ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

INTERNATIONAL SYMPOSIUM AND WORKSHOP ON THE CONSERVATION AND RESEARCH OF THE ARUBA ISLAND RATTLESNAKE

POPULATION AND HABITAT VIABILITY ASSESSMENT

30 November 1992

Palm Beach
Aruba Island
5-7 February 1992

ARUBA DEPARTMENT OF AGRICULTURE HUSBANDRY & FISHERIES

CAPTIVE BREEDING SPECIALIST GROUP (CBSG/SSC/IUCN)

AMERICAN ASSOCIATION OF ZOOLOGICAL PARKS AND AQUARIUMS

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ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

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(*Crotalus durissus unicolor*)

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INTRODUCTION

INTRODUCTION

Aruba Island is located thirty kilometers north of the coast of Venezuela and is the western most Dutch Leeward Island. The island is composed of volcanic igneous rock and limestone formations that are the remnants of coral reefs. Unlike its closest neighbors, Curacao and Bonaire, Aruba lies within the confines of the South American continental shelf and the sea separating it from the mainland does not exceed 135m in depth. This close relationship to South America has impacted the fauna of Aruba which includes species that are not found elsewhere in the Caribbean. Even with its close proximity to the mainland, Aruba has maintained a high degree of isolation. This is reflected in the number of endemic forms that include the rattlesnake (*Crotalus*), cat-eyed snake (*Leptodeira*), gecko (*Phyllodactylus*), whiptail lizard (*Cnemidophorus*), and burrowing owl (*Speotyto*).

With an average yearly rainfall of less than 0.5m, the habitat of Aruba is xeric, dominated by a variety of desert flora. It has been reported that Aruba was more heavily forested in pre-Colombian times. The trees were presumably harvested for charcoal production shortly after the arrival of the first European explorers. Today feral goats and sheep have extensively overgrazed the land, resulting in a general alteration of the wild flora to inedible varieties.

The Aruba Island rattlesnake, *Crotalus durissus unicolor* (=*Crotalus unicolor*), is a moderately sized snake (<1m) which is restricted to 44 km^2 of the cunucu (undeveloped countryside) of Aruba. Although recent literature has suggested that this animal is a subspecies of the neotropical rattlesnake, *C. durissus*, it is a genetically isolated population with distinct morphology. Juvenile snakes have a characteristic pattern like *C. durissus*, but as animals mature this pattern becomes less conspicuous. Many adults become almost uniformly colored in a pastel grey, brown, or white for which the scientific name "unicolor" (one color) is derived. To determine the exact relationship of the Aruba Island rattlesnake to the mainland forms of Venezuela, DNA analysis will be required. In any case, this animal is indisputably unique in comparison to any other form of rattlesnake found elsewhere in the world.

The Aruba Island rattlesnake is the top terrestrial predator of the Aruba ecosystem. In many other ecosystems, this status is reserved for large mammalian carnivores which may include felids (cats), ursids (bears), or canids (wild dogs). As the top terrestrial predator, the Aruba Island rattlesnake can be considered a flagship species. By preserving a healthy population of rattlesnakes, many other species would benefit and be preserved. This would include the Aruba burrowing owl and several endemic species of lizards.

Although this snake is venomous and capable of delivering a strong poison, it is also generally inoffensive; rarely resorting to biting as a defense against humans. In recent years there have only been a few snake bites reported, all of which were the result of people deliberately harassing animals.

Rattlesnakes are highly adapted predators, having a sleek body form that allows them to move through small openings and burrows, coupled with an efficient means of capturing and subduing prey with venom. The Aruba Island rattlesnake is ideally suited as a rodent controlling predator and rodents are the preferred diet of adult animals.

Historical reports from earlier workers and accounts by older Aruban citizens have implied that this animal was more widely distributed and in greater numbers than it is today. Recent field work has shown that the Aruba Island rattlesnake is difficult to encounter and should be considered rare. Although no general census has been performed, it appears that the Aruba Island rattlesnake is in a steady decline. Even the most optimistic estimates place the current numbers at about 1000 animals. This may be an over estimation and the real numbers may be less than 500.

The reason for the decline of the rattlesnake is not easily apparent. Initial analysis has indicated that the incidental take by humans of adult animals may be having a substantial negative impact on the population. The rate of this incidental take is proportionate to the number of snake/human interactions that occur. The high human population density on Aruba (65,000 permanent residents, 500,000 yearly tourists) and the close proximity of human habitation to the rattlesnake's habitat, places the future of this animal in jeopardy. Without some intervention, the probability of its extinction is high, and its actual status may already be critical.

Although it is protected against exportation from Aruba, the rattlesnake has no legal protection on the island. It may be collected, held, or killed. The future of the remaining habitat is also in peril. There has been a moratorium on development of the cunucu for the last several decades, but with the increasing human population on the island, significant encroachment of the remaining rattlesnake habitat has already been proposed.

During 3-5 February 1992, a group of people concerned about the survival of the Aruba Island rattlesnake convened on Aruba to review the current knowledge, status, and future of this endemic snake. This conference was a group effort of the Aruba Department of Agriculture, Husbandry and Fishes; The IUCN - World Conservation Union - CBSG; and the American Association of Zoological Parks and Aquariums Species Survival Plan. The entire program was made possible though a generous grant from the Coastal Aruba Refining Company. During these meetings, a plan of action was developed to minimize the probability of extinction of the Aruba Island rattlesnake. this volume contains the results of these meetings and presents this plan.

ARUBA ISLAND RATTLESNAKE

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SECTION 2

SUMMARY AND GENERAL POINTS

GENERAL POINTS OF AGREEMENT AND RECOMMENDATIONS

Crotalus durissus unicolor

Population and Habitat Viability Analysis Workshop
5-7 February 1992

1) The people and government of Aruba are to be commended for their commitment to the protection of their unique terrestrial and marine ecosystems and the plants and animals species that are endemic to Aruba.

2) The rapid expanding tourist industry on Aruba and the development planned to support this growth will require special planning and education efforts to protect the unique character of Aruba and the viability of its ecosystem and the species they contain.

3) Designation and protection of adequate habitat for a viable population of the Aruba cascabel, as a flagship species, is of the highest priority and will provide habitat for other endemic Aruban species. Creating and support of the new wildlife refuge encompassing 40 km^2 of current cascabel habitat is recommended. This area would include the presently designated "preservation zone" which will be completely protected from development as National Park land. The remaining surrounding cascabel habitat area would be designated a Conservation Management Area where development would be limited to prevent any negative impact to cascabel population.

4) Recognition of the endangered status of the Aruba cascabel and its legal protection are necessary to ensure that it is not collected, disturbed, or exported except for conservation purposed.

5) Education of the citizens of Aruba about the biology, ecology, and the importance of the Aruba cascabel is essential for its survival. .

6) Control the importation of exotic vertebrate species is essential to prevent the destruction and loss of the native wildlife of Aruba. No exotic animals should be released in Aruba.

7) A determined effort should be made to eradicate, using ecologically safe methods, the introduced marine toad Bufo marinus from Aruba since its spread is likely to result in the loss of several endemic species.

8) A carefully designed field study of the population status and population dynamics of the Aruba cascabel is essential to provide quantitative information on the decline of the species, to verify the critical threats to the species, and to develop techniques for long term monitoring of the population. The training of several Aruban biologists or wildlife technicians to provide long term management expertise for the National Parks and Conservation Management Zones should be a part of this program.

9) Suggested conservation goals for the Aruba cascabel are a) to reduce the risk of extinction of the wild population to less than 1% in 100 years, b) to manage for a wild population of at least 1000 snakes greater than 1 year of age, and c) to maintain a captive population capable of retaining 95% of the current genetic diversity in the wild population.

10) Secure and endorse local corporate sponsorship of the conservation of the cascabel and its habitat as a flagship program for the endemic wildlife and ecology of Aruba.

