PopFrog.org

Amphibian Population Management Tools

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Contents

PopFrog User Manual 3
Introduction 3
Home Page 3
PopFrog Tool Box 4
PopFrog Tools 5
Carrying Capacity for a new program 5
Carry Capacity for existing population 6
Multiple Factor Tool 7
Group vs. Pedigree Management 8
Dealing with a demographic crisis 9
Documentation 10
Return to Home Page 10
Manual 10
Definitions 10
Source Code 10
AArk POPULATION MANUAL INTRODUCTION 11
DATA MANAGEMENT FOR AMPHIBIAN POPULATIONS 13
DEMOGRAPHY 13
POPULATION GENETICS 13
RECORD KEEPING FOR INDIVIDUAL MANAGEMENT 14
RECORD KEEPING FOR GROUP MANAGEMENT 14
INITIAL DATA ENTRY 14
ONGOING DATA COLLECTION 14
Literature Cited 15
GENETIC MANAGEMENT OF AMPHIBIAN POPULATIONS 15
BASIC GUIDELINES FOR GOOD GENETIC MANAGEMENT: 15
FOUNDERS 15
BREEDING – HOW MANY? 15
POPULATION GROWTH – HOW QUICKLY SHOULD THE POPULATION GROW? 15
ENVIRONMENT 16
BREEDING – WHICH INDIVIDUALS/GROUPS? 16
CULLING 16
SPECIAL CONSIDERATIONS FOR POPULATIONS MANAGED AS GROUPS 17
GROUP SIZE 17
GROUP BREEDING STRATEGIES 17
Literature Cited 18
DEMOGRAPHIC CONSIDERATIONS FOR MANAGEMENT OF AMPHIBIAN POPULATIONS 18
Literature Cited 19

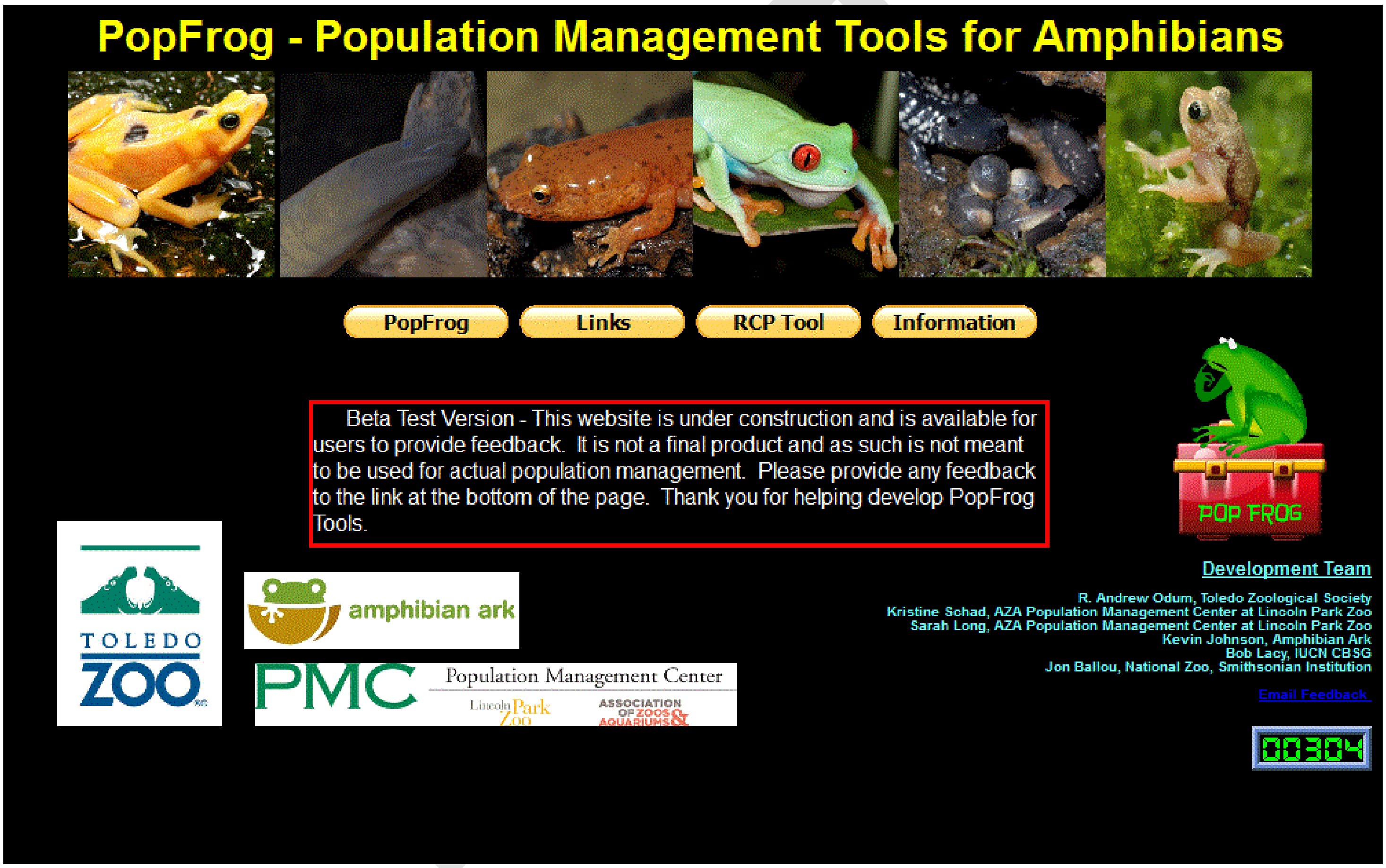
PopFrog User Manual

Introduction

PopFrog is a suite of interactive management tools to aid captive population managers to set population goals and methodology for ex-situ conservation populations.

