote sensing technologies. The working group also recommended the need to identify all protected areas, or private areas that are viable habitats for golden frogs and survey them for their potential for Bd climate refuges. To address the primary issue of site suitability, the group recommends that golden frog conservation authorities acquire suitable habitat for golden frog reintroduction within both protected areas and private reserves.

The Population Viability Analysis Working Group used sophisticated simulation models of amphibian population demography (the model *Vortex*) and disease epidemiology (the model *Outbreak*) to evaluate population-level demographic processes under a variety of threat and management scenarios. Specifically, the scenarios helped to determine what parameters are needed to make future projections of population abundance, to explore whether the population viability analysis (PVA) modeling techniques will be useful for assessing threats and options for these species, and to begin to see what even preliminary projections indicate about the likely fates of the populations.

Results of exploratory models suggested that a very small remnant golden frog population (i.e., no more than 50 individuals) that may survive a chytrid infection may not be likely to recover on its own even if it is resistant to chytrid. Additional models were developed to examine the possible prospects for a population that might be re-established from released animals, on the optimistic assumption that the problems with chytrid had somehow been overcome. The results from this model suggest that if the problems with chytrid can be overcome (through developing resistance or somehow removing chytrid from the environment), then the high reproductive potential of the species could allow for rapid reestablishment of populations from released frogs. Exploratory disease modeling, incorporating the existence of chytrid resistance among selected individuals, suggested that the frequency of resistance is probably too low to facilitate successful recovery of a population that is severely reduced in abundance due to a chytrid outbreak. All of these models were based on expert judgment in the absence of definitive field data on golden frog demography and Bd ecology and epidemiology. Significant effort must be devoted to estimating population demographic and disease parameters in order for these valuable tools to be most helpful in conservation planning for these species.

The Communication and Collaboration Working Group identified poor communication as a significant barrier to effective golden frog conservation in Panama. The various players involved in amphibian conservation in Panama–local and international scientists, research institutes, zoos, natural resource managers, conservation groups, educators and others groups–do not effectively coordinate and collaborate efforts around research, protection, monitoring, enforcement and education. This issue may be especially acute between ANAM, the governmental agency in Panama responsible for environmental protection and management of natural resources, and scientists carrying out research and conservation efforts in the field. There is also little coordination among key parties and efforts in terms of community engagement and outreach, and the links between institutions with expertise in science and education such as the Smithsonian Tropical Research Institute, amphibian breeding centers, and the formal education system in Panama are not well developed when it comes to amphibian conservation and education.

To address these issues, the working group recommended, among other things, to develop a three-year community engagement and education strategy to expand outreach that is aligned with the education and outreach goals of Panama's National Plan for Amphibian Conservation. Importantly, they also recommend that priority information on the species and their conservation be translated between Spanish and English in order to remove language barriers that may hinder proper communication. Collaboration among the important conservation groups can be improved through the creation of a coordinating group to lead inter-institutional communications / collaboration especially between scientists and management agencies for exchange of critical information.

Summary of Working Group Goals

The full participant body reviewed all the goals identified by each working group and was asked by the workshop facilitator to express their individual views about priority across the complete set of goal statements. While all goals were endorsed by the workshop participants as important for golden frog conservation in Panama, a subset of those goals stood out as more critical for the species' survival in the wild:

1. Create capacity for and maintain sustainable captive populations of *Atelopus zeteki* and *A. varius* in Panama, with a business plan in place.
2. Identify an organizational coordination structure to meet the needs of all stakeholders.
3. Establish a working / coordinating group to drive / lead Panamanian golden frog conservation efforts.
4. Develop a community engagement / education strategy.
5. Develop a research plan for *in situ* mitigation and surveillance of chytrid fungus in the environment.
6. Identify suitable habitat areas (protected and private) that could serve as golden frog reintroduction sites.
7. Develop a chytrid fungus mitigation research program for reintroduction of Panamanian golden frogs to the wild.
8. Identify data needs for the development of population viability models to inform conservation planning.
9. Develop studies to understand and meet the nutritional needs of Panamanian golden frogs in captivity.
10. Create and sign an agreement (MOU) to solidify and ensure the commitment of all parties to Panamanian golden frog conservation.

This conservation planning workshop report and the recommendations within it are considered advisory to the local and regional golden frog management teams and other collaborators to help guide actions thought to be beneficial to the long-term survival of the species in Panama.

Creating a Golden Frog Global Conservation Communication Group

The workshop ended with a final plenary session that featured a discussion of how communication and collaboration was to be coordinated within the body of people working on golden frog conservation in the United States and Panama – effectively, the people attending the present workshop. After lengthy and very productive conversations, the following organizational communication structure was adopted:

Communication / Collaboration Coordinators

Brian Gratwicke, Smithsonian Conservation Biology Institute
Angie Estrada, Amphibian Rescue Center - Gamboa

Working Group Representatives

Captive Population Management
Gina DellaTogna, Smithsonian Conservation Biology Institute

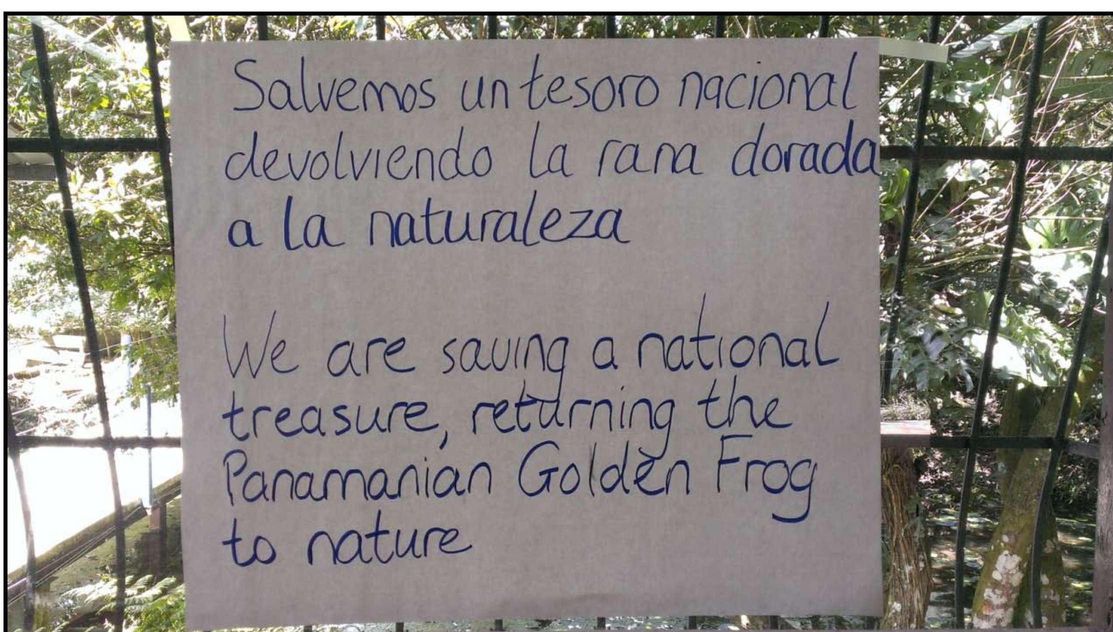
Disease Management
Della Garelle, Cheyenne Mountain Zoo

Habitat Management
Edgardo Griffith, El Valle Amphibian Conservation Center
Adrian Benedetti, HGA – MPSA

Population Viability Analysis
Roberto Ibanez, Smithsonian Tropical Research Institute

Communication / Collaboration
Sharon Ryan, Smithsonian Tropical Research Institute

The group agreed on a general communication protocol, with conference calls scheduled every two months and larger meetings at two-year intervals.



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Section 2
Workshop Participant Goals, Statements of Conservation Challenges

Workshop Participant Goals, Statements of Conservation Challenges

At the beginning of the workshop, each participant was asked to state their personal goals for attending the meeting, and to provide their perspective on what they thought were the major challenges to effective management of golden frogs in Panama over the next 25 years. These statements are recorded below.

Workshop Participant Goals

- To help integrate efforts to conserve our golden frogs
- To open lines of dialogue between management groups to safely and responsibly bring golden frogs back to the wild
- To collaborate with local biologists on golden frog conservation
- To become part of the golden frog conservation community
- To identify potential collaborations around golden frog conservation in Panama
- To establish communication between different fields of expertise, and to combine multiple management efforts to more effectively promote golden frog conservation
- To find opportunities for collaboration in support of golden frog conservation in central Panama
- To work with other interested individuals and organizations in the area of improving golden frog reproduction in captivity
- To gain insights from the golden frog program that could be beneficial to similar programs in Australia
- To learn as much as possible from the experts
- To learn more about the state of the science and biology of the species
- To learn about the breadth and depth of current research and conservation activities
- To develop a plan of conservation action for the species
- To emerge with a conservation strategy that will result in golden frog restoration in the wild as living components of Panama's heritage
- To prioritize research needs in captivity as a way to assist with wild population conservation
- To realize a formalized action plan to achieve our goal of golden frogs back in the wild
- To make sure that there are procedures in place to evaluate the impact of golden frog reintroductions on the rest of the amphibian community
- To create a plan for golden frogs reintroduction in protected areas within Panama
- To develop a long-term plan for establishing viable golden frog populations in Panama, both in the wild and in captivity
- To develop a "road map" for returning golden frogs back into the wild in Panama
- To help create a reintroduction plan that addresses disease management
- To create a reintroduction plan that everyone can agree with
- To offer insights into similar programs in Australia
- To relate my experiences in local education on environmental issues
- To provide information on monitoring golden frog populations in Panama
- To support conservation and protection of golden frogs and other endangered species in Panama
- To provide information on how disease may create a challenge to successful reintroduction and to consider how reintroduction may affect existing wild amphibian populations
- To share information about golden frogs in the wild and establish collaborations for future research and analysis
- To share knowledge on how artificial reproduction techniques (e.g., cryopreservation) can help in the larger golden frog conservation program

Challenges to Long-Term Management of Panamanian Golden Frogs

- Developing a robust and efficient long-term captive insurance colony
- Maintaining high levels of reproductive success in captivity
- Understanding the requirements for successful reproduction of golden frogs in captivity
- Lack of information on the species' natural history
- Lack of proper understanding of the current species status in the wild and the threat posed by chytrid fungus
- The continued presence of chytrid fungus in the wild
- Trying to adapt golden frogs to live with the chytrid fungus – genetically, behaviorally, ecologically
- Disease in the environment – chytrid, ranavirus, etc.
- Infectious disease management
- Maintaining long-term wild population health
- Understanding how to help golden frogs coexist with chytrid fungus
- Overcoming disease susceptibility in wild golden frog populations
- Integrating ex situ / in situ conservation of the species with local human communities in Panama
- Creating an integrated recovery program that covers research, management, and community engagement
- Improving natural resource education among local communities
- Identifying the proper mechanisms for involving local communities in golden frog conservation efforts
- Identifying effective communication strategies to engage public support for conservation
- Continued habitat loss – the human population continues to expand and use more natural resources
- Continued habitat destruction
- Long-term habitat availability
- Developing methods for successful re-establishment of self-sustaining population of golden frogs in the wild
- Effective coordination of conservation efforts – across communities, institutions, and governments
- The difficulty of monitoring individuals once they are released from a captive population
- Lack of a coordinated conservation program in the wild
- No strategic plan for golden frog reintroduction
- Creation of a proper species reintroduction plan
- Lack of a long-term population management strategy
- Collaborating effectively to achieve long-term goals
- Generating a truly effective conservation strategy that will be supported by the local communities
- Understanding the different interests and priorities of the various organizations – research, government, public – that must be involved in golden frog conservation
- Involving all the key players (stakeholders) in a single conservation strategy

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Section 3
Conservation Issues Analysis

Panamanian Golden Frog Conservation Issues Analysis

On the first afternoon of the workshop, participants were asked to brainstorm their views of the issues and challenges to golden frog conservation in Panama. These issues were presented graphically on a wall in the main plenary meeting room, with each participant encouraged to contribute ideas to the growing diagram in a process known as "brainstorming". The participatory nature of the activity is an important component of the overall workshop process, giving ownership of species management among all those attending the workshop. The final diagram is presented on the next page of this report.

Once the issues diagram was developed, it was possible to identify clusters of related issues that could form the basis of working groups that could discuss the issues in more detail. The working groups included:

1. Captive population management
2. Disease management
3. Habitat management
4. Population viability analysis
5. Communication and collaboration

Each of the five working groups followed the same basic process, working through the specific tasks outlined below:

TASK 1. **Brainstorm Problems/Issues** for your group's topic, based on the "mind map" generated in plenary.
Consolidate the ideas and problems generated in the first step into a smaller number of topics. Write a one or two sentence 'problem statement' for each problem.
Prioritize the problem statements. This process promotes careful examination of each statement and possible further consolidation or better definition. It also assists making choices for the next step if time is limited.

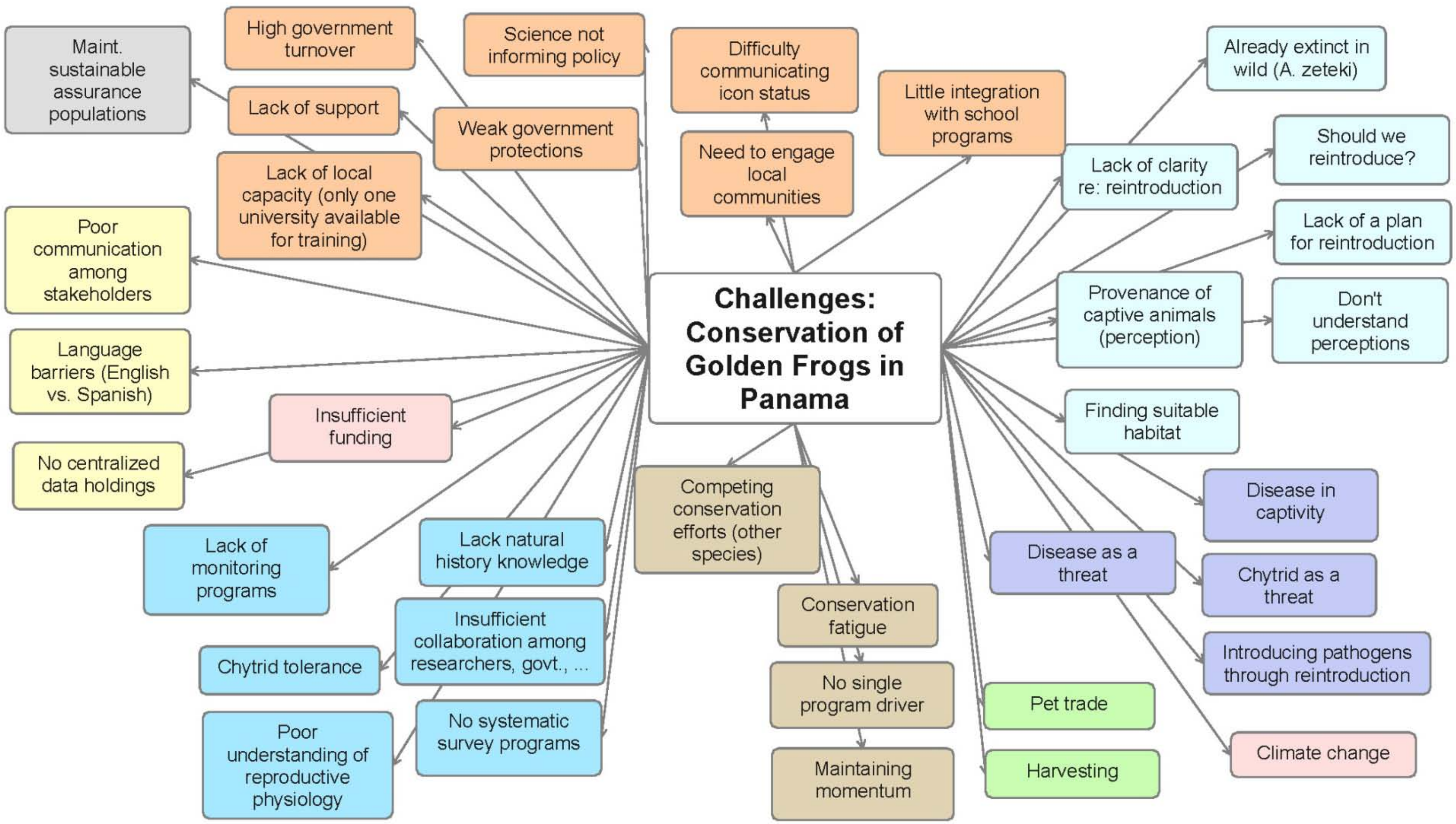
TASK 2. **Data assembly and analysis.** Begin a systematic process to determine the facts and assumptions that are pertinent to your group's issues. What do we *know*? What do we *assume* we know? How do we justify our assumptions? What do we *need* to know?

TASK 3. **Prepare short-term (1 year) and long-term (5 years) goals** (minimum and maximum for each problem. Goals are intended to guide actions to help solve the problem. Prioritize your goals across each problem you have identified.
High-priority working group goals are brought to plenary and the entire set of goals is prioritized by the full body of workshop participants under a single set of criteria.