International Symposium Coordinators Report

Throughout the world, the growing human population has placed increasing pressures on the wild ecosystems of the planet with many negative effects. These pressures have caused the extinction of many organisms, and in some cases, the collapse of the entire ecosystem, in which whole communities of plants and animals perished. This is particularly true for the smaller isolated ecosystem of islands. The very nature of islands, with their limited size, strong natural barriers, and specialized life forms, make them particularly vulnerable to human development and intervention. Because many of the unique life forms on islands have evolved independently, they are particularly vulnerable to the effects of introduced, non-native, species. Inability to compete with less specialized introduced forms, susceptibility to introduced predators, and vulnerability to exotic diseases are a few of the reasons for the decline of native species after humans have imported non-native organisms to islands. Combining these factors with the limited habitat that is generally available on islands, increases the potential impact of human activity on the environment.

Aruba is a small island, thus its top native terrestrial predator, the cascabel, is also small. The health of an ecosystem can be judged through health of the population of its top predator. For this reason, the Aruba Island rattlesnake should be considered a flagship species for the entire cunucu ecosystem. If conditions are maintained to preserve the cascabel, many other native species of Aruba will also benefit, and the unique cunucu of Aruba will be preserved for the future.

The International Symposium and Workshop on the Conservation and Research of the Aruba Island Rattlesnake was separated into four distinct components. First, a general symposium was held to review the current knowledge about the rattlesnake. Second, an education workshop was held to train local teachers and teachers-in-training about conservation and ecology. This education program included field trips into rattlesnake habitat to generate an appreciation for wild Aruba. Third, a snake envenomation management workshop for medical personnel was conducted. Fourth, a Population and Habitat Viability Assessment (PHVA) workshop was conducted. The participants in these meetings included Aruba government officials, members of Aruban conservationists organizations, and interested local citizens, as well as conservation biologists from the United States, Canada, and Holland.

The participants of these meetings developed an action plan to help assure the future survival of the Aruban cascabel. The following is a brief overview of the general recommendations established during these meetings:

1) Establish a wildlife refuge
2) Afford legal protection to the cascabel
3) Continue and expand education programs concerning ecology and the importance of the cascabel
4) Reduce the number of cascabels killed or removed by the public
5) Perform additional field studies to obtain quantitative data on the status, population dynamics, morality, and ecology of the cascabel

The remainder of this document presents the results of these meetings in detail.

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(*Crotalus durissus unicolor*)

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30 November 1992

SECTION 3

SMALL POPULATION OVERVIEW

FLORIDA PANTHER

Felis concolor coryi

VIABILITY ANALYSIS & SURVIVAL PLAN

SMALL POPULATION OVERVIEW

15 December 1989

Date form completed: 15 November 1989.

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References: Reference list included in PVA, Studbook, and VASP reports. Much of this information was compiled from data and reports of field workers, ISIS data on the captive population of panthers, and the review paper by Lindzey.

Lindzey, F. 198 . Mountain lion. in

Anderson, A.E. 1983. A critical review of literature on puma (Felis concolor). Colorado Div. Wildl. Spec. Rep. 54. 91 pp.

Captive Breeding Specialist Group (SSC/IUCN). 1989a. Florida Panther: Population Viability Analysis. CBSG, Apple Valley, MN. 50 pp.

Captive Breeding Specialist Group (SSC/IUCN). 1989b. Florida Panther: Viability Analysis and Survival Program. CBSG, Apple Valley, MN. 140 pp.

Maehr, D.S., J.C. Roof, E.D. Land, and J.W. McCown. 1989. First reproduction of a panther (Felis concolor coryi) in southwestern Florida, U.S.A. Mammalia, 53:129-131.

U. S. Fish and Wildlife Service. 1987. Florida Panther (Felis concolor coryi) Recovery Plan.Prepared by the Florida Panther Interagency Committee for the USFWS, Atlanta, Georgia, 75 pp.

Comments:

Interactive Management of Small Wild and Captive Populations (T.J. Foose)

Introduction

Conservation strategies for endangered species must be based on viable populations. While it is necessary, it is no longer sufficient merely to protect endangered species *in situ*. They must also be managed.

The reason management will be necessary is that the populations that can be maintained of many species under the pressures of habitat degradation and unsustainable exploitation will be small, i.e. a few tens to a few hundreds (in some cases, even a few thousands) depending on the species. As such, these populations are endangered by a number of environmental, demographic, and genetic problems that are stochastic in nature and that can cause extinction.

Small populations can be devastated by catastrophe (weather disasters, epidemics, exploitation) as exemplified by the case of the black footed-ferret and the Puerto Rican parrot, or be decimated by less drastic fluctuations in the environment. Demographically, small populations can be disrupted by random fluctuations in survivorship and fertility. Genetically, small populations lose diversity needed for fitness and adaptability.

Minimum Viable Populations

For all of these problems, it is the case that the smaller the population is and the longer the period of time it remains so, the greater these risks will be and the more likely extinction is to occur. As a consequence, conservation strategies for species which are reduced in number, and which most probably will remain that way for a long time, must be based on maintaining certain minimum viable populations (MVP's), i.e. populations large enough to permit long-term persistence despite the genetic, demographic and environmental problems.

There is no single magic number that constitutes an MVP for all species, or for any one species all the time. Rather, an MVP depends on both the genetic and demographic objectives for the program and the biological characteristics of the taxon or population of concern. A further complication is that currently genetic and demographic factors must be considered separately in determining MVP's, although there certainly are interactions between the genetic and demographic factors. Moreover, the scientific models for assessing risks in relation to population size are still in rapid development. Nevertheless, by considering both the genetic and demographic objectives of the program and the biological characteristics pertaining to the population, scientific analyses can suggest ranges of population sizes that will provide calculated protection against the stochastic problems.

Genetic and demographic objectives of importance for MVP

Probability of survival (e.g., 50% or 95%) desired for the population;

Percentage of the genetic diversity to be preserved (90%, 95%, etc.);

Period of time over which the demographic security and genetic diversity are to be sustained (e.g., 50 years, 200 years).

In terms of demographic and environmental problems, for example, the desire may be for 95% probability of survival for 200 years. Models are emerging to predict persistence times for populations of various sizes under these threats. Or in terms of genetic problems, the desire may be to preserve 95% of average heterozygosity for 200 years. Again models are available. However, it is essential to realize that such terms as viability, recovery, self-sustainment, and persistence can be defined only when quantitative genetic and demographic objectives have been established, including the period of time for which the program (and population) is expected to continue.

Biological characteristics of importance for MVP

Generation time: Genetic diversity is lost generation by generation, not year by year. Hence, species with longer generation times will have fewer opportunities to lose genetic diversity within the given period of time selected for the program. As a consequence, to achieve the same genetic objectives, MVP's can be smaller for species with longer generation times. Generation time is qualitatively the average age at which animals produce their offspring; quantitatively, it is a function of the age-specific survivorships and fertilities of the population which will vary naturally and which can be modified by management, e.g. to extend generation time.

The number of founders. A founder is defined as an animal from a source population (the wild for example) that establishes a derivative population (in captivity, for translocation to a new site, or at the inception of a program of intensive management). To be effective, a founder must reproduce and be represented by descendants in the existing population. Technically, to constitute a full founder, an animal should also be unrelated to any other representative of the source population and non-inbred.

Basically, the more founders, the better, i.e. the more representative the sample of the source gene pool and the smaller the MVP required for genetic objectives. There is also a demographic founder effect; the larger the number of founders, the less likely is extinction due to demographic stochasticity. However, for larger vertebrates, there is a point of diminishing returns (Figure 1), at least in genetic terms. Hence a common objective is to obtain 20-30 effective founders to establish a population. If this objective cannot be achieved, then the program must do the best with what is available. If a pregnant female woolly mammoth were discovered wandering the tundra of Alaska, it would certainly be worth trying to develop a recovery plan for the species even though the probability of success would be low. By aspiring to the optima, a program is really improving the probability of success.