Initially PopFrog was developed to specifically address to provide guidance to amphibian population managers. Later a new section was added to expand its capabilities to analyze populations of species that have lower reproductive rates. This section is indicated as the RCP Tool.

Home Page



PopFrog Tool Box

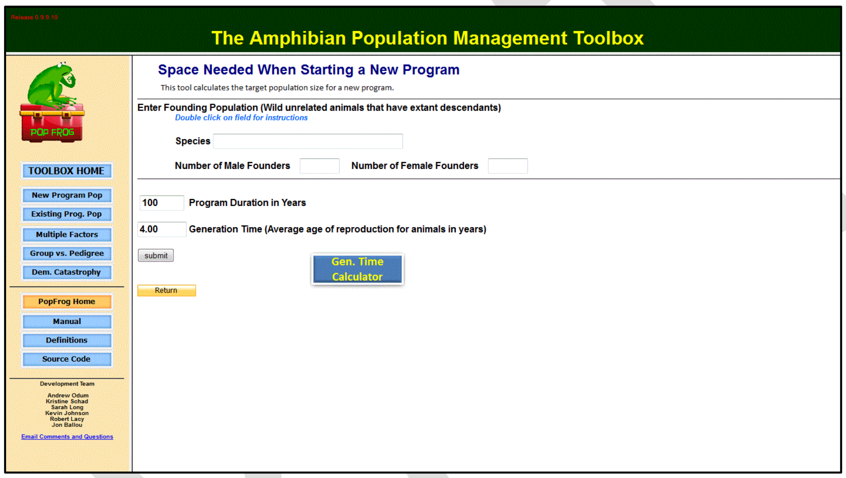
Below is the PopFrog Tool box home page. Each option on this page is discussed in more depth below.

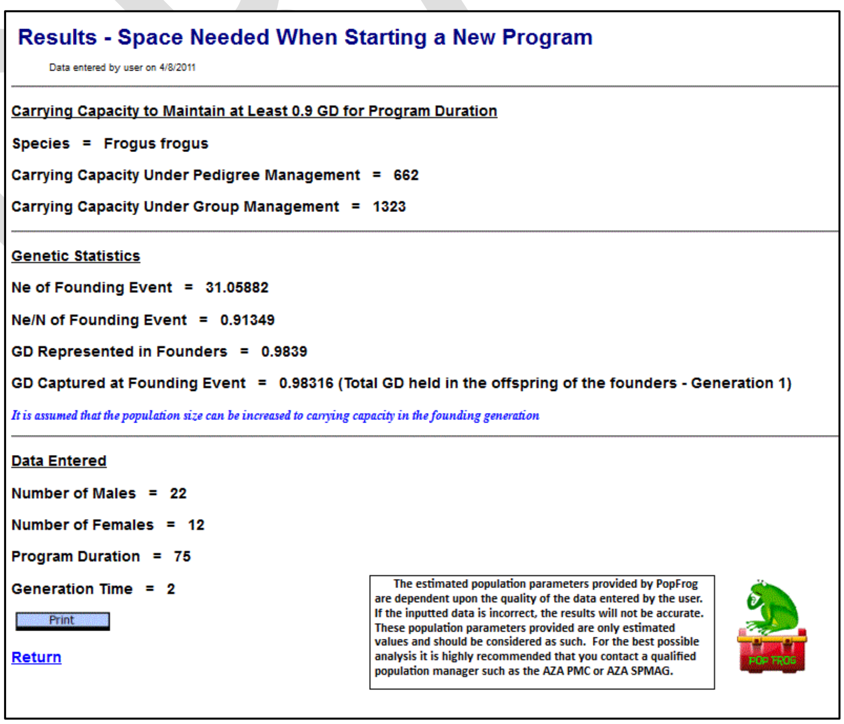
PopFrog Tools

Carrying Capacity for a new program

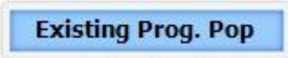
New Program Pop

This tool provides guidance to establish target population sizes for a new population that is directly founded from the wild. This is a tool for the rapid amphibian rescue when a species is in crisis and is brought into captivity for assurance. This tool would be used to provide guidance into what number of animals collected, their sex ratio, the population sized necessary to meet genetic goals under group or pedigree management. There is a helpful calculator to help estimate generation time. Click on the **Gen. Time Calculator** button to enter first and last age of reproduction. Double clicking any field provides additional instructions in a pop-up box. Enter the data and then click submit. Results can be printed for your records.