TASK 4. **Develop and prioritize Action Steps** for each of the high priority goals identified by the full body of workshop participants. These priority actions will form the body of the recommendations from the workshop.

Reports from each of these working groups are to be found in the following sections of this report.

Figure 1. Diagrammatic "mind map" of issues and challenges to golden frog conservation in Panama. See accompanying text for more information.



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Section 4
Captive Population Management Working Group Report

Captive Population Management Working Group Report

Working Group members:
Gina DellaTogna, SCBI/SNZ
Matt Evans, SCBI
Ron Gagliardo, Amphibian Ark
David Hunter, Government of New South Wales (Australia)
Vicky Poole, Fort Worth Zoo
Heidi Ross, EVACC
Olga Samaniego, Univ. Autonóma Chiriqúi

Introduction

The group initially agreed that the primary purpose for having Panamanian golden frogs (PGFs) in *ex situ* colonies is that they serve as a key component for species conservation in light of the risk of epizootic diseases and habitat loss. When faced with a pending decline of PGFs in the wild, captive populations were created to serve as assurance colonies against the extinction of the species. Wild and captive PGF populations have provided opportunities for research (husbandry, disease/health, and conservation) and education by yielding important information, support, and awareness for the long-term conservation of amphibians globally. We see that captive populations will continue to be valuable in both of these roles going forward. Ideally, the long-term goals are that offspring of *ex situ* golden frogs will be reintroduced into the wild when the researchers feel that the proper habitat, environmental parameters, and disease risks have been mitigated to ensure the best possible outcomes at release.

Current Status of Captive Populations

In 1999, due to the impending amphibian chytrid crisis and the lack of facilities equipped or skilled to maintain viable captive populations of PGFs within Panama, the Republic of Panama issued scientific collecting permits for a total of 20.20.100 *Atelopus* (*varius*) *zeteki* to Project Golden Frog/Proyecto Rana Dorada (PGF/PRD) personnel in order to conserve the species from extinction. CITES/ESA Importation permits for those specimens and all of their offspring were obtained and have been maintained by the Maryland Zoo in Baltimore (MZB; formerly known as the *Baltimore Zoo*) since 2000, with the ownership of the animals belonging to the permit holder (no specific request to retain ownership was made by the government of Panama at collection). The permits also limit the placement of specimens to AZA-accredited facilities only and require tracking within a managed studbook (also currently maintained by MZB). Under these permits, from 2001-2003 a total of 19.19.12 *A. zeteki* and 1.1.47 *A. varius* were collected and sent to two biosecure facilities the US. [NOTE: All were imported as *A. (varius) zeteki*, but genetics have since determined there are Evolutionarily Significant Units (ESUs) between the collection localities, so the SSP recognizes two unique species within the US (Jaramillo, et al, 2003; Zippel et al, 2006; Richards and Knowles, 2007).]

Additionally, to expand the potential founder pool, the Cleveland Zoo (CZ) was able to obtain collection permits and export 6.6.0 *A. (varius) varius* to the US in 2005. However, because of the species-level recognition discrepancies at importation, the USFWS has declined requests the captive population managers to allow for integration the MZB and the CZ populations for management (Poole, personal comm.).

In 2007, The Houston Zoo completed construction of the El Valle Amphibian Conservation Center (EVACC) to house assurance colonies of critically endemic amphibians within Panama, including golden frogs. Initially collecting ~50 *A. zeteki* - Highland in 2006 and ~50 *A. varius* - Highland in 2007; collection and monitoring of PGFs in the wild continued until populations were no longer evident. As this facility is on the property of the El Nispero Zoo within the range of the iconic golden frog, there is an educational exhibit area for local amphibian species with a giant center display for golden frogs.

In 2009 the Panama Amphibian Rescue and Conservation Project was formed as a partnership between Africam Safari, the Cheyenne Mountain Zoo, Defenders of Wildlife, the Houston Zoo, the Smithsonian Tropical Research Institute (STRI), the Smithsonian Conservation Biology Institute the Summit Municipal Park and Zoo New England with a goal to expand capacity to hold ex-situ populations of amphibians threatened by chytridiomycosis in Panama, and to begin research into mitigating the effects of Bd. The new facility initially located at the Summit Zoo in 2013 moved to STRI in Gamboa and is called the Gamboa Amphibian Rescue Center (Gamboa ARC). STRI also is renovating an exhibit area at Punta Culebra Nature Center (within Panama City) to inform visitors about the global amphibian crisis, and plans to include a display of the endemic golden frogs.

Minera Panama funded a dedicated, biosecure facility adjacent to EVACC that is tasked to house and breed amphibian species displaced through the mining project, including the *A. varius* – Lowland population.

As of February 2014, the status of captive populations of Panamanian golden frogs globally is as follows:

Species/ Population	**REGION**	**Males**	**Females**	**Unknown Sex**	**REGION TOTAL**	**GLOBAL TOTAL**
Atelopus zeteki - Highland	Panama AZA	12 342	12 256	0 270	24 868	892
Atelopus zeteki - Lowland	Panama AZA	?? 156	?? 159	?? 89	?? 404	Unknown 404
Atelopus varius - Highland	Panama AZA	6 70	10 44	0 48	16 162	178
Atelopus varius - Lowland	Panama AZA	?? 0	?? 0	?? 0	?? 0	Unknown 0

Each unique population listed above have been maintained uniquely since wild-collection in the event that any environmental adaptations from their varied habitats and elevations may provide some advantage if/when reintroductions would be possible. Facilities housing golden frogs within the US/Canada have a broad range of levels of biosecurity, although PGFs at both the Baltimore Zoo and Detroit Zoos have been maintained within model biosecure populations (in total isolation from global zoo collections) since collection, and other institutions have created isolated populations; Panama facilities are considered biosecure.

Within the AZA population, total available space limits population size, and USFWS allows for humane culling as a management tool to maintain genetically diverse populations. Fortunately, PGFs attractive and exhibit-well within educational displays, so specimens surplus to the genetically-maintained group can serve as a flagship species for Panamanian and global amphibian declines at ~50 AZA-accredited facilities within the US and Canada. Due to limited genetic diversity and space, in 2009, the Species Specialist Group (SSP) decided to prioritize space for the endemic *A. zeteki* over *A. varius* within the

North American populations, phasing out the *A. varius* population as an *ex situ* colony was created within Panama by this time; the *A. varius* studbook and breeding recommendations were discontinued.

EVACC is just beginning to have continuous breeding success of their populations of golden frogs, and space and resources are also limited. A dedicated POD at EVACC and those at the new PARC facility in Gamboa are being prepared to house golden frogs. The Mineras Panama facility will house the *A. varius* – Lowland population, exclusively, once collected.

Issues and Challenges

The group identified that the primary challenge is to create sustainable populations of PGFs within Panama to meet the demands for all purposes (i.e., captive population management, research, education, and reintroduction), and to build the capacity for it. Understanding the required (as opposed to the available) capacity (infrastructure, human resources, funding, etc.), research collaborations, and numbers needed for establishing educational, research and reintroduction programs is essential to plan and provide for the captive frogs as the needs change. Since it was important to identify the capacity requirements of captive breeding programs, David Hunter proposed a cost production model (CPM) approach to allow for flexibility on specimen numbers at every life stage based on various demands and financial impacts so that the captive population itself could remain sustainable equating what was being discussed to agricultural farming practices which seeks to maximize output and minimize costs. Within Panama at present, the two facilities currently capable of maintaining sustainable PGF populations are still in need of both capacity and animals. In the future, if the ability to release surplus golden frogs back into the wild is not yet advised, the facilities within Panama should be prepared to have a policy on culling surplus specimens of these two species for population management as space may quickly become insufficient.

Another major challenge is the lack of unification between the Panamanian and AZA captive and conservation programs, due to organizational timing and differences in primary purposes when originally created. As the species is a CITES Appendix 1 species, the bureaucracy and logistics of returning specimens is anticipated to be a long and complicated process. All members of the group expressed high concern for the potential transfer of diseases from zoos/aquariums with in the US when any specimens would be imported into Panama, and prioritized identifying only specimens be returned that comply to the most biosecure/pre-screened process as determined by the Disease Management Working Group.

Summary of Outcomes

Creating assurance colonies in Panama, building capacity to maintain them and repatriating animals from the US are our recommendation and the problems, goals and actions listed below represent our road map to get there!

Summarized primary challenges:

1. Lack of sustainable assurance colonies within Panama
2. We do not know the number of animals needed to satisfy research, education, in-house husbandry research, and reintroduction needs.
3. Need of information on the funding and needs for reintroduction programs of viable/fit populations
4. Lack of capacity for establishment of captive populations for education, research and reintroductions in Panama.
5. No coordinating entities/person within Panama and between the Panamanian and AZA programs.

Data Assembly

Issue 1: The current insurance colonies of golden frogs in Panama are undersized.

Facts	Assumptions	How we justify assumptions	Missing data that would help us
Panama captive population of *A. zeteki* (Highland) is 12.12.0.	Current colony is viable and will continue to grow. All will breed and be represented.	The animals are healthy, managed and we have the ability to breed them.	Need to understand the gene diversity of the current population.
Panama captive population of *A. varius* (Highland) is 6.10.0 and *A. varius* (Lowland) is unknown	Current colony is viable and will continue to grow. All will breed and be represented.	The animals are healthy, managed and we have the ability to breed them.	Need to understand the gene diversity of the current population.
No longer found in wild with no recruitment possible for captive population	Extinct?	Last seen in 2009 (E. Griffith, pers. comm.)	Additional surveys
At present only 2 possible facilities to maintain and breed them in Panama	Both facilities can maintain and breed the species.	Both have experience with *Atelopus* sp.	Insufficient capacity still remains

Issue 2: We do not know the number of animals needed to satisfy research, education, in-house husbandry research, and reintroduction needs.

Facts	Assumptions	How we justify assumptions	Missing data that would help us
No animals available at present for research within Panama; some available within the North America.	There will be a substantial need for additional animals	There are major knowledge gaps requiring research using surplus frogs.	Unknown number; Researchers must proactively communicate their needs well before the frogs are required.
Fifty zoos in North America using *Atelopus* for educational displays	This need will increase, especially in Panama	Construction of Punta Culebra Frog Exhibit which would like to exhibit Golden frogs.	Unknown number
Husbandry research is underway in North American collections	This will continue to expand in North America and Panama	Need knowledge to build sustainable population	Need more research questions identified and answered
Animals needed in Panama for reintroduction	There will be a need for frogs		No animals currently available, and a yet unknown quantity is needed

Issue 3: Husbandry knowledge is insufficient to maximize efficiency, capacity, and quality of the captive breeding programs.

Facts	Assumptions	How we justify assumptions	Missing data that would help us
Currently, not every egg/tadpole/frog survives to reproductive age in captivity	Improved husbandry knowledge will increase survivorship	Limited research in this area has allowed the AZA population to meet capacity.	More husbandry research and knowledge of survivability at every life stage.
No current protocols established for reproduction using ARTs. (*in process*)	Application of ARTs will greatly increase capacity	Progress with other species can be duplicated (Kouba et al. 2013)	No protocol for cryopreservation of sperm or eggs. No successful AI.

Issue 4: There is no formal integration of North American and Panamanian captive programs.

Facts	Assumptions	How we justify assumptions	Missing data that would help us
No coordinator or coordinating body integrating captive programs with other aspects of recovery efforts.	There would be one person/entity to oversee all aspects of the captive program as it relates to recovery efforts.	Based on other programs, a central coordinator or team is essential.	Need is not yet defined (no road map yet).
Currently the populations are managed separately.	As populations grow, their management will be coordinated.	To maintain overall genetic diversity and maximize genetic potential for each population.	Need is not yet defined (no road map yet).

Issue 5: Managing ex situ colonies of the same species from two different elevations.

Facts	Assumptions	How we justify assumptions	Missing data that would help us
While they are the same ESU's, there are differences in habitat and natural history of the two localities/populations.	There are may important local adaptation that should be maintained in the genetics of each	It has been shown that local adaptation can occur over a short range. Field observations suggest that there may be morphological and ecological differences between the two populations (Jaramillo, et al, 2003; Zippel et al, 2006; Richards and Knowles, 2007).	Fitness level of hybrids is undetermined. Fitness of specimens needs to be determined for each release site, so maintaining all current options for the future by not mixing at present.

Goals

For each of the problem statements described earlier in this section, the working group participants developed management goals to address these problems. Finally, the group placed these goals in order of priority in terms of their effectiveness in advancing golden frog conservation in Panama.

1. Create the capacity to maintain sustainable captive populations of *A. varius* and *A. zeteki* in Panama.
   A. varius Highland form: Minimum of 200 specimens + surplus
   A. varius Lowland form: Minimum of 200 specimens + surplus
   A. zeteki Highland form: Minimum of 200 specimens + surplus
   A. zeteki Lowland form: Minimum of 200 specimens + surplus
   A. Create a business plan for this effort, including personnel and financial requirements.
   B. Import all genetic variability represented in the US, using assisted reproductive technologies where appropriate.

2. Identify a coordinating entity that meets the needs of the all stakeholders, and identify the responsibilities of that coordinator.

3. Address husbandry and captive management issues,
   A. Identify the fitness level of the specimens, including the genetic variability in the captive population.
   B. Systematically address known issues such as tetany, nutrition, tadpole nutrition, adult mortality at breeding events, dystocia, etc. in order to maintain sustainable captive populations.

4. Identify the number of frogs required for research, education, husbandry and reintroduction (i.e., the *surplus* to sustainable population listed in Goal 1 above)
   A. Create effective communication between all impacted groups to meet target numbers
   B. Create the capacity to maintain numbers for these needs.

5. Confirm and get clarification that indeed we are dealing with four evolutionary significant units (ESUs) across both *A. zeteki* and *A. varius*.
   A. Expand genetic profiles on the four ESUs

Actions

Problem Statement 1
The current *A. zeteki* insurance colony in Panama is undersized.

Goal 1
Create the capacity to maintain sustainable populations of *A. varius* and *A. zeteki* in Panama.

Action 1: <u>Identify and document the existing resources at both facilities currently housing *Atelopus* (EVACC, Gamboa), including available space, staff, funds, power, water, food, veterinary services, nutrition, and consumables.</u>

Responsible Parties: Roberto Ibañez.
Timeline: By June 31, 2014.
Outcome: Written report on each facility.
Collaborators: Heidi Ross, Angie Estrada, Jorge Guerrel, Brian Gratwicke, Matt Evans.
Costs: Mostly staff time – approximately 40 hours.

Consequences: Baseline information on each facility's capacity. The report will provide information for business plan, implementation and follow up.
Obstacles: Communication, schedules.

Action 2: <u>Build a cost production model (CPM) for captive PGF populations (4 ESUs) that includes numbers for assurance colonies, research, education and reintroduction.</u>

Responsible Parties: Brian Gratwicke.
Timeline: By August 31 2014.
Outcome: List of costs.
Collaborators: Bob Lacy, David Hunter, Vicky Poole, Kevin Barrett, Heidi Ross, Roberto Ibañez, Edgardo Griffith.
Costs: Staff time.
Consequences: Usable tool and more accurate cost estimate. CPM report provides information for the business plan.
Obstacles: Bob Lacy's time, data from captive population.

Action 3: <u>Implementation and follow-up of the working CPM and list of needs and actions, as required: Hiring and training facility staff, expanding space, upgrading power infrastructure, etc</u>

Responsible Parties: Roberto Ibañez.
Timeline: June, 2015.
Outcome: Increased space, staff, and added capacity.
Collaborators: Heidi Ross, Angie Estrada, Jorge Guerrel, Edgardo Griffith, Brian Gratwicke.
Costs: Substantial financial requirements.
Consequences: Capacity achieved.
Obstacles: Funding, Smithsonian Institutional bureaucracy, logistics.

Action 4: <u>Import as much genetic variability as needed from the US, including the Highland form of *A. varius*, and the Lowland and Highland forms of *A. zeteki*. Activities include permitting, shipping, determining ownership and destination facility, and addressing biosecurity concerns.</u>

Responsible Parties: Vicky Poole.
Timeline: Present through December 2017.
Outcome: Additional frogs are in Panama.
Collaborators: Kevin Barrett, Roberto Ibañez, Allan Pessier, Ellen Bronson.
Costs: Time, shipping costs, meeting with governmental officials, customs, prescreening Costs.
Consequences: Adding more founders to start the Lowland *A. zeteki* and Highland *A. varius* colonies, and supplement the Highland *A. zeteki* assurance colony.
Obstacles: US/Panama bureaucracy, biosecurity, ARTs protocols completed, capacity being ready.

Action 5: <u>Collection of the Lowland form of *A. varius*, following the existing Action Plan.</u>

Responsible Parties: Edgardo Griffith.
Timeline: Present through December 2014,
Outcome: Sufficient founders collected.
Collaborators: Roberto Ibañez.
Costs: Time.
Consequences: Having founders to start the Lowland *A. varius* assurance colony.
Obstacles: Bureaucracy, biosecurity.

Problem Statement 2
There is no formal integration of North American and Panamanian captive programs.

Goal 1
Identify a coordinating entity that meets the needs of the all stakeholders, and identify the responsibilities of that coordinator.