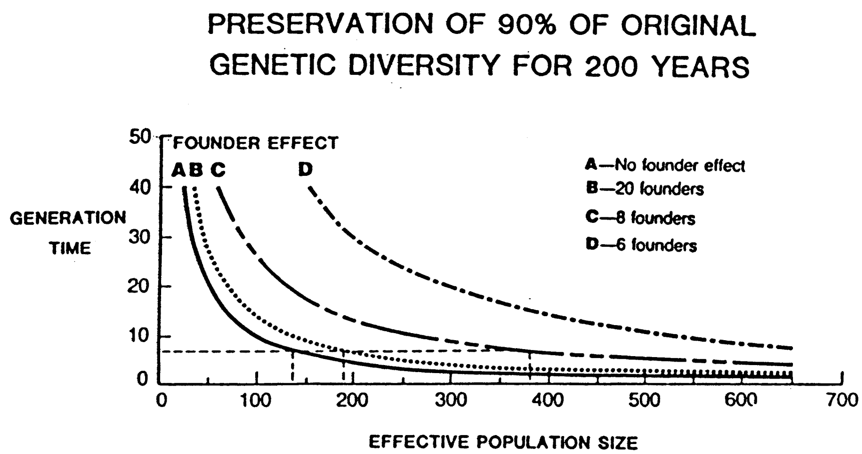

Figure 1. Interaction of number of founders, generation time of the species, and effective population size required for preserving 90% of the starting genetic diversity for 200 years.

Effective Population Size. Another very important consideration is the effective size of the population, designated N_e. N_e is not the same as the census size, N. Rather, N_e is a measure of the way the members of the population are reproducing with one another to transmit genes to the next generation. N_e is usually much less than N. For example in the grizzly bear, N_e/N ratios of about .25 have been estimated (Harris and Allendorf 1989). As a consequence, if the genetic models prescribe an N_e of 500 to achieve some set of genetic objectives, the MVP might have to be 2000.

Growth Rate. The higher the growth rate, the faster a population can recover from small size, thereby outgrowing much of the demographic risk and limiting the amount of genetic diversity lost during the so-called "bottleneck". It is important to distinguish MVP's from bottleneck sizes.

<u>Population viability analysis</u>

The process of deriving MVP's by considering various factors, i.e. sets of objectives and characteristics, is known as Population Viability (sometimes

Vulnerability) Analysis (PVA). Deriving applicable results in PVA requires an interactive process between population biologists, managers, and researchers. PVA has been applied to a number of species (e.g., Parker and Smith 1988, Seal et al. 1989, Ballou et al. 1989, Lacy et al. 1989, Lacy and Clark, in press).

As mentioned earlier, PVA modelling often is performed separately with respect to genetic and demographic events. Genetic models indicate it will be necessary to maintain populations of hundreds or thousands to preserve a high percentage of the gene pool for several centuries. Recent models allow simultaneous consideration of demography, environmental uncertainty, and genetic uncertainty.

MVP's to contend with demographic and environmental stochasticity may be even higher than to preserve genetic diversity especially if a high probability of survival for an appreciable period of time is desired. For example, a 95% probability of survival may entail actually maintaining a much larger population whose persistence time is 20 times greater than required for 50% (i.e., average) probability of survival; 90%, 10 times greater. From another perspective, it can be expected that more than 50% of actual populations will become extinct before the calculated mean persistence time elapses.

Species of larger vertebrates will almost certainly need population sizes of several hundreds or perhaps thousands to be viable. In terms of the stochastic problems, more is always better.

Metapopulations and Minimum Areas

MVP's imply minimum critical areas of natural habitat, that will be vast for large carnivores like the Florida panther. Consequently, it will be difficult or impossible to maintain single, contiguous populations of the hundreds or thousands required for viability.

However, it is possible for smaller populations and sanctuaries to be viable if they are managed as a single larger population (a metapopulation) whose collective size is equivalent to the MVP (Figure 2). Actually, distributing animals over multiple "subpopulations" will increase the effective size of the total number maintained in terms of the capacity to tolerate the stochastic problems. Any one subpopulation may become extinct or nearly so due to these causes; but through recolonization or reinforcement from other subpopulations, the metapopulation will survive. Metapopulations are evidently frequent in nature with much local extinction and re-colonization of constituent subpopulations occurring.

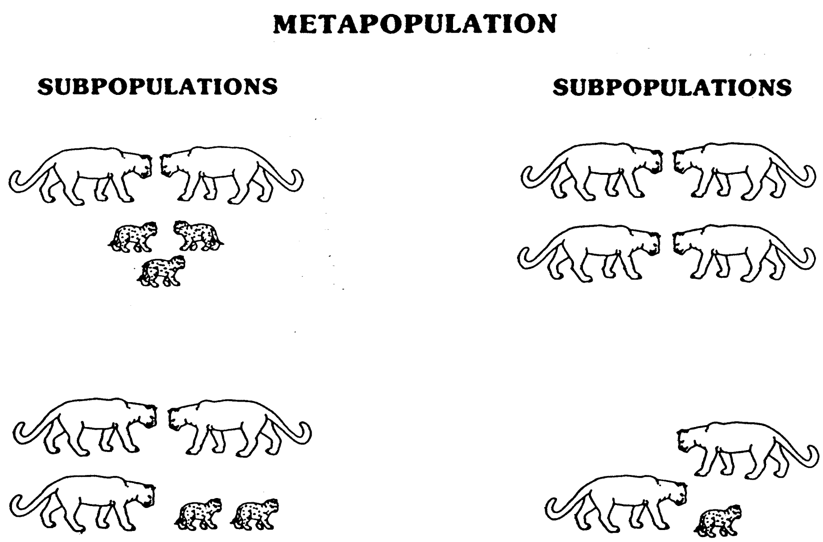

Figure 2. Multiple subpopulations as a basis for management of a metapopulation for survival of a species in the wild.

Unfortunately, as wild populations become fragmented, natural migration for re-colonization may become impossible. Hence, metapopulation management will entail moving animals around to correct genetic and demographic problems (Figure 3). For migration to be effective, the migrants must reproduce in the new area. Hence, in case of managed migration it will be important to monitor the genetic and demographic performance of migrants

Managed migration is merely one example of the kinds of intensive management and protection that will be desirable and necessary for viability of populations in the wild. MVP's strictly imply benign neglect. It is possible to reduce the MVP required for some set of objectives, or considered from an alternative perspective, extend the persistence time for a given size population, through management intervention to correct genetic and demographic problems as they are detected. In essence, many of these measures will increase the N_e of the actual number of animals maintained.

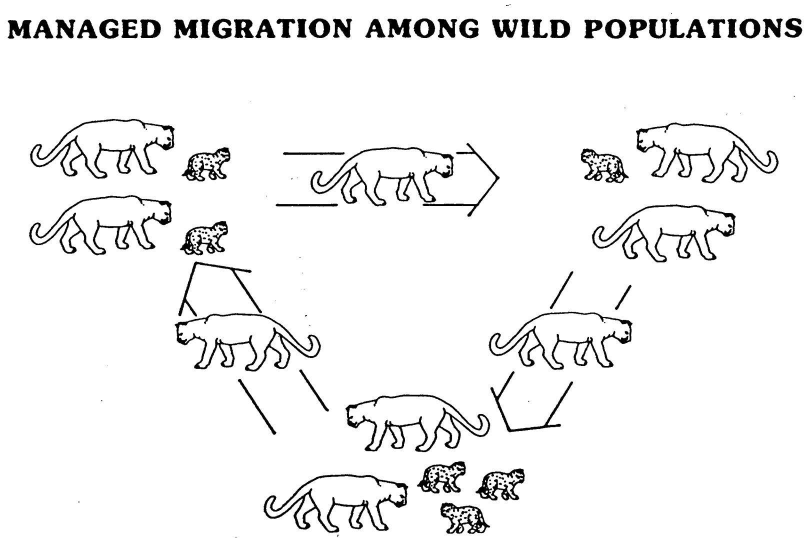

Figure 3. Managed migration among subpopulations to sustain gene flow in a metapopulation.