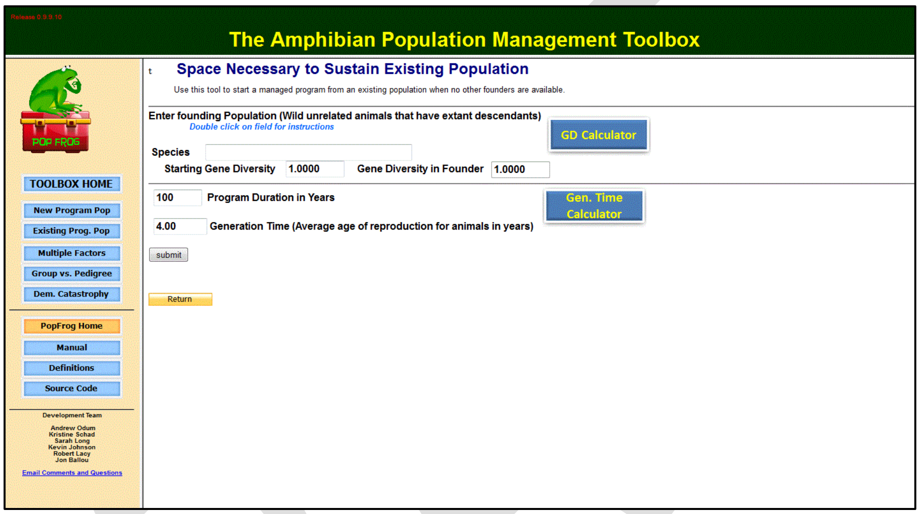


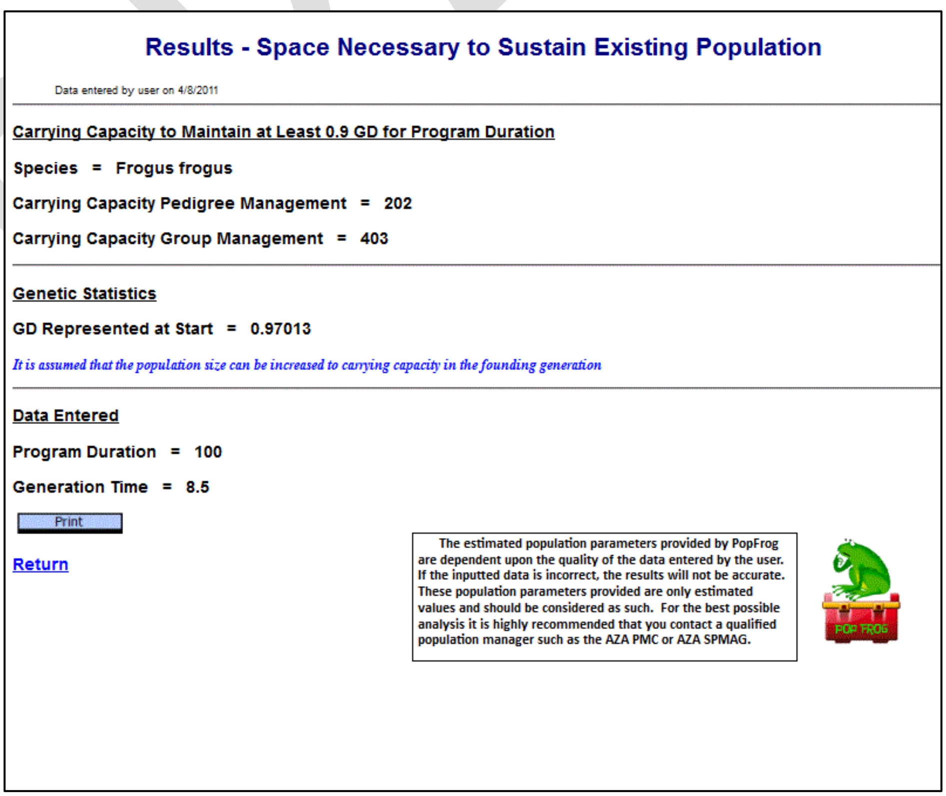


Carry Capacity for existing population



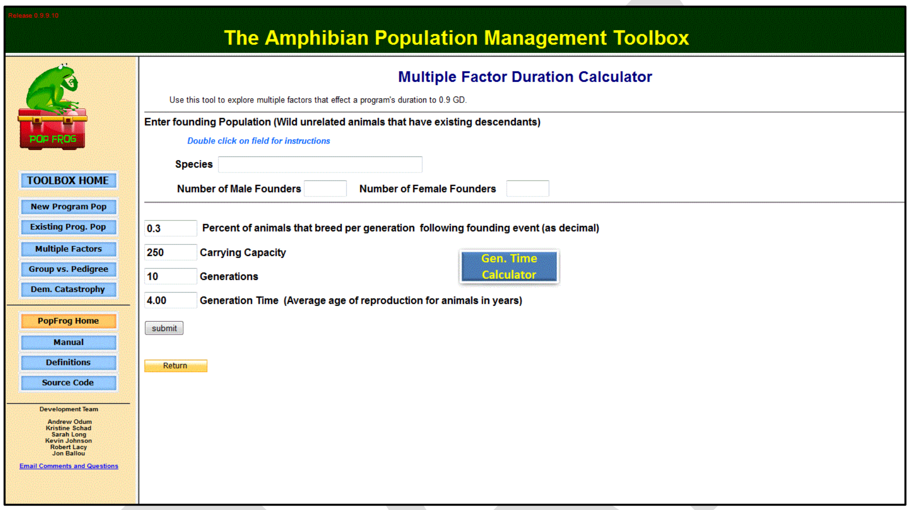
This tool provides guidance to change an existing unmanaged population into a population with genetic goals. The tool would be used to provide guidance for changing an existing population into a conservation population with specific genetic and demographic goals. There is a helpful calculator to help estimate the current gene diversity in the current population. Click on the GD Calculator button to enter the requested information. The calculator will then transfer the estimated GD into the appropriate fields. There is an additional calculator to help estimate generation time. Click on the Gen. Time Calculator button to enter first and last age of reproduction. Double clicking any field provides additional instructions in a pop-up box. Enter the data and then click submit. Results can be printed for your records.