Action 1: Identify population coordinator in Panama to work with their US counterpart (SSP coordinator). Support for population management, health and husbandry information, point of contact for availability of research, reintroduction and education specimens. Represents and coordinates the captive population interests of all the PGF facilities.

Responsible Parties: Roberto Ibañez.
Timeline: June 31, 2014.
Outcome: Population coordinator in place.
Collaborators: Heidi Ross, Edgardo Griffith, Angie Estrada, Jorge Guerrel, Vicky Poole.
Costs: Mostly staff time – approximately 40 hours.
Consequences: United approach to managing global and Panamanian captive populations.
Obstacles: Lack of agreement or acceptance of a candidate in Panama. Schedule of collaborators.

Problem Statement 3
Husbandry knowledge is insufficient to maximize efficiency, capacity, and quality of the captive breeding programs.

Goal 1
Address husbandry and captive management issues.

Action 1: Conduct a survey of all institutions US/Panama) to identify health, reproductive, and veterinary concerns. Gather data for comparisons between institutions to indentify common problems and research priorities.

Responsible Parties: Kevin Barrett.
Timeline: March - August, 2014.
Outcome: Final report shared with all institutions.
Collaborators: Angie Estrada, Vicky Poole, Matt Evans, Ellen Bronson.
Costs: Mostly staff time – approximately 150 hours.
Consequences: List of research priorities.
Obstacles: Non-compliance, poor record-keeping.

Action 2: Conduct husbandry research to address priorities identified in Action 1 (including tetany, water quality, reproductive issues, etc.) and aspects of population management.

Responsible Parties: Vicky Poole, Panamanian counterpart.
Timeline: Ongoing.
Outcome: Final report shared with all institutions.
Collaborators: AZA institutions, universities, PARC, additional TBD based on need.
Costs: Staff time, research funding.
Consequences: Results will be used to update husbandry manual, publications, improved sustainability of captive colonies.
Obstacles: Time and funding; difficulty in standardizing methods; variability between facilities; bureaucracy; poor record keeping; participation.

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The Golden Frogs of Panama (*Atelopus zeteki, A. varius*):
A Conservation Planning Workshop

19 – 22 November, 2013
El Valle, Panama

FINAL REPORT

Section 5
Disease Management Working Group Report

Disease Management Working Group Report

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Introduction

The disease *Batrachochytrium dendrobatidis* (Bd) is the causative factor of the decline and extinction of many species of harlequin frogs, and is believed to be the primary agent responsible for the disappearance of *Atelopus zeteki* and severe declines of *Atelopus varius.* The persistence of Bd in wild in surviving amphibian populations and the continued vulnerability of *Atelopus* to Bd infection is a major limiting factor for reintroduction programs. There is currently no vaccine for Bd and we have a poor understanding of the characteristics of disease resistance traits, their heritability. Some animals survive and persist in the wild yet we have a poor understanding of what allows survival.

There are many other diseases that do or are likely to affect these frogs in the wild and in captivity that may be caused by parasites, viruses and other disease-causing agents. Captive populations are subject to nutritional and husbandry-related issues that may impair frog health and reproduction.

The captive collection of *Atelopus zeteki* in the USA and the strong cooperation and leadership from the Species Survival Plan have facilitated a lot of important research, field studies of golden frogs and golden frog sites have resumed, but there are few sites and too few researchers.

Problem statements:

1. We have a poor understanding of Bd survivors' epidemiology in wild with regard to reintroduction.
2. There are health problems and nutritional deficiencies in captive golden frogs that could limit population sustainability, reproduction and successful reintroduction to the wild.
3. There are potential health risks of introducing novel infectious disease by returning captive populations in United States to Panama and by releasing captive animals in Panama to the wild (there are risks of disease transmission both from captive animals to wild animals AND wild animals to reintroduced captive animals).

Data Assembly

Problem 1: We have a poor understanding of Bd survivors' epidemiology in wild with regard to reintroduction.

Factor	Facts	Assumptions	Information Gaps
Bd in the environment.	Bd is strongly limited by temperature and humidity. Bd prevalence is strongly linked to season and altitude. There are non-frog environmental reservoirs for Bd.	Bd is everywhere in golden frog habitat. We can't eliminate Bd in habitat.	Maps with layers identifying: Bd prevalence, time since Bd arrived, host density, strains, micro-environment. Rate of Bd transmission in relation to habitat heterogeneity, canopy cover, remote sensing data. Identify environmental reservoirs of Bd.
Bd in frogs.	Disease outcome varies with environmental conditions in controlled experimental conditions. There is behavioral component to resistance. *A. zeteki* Bd survivors from experiments have a unique skin microbiome. *A. zeteki* has robust immune response to Bd but when exposed to highly virulent strain, prior exposure did not change in infection loads or disease outcome. All surviving golden frogs in the field are *A. varius*.	Nearly 100% mortality to Bd. *A. zeteki* is highly sensitive to Bd and could be a "super spreader" of Bd but doesn't live long enough. Bd susceptibility depends on life stage.	Species differences in susceptibility. Characterization of frog natural defenses, microbiome, peptides, immune response. MHC genes in golden frogs (Currently being studied). Infectivity of individuals, and contact rates. Threshold for frog mortality at different temperatures. Heritability of resistance (Jaime's work). What happens if: Take 1000 frogs: hit with Bd, breed survivors, repeat? Differential life-stage responses to Bd. Understanding of tolerance vs. resistance.

			The relationship between actual parasite loads determined via histology vs. genetic equivalents. Could golden frogs persisting at lowland sites under threat of habitat modification be translocated?
Bd characteristics.	Bd has been seen arriving in waves. Multiple strains exist. Bd is sensitive to changes in temperature and humidity. Bd's virulence in culture may change depending on culture methods and history.	Bd strains in nature may vary in virulence.	How are Bd strains distributed? How does Bd change over time? What affects virulence? Phylogenetic context of Bd is poorly understood.

Problem 2: There are health problems and nutritional deficiencies in captive golden frogs that could limit population sustainability, reproduction and successful reintroduction to the wild.

Successful reintroduction of golden frogs to the wild will require large numbers of healthy captive-reared animals. Addressing disease problems that affect the captive populations will help to maximize captive breeding, ensure maximal possible genetic diversity over the long-term and produce animals with suitable fitness for reintroduction. Many disease issues in captive populations may be husbandry related.

Facts	Assumptions	Information Gaps
Edema syndromes and kidney diseases have been observed in captive *A. zeteki* and *A. varius* in the United States and Panama. In Panama (EVACC) a polycystic kidney disease of unknown cause has a high prevalence in long-term captive animals. Nutritional problems have identified in both the United States and Panama, including vitamin A deficiency. Many of these problems may be related to diets based on captive-reared insects and vitamin-mineral supplementation of these insects. Problems are not limited	There will always be captivity related health concerns that affect success.	The role of water quality and composition in development of edema syndromes, kidney disease and other disease problems. Water quality refers to classic parameters measured in amphibian/ aquatic animal husbandry such as ammonia, nitrates, pH and bacterial loads. Water composition includes solute and metal concentrations, especially compared to what animals might encounter in the wild. Addressing these

to *Atelopus*, but affect all conservation programs for amphibians that include an ex-situ component. High mortality is associated with breeding stress and extended gravidity in captive *Atelopus*. The basis for mortality is not well understood. Syndromes with clinical signs of tetany have been observed in multiple captive populations. In some cases they are attributable to classic "metabolic bone diseases" related to dietary imbalances in calcium or phosphorus (e.g. domestic crickets are calcium deficient with supplementation). In the United States tetany has been associated with elevated phosphorus in water supplies. Other considerations include other mineral deficiency or excess problems such as Mg or Fl. Spindly leg syndrome in metamorphs has limited successful breeding in some populations. Factors contributing to spindly leg syndrome are not well understood. Eye problems have been a concern in the Maryland Zoo population (corneal lesions and hyphema)		questions could involve epidemiologic and experimental approaches. LC100 concentration of bleach and contact time for Bd (6% is way too high). Little is known about the need of *Atelopus* sp. for UV light exposure and effects on vitamin D/calcium metabolism. Detailed pathology and individual facility husbandry survey information for the SSP population in the United States. A survey of causes of mortality for the Panamanian population (EVACC) has been submitted for publication. Determine ideal methods for nutritional supplementation of insect-based diets.

Problem 3: There are potential health risks of introducing novel infectious disease by returning captive populations in United States to Panama and by releasing captive animals in Panama to the wild (there are risks of disease transmission both from captive animals to wild animals AND wild animals to reintroduced captive animals).

The example of chytridiomycosis as an introduced infectious disease that can have devastating consequences for wild amphibian populations has raised awareness of the need to proceed cautiously when contemplating the reintroduction of captive animals to the wild. This is especially true for captive Atelopus that have been housed in the United States assurance populations where there has been potential for exposure to amphibian pathogens originating from outside of Panama (novel infectious diseases). Other infectious disease considerations are the susceptibility of reintroduced animals to infectious diseases that are present in amphibians at proposed Atelopus release sites.

Facts	Assumptions	Information Gaps
A single case of ranaviral disease has been noted in a wild anuran (not *Atelopus* sp.) in Panama (Allan Pessier, personal observation). Ranaviruses have been a conservation concern in Europe. Common nematode (rhabditiforms such as *Rhabdias sp*. lungworm) infestation observed in *A. zeteki* in Maryland even during quarantine. These nematodes are commonly present in wild amphibians at low levels and the ability to cope with infection is desirable for reintroduced animals. Some US captive *Atelopus* populations have been held in isolation from cosmopolitan zoo amphibian collections to reduce the risk of exposure to novel pathogens. Some of these populations have been more biosecure than others. Populations with the best biosecurity such as Maryland Zoo may be best for repatriation of animals to Panama. Susceptibility of reintroduced *Atelopus* to chytridiomycosis (a major contributor to the original decline) is a concern for successful reintroduction. Bacterial flora of *Atelopus* skin (potentially effective for defense against Bd) are different in Maryland Zoo captive population vs. old samples of wild *Atelopus* collected by Cori Richards-Zawacki , although there is	There is a significant risk of introducing novel pathogens by reintroduction of captive animals to the wild. We can screen for some, but not all, infectious diseases of concern.	Ranaviruses: Are they a risk to reintroduced *Atelopus*? True prevalence/existence in Panama there is a need for a good diagnostic test to use for population surveys, surveillance now & post release. Is *Batrachochytrium salamandrivorans* in North America? Do we need to survey *Atelopus* prior to reintroduction? What is significance of GI or respiratory parasites currently present in captive populations? (Acceptable vs. potential for causing disease). Is there a need to specifically identify? Unknown pathogens—which are significant? Confirm biosecurity levels in North American *Atelopus* populations via survey. (A survey has been conducted by Maryland Zoo needs to be analyzed for best reintroduction candidate populations). Necropsy survey of captive populations in the United States. Are there identified

overlap.		infectious disease problems that are a concern for reintroductions? How far do we need to go in ensuring that animals for reintroduction are pathogen-free?

Goals

For each of the problem statements described earlier in this section, the working group participants developed management goals to address these problems. Finally, the group placed these goals in order of priority in terms of their effectiveness in advancing golden frog conservation in Panama.

Problem 1: We have a poor understanding of Bd survivors' epidemiology in wild with regard to reintroduction.

<u>Goals</u>

1. Increase communication & collaboration between researchers to maximize efforts, economies of scale, avoid duplication and build on each other's ideas.
2. Develop further Bd mitigation research programs (probiotics, genetic selective breeding, immunization, heritability) as candidates for reintroduction / translocation experiments. Understand susceptibility differences between *A. varius* and *A. zeteki* and different life stages.
3. *In situ* Bd transmission mitigation.
4. Identify and understand reservoirs, more fully understand community ecology aspects.
5. Identify and isolate Bd strains and understand virulence significance, *B. salamandrivorans*.
6. Enhance in-country surveillance and research capacity for Bd and other diseases, field training.

Problem 2: There are health problems and nutritional deficiencies in captive golden frogs that could limit population sustainability, reproduction and successful reintroduction to the wild.

<u>Goals</u>

1. Understand and meet nutritional needs for *A. zeteki* and *A. varius*, especially in regard to vitamin A, vitamin D & calcium, and requirements for UV light exposure.
2. Understand and establish optimum water quality and composition.
3. Improve understanding of population/ reproduction-limiting health concerns: tetany, spindly leg, kidney diseases and edema syndromes.
4. Develop timely and high-quality veterinary clinical and diagnostic support in-country for Panamanian populations.

Problem 3: There are potential health risks of introducing novel infectious disease by returning captive populations in United States to Panama and by releasing captive animals in Panama to the wild (there are risks of disease transmission both from captive animals to wild animals AND wild animals to reintroduced captive animals).

<u>Goals</u>

1. Initially establish a disease screening protocol for repatriation of golden frogs from the United States to Panama that will minimize risk for existing Panamanian captive populations. Use

established disease risk assessment tools (CBSG) to identify the lowest risk populations in the US. Short term goal is for small number of animals and long term is for larger number.
2. Next, establish a disease screening protocol for reintroduction of golden frogs to the wild.
3. Establish a framework for environmental and disease monitoring (of amphibians at release sites) pre-release and post-release health monitoring of golden frogs and other amphibian species in the release site community.

Actions

Problem 1: We have a poor understanding of Bd survivors' epidemiology in wild with regard to reintroduction.

Goal 1: Increase communication & collaboration between researchers to maximize efforts, economies of scale, avoid duplication and build on each other's ideas.

Action 1: Create PGF research coordinator position who keeps all informed of current and planned PGF research (Bd and other) via list serve, forwarding publications, encouraging appropriate research, funding. Perhaps create a research committee for proposal review.

Responsible Parties: Brian Gratwicke.
Timeline: 6 months (May 2014).
Outcome: Optimal prioritizing and planning of research for PGF, SSP.
Collaborators:
Costs:
Consequences:
Obstacles: Time, long term commitment.

Goal 2: Develop further Bd mitigation research programs (probiotics, genetic selective breeding, immunization, heritability) as candidates for reintroduction / translocation experiments. Understand susceptibility differences between *A. varius* and *A. zeteki* and different life stages.

Action 1: Selective breeding for Bd resistance – Create a working group to design experiment to test heritability of resistance, to include genome sequencing of *Atelopus*
Responsible Parties: Cori Richards-Zawacki, Jamie Voyles.
Timeline: 1 year to design, long term may be 5-10 years.
Outcome: Design feasible experiments/ produce research and grant proposal / ID collaborators.
Include: possible pre-screening of exposure candidates for immune loci known from wild survivors, microbiome signature, skin metabolite or other indicator such as the mucusome. Design experiment for reality in wild— using same strain, same temperature, same exposure load. Model heritability of traits—including behavior.
Collaborators: SSP/ EVACC/ USFWS/ researchers.
Costs:
Consequences: Major if can find genetically resistant lines, may select for deleterious alleles.
Obstacles:

Action 2: Test probiotic exposure throughout life history of PGF
Responsible Parties: Doug Woodhams, underway.
Timeline: Two years.
Outcome: Determine if microbiome can be manipulated at which life stages and determine if probiotic manipulation can increase Bd resistance.
Collaborators: SSP
Costs:
Consequences:
Obstacles:

Action 3: Genetic studies- working strategy, Captive and wild genetic diversity in *Atelopus* genome
Responsible Parties: Rob Puschendorf, Andrew Crawford, Cori Richards-Zawacki.
Timeline: Four months for proposal budget.
Outcome: Experimental design and sourcing for genetic research
Collaborators: Warren Johnson, Brian Gratwicke
Costs:
Consequences:
Obstacles: Funding

Goals 3 & 4: In situ Bd transmission mitigation. Identify and understand reservoirs, more fully understand community ecology.

Action 1: Develop working group to design studies for creation of and/or identify translocation or reintroduction sites aimed at increasing frog survival (less favorable for *Bd* transmission). Identify microrefugia, determine reservoirs.

Responsible Parties: Rob Puschendorf, Doug Woodhams, Graziella DiRenzo, Tate Tunstall.
Timeline: Four months for plan.
Outcome: Identify/create appropriate low Bd sites for reintroduction, identify and understand reservoirs, more fully understand community ecology aspects.
Collaborators:
Costs:
Consequences:
Obstacles: Available habitat and permits.

Goal 5: Identify and isolate Bd strains and understand virulence significance, *B. salamandrivorans.*

Action 1: Compare and test Bd strains in *Atelopus*

Responsible Parties: Jamie Voyles, Cori Richards-Zawacki.
Timeline: Two years, underway.
Outcome: Determine possible attenuation in virulence.
Collaborators:
Costs:
Consequences:
Obstacles: Obtaining needed Bd strains and animals, funding.

Goal 6: Enhance in-country surveillance and research capacity for Bd and other diseases; field training.

Action 1: Enhance field training

Responsible Parties: Cori Richards-Zawacki, Edgardo Griffith, Roberto Ibañez.
Timeline: Ongoing.
Outcome: Determine possible attenuation in virulence.
Collaborators: All researchers working on PGF in Panama.
Costs:
Consequences:
Obstacles:

Problem 2: There are health problems and nutritional deficiencies in captive golden frogs that could limit population sustainability, reproduction and successful reintroduction to the wild.