The Florida panther is already subject to management intervention: the movements of about half of the population are monitored regularly by radio-tracking, and panthers injured by collisions with automobiles are nursed back to health and then released into natural habitat. Such interventions are manifestations of the fact that as natural sanctuaries and their resident populations become smaller, they are in effect transforming into megazoos that will require much the same kind of intensive genetic and demographic management as species in captivity.

Captive Propagation

Another way to enhance viability is to reinforce wild populations with captive propagation. More specifically, there are a number of advantages to captive propagation: protection from unsustainable exploitation, e.g. poaching; moderation of environmental vicissitudes for at least part of the population; more genetic management and hence enhance preservation of the gene pool; accelerated expansion of the population to move toward the desired MVP and to provide animals more rapidly for introduction into new areas; and increase in the total number of animals maintained.

It must be emphasized that the purpose of captive propagation is to reinforce, not replace, wild populations. Captive colonies and zoos must serve as reservoirs of genetic and demographic material that can periodically be transfused into natural habitats to re-establish species that have been extirpated or to revitalize populations that have been debilitated by genetic and demographic problems.

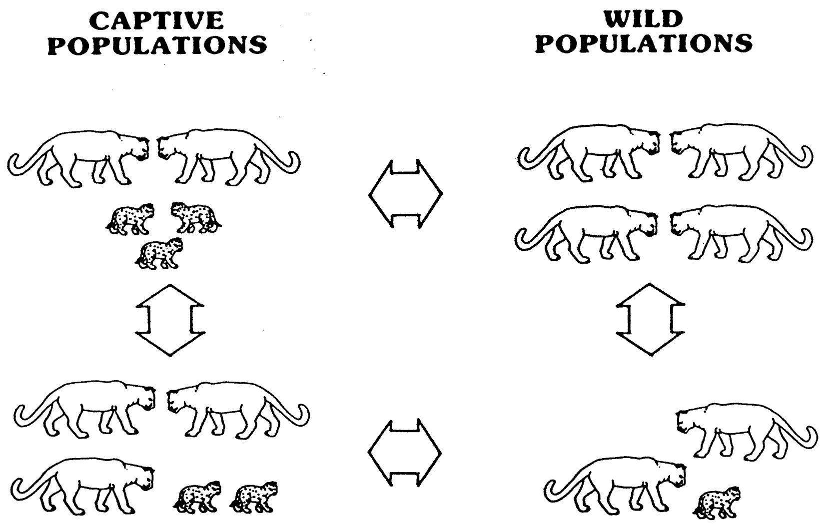

Figure 4. The use of captive populations as part of a metapopulation to expand and protect the gene pool of a species.

The survival of a great and growing number of endangered species will depend on assistance from captive propagation. Indeed, what appears optimal and inevitable are conservation strategies for the species incorporating both captive and wild populations interactively managed for mutual support and survival (Figure 4). The captive population can serve as a vital reservoir of genetic and demographic material; the wild population, if large enough, can continue to subject the species to natural selection. This general strategy has been adopted by the IUCN (the world umbrella conservation organization) which now recommends that captive propagation be invoked anytime a taxon's wild population declines below 1000 (IUCN 1988).

Species Survival Plans

Zoos in many regions of the world are organizing scientifically managed and highly coordinated programs for captive propagation to reinforce natural populations.

In North America, these efforts are being developed under the auspices of the AAZPA, in coordination with the IUCN SSC Captive Breeding Specialist Group (CBSG), and are known as the Species Survival Plan (SSP).

Captive propagation can help, but only if the captive populations themselves are based on concepts of viable populations. This will require obtaining as many founders as possible, rapidly expanding the population normally to several hundreds of animals, and managing the population closely genetically and demographically. This is the purpose of SSP Masterplans. Captive programs can also conduct research to facilitate management in the wild as well as in captivity, and for interactions between the two.

A prime examples of such a captive/wild strategy is the combined USFWS Recovery Plan/SSP Masterplan for the red wolf. Much of the captive propagation of red wolves has occurred at a special facility in Washington state, but there is also a growing number of zoos providing captive habitat, especially institutions within the historical range of the red wolf.

Another eminent example of a conservation and recovery strategy incorporating both captive and wild populations is the black-footed ferret. This species now evidently survives only in captivity. Because the decision to establish a captive population was delayed, the situation became so critical that moving all the animals into captivity seemed the only option, circumstances that also applied to the California condor. Another option may have been available if action to establish a captive population had occurred earlier as was done with the Puerto Rican parrot and plain pigeon. Consideration of the survivorship pattern, which exhibited high juvenile mortality for ferrets, as it does for many mammals and birds, suggested that young animals destined to die in the wild might be removed with little or no impact on the population. The AAZPA and CBSG/SSC/IUCN are involved in these kinds of strategies and programs worldwide.

Population Viability Analysis (R. C. Lacy)

Many wildlife populations that were once large, continuous, and diverse have been reduced to small, fragmented isolates in remaining natural areas, nature preserves, or even zoos. For example, black rhinos once numbered in the 100s of thousands, occupying much of Africa south of the Sahara; now a few thousand survive in a handful of parks and reserves, each supporting a few to at most a few hundred animals. Similarly, the Puerto Rican parrot, the only psittacine native to Puerto Rico, was formerly widespread on the island and numbered perhaps a million birds. By 1972 the species was reduced to just 20 birds (4 in captivity). Intensive efforts since have accomplished a steady recovery to 46 captive and 34 wild birds at the end of 1988. In 1989, the Luquillo forest which is home to both the captive and wild flocks of Puerto

Rican parrots was severely damaged by a hurricane. Apparently at least half of the wild parrots were killed, most of the traditional nest trees were destroyed, the food supply was decimated, and it is unlikely that a viable population remains in the wild.

When populations become small and isolated from any and all other conspecifics, they face a number of demographic and genetic risks to survival: in particular, chance events such as the occurrence and timing of disease outbreaks, random fluctuations in the sex ratio of offspring, and even the randomness of Mendelian gene transmission can become more important than whether the population has sufficient habitat to persist, is well adapted to that habitat, and has an average birth rate that exceeds the mean death rate. Unfortunately, the genetic and demographic processes that come into play when a population becomes small and isolated feed back on each other to create what has been aptly but depressingly described as an "extinction vortex". The genetic problems of inbreeding depression and lack of adaptability can cause a small population to become even smaller --which in turn worsens the uncertainty of finding a mate and reproducing -- leading to further decline in numbers and thus more inbreeding and loss of genetic diversity. The population spirals down toward extinction at an ever accelerated pace. The size below which a population is likely to get sucked into the extinction vortex has been called the Minimum Viable Population size (or MVP).

The final extinction of a population usually is probabilistic, resulting from one or a few years of bad luck, even if the causes of the original decline were quite deterministic processes such as over-hunting and habitat destruction. Recently, techniques have been developed to permit the systematic examination of many of the demographic and genetic processes that put small, isolated populations at risk. By a combination of analytic and simulation techniques, the probability of a population persisting a specified time into the future can be estimated: a process called Population Viability Analysis (PVA) (Soule 1987). Because we still do not incorporate all factors into the analytic and simulation models (and we do not know how important the factors we ignore may be), the results of PVAs almost certainly underestimate the true probabilities of population extinction.

The value of a PVA comes not from the crude estimates of extinction probability, but rather from identification of the relative importance of the factors that put a population at risk and assessment of the value (in terms of increased probability of population persistence) of various possible management actions. That few species recognized as Endangered have recovered adequately to be delisted and some have gone extinct in spite of protection and recovery efforts attests to the acute risks faced by small populations and to the need for a more intensive, systematic approach to recovery planning utilizing whatever human, analytical, biological, and economic resources are available.