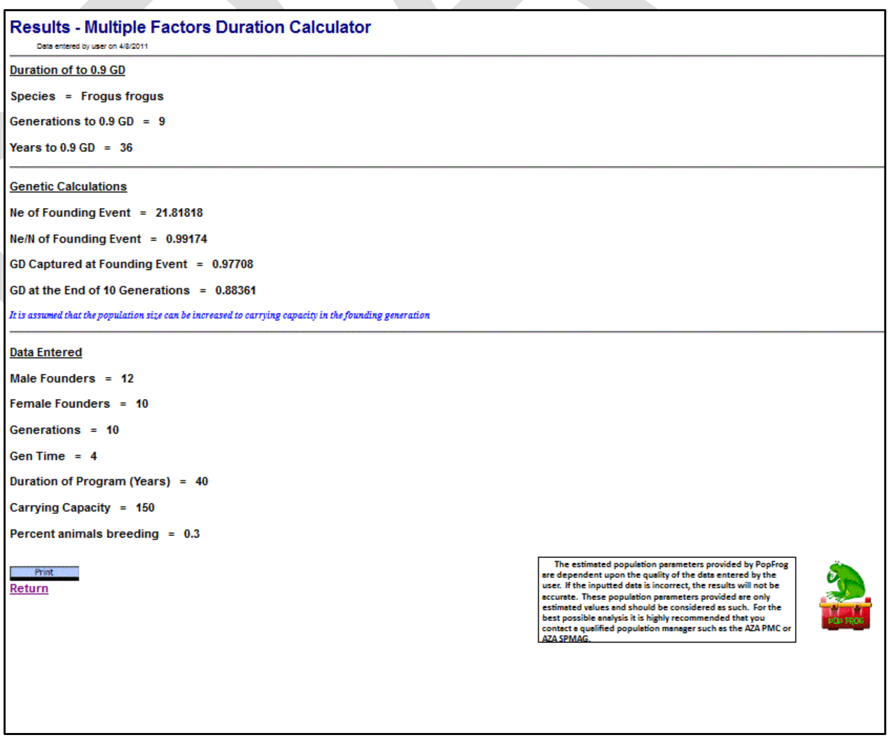




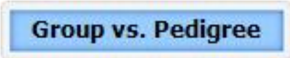
Multiple Factor Tool

This option is an interactive tool to explore the impact caused by different population parameters on carrying capacity, management protocols (group and pedigree), and program duration. It provides general insight into small population management. It also allows the user to test multiple scenarios not addressed by other tools. There is a helpful calculator to help estimate generation time. Click on the Gen. Time Calculator button to enter first and last age of reproduction. Double clicking any field provides additional instructions in a pop-up box. Enter the data and then click submit. Results can be printed for your records.