Goal 1: Understand and meet nutritional needs for *A. zeteki* and *A. varius*, especially in regard to vitamin A, vitamin D & calcium, and determine requirements for UV light exposure.

Action 1: Form a working group to address and improve nutrition in captive *Atelopus* species
Most of the nutritional issues facing captive Atelopus are similar to those faced by all ex-situ conservation programs for amphibians. A multidisciplinary workshop on Amphibian Health and Nutrition was held at Disney's Animal Kingdom in February 2013 and conclusions and publications from this workshop will help to direct recommendations for captive golden frogs.

Responsible Parties: Eric Baitchman, Ellen Bronson, Allan Pessier.
Timeline: 1 year
Outcome: Better define and prioritize important nutritional problems in captive *Atelopus*. Develop studies to address nutritional concerns.
Collaborators: Delegates (nutritionists, veterinarians, husbandry experts) from the Disney Nutrition workshop, SSP advisors.
Costs: None initially other than existing institutional support to responsible parties. If experimental studies are needed, costs will increase.
Consequences:
Obstacles:

Goal 2 & 3: Understand and establish optimum water quality and composition. Improve understanding of population/ reproduction limiting health concerns: tetany, spindly leg, kidney issues, edema, etc.

Action 1: Working group explores significant / population-limiting health issues in PGFs.

Responsible Parties: Eric Baitchman, Allan Pessier, Ellen Bronson.
Timeline: Four months
Outcome: Design short and long term studies to address disease.
Collaborators:
Costs:
Consequences:
Obstacles:

Goal 4: Establish timely and high quality veterinary clinical and diagnostic support in country.

Action 1: Enhance veterinary support in country, work with AARK and other zoos for capacity

Responsible Parties: Eric Baitchman, Della Garelle, Brad Wilson, Allan Pessier, Angie Estrada
Timeline: Four months to identify candidates.
Outcome:
Collaborators: AARK vet group.
Costs:
Consequences:
Obstacles: Language, candidate availability.

Action 2: Timely, histopathology support

Responsible Parties: Allan Pessier.
Timeline: One year
Outcome:
Collaborators:
Costs:
Consequences:
Obstacles:

Problem 3: There are potential health risks of introducing novel infectious disease by returning captive populations in United States to Panama and by releasing captive animals in Panama to the wild (there are risks of disease transmission both from captive animals to wild animals AND wild animals to reintroduced captive animals).

Goal 1: Establish a protocol for repatriation of Panamanian golden frogs. Use disease risk assessment to establish protocols and identify lowest-risk populations.

Goal 2
Establish screening protocol for reintroduction of *A. zeteki* to the wild.

Action 1 (for both Goals above): Disease Risk Assessment

Responsible Parties: Ellen, Allan Pessier, Eric Baitchman, Della Garelle.
Timeline: Short term: for repatriation: 2 month/ASAP.
Outcome: Finalize DRA to start planning and aid repatriation / reintroduction plan.
Collaborators:
Costs:
Consequences:
Obstacles:

Goal 3: Establish a framework for environmental and disease monitoring (of amphibians at release sites) pre-release and post-release health monitoring of golden frogs and other amphibian species in the release site community.

Action 1: Design Pre-release site environmental disease surveillance/ sampling protocol: decide which agents to look for and where.

Responsible Parties: Jamie Voyles, Tate Tunstall, Allan Pessier, Roberto Ibañez, Brian Gratwicke.
Timeline:
Outcome:
Collaborators:
Costs:
Consequences:
Obstacles:

Action 2: Design post-release disease surveillance in frogs and environment/community.

Responsible Parties: Allan Pessier, Roberto Ibañez.
Timeline:
Outcome:
Collaborators:
Costs:
Consequences:
Obstacles:

Action 3: Update sample wish list from field and SSP necropsy sample request list and keep current.

Responsible Parties: Allan Pessier, Jamie Voyles.
Timeline:
Outcome:
Collaborators:
Costs:
Consequences:
Obstacles:

Action 4: Create repository in Panama for amphibian tissue/samples and catalog system for retrieval (include amphibian parasites).

Responsible Parties: Roberto Ibañez. Repository in US: Ellen, Vicky Poole, Brian Gratwicke.
Timeline:
Outcome:
Collaborators:
Costs:
Consequences:
Obstacles:

The Golden Frogs of Panama (*Atelopus zeteki, A. varius*):
A Conservation Planning Workshop

19 – 22 November, 2013
El Valle, Panama

FINAL REPORT

Section 6
Habitat Management Working Group Report

Habitat Management Working Group Report

Working Group members:
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Introduction

Habitat

The two species of golden frogs are losing their habitat in the wild because of habitat modification from mining, urban development, farming and road construction. In addition to direct habitat modification, habitat changes can lead to increased landslides and sedimentation. Agricultural and urban runoff may reduce habitat quality for tadpoles through pollution of golden frog streams. In addition, government regulation of these human impacts is weak.

Reintroduction

The original threat, Bd, remains unmitigated and is a major obstacle to successful reintroduction of golden frogs in Panama. Any pilot reintroductions will require extensive research and monitoring to select reintroduction sites. We will need secure, breeding captive populations in Panama and more research on Bd resistance in frogs. Any reintroduction or conservation areas will require well-enforced protected areas or private reserve areas with assurances negotiated over the long-term that they will not be impacted, and that upstream catchments will not be destroyed. They would preferably be connected to other habitats. This may require the acquisition of priority sites and cooperation with the government, strong law-enforcement in the reintroduction sites and community buy-in.

Problem Statements

1. Habitat loss and anthropogenic changes are affecting the sustainability of the golden frog populations in the wild.

2. Because of a shortage of viable habitats, selecting reintroduction sites for golden frogs in Panama is challenging or not possible at present.

Data Assembly

Problem Statement 1: Habitat loss and anthropogenic changes are affecting the sustainability of the golden frog populations in the wild.

Facts	Assumptions	Justification	Information Gaps
Loss and conversion of habitat is harmful to Panamanian golden frogs.	Rate of forest conversion is increasing.	Concessions granted to clear areas are at a large scale, for multiple purposes such as urban growth and mining. Landowners convert forests to agriculture.	Information on permits to clear habitat is not public record. Need to assess future risk and rates of loss in prime golden frog habitats. We are not sure how many former golden frog sites could even support frogs today if reintroductions were to happen.
Reforestation with native species is happening in places.	Contributes to recovery of habitat for golden frogs.	The government has created several reforestation programs.	We need data on where reforestation programs are occurring and verify their success.
Organic and chemical pollution occurs in golden frog watersheds, impairing water quality and tadpole habitats.	People use agricultural and household chemicals that seep into golden frog streams and may harm tadpoles Organic household or agricultural waste is released untreated in some places and resulting eutrophication may harm tadpoles.	Large quantities of agricultural chemicals are used in Panama. Sewage treatment is usually through septic tanks and we sometimes encounter areas polluted by organic waste in streams.	We need to study water quality at known golden frog sites. We need to quantify the use of household and agricultural chemicals in golden frog habitats, and investigate household waste disposal. We do not know the tolerance of chemical contaminants or organic pollution on golden frogs.
Environmental impact assessments are not conducted for some developments.	Lack of law enforcement, fines and trained local capacity result in unregulated habitat loss in golden frog habitats.	Corruption and bribery may result in authorities looking the other way. Some of EIA's are routinely misclassified and then awarded.	We need to identify and share priority conservation areas where heightened scrutiny should be applied to EIA's.

Diseases cause amphibian declines even in protected areas with pristine habitats.	Can be the cause of local population extinctions and cannot currently be mitigated in the wild. Other possible ways to control the disease may be found including habitat modification to reduce suitability for Bd persistence.	Bd and ranavirus are examples that have been studied in Panama. Recovery of frogs in environmental refuges in Costa Rica point to possible microhabitat manipulations that favor frogs but not Bd.	Need to collect environmental data at former golden frog sites. We need more studies on disease distribution, susceptibility and alternative means of disease mitigation.
Invasive species may be introduced through trade in wildlife and displace native amphibians from good habitats.	We assume that it is possible to effectively regulate the trade in live amphibians.	The exotic pet trade (legal and illegal) continues to operate in Panama.	We need to understand what regulations and policies would help mitigate this risk.
Irresponsible large-scale development in golden frog habitat reduces the number of potential reintroduction sites.	Preferential laws favor developers and not wildlife.	There is a strong interest in economic benefits and getting quick results and returns on investment with few advocates for wildlife to balance these voices.	No information on which projects have been approved or not approved, or what the existing capacity is in place to manage and oversee this process.
Lack of environmental education means community is poorly engaged in habitat stewardship.	Environmental education is inadequate and stagnant.	There appears to be a widespread apathy and lack of interest.	The lack of environmental education reflects the poor overall state of education in general. We need to work with teachers in the existing system to find out opportunities to leverage it.
Poverty is a vicious circle that generates apathy towards the environment.	We assume poverty is widespread and increasing in poor rural areas in and near to important golden frog habitat.	Poor education land lack of opportunity leads to low income.	Census to determine extent of the problem and potential pathways for sustainable development.

Problem Statement 2: Because of a shortage of viable habitats, selecting reintroduction sites for golden frogs in Panama is challenging or not possible at present.

Facts	Assumptions	Justification	Information Gaps
Currently it is not possible to reintroduce golden frogs successfully because Bd is present at all known sites.	It is extremely likely that reintroduced frogs will quickly become infected with Bd and die.	The threat that eliminated frogs in the first place cannot currently be controlled.	Biology of golden frog resistance to Bd.
We have a lack of communication mechanisms to educate the public in golden frog areas.	Reintroductions will be inefficient unless there is a strong environmental education program to encourage good stewardship of frogs and habitat	Currently there is a general lack of community participation in golden frog conservation efforts.	Sufficient number of applicable environmental education programs. Efficient and effective school curricula.
We have not resurveyed all potential golden frog habitat and sites. Even at resurveyed sites, non-detection does not mean absence.	More fieldwork surveys will allow us to advance research and conservation.	We still don't have a good picture of the natural history and distribution of golden frogs in the wild.	Further studies on ecology and behavior are needed.
We lack local law-enforcement capacity to protect golden frogs in the field.	This illegal collection of golden frogs likely still occurs, and jeopardizes long-term viability.	Illegal collection of frogs for the pet trade occurs in Panama.	We lack incentives and resources to invest in golden frog conservation and law enforcement at the local level.
Even if we had a tool to reintroduce golden frog in the wild, habitats are being modified and may no longer be suitable for the frogs.	We must assume that areas once occupied by golden frogs should be protected for future recovery programs.	We need to ensure at least part of the golden frog's natural range and habitat remains intact to attempt future reintroductions.	We don't know the current state of habitat and environmental quality at potential golden frog sites.

Goals

Problem 1: Habitat loss and anthropogenic changes are affecting the sustainability of the golden frog populations in the wild.

Goals

1. Make GIS projections of short and long-term to estimate forest cover loss or recovery using remote sensing. A good resource for this work would be the global forest change http://earthenginepartners.appspot.com/science-2013-global-forest
2. Identify all protected areas, or private areas that are viable habitats for golden frogs and survey them as potential for Bd climate refuges. There is a need to clearly understand other variables such as tenure, access, community support and long-term projections for upstream habitat modifications.
3. Conduct medium-term monitoring of water quality, temperature, prevalence of Bd, *Atelopus* eDNA to determine the status of golden frogs and monitor long-term environmental health of potential habitat for reintroduction.
4. Conduct a systematic risk analysis of other threats to ensure that the habitat will not be affected by development projects and create habitat reserves for the golden frog.
5. Establish some pilot release areas to research the potential for release of amphibians looking into different life-stages of release, anti-Bd bacteria and inherent resistance.
6. Develop publicity and messaging strategy that will be optimal for safeguarding the long-term needs for protection of the frog and engage the local communities.
7. Plan for law enforcement and stopping trade. [Poaching of reintroduced frogs is seen as a major risk.]

Problem 2: Because of a shortage of viable habitats, selecting reintroduction sites for golden frogs in Panama is challenging or not possible at present.

Goals

1. Identify and acquire suitable habitat for reintroduction of golden frogs within protected areas and private reserves.
2. Maintain stable populations of golden frogs in captivity for reintroduction.
3. Establish environmental education programs that engage communities in golden frog conservation efforts.
4. Identify sites that have microclimates that could support frogs but be poor for Bd (hotter, sunnier sites with low existing *Bd* prevalence rates).
5. Ensure that the areas for reintroduction areas are legally protected for the long-term. Identify areas of connectivity and try to establish target metapopulations at pilot sites that are intensively monitored.

Actions

Problem Statement 1
Habitat loss and anthropogenic changes are affecting the sustainability of the golden frog populations in the wild.

Goal 1
Make GIS projections of short and long-term to estimate forest cover loss or recovery using remote sensing.

Action 1: Initiate remote sensing efforts and develop models for predicting habitat suitability, combined with layers projecting risk of degradation of habitat and land ownership, or protected area status.

Responsible: Roberto Ibáñez, Adrian Benedetti (Has access to land ownership info and REDD forest cover).
Timeframe: 1 year.
Outcome: Map of habitat suitability, historical golden frog distribution, land ownership, change and potential site selection.
Collaborators: Likely will need a student or post-doc or GIS contractor.
Resources: $20,000 for contracting work.
Consequences: 'Big picture' context to guide detailed site-selection efforts, and surveys of potential undiscovered frog populations.
Obstacles: Insufficient time, money, expertise.
(Note: A good resource for this work would be the global forest change http://earthenginepartners.appspot.com/science-2013-global-forest)

Goal 2
Identify all protected areas, or private areas that are viable habitats for golden frogs and survey them as potential for Bd climate refuges. We will need to clearly understand other variables such as tenure, access, community support and long-term projections for upstream habitat modifications.

Action 1: List all potential sites for both species.

Responsible: Edgardo Griffith, Luis Elizondo, Cori Richards-Zawacki, Jamie Voyles
Time: 2 years
Outcome: Prioritized sites for reintroduction, with ground-truthing.
Collaborators: Will likely need a student/ postdoc.
Resources: Personal time and $6,000. local travel.
Consequences: Prioritized list of potential reintroduction sites.
Obstacles: Access to sites, paid time to focus on this and central coordination.

Action 2: Develop a map of species distribution and Bd prevalence rates in surviving populations.

Responsible: Cori Richards-Zawacki, Roberto Ibañez, Rob Puschendorf, Lisa Belden
Time: 6 months
Outcome: Clear idea of where Bd prevalence and persistence is high and likely to be unsuitable as reintroduction sites.
Collaborators: Will likely need a student / post doc.
Resources: Budget will need to be defined.

Consequences: Map of the distribution of Bd survivors and prevalence rates.
Obstacles: Insufficient data, data sharing between groups, coordination.

Goal 3
Conduct medium-term monitoring of water quality, temperature, prevalence of Bd, *Atelopus* eDNA to determine the status of golden frogs and monitor long-term environmental health of potential habitat for reintroduction.

Action 1: Start programs to monitor priority sites.

Responsible: Jorge Guerrel, Edgardo Griffith, Cori Richards-Zawacki, Luis Elizondo, Ángel Sosa, Lisa Belden, Matt Evans, Tate Tunstall, Grace DiRenzo.
Time: 2 years
Outcome: Clear understanding of habitat suitability at each potential reintroduction site.
Collaboration: Project Atelopus
Resources: To be defined
Consequences: Baseline data on environment and microhabitats and establishment of reintroduction sites.
Obstacles: Time, money and access to sites.

Action 2: Initiate eDNA monitoring program.

Responsible: Brian, Gratwicke, Cori Richards-Zawacki, Lisa Belden.
Time: 1 year to define methodology and initiate, will continue beyond that point as needed.
Outcome: Clearer idea about whether golden frogs are truly extinct or not at any given site, or upstream from that point.
Collaboration: Various research groups.
Resources: $10,000 field work, time, lab space and undefined budget for DNA analysis.
Consequences: A clearer idea about whether golden frogs are truly extinct at each potential reintroduction site.
Obstacles: Time, money and access to sites.

Goal 4
Conduct a systematic risk analysis of other threats to ensure that the habitat will not be affected by development projects and create habitat reserves for the golden frog.

Action 2: Establish a strategic advisory group composed of scientific, government, and legal advisors that recommend the best course of actions once possibilities have been investigated.

Responsible: Adrián Benedetti, Roberto Ibáñez, Edgardo Griffith, ANAM (Francisco Abre) (CIAM/ANCON)
Time: 3 years
Outcome: Define a protected area for golden frogs and develop a plan to protect or acquire it.
Collaboration: A Panamanian environmental non-profit such as CIAM Panama http://www.ciampanama.org or ANCON http://www.ancon.org
Resources: To be defined will vary greatly depending on recommendations.
Consequences: Define the approach, governance and enforcement of a golden frog preserve.
Obstacles: Institutional capacity and willpower in Panama.

Goal 6
Develop publicity and messaging strategy that will be optimal for safeguarding the long-term needs for protection of the frog and engage the local communities / Plan for law enforcement and stopping trade * Poaching of reintroduced frogs is seen as a major risk.

Action 1: Host a workshop specifically focused on community engagement.