Genetic Processes in Small and Fragmented Populations

Random events dominate genetic and evolutionary change when the size of an inter-breeding population is on the order of 10s or 100s (rather than 1000s or more). In the absence of selection, each generation is a random genetic sample of the previous generation. When this sample is small, the frequencies of genetic variants (alleles) can shift markedly from one generation to the next by chance, and variants can be lost entirely from the population -- a process referred to as "genetic drift". Genetic drift is cumulative. There is no tendency for allele frequencies to return to earlier states (though they may do so by chance), and a lost variant cannot be recovered, except by the reintroduction of the variant to the population through mutation or immigration from another population. Mutation is such a rare event (on the order of one in a million for any given gene) that it plays virtually no role in small populations over time scales of human concern (Lacy 1987a). The restoration of variation by immigration is only possible if other populations exist to serve as sources of genetic material.

Genetic drift, being a random process, is also non-adaptive. In populations of less than 100 breeders, drift overwhelms the effects of all but the strongest selection: Adaptive alleles can be lost by drift, with the fixation of deleterious variants (genetic defects) in the population. For example, the prevalence of cryptorchidism (failure of one or both testicles to descend) in the Florida panthers (Felis concolor coryi) is probably the result of a strongly deleterious allele that has become common, by chance, in the population; and a kinked tail is probably a mildly deleterious (or at best neutral) trait that has become almost fixed within the Florida panthers.

A concomitant of genetic drift in small populations is inbreeding -- mating between genetic relatives. When numbers of breeding animals become very low, inbreeding becomes inevitable and common. Inbreeding has been documented in the Florida panthers: recent litters include progeny of a father-daughter mating and a mother-son mating. Inbred animals often have a higher rate of birth defects, slower growth, higher mortality, and lower fecundity ("inbreeding depression"). Inbreeding depression has been well documented in laboratory and domesticated stocks (Falconer 1981), zoo populations (Ralls et al. 1979, Ralls and Ballou 1983, Ralls et al. 1988), and a few wild populations.

Inbreeding depression probably results primarily from the expression of rare, deleterious alleles. Most populations contain a number of recessive deleterious alleles (the "genetic load" of the population) whose effects are usually masked because few individuals in a randomly breeding population would receive two copies of (are "homozygous" for) a harmful allele. Because their parents are related and share genes in common, inbred animals have much higher probabilities of being homozygous for rare alleles. If selection were efficient at removing deleterious traits from small populations, progressively inbred populations would become purged of their genetic load and further inbreeding would be of little consequence. Because random drift is so much stronger than selection in very small populations, even decidedly harmful traits can become common (e.g., cryptorchidism in the Florida panther) and inbreeding depression can drive a population to extinction.

The loss of genetic diversity that occurs as variants are lost through genetic drift has other, long-term consequences. As a population becomes increasingly homogeneous, it becomes increasingly susceptible to disease, new predators, changing climate, or any environmental change. Selection cannot favor the more adaptive types when all are identical and none are sufficiently adaptive. Every extinction is, in a sense, the failure of a population to adapt quickly enough to a changing environment.

To avoid the immediate effects of inbreeding and the long-term losses of genetic variability a population must remain large, or at least pass through phases of small numbers ("bottlenecks") in just one or a few generations. Because of the long generation times of the Puerto Rican parrot, the present bottleneck has existed for just one or two generations, and could be exited (successfully, we hope) before another generation passes and further genetic decay occurs. The Florida panther has evidently been in a bottleneck for much of this century, perhaps for tens of generations. Although we cannot predict which genetic variants will be lost from any given population (that is the nature of random drift), we can specify the expected average rate of loss. Figure 5 shows the mean fate of genetic variation in randomly breeding populations of various sizes. The average rate of loss of genetic variance (when measured by heterozygosity, additive variance in quantitative traits, or the binomial variance in allelic frequencies) declines by drift according to:

$$V_g(t) = V_g(0) \times (1 - 1/(2N_e))^t,$$

in which V_g is the genetic variance at generation t, and N_e is the effective population size (see below) or approximately the number of breeders in a randomly breeding population. As shown in Figure 6, the variance in the rate of loss among genes and among different populations is quite large; some populations may (by chance) do considerably better or worse than the averages shown the Figure 5.

The rate of loss of genetic variation considered acceptable for a population of concern depends on the relationship between fitness and genetic variation in the population, the decrease in fitness considered to be acceptable, and the value placed by humans on the conservation of natural variation within wildlife populations. Over the short-term, a 1% decrease in genetic variance (or heterozygosity), which corresponds to a 1% increment in the inbreeding coefficient, has been observed to cause about a 1-2% decrease in aspects of fitness (fecundity, survival) measured in a variety of animal populations (Falconer 1981). Appropriately, domesticated animal breeders usually accept inbreeding of less than 1% per generation as unlikely to cause serious detriment. In contrast, we may expect that the two litters of panthers known to be inbred (with inbreeding coefficients of .25) will suffer 25% to 50% lower viability and fecundity than would non-inbred panthers. The relationship between fitness and inbreeding is highly variable among species and even among populations of a species, however. A few highly inbred populations survive and reproduce well (e.g., northern elephant seals, Pere David's deer, European bison), while attempts to inbreed many other populations have resulted in the extinction of most or all inbred lines (Falconer 1981).

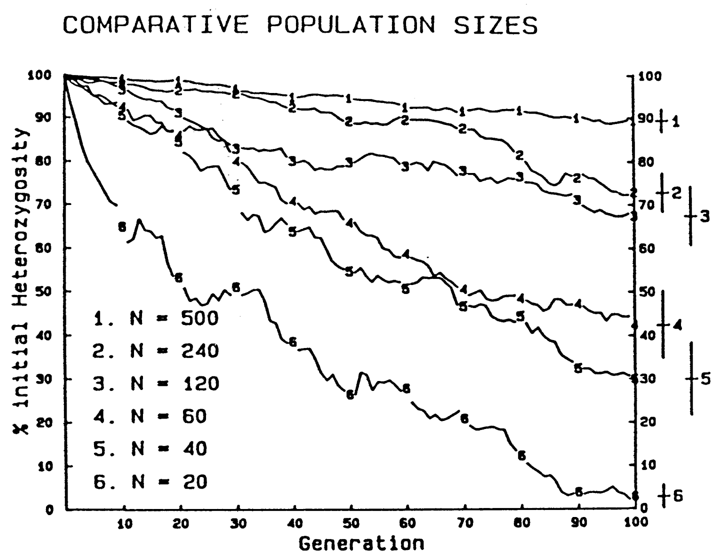

Figure 5. The average losses of genetic variation (measured by heterozygosity or additive genetic variation) due to genetic drift in 25 computer-simulated populations of 20, 50, 100, 250, and 500 randomly breeding individuals. Figure from Lacy 1987a.

Concern over the loss of genetic adaptability has led to a recommendation that management programs for endangered taxa aim for the retention of at least 90% of the genetic variance present in ancestral populations (Foose et al. 1986). The adaptive response of a population to selection is proportional to the genetic variance in the traits selected, so the 90% goal would conserve a population capable of adapting at 90% the rate of the ancestral population. Over a timescale of 100 years or more, for a medium-sized vertebrate with a generation time of 5 years such a goal would imply an average loss of 0.5% of the genetic variation per generation, or a randomly breeding population of about 100 breeding age individuals.