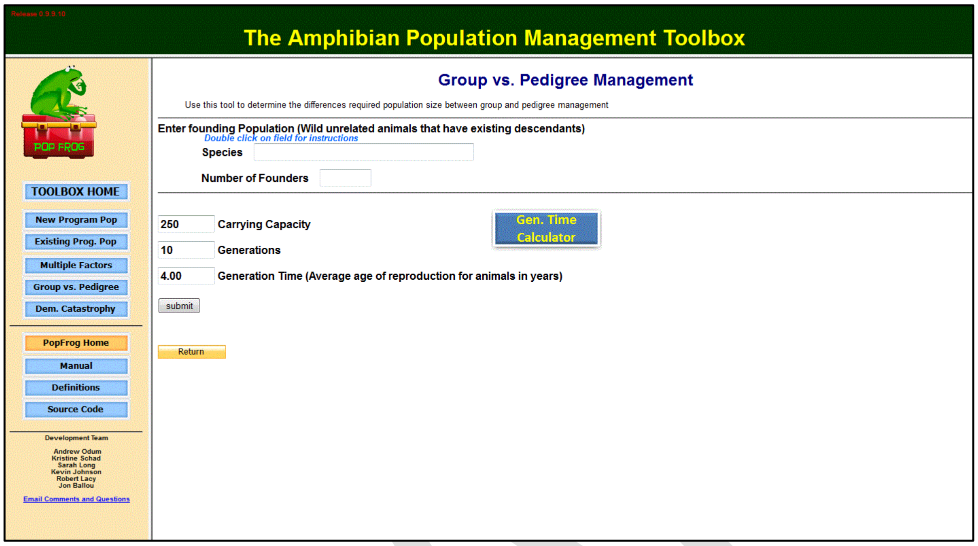


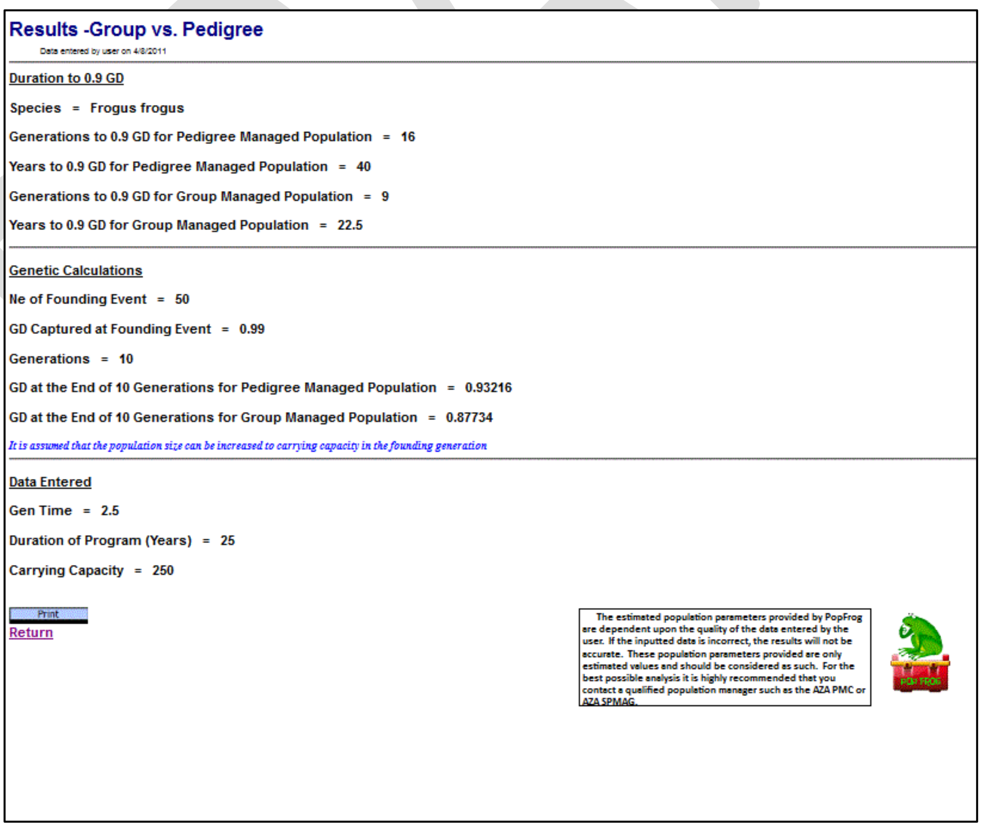


Group vs. Pedigree Management



This tool allows you to explore the implications on carrying capacity and program duration created by either group or pedigree management techniques. There is a helpful calculator to help estimate generation time. Click on the **Gen. Time Calculator** button to enter first and last age of reproduction. Double clicking any field provides additional instructions in a pop-up box. Enter the data and then click submit. Results can be printed for your records.



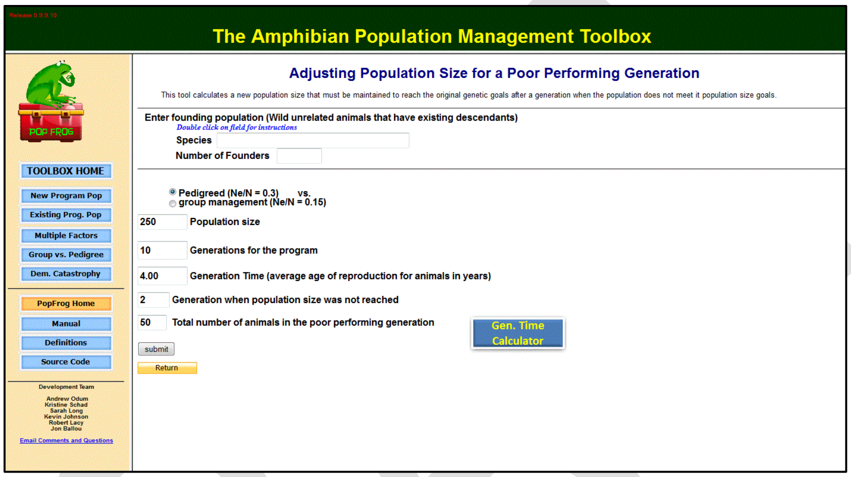


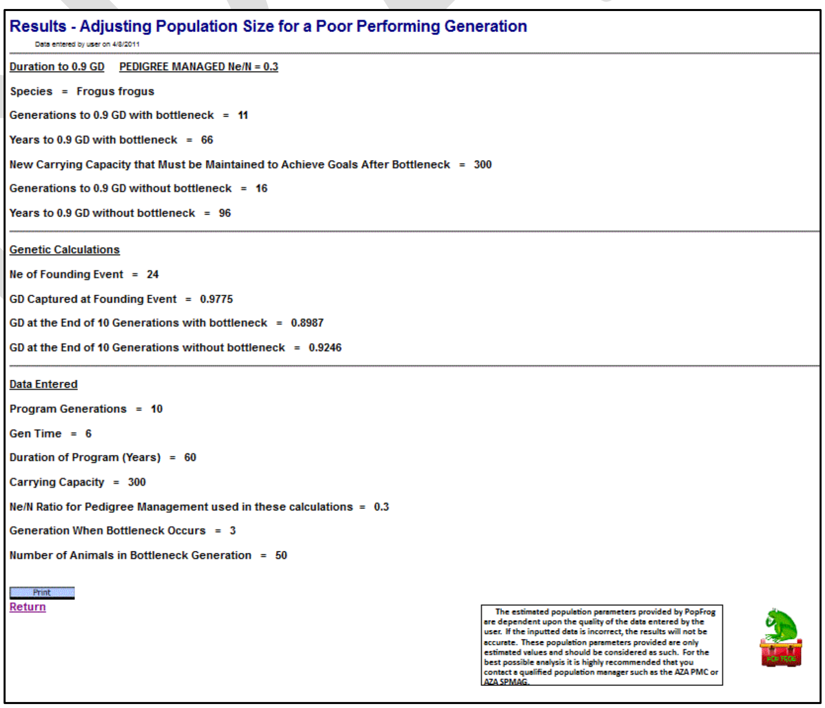
Dealing with a demographic crisis

Dem. Catastophy

This tool provides recommendations for changes in carrying capacity to mitigate the effects of a poorly performing generation when the population numbers are significantly below the target carrying capacity. A generation well below the targeted carrying capacity causes a genetic bottleneck. This too recommends how overcome this bottleneck by increasing the carrying capacity for the remainder of the program.

There is a helpful calculator to help estimate generation time. Click on the **Gen. Time Calculator** button to enter first and last age of reproduction. Double clicking any field provides additional instructions in a pop-up box. Enter the data and then click submit. Results can be printed for your records.



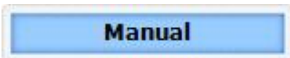


Documentation

Return to Home Page

This option returns to the opening home page for PopFrog.org.

Manual

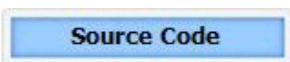


This button links to the manual you are currently reading.

Definitions

This button provides demographic and genetic definitions of the most important factors of population management.

Source Code



This page provides portable document files (pdf) files of the population parameter calculation source code for each PopFrog tool.