Responsible: Edgardo Griffith, Adrián Benedetti, Jorge, Luis Elizondo, Ángel Sosa, Francisco Abre, Angie Estrada, Vicky Poole, Sharon, Gina DellaTogna
Time: 2 years
Outcome: Begin the process of engagement with key community leaders and get commitments to help.
Collaborators: PARC, Amphibian Ark, ANAN; ANCON
Resources: To be defined.
Consequences: Stimulate community interest and participation in and around golden frog sites and strengthen laws and people's behavior so that they will not collect the reintroduced frogs for the trade or pets.
Obstacles: Apathy towards golden frogs among residents.

We decided that, in terms of habitat, we need 2 different approaches to conservation for each species of golden frog. While many of the preceding goals apply to both species, some are species-specific. We aim to clarify the two different approaches here. *Atelopus zeteki is* thought to be extinct in the wild and will definitely need to be reintroduced. *Atelopus varius* persists in places and has been translocate at some sites. We felt that establishing some protected areas around existing, surviving frogs and creating safeguard insurance colonies would be the most cost-effective approach and likely to succeed, especially as some of these individuals have been living with *Bd* for some time yet still persist, perhaps survivors have some advantage already that has accumulated through natural selection.

***Atelopus zeteki* actions**

Action 1: Reintroduce frogs to establish functioning metapopulations.

Responsible: Heidi Ross, Edgardo Griffith, Roberto Ibañez, and everyone at the workshop!
Time: 4 years
Outcome: *Atelopus zeteki* back in the wild!
Collaborators: EVACC, PARC and coordination research group
Resources: A combination of many previous actions and work plan from all groups.
Consequences: Re-establish wild populations of Panama's national animal.
Obstacles: Funding, diseases and lack of tools to mitigate disease, stochastic factors, lack of reintroduction sites, poaching.

Action 2: Monitoring of environmental and biological variables at reintroduction sites, and post-release monitoring of amphibians.

Responsible: Cori Richards-Zawacki, Jamie Voyles, Lisa Belden.
Time: Indefinite.
Outcome: Clear understanding of what factors may inhibit recovery.
Collaborators: PhD students and research labs.
Resources: To be defined.

Consequences: Clear understanding of the processes, natural history and ecological interactions associated with release program.
Obstacles: Funding, diseases and lack of tools to mitigate disease, stochastic factors, lack of reintroduction sites, poaching.

Atelopus varius **Actions**

Action 1: Find the sites where *Atelopus varius* is still present and monitor status (there are possibly some sites that will be protected as offset areas connected with a mining operation that will have populations. We need to negotiate site protection and access for research and monitoring).

Responsible: Edgardo Griffith, Luis, Eric Baitchman, Cori Richards-Zawacki, Roberto Ibañez, Cesar Jaramillo.
Time: 1 year
Outcome: Protected areas established with existing populations of *Atelopus varius* monitored.
Collaboration: Minera Panamá, ANAM, PARC, research community.
Resources: To be defined.
Consequences: Discover new populations
Obstacles: Access and funding.

Action 2: Start population monitoring at sites where *A. varius* is still present including offset areas near the mine.

Responsible: Edgardo Griffith, Jorge Guerrel, Roberto Ibañez, Luis, Ángel Sosa, Cori Richards-Zawacki, Santana Arcia
Time: 1 year
Outcome: A list of stable wild populations of *A. varius*
Collaboration: Minera Panamá, ANAM, PARC
Resources: To be defined.
Consequences: Knowledge and demographics and disease dynamics of the species.
Obstacles: Funding.

Action 3: Develop agreements to secure these sites as protected areas for the frogs.

Responsible: Edgardo Griffith, Roberto Ibañez, Adrián Benedetti
Time: 5 years
Outcome: Long term habitat preservation for *Atelopus varius*.
Collaboration: ANAM , ANCON, Minera Panamá.
Resources: To be defined
Consequences: Long term habitat preservation for *Atelopus varius* and possible survival of an *Atelopus* population in the presence of Bd.
Obstacles: Depends on cooperation of institutions and individuals involved.

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FINAL REPORT

Section 6
Population Viability Analysis Working Group Report

Population Viability Analysis Working Group Report

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Tate Tunstall, University of Maryland

Introduction

Population Viability Analysis (PVA) is a method that allows us to project the future of endangered species' populations under various scenarios describing current and future conditions. This method is used in the management of threatened species to develop plans of action, judge outcomes of proposed management options, evaluate population recovery efforts and assess possible impacts of habitat modification or loss. It considers the interacting factors that could drive populations to extinction (Fig. 1). PVA is used to estimate the likelihood of a population becoming extinct and to point out the need for conservation efforts, identifying key life stages or processes that should be the target of such conservation efforts.

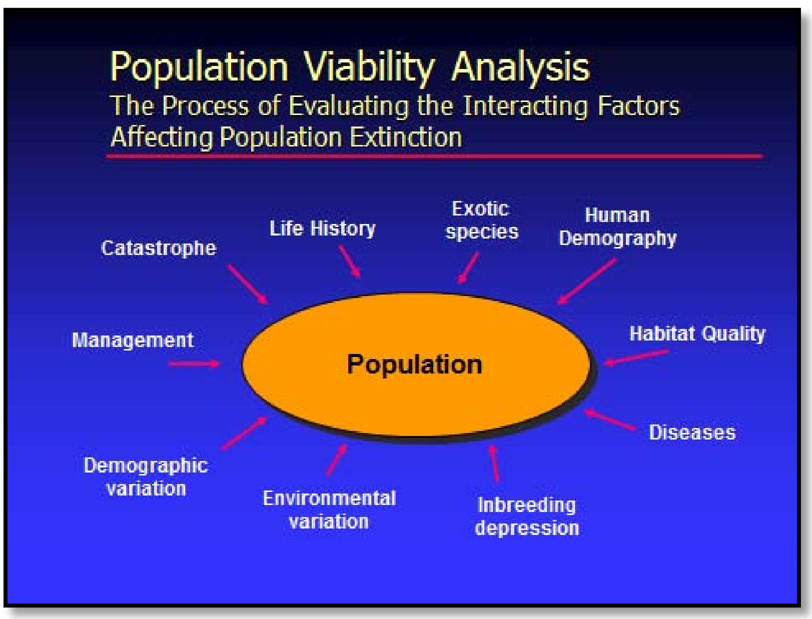

Fig.1. Population Viability Analysis evaluates key factors that affect populations to assess likelihood of extinction.

Computer software is one of the tools used in Population Viability Analyses. A frequently used PVA software program is Vortex. Vortex is an individual-based simulation of deterministic forces as well as demographic, environmental and genetic stochastic events on wildlife populations. It can model many of the extinction vortices that can threaten persistence of small populations. Vortex models population dynamics as discrete, sequential events that occur according to probabilities that are random variables following user-specified distributions. Vortex simulates a population by stepping through a series of events that describe an annual cycle of a typical sexually reproducing, diploid organism: mate selection, reproduction, mortality, increment of age by one year, dispersal among populations, removals, supplementation, and then truncation (if necessary) to the carrying capacity of the habitat. The simulation of the population is iterated many times to generate the distribution of fates that the population might experience. Vortex is freely available at: www.vortex10.org. Other software for managing captive populations, modeling dynamics of infectious diseases, etc., can be also downloaded from the same URL.

PVA Objectives and Preliminary Models

For Panamanian golden frogs, we are interested in using Vortex to model the demographics of populations under a variety of threat and management scenarios. The scenarios we have identified include: (1) pre-*Bd* population dynamics, to understand baseline population demography, (2) population reintroductions, to assess the potential for success in both the near- and the long-term and to guide planning for such efforts, (3) remnant populations in *Bd*-endemic areas, to estimate the risk of extinction these small and apparently isolated populations face, and (4) captive assurance colonies, to assess the viability of ex-situ populations and guide the management of these breeding programs. While there are likely to be many similarities among *A. varius* and *A. zeteki* model parameters, at least for now, we plan to model each species separately. In cases where we have insufficient data to model them separately, we will consider combining available data for modeling purposes.

At the workshop in El Valle, we began developing preliminary models of the golden frog populations in order to determine what parameters are needed to make projections, to explore whether the PVA modeling techniques will be useful for assessing threats and options for these species, and to begin to see what even preliminary projections indicate about the likely fates of the populations. To start, we used Vortex to develop a preliminary model of the viability of golden frog populations, based on the data available at the time of the workshop, while recognizing that more work would be needed to determine the best estimates of each important parameter. We decided to begin with *A. zeteki*, and to model the large-bodied, upland (e.g., Sora) phenotype separately from the small-bodied, lowland (e.g., Rio Mata Ahogado) phenotype, as we expect that there is little or no dispersal among these groups and some aspects of the life history of these distinct phenotypes are known to differ in ways that may affect model outcomes. For this preliminary model, we opted not yet to enter population-specific estimates of demographic rates, but instead just modeled a larger lowland and smaller highland population. Later analyses should incorporate what is known about differences in the biology of the two forms.

We decided that it would be important to consider the impacts of inbreeding on demography, especially for remnant populations in *Bd*-endemic areas and for modeling reintroduction scenarios. However, our first modeling attempt focused on a pre-*Bd* scenario, and in this case we decided to set the level of inbreeding depression low (at 2 lethal equivalents), as pre-*Bd* populations were not thought to be small enough for inbreeding to pose much of a threat and we were not yet focused on considering the effects of inbreeding. Because *A. zeteki* (especially the small-bodied phenotype) breeds in a different habitat (streams) from where they spend most of their time during the non-breeding season (forest), we modeled the population without concordance between reproduction and survival. We decided to include environmental correlation among populations because rainfall is thought to strongly influence both breeding and survival, and given the small geographic range of *A. zeteki*, seasonal and yearly rainfall patterns are likely to affect all populations in a similar manner.

One component of PVA modeling is the identification and quantification of "catastrophes" that have some likelihood of impacting populations. For golden frogs we included disease, drought (and other climate anomalies), poaching/over-collection, and habitat destruction/modification (including clearing and other disturbances to upstream habitat, introduction of invasive species, and effects of agricultural practices) among the list of potential catastrophes. However, for our preliminary model, we simply considered one generic type of catastrophe that could represent the suite of possibilities, although disease may be the dominant catastrophe affecting any remnant, recovering, or reintroduced populations.

Vortex also incorporates information about reproduction into estimates of population viability. For *A. zeteki*, little information on reproduction is available from wild populations and, thus, many of these estimates have come from captive colonies. In captivity, it has been observed that male *A. zeteki* are able to begin reproducing at a younger age (~ 10 months) than females (~ 1.5 years). This pattern of younger reproduction for males than females is thought to hold true for wild populations as well, but the age at first reproduction is likely greater for both sexes in the wild. Setting metamorphosis as the start of one iteration of a golden frog life cycle, we decided upon 2 – 3 years as the mean age at which frogs start to be successful breeders for our preliminary model. We also used a maximum reproductive age of 10 and a maximum of one brood per year (based on estimates from captive frogs). We assumed that 90% of females breed each year, based on observations that female golden frogs tend to become gravid every year in captivity. Estimates for this variable are not available for wild populations, but we assumed that most adult females breed each year. Our estimate of brood size (mean of 185) came from the observation that in captivity more than 300 metamorphs have been produced from a single clutch of golden frog eggs, though brood sizes of 150 – 200 are more commonly observed.

Vortex also requires estimates of initial population sizes and mortality rates. For mortality, we assumed annual survival from metamorph to adult was low (~ 24%), but that the year-to-year survival of breeding age frogs was higher (~ 50%). These estimates came from observations of survival in captivity. We estimated an initial population size of 5,000 individuals for the lowland (small-bodied) *A. zeteki* phenotype and 1,000 for the upland (large-bodied) phenotype based on observations of a higher breeding population density in the lowland populations, but we also examined some models starting with very low numbers (50 and 10, respectively), as might represent remnant populations still persisting after the arrival of chytrid. We set the initial carrying capacity to be the same as the starting population sizes of 5000 and 1000, but then assumed that both areas would lose 50% of the habitat over the next two decades.

Initial Results for Preliminary Models

Our first model, in which we examined the prospects for remnant populations (of initial size 50 and 10) to recover, projected a very high probability of extinction (93%) of the very small upland population, and a 40% probability of extinction for the lowland population. Extinctions of simulated populations occurred quickly (usually with 10 years, and almost always within 20 years), while populations that did not go extinct would recover up to the carrying capacity but often not until decades later. (See Fig. 2.) This suggests that a very small remnant population, if it exists, may not be likely to recover on its own even if it is resistant to chytrid.

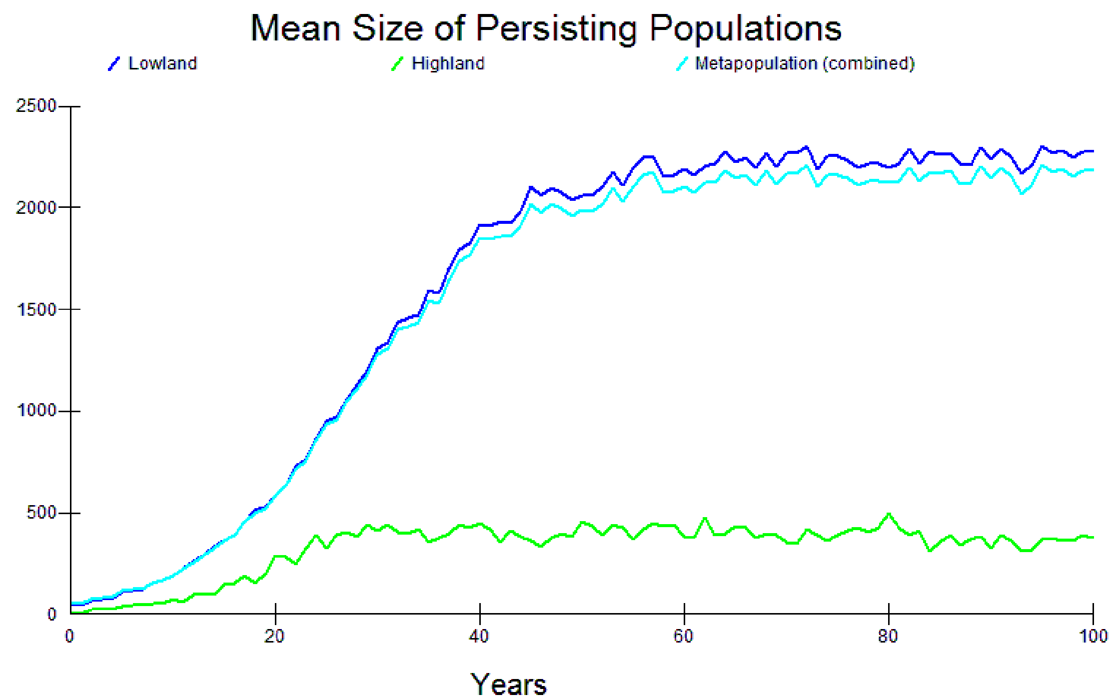

Fig.2. Mean size of extant simulated populations, projected for recovering populations of initial size 50 and 10 for Lowland and Highland populations, respectively.

To examine the possible prospects for a population that might be re-established from released animals (on the optimistic assumption that the problems with chytrid had somehow been overcome), we ran a model of a population started with N = 100, to which 20 frogs (10 males and 10 females) were added for each of the first 10 years. In this test scenario, the reintroduced populations always persisted and grew, reaching the carrying capacity typically within 15 years. (See Fig. 3.) This suggests that if the problems with chytrid can be overcome (through developing resistance or somehow removing chytrid from the environment), then the high reproductive potential of the species could allow for rapid reestablishment of populations from released frogs. It should be emphasized, however, that these preliminary models were run with initial, provisional estimates of demographic rates and other parameters. More thorough analyses with well-researched input values are needed before we can draw any conclusions about the likelihood of population extinction or recovery.

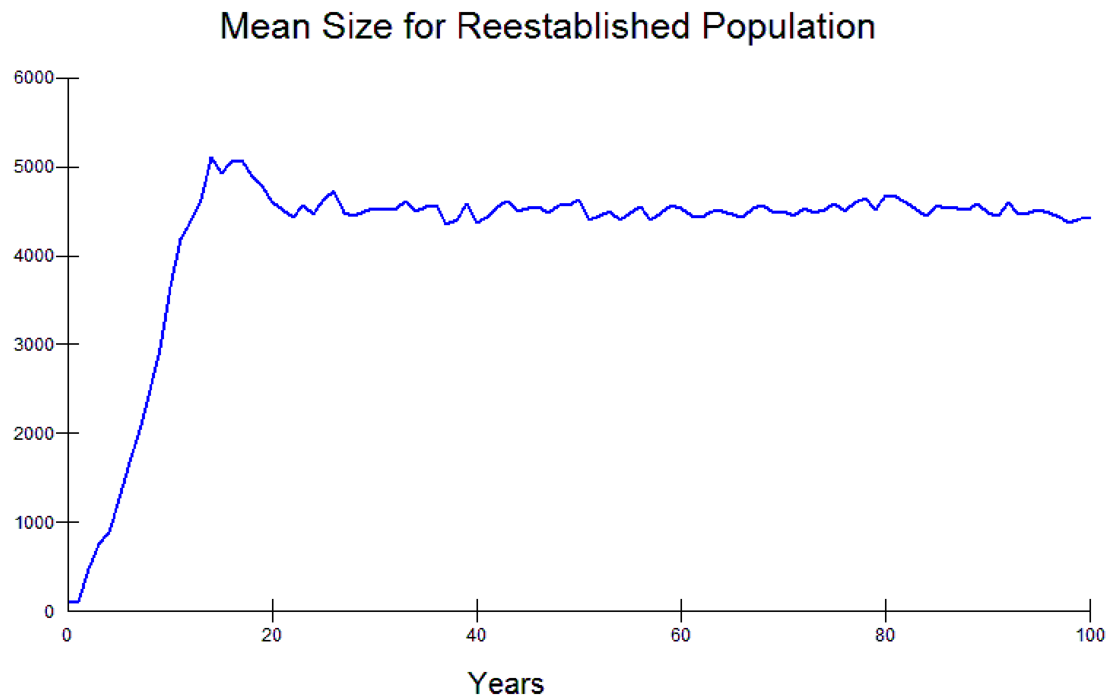

Fig. 3. Projected mean size of a population re-established with N = 100 initial frogs, to which 20 more frogs were added in each of the first 10 years.