Most populations, whether natural, reintroduced, or captive, are founded by a small number of individuals, usually many fewer than the ultimate carrying capacity. Genetic drift can be especially rapid during this initial bottleneck (the "founder effect"), as it is whenever a population is at very low size. To minimize the genetic losses from the founder effect, managed populations should be started with 20 to 30 founders, and the population should be expanded to carrying capacity as rapidly as possible (Foose et al. 1986, Lacy 1988, 1989). With twenty reproductive founders, the initial population

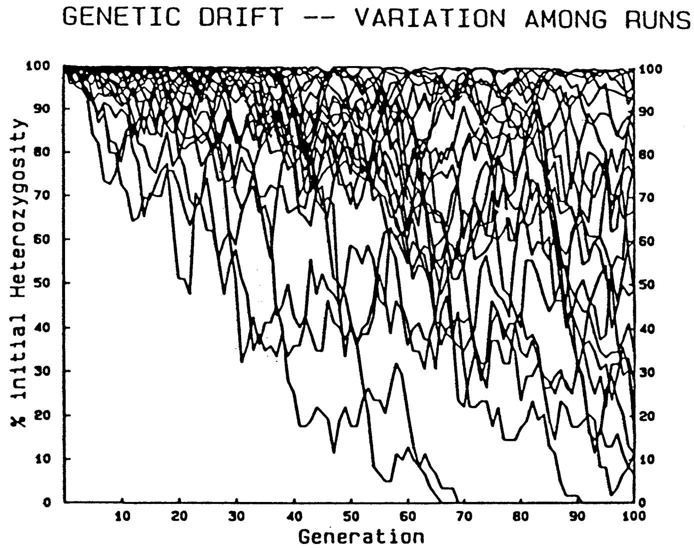

Figure 6. The losses of heterozygosity at a genetic locus in 25 populations of 120 randomly breeding individuals, simulated by computer. Figure from Lacy 1987a.

would contain approximately 97.5% of the genetic variance present in the source population from which the founders came. The rate of further loss would decline from 2.5% per generation as the population increased in numbers. Because of the rapid losses of variability during the founding bottleneck, the ultimate carrying capacity of a managed population may have to be set substantially higher than the 100 breeding individuals given above in order to keep the total genetic losses below 90% (or whatever goal is chosen).

The above equations, graphs, and calculations all assume that the population is breeding randomly. Yet breeding is random in few if any natural populations. The "effective population size" is defined as that size of a randomly breeding population (one in which gamete union is at random) which would lose genetic variation by drift at the same rate as does the population of concern. An unequal sex ratio of breeding animals, greater than random variance in lifetime reproduction, and fluctuating population sizes all cause more rapid loss of variation than would occur in a randomly breeding population, and thus depress the effective population size. If the appropriate variables can be measured, then the impact of each factor on N_e can be calculated from standard population genetic formulae (Crow and Kimura 1970, Lande and Barrowclough 1987). For many vertebrates, breeding is approximately at random among those animals that reach reproductive age and enter the breeding population.

To a first approximation, therefore, the effective population size can be estimated as the number of breeders each generation. In managed captive populations (with relatively low mortality rates, and stable numbers), effective population sizes are often 1/4 to 1/2 the census population. In wild populations (in which many animals die before they reach reproductive age), Ne/N probably rarely exceeds this range and often is an order of magnitude less.

The population size required to minimize genetic losses in a medium sized animal, therefore, might be estimated to be on the order of N_e = 100, as described above, with N = 200 to 400. More precise estimates can and should be determined for any population of management concern from the life history characteristics of the population, the expected losses during the founding bottleneck, the genetic goals of the management plan, and the timescale of management.

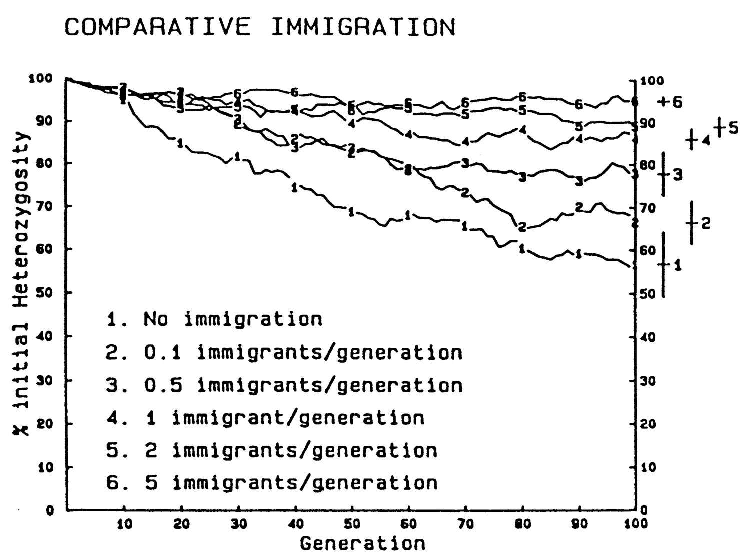

Figure 7. The effect of immigration from a large source population into a population of 120 breeding individuals. Each line represents the mean heterozygosity of 25 computer-simulated populations (or, equivalently, the mean heterozygosity across 25 non-linked genetic loci in a single population). Standard error bars for the final levels of heterozygosity are given at the right. Figure from Lacy 1987a.

Although the fate of any one small population is likely to be extinction within a moderate number of generations, populations are not necessarily completely isolated from conspecifics. Most species distributions can be described as "metapopulations", consisting of a number of partially isolated populations, within each of which mating is nearly random. Dispersal between populations can slow genetic losses due to drift, can augment numbers following population decline, and ultimately can recolonize habitat vacant after local extinction.

If a very large population exists that can serve as a continued source of genetic material for a small isolate, even very occasional immigration (on the order of 1 per generation) can prevent the isolated subpopulation from losing substantial genetic variation (Figure 7). Often no source population exists of sufficient size to escape the effects of drift, but rather the metapopulation is divided into a number of small isolates with each subjected to considerable stochastic forces. Genetic variability is lost from within each subpopulation, but as different variants are lost by chance from different subpopulations the metapopulation can retain much of the initial genetic variability (Figure 8). Even a little genetic interchange between the subpopulations (on the order of 1 migrant per generation) will maintain variability within each subpopulation, by reintroducing genetic variants that are lost by drift (Figure 9). Because of the effectiveness of even low levels of migration at countering the effects of drift, the absolute isolation of a small population would have a very major impact on its genetic viability (and also, likely, its demographic stability). Population genetic theory makes it clear that no small, totally isolated population is likely to persist for long.

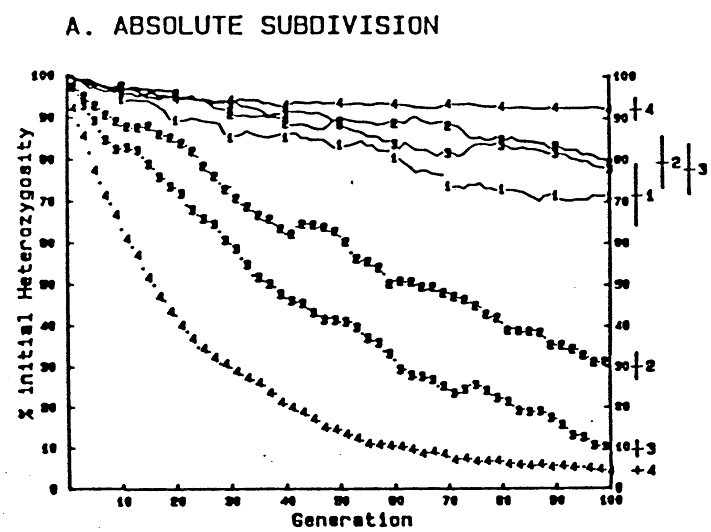

Figure 8. The effect of division of a population of 120 breeders into 1, 3, 5, or 10 isolated subpopulations. Dotted lines (numbers) indicate the mean within-subpopulation heterozygosities from 25 computer simulations. Lines represent the total gene diversity within the simulated metapopulation. Figure from Lacy 1987a.