AArk POPULATION MANUAL INTRODUCTION

Compiled by Brandie Smith, National Zoo

The maintenance of genetic variation within a population increases the probability of both its long- and short-term survival and that of the comprising individuals. As the basis for evolution, genetic variation allows populations to adapt to changing environments (Allendorf 1986; Lewontin 1974; Selander 1983) and many studies have shown its benefits to individual fitness (Hedrick et al. 1986; Allendorf and Leary 1986; Ralls et al. 1995; Lacy et al. 1993; Wildt et al. 1987). Small populations are especially susceptible to loss of genetic variation through the process of genetic drift (Nei et al. 1975). This random fluctuation in allele frequencies can greatly impact the genetic composition of small populations, hastening their demise.

The science of population management has been greatly advanced through programs developed for captive populations (Ballou and Lacy 1995; Lacy et al. 1995; Ballou and Foose 1996). Professionally managed zoos and aquariums maintain populations of animals for display, conservation, research, and education purposes (Hutchins & Conway 1995). Because these populations are small and widely dispersed, they are managed cooperatively through captive breeding programs such as the Association of Zoos and Aquariums (AZA) Species Survival Plan (SSP®) and Population Management Plan (PMP), the Australasian Regional Association of Zoological Parks and Aquaria (ARAZPA) Australasian Species Management Program (ASMP), and the European Association of Zoos and Aquaria (EAZA) Endangered Species Programme (EEP). Through these programs, specific breeding recommendations are made to help maintain sustainable populations that are genetically diverse and demographically stable.

The goal of captive genetic management is to stop evolution. More specifically, management is intended to minimize changes in a population's gene pool to retain as many of the genetic characteristics of the population's original founders as is possible (Ballou and Lacy 1995). Founders are individuals that are assumed to be unrelated and that have living descendents. It is currently feasible to slow the loss of genetic diversity in pedigreed populations through intense management. The genetic constitution of the entire population can be examined from information found in the pedigree, animal-by-animal breeding recommendations can be made, and the effects of long-term management evaluated.

The current strategy used worldwide by cooperative captive breeding programs to minimize loss of genetic diversity pairs individuals according to a mean kinship (MK) value (Ballou and Lacy 1995). Under this strategy, an individual's genetic importance can be assessed based on the number and degree of relatives that the individual has in the population. Individuals with the lowest mean kinship are priority breeders. Mean kinship has proven to be the best strategy at maintaining genetic diversity in pedigreed populations, tested against alternatives in both a computer simulation (Ballou and Lacy 1995) and on living organisms (Montgomery et al. 1997). Mean kinship is only effective when the entire pedigree is known and pairings can be controlled. This strategy is practical for many species in captivity including elephants, komodo dragons, and vultures, but impractical for species with insufficient information or those where we have less control of pairings. For these species, recommendations are more lenient by attempting to minimize inbreeding and prevent fixation of alleles in subpopulations.

The class Amphibia includes three orders – anurans (frogs and toads), caecilians, and caudates (salamanders and newts) – and covers over 6000 species which exhibit a wide range of natural histories and reproductive strategies. Although some amphibians follow a reproductive model that allows individual identification, known parentage, and controlled pairings, many more do not. In addition, behavioral considerations are very important in maintaining captive amphibian populations and specific environmental cues may be needed to achieve reproduction in captive breeding programs (Pramuk and Gagliardo 2008). Consequently many species of amphibians in captivity do not fit the mean kinship model and a diverse range of specific management techniques must be implemented to maximize the maintenance of genetic diversity. These techniques are the topic of these 'Amphibian Population Management Guidelines.'

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DATA MANAGEMENT FOR AMPHIBIAN POPULATIONS

Compiled by Sarah Long and Kristine Schad, AZA Population Management Center

Management of amphibian populations in zoos depends on databases called "studbooks." A studbook is a record of the chronological history of a single managed species. It is compiled from institutional data based on all known information about each individual in the population, including its relationships to other individuals and dates of birth and death. Studbooks provide the data for demographic and genetic analyses, which in turn help ensure a population's survival in zoos & aquariums. Studbooks tracking individuals can be created easily using SPARKS or PopLink software (see below).

DEMOGRAPHY

Definition: Demography is the science of how a population's size, structure, and distribution have changed in the past and how they might be expected to change in the future.

Goals: To achieve and maintain desired population sizes, stable age structures, and biologically appropriate sex distributions.

Implementation: Determining and recommending the number of births or hatches that will help the population achieve its demographic goals.

Information required: In order to plan the appropriate number of births or hatches, we need to know information about the animals' reproductive capabilities (e.g., age at first and last reproduction, litter/clutch size, interbirth interval, probabilities of breeding at various ages, etc.) and mortality rates (probability of dying at different ages, lifespan, etc.).

Raw data required: Reproductive and mortality data are essentially derived from four critical pieces of information—birth dates, parentage or other monitoring of reproductive performance, death dates, and sex.

POPULATION GENETICS

Definition: Population genetics is the study of how a population's genetic structure, more specifically, how the frequencies of alleles (variants of genes), are distributed within and between populations, as well as how these distributions change over time.

Goal: To preserve gene diversity and avoid inbreeding.

Implementation: Gene diversity is maintained and inbreeding is avoided through the careful selection of breeding individuals or groups.

Information Required: In order to determine which males, females, or groups should be reproducing, we need to know their pedigrees. Pedigrees give us information about the comparative genetic value of each animal or group (how unique or common their alleles might be) and their relatedness to each other. If individual or group parentage is unknown or uncertain, then the other variables become important as clues for how animals may be related (e.g., source, location, and date of birth or immigration, etc.).

Raw data required: Pedigree and relatedness information is based on parentage data that are traced through the generations from the living animals back to the wild born/hatched founders.