Problems and Areas of Data Deficiency

In developing our preliminary Vortex models, we also articulated a list of problem statements related to our ability to generate a model of population viability that will be adequate for conservation planning. One problem we identified was a **lack of demographic and natural history information for Panamanian golden frogs**. We developed a list of key variables needed to generate a useful PVA model, but for which estimates are currently unavailable or highly speculative. These included (1) annual mortality rates, (2) proportion of females that breed each year, (3) juvenile recruitment rates, (4) the rate/extent or projected habitat loss, and (5) the extent to which demographic rates vary among populations, phenotypes, and species. The adequacy of the PVA models we develop for conservation planning will hinge to some extent upon the accuracy of these estimates. A second problem we identified is that there are **no extant populations of *A. zeteki* and only a few extant populations of *A. varius* known**. This means that our ability to design studies to generate estimates of essential model parameters from wild populations is limited at best, and in the case of *A. zeteki*, may be impossible. More than likely we will have to rely upon estimates derived from other species or from golden frogs in captivity for estimates of many of our Vortex parameters. We also identified **uncertainty about future conditions, especially with respect to habitat, climate and disease** and **unknown or uncharacterized differences among golden frog species and populations** as challenges to developing a useful PVA model.

As we proceeded in developing our preliminary Vortex model, we also made a list of parameters we would need to estimate, noting those for which we have relevant data and those for which such data are lacking. We began by diagramming the life cycle of the golden frog and identifying data we have and need pertaining to each developmental stage. For the egg stage, we have good information on clutch sizes (averages and variation) from *A. zeteki* in the wild. These data for *A. varius* could come from studies of extant populations or captive animals. We do not have hatching success information for either species from wild populations, but could get estimates of this parameter from captive animals. For the tadpole stage, we have no information on survival from the wild, but we could get estimates of this parameter from captivity and/or studies of related species. For recent metamorphs and juveniles, survival information will also have to come from captivity or related species, although some information could possibly be derived from mining existing capture-mark-recapture (CMR) datasets. However, because this life stage is thought to disperse, estimating survival with CMR would be complicated by emigration from the study area. For adults, we may be able to derive useful survival estimates for a few populations by mining CMR datasets. If this does not produce useful estimates, information from captivity or related species will have to be used or new studies will need to be undertaken (e.g., for *A. varius*). Estimates of the frequency of reproduction and the age at first reproduction will likely come from related species and/or captivity, though some information about the age at first reproduction for one *A. zeteki* (Mata Ahogado) and one *A. varius* (Rio Marta) population may be able to be extracted from existing skeletochronology data, perhaps in conjunction with growth curve estimates from captive frogs.

Our ability to estimate population size, which is used as a starting point for Vortex analysis, will depend upon the modeling question at hand. For models of pre-*Bd* dynamics, population size estimates may be able to be derived from existing CMR datasets. For prospective models, the appropriate starting population size for *A. zeteki* may be zero, as no extant populations are known. No reliable estimates of population size are available for the extant *A. varius* populations, though studies could be designed to generate these estimates. Information on site-to-site and year-to-year variation in population size may be attainable by compiling information across CMR studies but is not currently available. While pre-*Bd* estimates of population density may be able to be derived from CMR datasets, estimates of carrying capacity would have to be derived from related species.

As discussed above, we included disease, drought (and other climate anomalies), poaching/over-collection, and habitat destruction/modification (including clearing and other disturbances to upstream habitat, introduction of invasive species, and effects of agricultural practices) among the list of potential catastrophes threatening golden frog population viability. Climate data (e.g., rainfall) data are available for estimating the frequency and/or risk of flood and/or drought, perhaps in combination with stream flow estimates derived from GIS data (e.g., Arc HydroGeo program). No sources for estimates for the other categories of catastrophe were discussed at the meeting.

Prospective PVA and Disease Modeling

Our further modeling at the meeting was focused not on immediately generating what we expected to be realistic models with well justified parameter values, but rather on exploring how models might be used and what kinds of data (especially related to disease) would be needed. We discussed using Vortex as a tool to inform the development of golden frog reintroduction strategies. Doing so would take advantage of Vortex's flexibility in allowing users to define parameters that describe characteristics or "states" that are expected to vary among populations and individuals. Our discussion of state variables centered on susceptibility to *Bd* in a reintroduction scenario. In this case, variables that might be important to consider would include the number of animals released, the proportion of individuals released that are resistant to *Bd* infection, the heritability of *Bd* resistance, and annual risk of exposure. Estimates of these parameters are not currently available, but Vortex could be used to investigate how variation in these parameters affects the likelihood of establishment of a viable population (i.e., sensitivity analysis).
To demonstrate how Vortex could be used in this way, we developed a very preliminary model in which we modeled the disease resistance of each frog and projected whether a released population could grow in spite of the presence of the disease. We specified that 1000 frogs would be released, we set the initial proportion of a released population that would be resistant to 1%, and we modeled resistance as a

completely heritable trait passed on from parents to offspring. We assumed that 50% of the frogs would be exposed each year, and that the exposed frogs would die if they were not genetically resistant.

This test model projected that the population would have about a 90% chance of extinction, with extinction typically occurring within the first 10 years as the few *Bd*-resistant frogs were not enough to initiate population recovery. In the few simulated populations that did persist, the populations rapidly crashed as the non-resistant frogs quickly became infected and succumbed to the disease, but then the populations recovered as the new generations inherited *Bd* resistance from the survivors (Fig. 4). However, population recovery from the few initially resistant frogs was often not apparent until after about 20 years, and full recovery up to carrying capacity often required more than 50 years.

Again, it is important to note that this preliminary model was examined only to determine how such models might be used to inform risk assessments and conservation planning; we do not yet know if the model we created at the workshop represents the likely dynamics of *Bd* in golden frog populations. More meaningful analyses will require careful consideration of the model structure (e.g., whether to model resistance as heritable or not), and exploration of the range of plausible values for each variable in the model (e.g., the proportion of frogs initially resistant, and the likelihood of infection of non-resistant frogs).

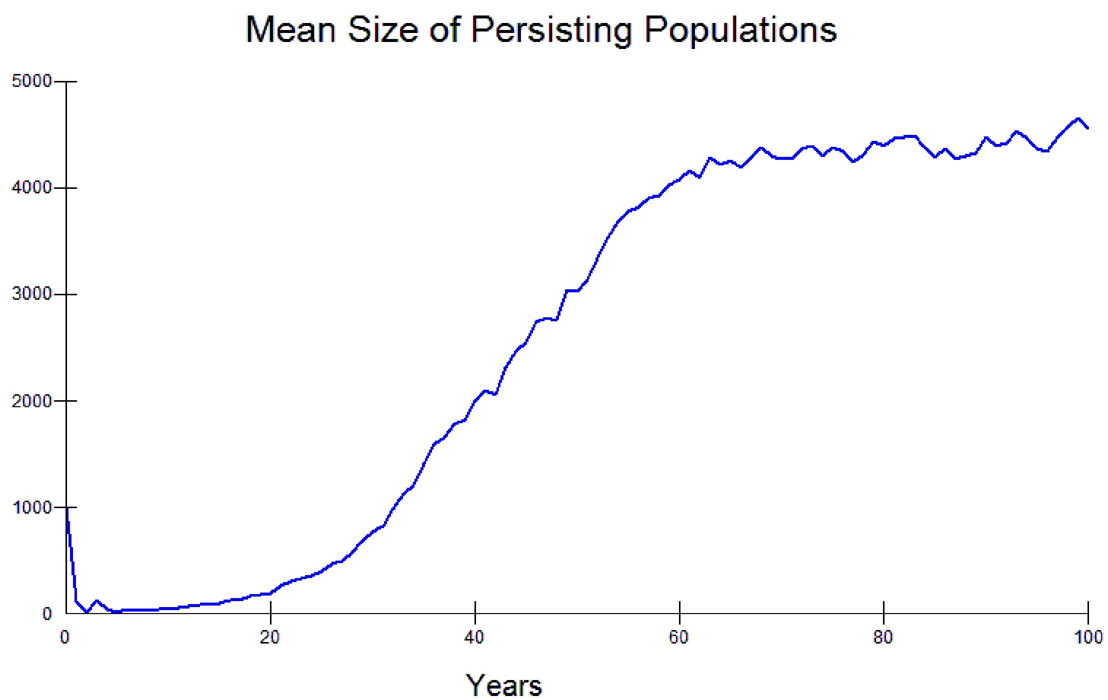

Fig. 4. Projected mean size of populations that persisted in spite of the continued presence of chytrid, under a set of assumptions about the initial proportion of frogs that are resistant (1%), the complete heritability of that resistance, a high likelihood of infection of non-resistant frogs, and 100% mortality of infected frogs.

As an alternative to Vortex in investigating the impact of *Bd* on extant and/or reintroduced golden frog populations, we tested the use of the software Outbreak, an epidemiological model of infectious disease that simulates disease dynamics under an individually based model of transitions among **s**usceptible, **e**xposed, **i**nfectious and **r**ecovered individuals (SEIR model). Outbreak can be downloaded for free at: http://vortex10.org/Outbreak.aspx. Outbreak provides a more detailed model of the infectious disease process than is possible in Vortex, but Vortex provides a more detailed model of the demographic dynamics of the populations. We used the Outbreak software, again, based on the data available at the time of the workshop, to develop a preliminary model of the dynamics of a *Bd*-exposed population.

To generate our preliminary Outbreak model, we first needed to define the probabilities of frogs moving between classes (pre-susceptible, susceptible, exposed, infected and recovered). For the pre-susceptible class, we considered the probability that an individual is born with complete *Bd* resistance (i.e., can't be colonized by the pathogen) to be a function of the condition of both the dam and the sire (i.e., if both parents are genetically resistant, the offspring has life-long resistance as well; if one parent is resistant, then the offspring has a 50% chance of being resistant). We assumed that otherwise the odds of genetic resistance were 1%, and that there was no particular life stage when an individual is not susceptible to *Bd*. For the susceptible class, we considered transmission to be dependent upon the distance between individuals and modelled the encounter rate between individuals as a function of distance. For each encounter with an infected frog, we assigned the chance of transmission as 50%. We assumed that the chance of contracting a *Bd* infection via environmental transmission was lower, and accordingly set this value at 1%. For the exposed class, parameters we will need to estimate include the duration of incubation (latency) and how soon after exposure a frog starts shedding zoospores into the environment. For the infectious class, we will need to estimate the probability of recovery, once infected, the probability of returning to the susceptible class after an infection, the probability of death due to *Bd* infection, and the probability of staying in the infectious class permanently. We estimated the incubation period to be 4 to 10 days, and the duration of the infectious period as being from 8 and 120 days. For the recovered class, we will need to estimate the proportion of individuals that acquire permanent immunity to *Bd* and the duration of resistance for individuals without permanent immunity. Lacking any data at the workshop on which to base even guesses about these parameters, for an initial run of a simulation we simply assumed that all frogs that become infected (i.e., ones that lack inherent resistance and become exposed) will die.

Other parameters that must be defined in Outbreak include the distribution of individuals across disease classes in the starting population, the demography of the population (i.e., fecundity rates, survival rates for each sex, age class and disease category, and carrying capacity) and any seasonality in infection dynamics. We will also need to define coordinates for spatial aspects of transmission and animal movement and boundary rules (i.e., what happens when a frog hits the end of the virtual landscape we have created – do they turn around and stay within the original boundaries or do they keep dispersing outward).

With initial guesses as to plausible disease parameters, an Outbreak model projected that most frogs would quickly become infected and die. When surviving frogs produced a new cohort of metamorphs, the new susceptible frogs too would quickly become infected and die. (See Fig. 5.) The few frogs that were resistant in the model were too few to allow recovery of the population. (Although the line showing the few survivors cannot be distinguished in the graph, at the end of the simulated year there were still a few resistant frogs surviving.)

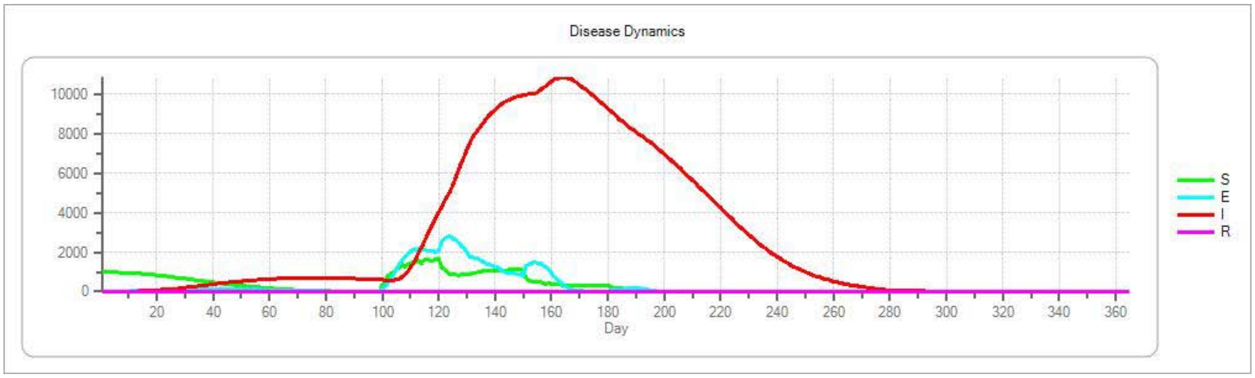

Fig. 5. Projected changes to the numbers of susceptible (green line), exposed (blue), infectious (red), and recovered (magenta) frogs over 1 year simulated in the Outbreak epidemiology model.

We identified a number of questions that could be addressed using Outbreak models. These include (1) whether a single infected individual could result in a *Bd* outbreak that kills off the whole population and (2) how the models could be used to inform conservation strategies. Options for informing conservation that were discussed include the potential for vaccination (i.e., any kind of protective treatment) and culling of animals when a local outbreak occurs. Based upon the available research, vaccination does not look like a viable option at this time, but if that should change, Outbreak could be used to ask questions about how vaccination strategies could impact population viability. For example, it could be used to ask questions about the point at which vaccination should be considered, and how the number of animals that are treated and how often, the effectiveness of the vaccine (i.e., the proportion of individuals that acquire immunity), and how long immunity lasts might impact the efficacy of vaccination strategies. We decided that culling (the practice of purposely decreasing population numbers a when disease occurs to stop its spread) was probably inappropriate for these species.

Toward the end of the workshop we brainstormed additional key questions that could be addressed with prospective PVA and/or disease modelling. These included: (1) How quickly can a population recover from a serious decline (e.g., *Bd* epidemic)? (2) How many individuals need to persist in a remnant population to give a good chance for recovery? (3) To what extent can we use information from other species to inform our models (i.e., are there "normal" patterns of population fluctuation in amphibians we can use to parameterize our model)? (4) Could we breed resistance into frogs in captivity, and in what timeframe is that useful? (5) If a golden frog is in an environment where *Bd* is present, what is the probability it would pick up the pathogen, and how quickly would they pick it up (i.e., what is the force of infection)? (6) How can modelling results inform future research questions?

Comparison of Outbreak Results to Other Modeling Approaches

Bd is thought to be transmitted by zoospores shed from the skin of the infected host, and the shedding rate is believed to be a function of the number of zoospores on the animal. Previous attempts to model *Bd* disease dynamics have used an individual based simulation approach (modeling the dynamics of the disease on each frog) developed specifically for modeling *Bd* to track the number of zoospores on infected hosts. We will compare the results from the more generic Outbreak SEIR model to individual based methods to see which models best capture *Bd* dynamics, and what information might be lost in simplifying to an SEIR type model. Individual based models require additional parameters, such as the growth rate of *Bd* on the host, and the maximum *Bd* load tolerated before death. These parameters will have to be estimated from the literature or measured in the field.

Impact on Other Species

Modeling might also be used to help assess the potential impact of *Atelopus* reintroductions on the *Bd* disease dynamics of other species already present at reintroduction sites. We will attempt to answer questions such as: What is the transmission rate of *Bd* between *Atelopus* and other species? How does the reintroduction of *Atelopus* affect the prevalence and intensity of *Bd* in other species?