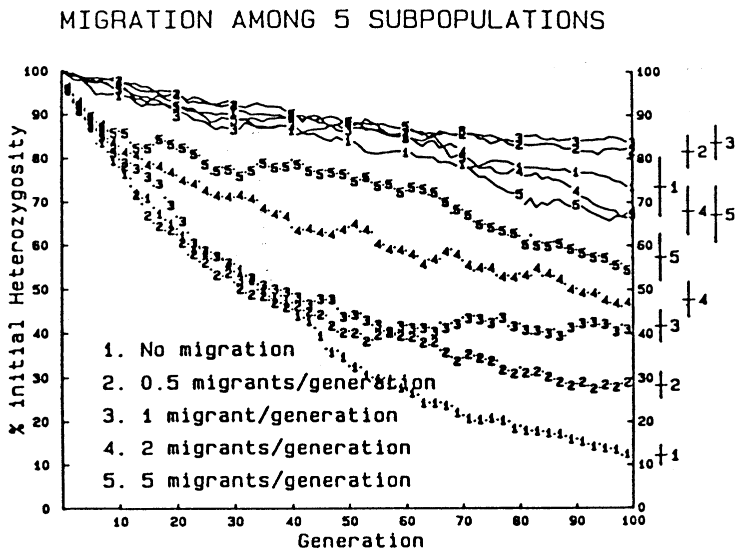

Figure 9. The effect of migration among 5 subpopulations of a population of 120 breeders. Dotted lines (numbers) indicate the mean within-subpopulation heterozygosities from 25 simulations. Lines represent the total gene diversity within the metapopulation. Figure from Lacy 1987a.

Demographic Processes in Small and Fragmented Populations (J. Ballou)

Extinction rates (persistence times) of populations are determined by the population size, growth rate, susceptibility to demographic challenges (sometimes measured as variation in growth rate), and its spatial distribution. In turn, growth rate, and population's susceptibility to demographic challenges is determined by the population's life history characteristics, and such random factors as the severity of demographic, environmental, genetic, disease and catastrophic events affecting the population.

Preliminary models are available for estimating persistence times for specific populations providing data are available on the demographic characteristics of the population. These model have been most useful for developing conservation strategies for small populations.

While the mean (expected) persistence time can be roughly estimated, these models show that persistence time is distributed as an approximate exponential distribution. Hence there is a high probability that the population will go extinct well before its calculated mean time. Model results that indicate long mean persistence times are therefore misleading since more than 50% of the time populations will go extinct before the indicated mean time period.

To protect against this, very large populations or a number of different populations will be needed to assure high certainty of population survival for significant periods of time. Furthermore, management decisions need to specify both time frame for management and degree of certainty as specific management goals (e.g. 95% certainty of surviving for 100 years) in order to accurately evaluate available management options and develop Minimum Viable Population Size ranges for populations.

Goals

Goals of single-species conservation programs are, in general, specifically directed towards mitigating the risks of extinction for those species of interest. This is best accomplished by understanding, identifying and redressing those factors that increase the probability of the population going extinct.

Small populations, even if stable in the demographic sense, are particularly susceptible to a discouraging array of challenges that could potentially have a significant impact on their probability of survival (Soule 1987). Among these challenges are Demographic Variation, Environmental Variation, Disease Epidemics, Catastrophes and Inbreeding Depression.

Challenges to Small Populations

Demographic Variation: This is the variation in the population's overall (average) birth and death rates caused by random differences among individuals in the population. The population can experience 'good' or 'bad' years in terms of population growth simply due to random (stochastic) variation at the individual level. This can have consequences for the population's survival. For example, one concern in captive propagation is the possibility that all individuals born into a small population during one generation are of one sex, resulting in the population going extinct. Figure 10 illustrates the probability of this occurring over a 100 generation period in populations of different size. There is a 50% chance of extinction due to biased sex ratio in a population of size 8 sometime during this time period. However, these risks are practically negligible in populations of much larger size. Similar consequences could result from the coincidental but random effects of high death rates or low birth rates.

In general, the effect of any one individual on the overall population's trend is significantly less in large populations than small populations. As a result, Demographic Variation is a minor demographic challenge in all but very small populations.

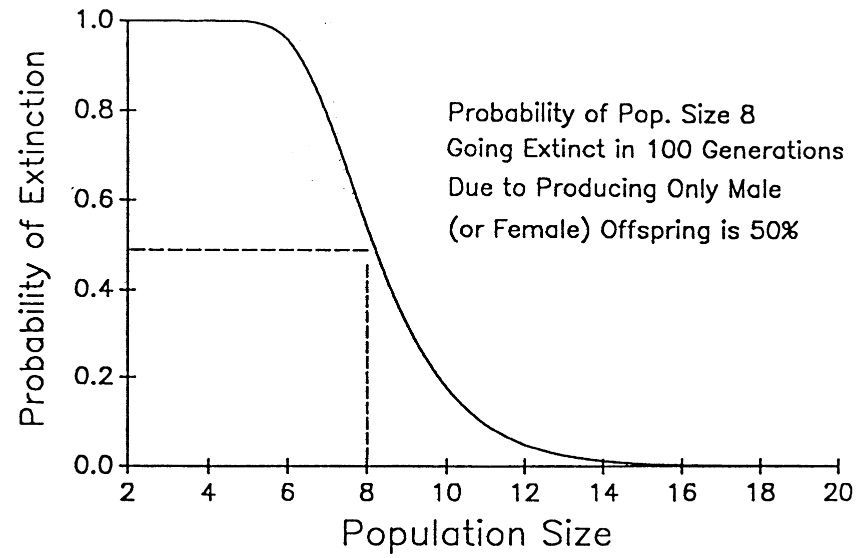

Figure 10. Example of Demographic Variation: Probability of extinction sometime during a 100 generation period due solely to producing only one sex of offspring.

Environmental Variation: Variation in environmental conditions clearly impact the ability of a population to reproduce and survive. As a result, populations susceptible to environmental variation vary in size more than less susceptible populations, increasing the danger of extinction. For example, reproductive success of the endangered Florida snail kite (<u>Rostrhamus</u> <u>sociabilis</u>) is directly affected by water levels, which determines prey (snail) densities: nesting success rates decrease by 80% during years of low water levels. Snail kite populations, as a result, are extremely unstable (Beissinger 1986).

Disease Epidemics: Disease epidemics and catastrophes are similar to other forms of environmental variation in the sense that they are external to the population. However, they are listed separately because we are just beginning to appreciate their role as recurrent but difficult to predict environmental pressures exerted on a population. They can be thought of as relatively rare events that can have devastating consequences on the survival of a large proportion of the population. Less devastating diseases and parasites are a natural accompaniment of all species and populations which may act to decrease reproductive rates and increase mortality rates.

Epidemics can have a direct or indirect effect. For example, in 1985 the sylvatic plague had a severe indirect effect on the last remaining black-footed ferret population by affecting the ferrets prey base, the prairie dog. Later that same year, the direct effect of distemper killed most of the wild population and all of the 6 ferrets that had been brought into captivity (Thorne and Belitsky 1989).

Catastrophes: From a demographic perspective, catastrophes are one-time disasters capable of totally decimating a population. Catastrophic events include natural events (floods, fires, hurricanes) or human induced events (deforestation or other habitat destruction). Large and small populations are susceptible to catastrophic events. Tropical deforestation is the single most devastating 'catastrophe' affecting present rates of species extinction. Estimates of tropical species' extinction rates vary between 20 and 50% by the turn of the century (Lugo 1988).