RECORD KEEPING FOR INDIVIDUAL MANAGEMENT

- Individually identify, mark, and record the different founders and their descendants, if possible.
- Use any feasible method – transponders, implanted tags, photographs of unique markings, separate enclosures (both for individuals and groups), etc.
- Parentage of individuals
- Record sire and dam whenever possible
- Sex of each individual, if possible
- Birth/hatch date, Location, and Origin
- If wild caught, record date, site location, possible relationship to other wild caught individuals (i.e., several amphibians captured from same water source), and date animal entered captivity
- If zoo/aquarium born, record parents and their wild caught locations
- Locations and transfers of individuals (i.e., moving to a new enclosure, mixing with a new individual/group, transferring to a new institution)
- Enclosure composition (i.e., who housed with whom, in breeding situation or not)
- Death date, Location, and Cause
- Note if death was due to various natural causes vs. managed cull

RECORD KEEPING FOR GROUP MANAGEMENT

INITIAL DATA ENTRY

- Identify, mark, and record the different founders or founder groups with unique identifiers.
- Use any feasible method –label separate enclosures, etc.
- Track enclosures, locations
- Origin or parentage of group (founders from the wild, split from another group, combinations of other groups). Be as specific as possible to track group pedigree and genetic composition.
- If wild caught, record date, site location, possible relationship to other wild caught individuals (i.e., several amphibians captured from same water source), and date animals entered captivity.
- Group composition (who is housed with whom)
- Generation number (e.g., founder, F1, F2, etc.)

ONGOING DATA COLLECTION

- Take regular census counts (weekly, monthly, or as often as is feasible) and record dates associated with these counts to identify:
- Number in each life stage (i.e. eggs/clutches, metamorphs, adults)
- Number of each sex (if possible)
- Number of deaths
- Cause of death (various natural causes vs. managed cull)
- Record any events and dates associated with them
- Transfer of groups (new enclosure, location information)
- Splitting groups (record ID & location of new subgroups)
- Merges of groups (record ID & location of new combined group)
- Reproductive or developmental events

Literature Cited

Ballou J.D. and Foose T.J. 1996. Demographic and genetic management of captive populations. In Kleiman D.G., Lumpkin S., Allen M., Harris H., Thompson K. (eds.) *Wild Mammals in Captivity*. Chicago, IL: University of Chicago Press. p. 263-283.

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****Please Note:** Throughout this document, the notation x.y will be used to signify x number of males and y number of females.

GENETIC MANAGEMENT OF AMPHIBIAN POPULATIONS

Compiled by Sarah Long, AZA Population Management Center

Generally, high levels of gene diversity are associated with GREATER/HIGHER values of the following:

• Number of founders (founders = unrelated individuals who help establish a population) (See Appendix A, Figures 1, 2, & 3)
• Proportion of breeding individuals (# breeding individuals / total # individuals) (See Appendix A, Figures 4, 5a, & 5b)
• Population growth rate (See Appendix A, Figures 6 & 7)
• Population size (starting size and target size) (See Appendix A, Figure 4)
• Number of offspring that survive to reproduce

BASIC GUIDELINES FOR GOOD GENETIC MANAGEMENT:

FOUNDERS

- Start the population with at least 20 founders, ideally with an equal sex ratio (i.e., 10.10). (Note: throughout this document, the notation x.y will be used to signify x number of males and y number of females.) (See Appendix A, Fig. 1, 2, & 3)
  - This means at least 20 individuals (or groups of individuals) that are unrelated and that will successfully reproduce. Realize that many more than this number may have to be captured to ensure that 20 actually survive and successfully reproduce.
  - Collection of founders should be targeted towards obtaining as many unique lineages as possible (e.g., collect from different locations and, if possible, different sites at each location to reduce the probability of collecting related animals).

BREEDING – HOW MANY?

- Produce an equal number of offspring from each founder to equalize family sizes within the space available for the taxon. (See Appendix A, Figures 4, 5a, & 5b)
  - Produce at least 5 offspring per founder.
  - Keep numbers of offspring equal across founders – based on the amount of space available, divide spaces for offspring equally for each founder.

POPULATION GROWTH – HOW QUICKLY SHOULD THE POPULATION GROW?

Species with short generation times (reproductive lifespan < 5 years) will need to have as many individuals produce as many offspring as fast as possible. A larger target population size is also beneficial (both to avoid demographic crisis and better retain genetic diversity).

ENVIRONMENT

Environmental conditions should encourage reproduction and minimize unintentional selection in the highly altered zoo environment. However, conditions should also not be so narrow and rigid as to encourage unintentional selection to specific captive conditions. Variation in the captive environment will help maintain genetic variation and allow for testing of possible improvements in husbandry.

BREEDING – WHICH INDIVIDUALS/GROUPS?

Once founders have successfully reproduced, keep these same pairs/groups together; do not mix and match unnecessarily. If potential founder pairs fail to breed successfully, then try other pairings and any other available manipulations to try to propagate their genes.

- Prioritize breeding the parental generation before the offspring.
    - Parents are always more genetically valuable than their offspring.
    - However, attempt to breed the 2nd generation before the founders die to test husbandry methods.
    - Descendants can be bred with founders when there are no other options.
- Prioritize underrepresented lineages (those with fewer descendants) for breeding and pair animals with similar genetic value:
    - If lineages are unequal, breed the smaller, underrepresented family lines with other underrepresented family lines.
    - If space allows, breed overrepresented family lines with other overrepresented family lines.

**Note: if individuals can be marked and individual pedigrees tracked, then breeding those with the lowest mean kinship will achieve several of the above goals.

CULLING

Cull surplus offspring from the population when necessary in order to equalize founder lineages & to stay within target population size.