Population Dynamics Problem Statements

After our preliminary trials using Vortex and Outbreak, we identified the following issues that need to be considered for future modeling efforts:

- We don't have estimates of key demographic rates to build a model of population dynamics that we have confidence will be adequate for conservation planning.
- We don't know of existing wild populations of *A. zeteki* and there are perhaps only a few populations of *A. varius* for study of the species biology, so we may have to rely on extrapolation from other species or from captive populations.
- There is uncertainty about future conditions, especially with respect to habitat and diseases.
- Species and populations may differ in characteristics important to the model, but we have little understanding of those differences.

All of these problems reinforce the need for research, including collection of new data, mining and sharing and timely analysis of existing data in developing population viability models for golden frogs.

Goals

1. Create an ongoing working group of collaborators to coordinate work to achieve goals 2, 3, and 4.
2. Identify priorities for what data will be needed to support population viability assessments and conservation planning with respect to data on (a) demography of PGF, (b) disease priorities and (c) habitat changes.
3. Assemble available data from multiple sources, including (a) captive data, (b) literature on related species, (c) ongoing monitoring and (d) past surveys.
4. Compare usefulness of different modeling approaches to determine which make the best use of available data to inform conservation.

Actions

Goal 1
Create an ongoing working group of collaborators to coordinate work to achieve goals 2, 3, and 4.

Action 1: Identify people through nominations/volunteers. Potential collaborators were identified, a list of these persons were included in Action 2. More collaborators could be added in the future, as they are identified.

Action 2: Identify skill sets of collaborators.
- Population viability analyst – Bob Lacy
- Disease modeling - Tate Tunstall
- Database management – Cori Richards-Zawacki
- PGF biology/ecology – Roberto Ibáñez, Karen Lips, Erik Lindquist, Edgardo Griffith, Joni Criswell, Kevin Barrett, Kevin Zippel, Cesar Jaramillo
- GIS specialist for habitat modeling – to be named at Clark University
- Contacts with various entities

Action 3: Send an invitation to the working group – Roberto Ibáñez [invitation was composed at the workshop, and soon thereafter sent to the initial list of potential collaborators]

Goal 2
Identify priorities for what data will be needed to support population viability assessments and conservation planning with respect to data on (a) demography of PGF, (b) disease priorities and (c) habitat changes

Action 1: Create 3 tables with columns for each variable needed for existing models, with columns for data from wild, from captive, from other species, and source.
Need a table for each of:
- Population biology models – Lacy to create skeletal table, all others fill in [initial table was developed immediately after the workshop; working group members have provided feedback; and it is ready to start receiving information from the collaborators identified in Goal 1.]
- Epidemiological models – Tate and Bob
- Habitat models – Person TBD

Action 2: Make table available via DropBox for group to start filling in data – Bob (to be filled in by year's end)

Action 3: Begin planning a working/training workshop in July? (all of us)

Action 4: Discuss funding needs for data collection and analysis as well as training, meeting, etc.

Action 5: Develop preliminary models to determine data sensitivity – Bob & Tate & Cori (semi-polished model for PVA side by end of March)

Goal 3
Assemble available data from multiple sources, including (a) captive data, (b) literature on related species, (c) ongoing monitoring and (d) past surveys

Action 1: Extract parameter estimates from existing datasets
- Poll working group members – whole group (table mentioned above, filled in by year's end)
- Analyze data – Cori (end of March for CMR data sets)
- Publish data

The Golden Frogs of Panama (*Atelopus zeteki, A. varius*):
A Conservation Planning Workshop

19 – 22 November, 2013
El Valle, Panama

FINAL REPORT

Section 7
Communication and Collaboration Working Group Report

Communication and Collaboration Working Group Report

Working Group members:
Francisco Abre, National Environment Authority of Panama (ANAM)
Angie Estrada, ARC in Gamboa
Eric Flores, Amiparque /Panama Wildlife Conservation, Santa Fe
Victor Marilla, ANAM
Irma Rodriguez, ANAM
Sharon Ryan, Smithsonian Tropical Research Institute (STRI)
Maria Sanjur ANAM
Sonia Tejada, STRI

Introduction

The working group identified three key issues related to collaboration, communication and education that should to be addressed in developing a strategic plan for amphiban conservation.

Lack of Collaboration and Information Exchange

The various players involved in amphibian conservation in Panama–local and international scientists, research institutes, zoos, natural resource managers, conservation groups, educators and others groups–do not effectively coordinate and collaborate efforts around research, protection, monitoring, enforcement and education. There is a lack of exchange of information i.e. about scientific research, management policies and education and outeach programs taking place. Moreover, there are few established mechanisms in place to facilitate this exchange of information and promote collaboration.

In particular, communication is lacking between officials of ANAM, the governmental agency in Panama responsible for environmental protection and management of natural resources, and scientists carrying out research and conservation efforts in the field. Within ANAM, communications between the head office and regional ANAM field stations is not always efficient or consistent. This may be due in part to a lack of institutional capacity for effective communication tools for broader outreach, such as web infrastructure that would allow ANAM to share existing information. For example, workshop participants noted they cannot always access ANAM's information on specific research topics or management policies as needed. Finally, frequent turnover in government positions and researchers working in the field can lead to uncertainty over key personnel and leadership roles, both for ANAM staff and scientists.

A language barrier further complicates communication between the scientists and ANAM or other government bodies. Most scientific research is published in English, the international language of science. ANAM's documents are all in Spanish, and Spanish is the first language of its employees. As a result, ANAM may not have timely access to research results that would inform its management decisions. Scientists meanwhile may not be able to access critical information on management policies and development projects in sensitive areas.

Outreach

Amphibian conservation is a national challenge, but most of the community engagement and outreach takes place at the local level, and is limited to two sites. For example, there are *Atelopus*, one of the critically endangered species in Panama, in both Veraguas and Cocle, yet the Panamanian Golden Frog Day festivities are concentrated mainly in El Valle and Panama City (even though the Panamanian Golden Frog Day was declared to be a "national" day by legal Decree).

There is also little coordination among key parties and efforts in terms of community engagement and outreach. Key actors do not integrate their efforts including local NGOs, community groups, ANAM, El Valle Amphibian Conservation Center (EVACC), Amphibian Rescue and Conservation Project in Gamboa (PARC), STRI, Comité Pro-rescate de la Rana Dorada, community members, schools, decision makers, tourism, to name a few.

Education

The links between institutions with expertise in science and education such as STRI, zoos, and EVACC, and the formal education system in Panama are not well developed when it comes to amphibian conservation and education.

Few education materials, such as curricula related to the plight of the Panamanian Golden Frog for teachers to implement in the classroom, have been developed or are widely disseminated to date. Those materials and resources that do exist are not easily accessible in any single place, and are often in English only e.g. Mission Critical, a film by the Smithsonian Institution (SI) chronicling the spread of chytrid fungus and what scientists are doing about it, is only available in English.

Many teachers, field scientists and other educators may not have training in science communication and education around how to educate and engage audiences and promote conservation attitudes and behaviors.

Problem Statements

Collaboration

There is a lack of accessible, bilingual information and resources (scientific, management and educational) and communications between key stakeholders due to language barriers, changing players, and lack of formal mechanisms to facilitate sharing and collaborative program development at all levels.

Outreach

Amphibian decline is a national challenge but we lack a national communications and engagement strategy for integrating and coordinating efforts of all the players.

Education

In education, amphibian conservation is hampered by the absence of an education strategy and resources for this issue e.g. materials, training and evaluation of the effectiveness of education programs in the formal and informal science education systems.

Data Assembly

Problem Statement 1: There is a lack of accessible, bilingual information and resources (scientific, management and educational) and communications between key stakeholders due to language barriers, changing players, and lack of formal mechanisms to facilitate sharing and collaborative program development at all levels.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography
We have lot of research on diverse topics such as species distribution, reproduction, genetics, and amphibian diseases in the wild.	Scientists will share their findings with ANAM; those findings will be reviewed and understood by ANAM and will be used / useful in management decisions / plans.	ANAM needs up-to-date information / relevant lines of Golden Frog research in Spanish.	Research is being carried in the range of the Panamanian Golden Frog: el Cope, Campana, El Valle, Santa Fe; USA.	Check with PVA for bibliography
We know major critical threats facing them (habitat loss, chytrid, pollution in streams and rivers).	We assume that scientific information is the most important information needed for management decisions (ANAM/STRI/scientists assume this).	Clear, concise and timely information from ongoing studies and new results as they emerge for natural resource managers / policymakers.	Research is being carried out in the range of the Panamanian Golden Frog: el Cope, Campana, El Valle, Santa Fe; USA.	PVA
We have up to date information on captive breeding programs (species & numbers in captivity; successes).	We do not have enough information at this time to make decisions about reintroductions even if we had enough frogs ready.	No release trial has been done to date with documented results.	El Valle; Gamboa	amphibianrescue.org; amphibianark.org
Manual of Captive Rearing Husbandry	Scientists carry out research and follow Panamanian laws when doing so.	Up to date manual in English and Spanish.	Wherever amphibians are being reared or kept in captivity.	amphibianrescue.org; amphibianark.org
ANAM has a comprehensieve Action Plan for the Conservation of Amphibians in Panama.	We assume it is being implemented; we assume people have access to it and can use it.	The plan should be readily available to the public and decision makers in English and Spanish. It needs to be translated	Nationwide, international.	http://www.amphibians.org ANAM website

		into English for scientists and international conservation organizations working on this issue.		
Database on all research projects taking place in-country (by theme / by region)	ANAM maintains an up to date database and has the personnel to update it.	Collated information and research needs in English and Spanish, and available to public.	Panama and international level.	ANAM (not accessible to public)
There is little information available on development projects taking place or planned in Panamanian Golden Frog habitat.	ANAM maintains an up to date database and has the personnel to update it.	Collated information in Spanish and English needed.	Projects being carried out or planned in the range of the Panamanian Golden Frog: el Cope, Campana, El Valle, Santa Fe.	ANAM (not accessible to public)
STRI Database of Research Projects	STRI maintains an updated database of scientific research of its scientists and visiting scientists that is accessible to public. STRI is informed about priority research projects for amphibian conservation and helps to avoid replication of similar projects. There is a designated STRI contact for information.	Scientific research is not available to researchers and public in a timely, accessible way. Scientific information is mainly in English and not searchable (amphibian research). There is no contact person on STRI amphibian research.	Nationwide and researchers home country.	STRI internal
Dispersion of chytrid in Panama is largely unknown.	Information is up to date and readily available.	There is no information database integrated to GIS for decision making as to what areas are considered at risk.	Nationwide; international.	EVACC, Corine Richards research group
Key groups in amphibian conservation and education are known.	All groups have and use the same information.	Names of individuals and organizations involved, and contact information.	Panama, USA.	ANAM, STRI, PARC, Amphibian Ark, Zoos.

Problem Statement 2: Amphibian decline is a national challenge but we lack a national communications and engagement strategy for integrating and coordinating efforts of all the players.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography / Source
We know many of the groups involved and key audiences.	Panamanians really care about saving Golden Frogs or amphibians in general.	Little information on attitudes/perceptions of stakeholders.	El Valle; Santa Fe; Chiriqui, El Cocle, Veracruz, Panama City.	Andecdotal evidence; ANAM's Plan for Amphibian Conservation.
Good tools / channels for communicating exist.	People know how to locate the tools and how to use them effectively.	List of Assets / Tools available i.e. products or information or studies.	Nationwide, international (e.g. zoos, AZA, web sites).	STRI Punta /EVACC/Circulo Herpetológico de Panamá, sitio del redes de ONGs/Stakeholders. amphibianconservation.org amphibianark.org
There is interest and support for the cause.	If we raise awareness, Panamanians will care and take conservation actions.	Target audiences and stakeholders in different parts of the country. Attitudes and knowledge levels.	El Valle; Santa Fe; Chiriqui, El Cocle, Veracruz, Panama City, USA.	Anecdotal evidence. Attendance numbers for events (6000+ for 2013, and 25,000 clicks on the event poster online). High level of coverage by national and local media.
Education / Outreach materials (assets)	Some education materials exist and people use them.	One stop shopping / clearinghouse for materials. Lack materials in Spanish, and targeted to reach Panamanian audiences.	Panama & USA.	ANAM-Direccion de Fomento a la Cultura; STRI; Internet; USA organizations.
Information on the role of frogs in Panamanian culture	The cultural issue and relevance of Panamanian Golden Frogs is well understood.	Accessible, understandable, engaging, dynamic information.	Panama	STRI (Dr. Richard Cooke), INAC; amphibianrescue.org; amphibianark.org

General research / best practices on communication planning; social marketing.	People know these practices and how to implement them.	Locally and cultural relevant information in Panama.	Panama	NGOs: e.g. ANCON, CIAM, STRI, Smithsonian, Internet.
Tools for evaluation of communication and engagement programs exist.	We assume there are channels between information generators / decision-makers and audiences.	List of available tools / materials. Interpretation training / skills. Information on effective program evaluation, formative and summative.	El Valle; Santa Fe; Chiriqui, El Cocle, Veracruz, Panama City, USA.	Internet, marketing firms; Smithsonian, Zoos' education department / ANAM, other agencies.

Problem Statement 3: In education, amphibian conservation is hampered by the absence of a national education strategy and resources e.g. materials aligned with school curriculum, training and evaluation of the effectiveness of education programs in the formal and informal science education systems.

Facts	Assumptions	Information Gaps	Regional Specificity	Bibliography / Source
We have the law on Golden Frog conservation that includes an education component: INAC/MEDUCA/ANAM	We assume people know the law; or what it means for them.	Law not available in English.	All of Panama	ANAM/MEDUCA/INAC/ STRI/Other NGOs/
There are Education Centers / Education Programs that focus on Golden Frog conservation.	People receive the messages and respond to them.	Materials in Spanish.	All of Panama	STRI/EVACC/Summit Park/ANAM
We have amphibian exhibitions in two major communities (one is under construction).	Exhibitions are effective educational tools for changing attitudes and behaviors.	Study on perceptions of visitors to exhibitions, and whether target messages are getting through. Complementary education materials targeted to different levels and general publics.	El Valle and Panama City	STRI (PCNC)/EVACC
We have education materials (curriculum / modules / coloring books).	We assume the materials are effective / useful in raising awareness, conveying key messages, changing attitudes and behaviors.	List of assets; curricula / materials on the issue. Most information is in English. Learning outcomes. Impacts on behavior change.	Panama	AmphibianArk.org

There is good research on best practices in informal science education, EE, and teacher training etc.	In public schools teachers don't have access to materials, tools or training to implement them well. We assume there is no follow up. We assume there are many competing priorities on teacher's time - how do we get this on their radar.	Information and educational needs of Panamanian teachers and educators.	Panama	MEDUCA, CEASPA
Teacher / educator professional development.	There is little training for teachers especially in those areas where *Atelopus* are thought to exist in the wild.	Teacher / educator training workshops / materials / coordinator.	El Valle, PN Omar Torrijos (Coclé), PN Santa Fe (Veraguas), PN La Amistad (Chiriquí)	MEDUCA, ANAM, STRI
Strong relationship with MEDUCA / accreditation for teacher professional development.	MEDUCA: Directors understand the importance of PGF conservation and education.	MEDUCA's stated needs in terms of materials and training.	El Valle, PN Omar Torrijos (Coclé), PN Santa Fe (Veraguas), PN La Amistad (Chiriquí)	STRI, MEDUCA, ANAM

Goals

<u>Community Engagement and Education</u>

- Establish committee with representation from key institutions
- Plan and execute education and outreach programs in progress for 2014
- Translate priority information into Spanish / vice versa specifically Action Plan for Amphibian Conservation (ANAM) and the Manual of Amphibian Husbandry
- Working through committee, develop a 3-year community engagement and education strategy to expand reach that is aligned with the education and outreach goals of the National Plan for Amphibian Conservation including:
    - Research on perceptions / attitudes / needs / Assets
    - Goals
    - Define Audiences
    - Key Messages
    - Develop Activities (teacher training, curriculum development; exhibitions; ISE programs: training in science communication for scientists / ANAM rangers/staff, traveling exhibits)
    - Identify channels of communication and marketing tools
    - Resources / Budget
    - Evaluation Metrics / Measures of success

<u>Inter-Institutional Communication and Collaboration</u>

- Establish driver or coordinating group to lead inter-institutional communications / collaboration especially between scientists and management agencies for exchange of critical information
- Create MOU (memorandum of understanding) between parties
- Identify information needs and mechanisms for exchanging information in timely and accessible ways
- Promote the knowledge about GF Law among the parties

Actions

Action 1: <u>Form Education and Outreach Committee. Send invitation to key stakeholders to participate in committee</u>

Responsible Parties: Sharon Ryan / Francisco Abre.
Timeline: First meeting, April 2014.
Outcome: Committee formed, 2014 actions mapped out
Collaborators: Invitees include representatives of STRI/EVACC/ANAM/ARC in Gamboa, Amphibian ARK, INAC, ATP, Cope, Santa Fe, El Valle.
Costs: $600.
Consequences: New committee and collaboration mechanism in place, Y1 plan.
Obstacles: Funds, institutional priorities, distance, timing, level of interest.

Action 2: <u>Launch amphibian exhibit, school program, teacher training and amphibian classroom curriculum in 2014.</u>

- Build and launch Amphibian Exhibit at Punta Culebra Nature Center to reach 100,000 visitors annually.
- Finalize amphibian school program for 35,000 school children / 300+ school groups
- Finalize, design, print and distribute Classroom Curriculum to at least 200 schoolteachers.

- Include Amphibian Curriculum in STRI's annual intensive teacher training program.
- If funding and time allow, offer training workshops to scientists and ANAM staff in education and outreach skills building.

Responsible Parties: Sharon Ryan, STRI.
Timeline: Curriculum design: December 2013 (Final draft completed)
Pilot modules with school groups (Completed)
Teacher Training (weeklong workshop) in Panama City and Bocas del Toro: January and February 2014 (Completed)
Docent / Guide training at Punta Culebra: March 10-12, 2014
Exhibit and School Program launch: March 2014
School Program: March-December 2014
Outcomes: Amphibian education modules delivered to 35,000 students 300 schools / teachers in one year; 100,000 visitors per year to new exhibit; 200 plus teachers receive curriculum; 75 teachers participate in training workshops with amphibian modules.
Collaborators: MEDUCA, STRI, Peace Corps
Costs: $15,000
Consequences: Teacher and students learn about amphibians, what's threatening them and how scientists and partners are racing against the clock to help them through research, rescue and conservation.
Obstacles: Lack of resources; delays in construction or finalizing curriculum; internal approvals denied etc; lack of personnel to implement; training, federal sequestration.

Action 3: <u>Plan and deliver National Panamanian Golden Frog Day Festivities</u>

- Form committee to coordinate events (EVACC, PARC, NGOs, ANAM, etc)
- Contract or designate coordinators (STRI has enlisted a Peace Corps volunteer for one year who will coordinate activities in 2014)
- Plan activities in Panama City, El Valle and Santa Fe
- Design and produce promotional materials for events
- Implement activities
- Engage sponsors ie. Rana Dorada Restaurant Pub, others.
- Measure results
- Write and distribute report on events to stakeholders and committee members

Responsible Parties: Angie Estrada.
Timeline: First meeting: March 2014
Planning / Production of materials: April-July 2014
Media Plan: June 2014
Week of Events: August 14-19 2014 (TBD)
Outcome: Reach more than 7000 people participate in 2014; Receive 30,000 Facebook hits on posters and fliers, 500,000 media impressions, raise at least $4000 in sponsorships
Collaborators: ANAM, EVACC, STRI, Panama Wildlife Conservation, other partners, Newspapers, TV channels
Costs: $10-$15,000.
Consequences: The National Panamanian Golden Frog Day exceeds attendance, publicity and funding goals of 2013. Expands reach to Santa Fe.
Obstacles: Election year; other major events (e.g., 100th Anniversary of Panama Canal on August 14); Lack of funds; competing priorities.

Action 4: Develop media plan for Golden Frog Day

- Participate in committee meetings
- Write press releases; post media release and promotional materials on Facebook; invite media to events, etc

Responsible Parties: Sonia Tejada.
Timeline: June 2014; execute in August 2014
Outcomes: Increased positive publicity for event and cause; Receive 30,000 Facebook hits on posters and fliers, 500,000 media impressions,
Collaborators: All committee partners; Local and national media; sponsors
Costs: $500; Sonia's time.
Consequences: Extensive positive publicity for the cause and festivities in major media outlooks in the country.
Obstacles: Availability, competing priorities; near dates of Panama Canal's 100th anniversary.

Action 5: Develop a Panamanian Golden Frog educational video

- Film programs / sites, produce video
- Distribute via YouTube; to ANAM; website; in schools.

Responsible Parties: Eric Flores.
Timeline: August 2014
Outcome: First locally produced video on GF conservations and education
Collaborators: ANAM (filming permits), EVACC, INAC, Herbios Group Panama, Cable TV distributor companies.
Costs: $ 3,500.00 (field trips costs, video editing)
Consequences: Video widely distributed on the Internet, public video channel, distribution to schools as students have laptops in public schools and internet access. Raised awareness of issues in other regions of Panama. Extended reach of educational materials.
Obstacles: permits gathered on time, lack of funds, collaborators' commitment.

Action 6: Unidad Viajera – traveling education truck

- Contact the Department of Fomento a la Cultura Ambiental of ANAM
- Provide Golden Frog materials to traveling education vehicles

Responsible Parties: Irma Rodriguez.
Timeline: April – December 2014.
Outcome: 7000 students reached annually with amphibian education materials and messages (visit schools in all regions of Panama, specially El Valle, Santa Fe and Chiriquí).
Collaborators: EVACC, Gamboa PARC, STRI / Punta Culebra Nature Center.
Costs: $2,000.00. Printing of materials.

Action 7: Produce ANAM stand in Feria Artesanales on El Valle with Panamanian Golden Frog materials / activities.

Responsible Parties: Victor Bethancourt.
Timeline: March 2015
Outcome: Reach 5000 visitors; 7 schools; 3000 students with amphibian education materials and messages.
Collaborators: ANAM/STRI (information / amphibian posters if available)
Costs: TBD.
Consequences: Local vehicle and new audiences for disseminating educational materials and conservation messages.
Obstacles: No budget or cannot obtain approval from ANAM

Action 8: Develop draft of 3-5 Plan for community engagement and outreach

- Organize 1-2 meetings of Committee to develop global plan (national and international) for Amphibian Education & Outreach

Responsible Parties: Committee Lead (possibly Peace Corps Volunteer)
Timeline: September – December 2014
Outcome: 3-year strategy and multilevel collaboration taking place around amphibian education and outreach.
Collaborators: Committee members
Costs: TBD
Consequences: Broadened and expanded reach of amphibian education and conservation.
Obstacles: Lack of will, resources and time; competing priorities.

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Section 8
Group Prioritization of Goal Statements

Group Prioritization of Goal Statements

Once the working groups had developed all of their goals, they presented and discussed these goals with the rest of the workshop participants in plenary so that all participants were able to have input into all issue and goals. Goals were examined across the four groups and, if necessary, were consolidated, split, or otherwise refined to equalize the level of action and to increase clarity. This resulted in a total of 43 goals endorsed by the workshop participants, all of which are recommended to benefit the two species of golden frogs in Panama.

An overall prioritization of all workshop goals helps to guide working groups in developing recommended actions, especially if resources (funding, time, staff) are limited, and can help focus attention on the primary issues of concern. Once the goals were finalized, the participants were asked to consider the importance of each goal in terms of its expected impact on Panamanian golden frog population management.

The goals were displayed on flip charts, and participants were asked to prioritize these goals with respect to a common criterion: The greatest immediate positive impact on golden frog conservation in Panama.

It is again important to recognize that all conservation goals have been endorsed and seen as important to achieve within the larger context of Panamanian golden frog conservation. The relative ranking presented here gives a sense of the urgency and/or priority of all goals when compared as a whole.

Goal Statement	Participant Score
Create capacity for and maintain sustainable captive populations of *Atelopus zeteki* and *A. varius* in Panama, with business plan in place	**16**
Identify an organizational coordination structure to meet the needs of all stakeholders **Establish a working / coordinating group to drive / lead Panamanian golden frog conservation efforts**	**11**
Develop a community engagement / education strategy	**10**
Develop a research plan for in situ mitigation and surveillance of chytrid fungus in the environment	**9**
Identify suitable habitat areas (protected and private) that could serve as golden frog reintroduction sites	**8**
Develop a chytrid fungus mitigation research program for reintroduction of Panamanian golden frogs to the wild	**6**
Identify data needs for the development of population viability models to inform conservation planning	**6**
Develop studies to understand and meet the nutritional needs of Panamanian golden frogs in captivity	**5**
Create and sign an agreement (MOU) to solidify and ensure the commitment of all parties to Panamanian golden frog conservation	**5**
Establish a protocol for repatriation of Panamanian golden frogs	4
Identify and acquire suitable habitat for reintroduction of golden frogs within protected areas and private reserves.	4
Increase communication & collaboration between researchers to maximize efforts & avoid duplication.	3
Establish a framework for pre-release site environment disease monitoring and post-release monitoring in Panamanian golden frogs and for other species/community effects	3
Conduct a systematic risk analysis of other threats to ensure that the habitat will not be affected by development projects and create habitat reserves for the golden frog.	3
Create an ongoing working group of collaborators to coordinate work on population viability analysis.	3
Develop a fundraising strategy (sources, funding goals, proposals)	3
Develop a plan for increasing law enforcement and eliminating trade.	2
Determine the number of frogs required for research, education, husbandry and reintroduction	2
Develop a plan to identify and study disease reservoirs, and to more fully understand other community ecology aspects	1
Develop / improve in-country health support	1
Develop research plans to identify and investigate ID Bd strains and understand virulence significance, B.s. as well	1

Identify all protected areas, or private areas that are viable habitats for golden frogs and survey them as potential for Bd climate refuges. There is a need to clearly understand other variables such as tenure, access, community support and long-term projections for upstream habitat modifications.	1
Develop a plan for collaboration / communication (execute in phases)	1
Conduct medium-term monitoring of water quality, temperature, prevalence of Bd, *Atelopus* eDNA to determine the status of golden frogs and monitor long-term environmental health of potential habitat for reintroduction.	1
Plan for law enforcement and stopping trade.	1
Develop studies to understand and meet nutritional of Panamanian golden frogs	1
Develop and enhance in-country surveillance and research capacity for Bd and other diseases	1
Ensure that the areas for reintroduction areas are legally protected for the long-term. Identify areas of connectivity and try to establish target metapopulations at pilot sites that are intensively monitored	0
Publicize reserve areas to help secure status in communities and deter development attempts in the general area but keep specific localities limited.	0
Establish some pilot release areas to research the potential for release of amphibians looking into different life-stages of release, anti-Bd bacteria and inherent resistance.	0
Make GIS projections of short and long-term to estimate forest cover loss or recovery using remote sensing.	0
Maintain stable populations of golden frogs in captivity for reintroduction.	0
Establish environmental education programs that engage communities in golden frog conservation efforts	0
Identify sites that have microclimates that could support frogs but be poor for Bd (hotter, sunnier sites with low existing *Bd* prevalence rates).	0
Develop research to optimize water quality and composition	0
Align collaboration / communication strategy with the Plan for Amphibian Conservation's Education goals	0
Confirm and get clarification that indeed we are dealing with four evolutionary significant units (ESUs) across both *A. zeteki* and *A. varius*.	0
Assemble available population dynamics data from multiple sources, including (a) captive data, (b) literature on related species, (c) ongoing monitoring and (d) past surveys	0
Compare usefulness of different modeling approaches to determine which make the best use of available data to inform conservation	0
Identify communication needs / best ways to collaborate	0
Address husbandry and captive management issues	0
Establish a protocol for reintroduction and translocation of Panamanian golden frogs	0
Develop studies to elucidate significant health problems	0

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Appendix I
Workshop Participants and Agenda

The Golden Frogs of Panama (*Atelopus zeteki*, *A. varius*): A Conservation Planning Workshop 19 – 22 November, 2013

List of Workshop Participants

Name	Organization	Country	Telephone	E-mail
Francisco Abre	ANAM/Biod/del	Panamá	507-6210-2536	fabre@anam.gob.pa
Santana Arcia	Grupo Ambiental del Copé	Panamá	507-6760-5824	arciasantana@hotmail.com
Eric Baitchman	Zoo New England	USA	617-828-7033	ebaitchman@zoonewengland.com
Kevin Barrett	Maryland Zoo	USA	443-992-4588	kevin.barrett@marylandzoo.org
Lisa Belden	Virginia Tech University	USA	540-231-2505	belden@vt.edu
Victor Bethancourth	ANAM	Panamá	983-6411	victorbethancourt@hotmail.com
Ellen Bronson	Maryland Zoo	USA	443-823-3691	ellen.bronson@marylandzoo.org
Andrew Crawford	UniAndes	Colómbia		crawfordaj@gmail.com
Gina Della Togna	SCBI/SNZ	Panamá	571-294-1656	dellatognag@si.edu
Graziella DiRenzo	University of Maryland	USA	6801-8637	gdirenzo@umd.edu
Luis Elizondo	University de Panamá	Panamá	507-6449-1795	elizondolui@gmail.com
Angie Estrada	Gamboa ARC	Panamá	507-6997-9443	angiestrada@gmail.com
Matthew Evans	Smithsonian	USA	202-633-3252	evansmj@si.edu
Vicky Flechas	UniAndes	Colómbia		s-flecha@uniandes.edu.co
Eric E. Flores	AmiParque	Panamá	507-6819-9508	eric@panamawildlife.org
Ron Gagliardo	Amphibian Ark	USA	404-455-6832	ron@amphibianark.org
Della Garelle	Cheyenne Mountain Zoo	USA	719-433-1223	dgarelle@cmzoo.org
Brian Gratwicke	SCBI	USA	202-633-0257	gratwickeb@si.edu
Edgardo Griffith	EVACC	Panamá	507-6676-8094	virolasboy01@yahoo.com
Jorge Guerrel	Gamboa ARC	Panamá	507-6532-0317	jguerrel@gmail.com
Myra Hughey	Virginia Tech University	USA	507-6730-4804	myrahughey@gmail.com
David Hunter	Government of Australia	Australia	616-229-7115	David.hunter@environment.nsw.gov.au
Roberto Ibañez	STRI	Panamá	212-8111	ibanezr@si.edu
César Jaramillo	Circulo Herpetológico de Panamá	Panamá	507-6817-3214	jaramilc@si.edu
Bob Lacy	Chicago Zoological Society	USA	315-440-5756	rlacy@ix.netcom.com
Phil Miller	CBSG	USA	952-997-9800	pmiller@cbsg.org

Allan Pessier	San Diego Zoo	USA	619-569-5635	apessier@sandiegozoo.org
Vicky Poole	Fort Worth Zoo / PGF SSP	USA	817-759-7162	vpoole@fortworthzoo.org
Rob Puschendorf	Plymouth University	UK	+44-1752-584-658	robert.puschendorf@plymouth.ac.uk
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Sharon Ryan	STRI	Panamá	507-212-8044	ryansm@si.edu
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Sonia Tejada	STRI	Panamá	212-8111	tejadas@si.edu
Tate Tunstall	University of Maryland	Panamá	510-213-8287	tatet2@gmail.com
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Doug Woodhams	University of Colorado	USA	720-245-5828	dwoodhams@gmail.com

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Workshop Agenda

Tuesday, 19 November

8:00A	Depart STRI offices (Panama City) for El Valle
11:45	Lunch
12:15P	Workshop Opening – *Heidi Ross, PARC*; *Vicky Poole, Project Golden Frog*; *Roberto Ibáñez, PARC* Participant Introductions
12:45	Keynote presentations – *Edgardo Griffith, EVACC; Eric Flores, Panama WildLife Conserv.*
1:20	Introduction to CBSG and PHVA workshop process – *Phil Miller, CBSG*
1:50	Update on species status in the wild – *Cori Richards, Tulane University*
2:00	Update on species status in captivity – *Kevin Barrett, Maryland Zoo*; *Heidi Ross, PARC*
2:20	Update on disease research in amphibians of Panama – *Brian Gratwicke, Smithsonian*
2:40	Break
3:00	Introduction to PVA and preliminary PGF models – *Bob Lacy, Chicago Zoological Society*
3:45	<u>Plenary Session I:</u> Create a vision for PGF conservation in Panama
4:30	<u>Plenary Session II:</u> Identify challenges to PGF conservation – mind-mapping
	Working group formation
5:45	Adjourn
7:00	Dinner

Wednesday, 20 November

7:30A	Breakfast
9:00	<u>Working Group Session I:</u> Generate and prioritize challenges to PGF conservation
10:30	Break
10:45	<u>Plenary Session III:</u> Present prioritized challenges to PGF conservation
11:30	<u>Working Group Session II:</u> Identify information/data gaps on species biology, management
1:00P	Lunch
2:00	<u>Working Group Session II: (cont'd.)</u>
	(Break at 3:30)
3:45	<u>Plenary Session IV:</u> Present information/data gaps
4:45	<u>Working Group Session III:</u> Develop PGF conservation goals
5:30	Adjourn
	Tour of EVACC facilities
7:00	Dinner

Thursday, 21 November

7:30A	Breakfast
9:00	Working Group Session III: (cont'd.)
	(Break at 10:30)
11:00	Plenary Session IV: Present and discuss PGF conservation goals
	Group prioritization of conservation goals
1:00	Lunch
2:00	Working Group Session IV: Develop PGF conservation actions
3:30	Break
3:45	Working Group Session IV: (cont'd.)
5:30	Adjourn
7:00	Dinner

Friday, 22 November

7:30A	Breakfast
9:00	Plenary Session V: Present and discuss preliminary PGF conservation actions
10:00	Working Group Session V: Revise and finalize PGF conservation actions
10:30	Break
10:45	Working Group Session V: (contd.)
12:00P	Plenary Session VI: Present and discuss final PGF conservation actions
1:00	Lunch
2:00	Plenary Session VI: Present and discuss final PGF conservation actions (cont'd.)
2:30	Next steps – where to go from here?
3:00	Workshop Closing – *Vicky Poole, Project Golden Frog; Roberto Ibáñez, PARC*
4:00	Depart for Panama City