- "Culling" is used here to refer to any method of permanently removing individuals from the primary breeding population, such as:
- Transfer to any nonbreeding population (for research, display, etc.)
- Release back into native environment when appropriate
- Euthanasia (when animals are euthanized, biomaterials should be preserved, for example by depositing in the frozen zoo at San Diego Zoo, California, U.S.A. or Frozen Ark, University of Nottingham, UK)
- To avoid selection prejudices:
    - The number of individuals/groups to be culled should be based on equalizing family size.
    - The selection of which individuals/groups to be culled from a family lineage should be randomly chosen (e.g. do not target for culling only the fast- developing tadpoles, the slowest swimmers, the ugliest specimens, etc.).
    - If individuals and pedigrees are tracked, then culling those animals with the highest mean kinships will achieve the two goals above
    - If culling is necessary, it should be done at the earliest life stage possible without compromising the stability and survival of the population.
- Culling should follow appropriate disposition policies (government, institution, association, etc.).

SPECIAL CONSIDERATIONS FOR POPULATIONS MANAGED AS GROUPS - Basically, the same rules as described above apply to groups, but some special considerations are worth mentioning:

GROUP SIZE

- Keep group sizes as small as is effective for the biology of the species while meeting the husbandry needs for captive management
- Keep as many groups as space and reproductive biology allows.
- Equalize family size across groups by keeping clutch sizes as equal as possible.
- If successfully breeding individuals within groups can be identified, consider removing them from the group after they breed to allow other individuals to breed.

GROUP BREEDING STRATEGIES

There are several strategies to retain gene diversity in populations of group-living animals:

A. Once reproduction occurs, systematically transfer individuals among groups in a "round robin" manner (see figure). We recommend one of these methods:

    - Transfer about 5 individuals per generation – This number may need to be increased if mortality is high or fecundity is low.
    - Transfer all juveniles – Move all juveniles out of their natal group to establish new next-generation groups before they reach reproductive maturity.
    - Transfer all of one sex – Move all males (or females) from one group to the next group to avoid inbreeding with offspring and to mix genetic lines.

OR

B. Keep each unique founder group together indefinitely and allow them to interbreed (and inbreed) without mixing with other groups. This method does not imply maintaining the entire population of a species as a single group (i.e. do not put all your eggs in one basket). Rather, this method assumes some initial subdivision into many smaller groups, to safeguard against catastrophic events, and then moving forward with isolated group breeding. This strategy can maintain founder lineages in each group, but also involves the risks of rapid genetic loss, if some groups are lost, and quick, possibly deleterious, inbreeding. The population should be monitored for signs of inbreeding depression, so transfers to reverse inbreeding can be implemented if inbreeding is threatening success. Transfers may be necessary eventually if inbreeding depression develops.

OR

C. Split the starting founder population in half and follow both strategies A and B (above) to increase chances of breeding success.

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DEMOGRAPHIC CONSIDERATIONS FOR MANAGEMENT OF AMPHIBIAN POPULATIONS

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Establishing stable and viable populations of amphibians in captivity is initially dependent on working out the husbandry techniques to ensure survival and reproduction of wild-caught individuals. Once those techniques are established, the decision of how large a population should be maintained to ensure long-term viability should be considered, ideally for each individual population by an experienced population biologist. It is difficult to generalize about a single magic number that is a minimum viable population size from a demographic perspective because the demographic patterns of amphibian species in the wild fall into a wide range of life histories and the goals for a captive population may vary. Amphibian populations can be very "fast" species with high fecundity, high mortality, and large fluctuations in population size over time or "slow" species with lower fecundity and mortality which have more stable population sizes over time, or may lie somewhere in between the two life history extremes (for a good summary, see Green 2000).

However, demographic theory and some pre-existing research on amphibians can provide some minimal starting guidance on important demographic considerations for captive amphibian management. If a population's size is too small, it becomes susceptible to stochasticity, which is variability in survival and reproduction that can be due to demographic or environmental processes, which can result in further declines in population size or extinction. A general rule of thumb is that populations may be less susceptible to demographic stochasticity if they are at least 100 individuals (Morris and Doak 2002).

In addition, the total population size is not the only important determinant of a population's viability, as different life stages can be more or less important to long-term persistence. Biek et al. (2002) looked at several amphibian populations with a range in demography (although most would still be considered "fast" species) to determine the importance of different life stages to the population's long-term growth rate. They found that post-metamorphic vital rates were more critical to long-term growth than pre-metamorphic vital rates. This indicates that, once basic husbandry techniques have been worked out, improving survival rates in post-metamorphic stages is the most important objective for increasing the size of a captive population.

An additional important consideration for management of demographic risks includes protecting populations from catastrophic loss by essentially "not putting all your eggs in one basket". When setting up a new captive population, it would be extremely risky to setup the entire population in a single tank because of the risks from common catastrophes such as electrical failures, disease outbreaks, issues with water contamination, food problems, etc. These risks can be mitigated by spreading the population across multiple tanks in the same area, in multiple locations across an institution, or at multiple institutions.

Ultimately, once husbandry techniques have been perfected for new taxa, managers and population biologists should fully evaluate its population biology. A target population size can be set based on genetic goals, and then demographic management tactics can be planned to meet that target size goal based on the population's survival and fecundity rates. Amphibians can vary hugely with respect to fecundity, although husbandry considerations and high mortality of early life stages will narrow the range that reach metamorphosis. From a population management perspective, the important consideration for population growth is the number of progeny per brood that survive to breeding age. Culling of individuals from large broods to reduce numbers to a desired or manageable level should generally aim to leave equal numbers per brood, or should use mean kinship strategies to determine which ones to cull.

Literature Cited

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