Inbreeding Depression: In small closed populations, mate choice is soon limited to close relatives, resulting in increased rates of inbreeding. The deleterious effects of inbreeding are well documented in a large variety of taxa. Although inbreeding depression has a genetic mechanism, its effects are demographic. Most data on exotic species come from studies of inbreeding effects on juvenile mortality in captive populations (Ralls, Ballou and Templeton 1988). These studies show an average effect of approximately 10% decrease in juvenile survival with every 10% increase in inbreeding. Data on the effects of inbreeding on reproductive rates in free ranging wild species is limited (lions; Wildt et al. 1987); however, domestic animal sciences recognize that inbreeding effects on reproduction are likely to be more severe than effects on survival. Inbreeding also may reduce disease resistance, and ability to adapt to rapidly changing environments (O'Brien and Evermann 1988).

Interacting Effects: Clearly, demographic challenges do not act independently in small populations. As a small population becomes more inbred, reduced survival and reproduction are likely; the population decreases. Inbreeding rates increase and because the population is smaller and more inbred, it is more susceptible to demographic variation as well as disease and severe environmental variation. Each challenge exacerbates the others resulting in a negative feedback effect (Figure 11). Over time the population becomes increasingly smaller and more susceptible to extinction (Gilpin and Soule 1986).

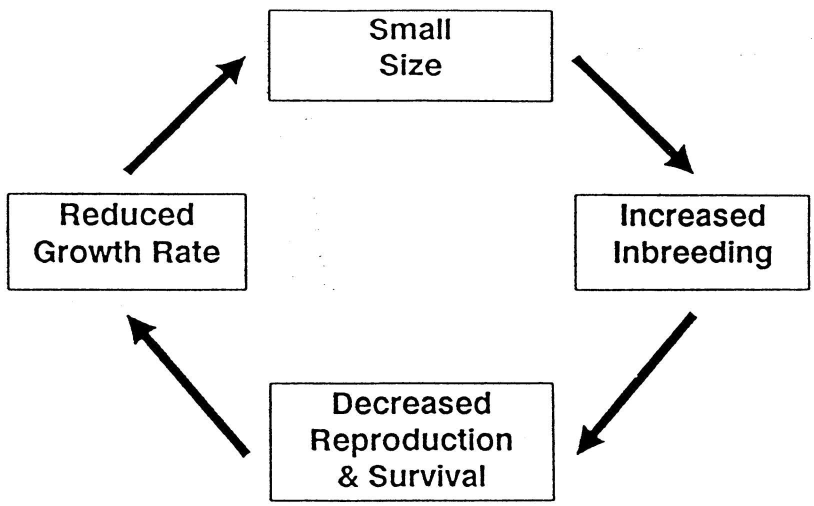

Figure 11. Negative feedback effects of inbreeding on small populations.

Susceptibility to Demographic Challenges

Populations differ in their susceptibility to demographic challenges. As mentioned above, population size clearly effects vulnerability. Large populations are relatively unaffected by demographic variation and are less apt to be totally devastated by environmental variation than small populations.

The severity of the demographic challenge is also important. A population in a fairly stable environment is less likely to go extinct than a population in a highly variable environment or an environment vulnerable to catastrophes.

A third important factor is a population's potential for recovering from these demographic challenges, in other words, the population's growth rate. A population at carrying capacity experiences normal fluctuation in population size; the degree of fluctuation depending on the severity of demographic challenge. Populations with low growth rates remain small longer than populations with rapid growth potential and therefore are more vulnerable to future size fluctuations.

A fourth important consideration is the population's spatial distribution. A population that is dispersed across several 'metapopulations,' or patches, is significantly less vulnerable to catastrophic extinctions than a same-sized population localized in a single patch. Extinction of one patch among many does not extinguish the entire population and colonization between patches could reconstitute extinct patches (Gilpin 1987).

Populations dispersed over a wide geographic range are also unlikely to experience the same environment over the entire range. While part of a population's range may suffer from extreme environmental stress (or catastrophes), other areas may act as a buffer against such effects.

Estimating Susceptibility with Persistence Time Models

A population's susceptibility to demographic challenges can be measured in terms of the amount of time it takes a population to go extinct. This is often referred to as the persistence time of the population. Ideally, persistence time should be estimated from data on all the variables discussed above. Persistence times are usually estimated from mathematical models that either simulate the population over a period of time (stochastic models) or estimate the population's expected (mean) persistence time (deterministic models).

Unfortunately, methods are not (yet) available to simultaneously consider the effect of all the above variables on persistence time. Usually, persistence times are estimated by considering the effects of only one or two variables. The effects of spatial distribution are the most important; however, they are also the most difficult and consequently are not considered (or only rudimentarily considered) in most persistence time models. These models assume a single, geographically localized population.

Goodman (1987) presents an example of a deterministic persistence time model. This model estimates the mean persistence time of a population given its size, growth rate and its susceptibility to environmental and demographic challenges.

In Goodman's model, susceptibility to demographic challenges is represented by the variance in the population's growth rate. A population that is very susceptible to environmental perturbations will vary drastically in size from year to year, which, in turn, will be reflected as a high variance in the population's growth rate. Goodman's model is:

$$\textbf{Mean Extinction Time} = \sum_{x=1}^{N} \sum_{y=x}^{N} \frac{2}{y(yV - r)} \sum_{z=x}^{Y-1} \frac{zV + r}{zV - r}$$

where: r = exponential annual growth of the population
V = variance in r
N = Maximum (ceiling) population size

The mean persistence times for populations of size 30 and 50 (which bracket estimates for the Florida panther population) with low growth potentials (.5% and 2% per year) are shown in Figure 12. These graphs are provided simply to introduce the concept of persistence time models and are not suggested as realistic models of the panther population. More realistic models, based on life history data collected from the field, are provided below.

The mean time to extinction is inversely related to the variation in the growth rate: if variance is extremely high, regardless of the population sizes or potential growth rates, the mean persistence time (time to extinction) is approximately 10 years. However, with variances of .2, mean persistence time varies from 42 to 57 years.

To provide perspective on the meaning of variance in r, if the growth rate is distributed as a normal random variable, a variance of .2 would mean that 75% of the growth rates experienced by the population would fall within the range of 50% increase per year and 50% population decline per year.

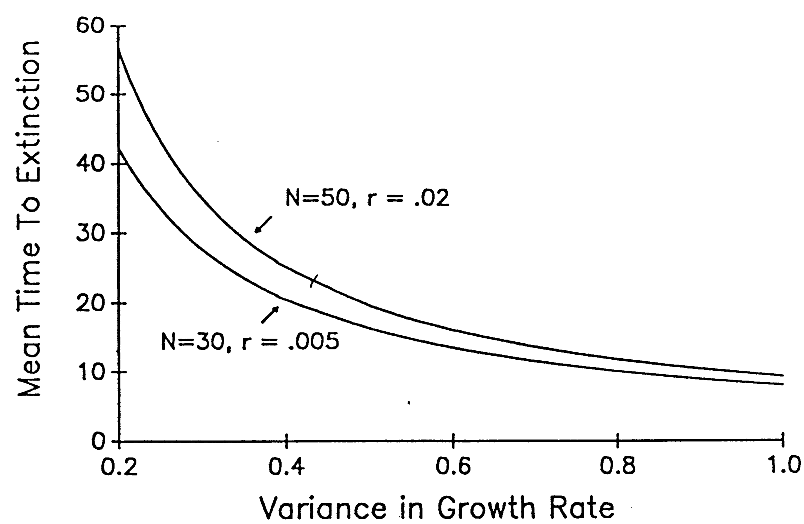

Figure 12. Mean time to extinction (persistence time) for a population of 50 animals with exponential growth rate of .02 (approx. 2% per year) and population of 30 animals with exponential growth rate of .005 (approx. 0.5% per year) under different levels of variation on growth rate. Variation in growth rate is a measure of the population's susceptibility to demographic challenges.

Persistence Time is Exponentially Distributed

An important characteristic of persistence time is that it has an approximately exponential distribution. The models provide the mean, or expected time to extinction; however, there is significant variation around this mean. Many population go extinct well before the mean time; a few go extinct long after.

The exponential distribution of persistence time for a population of 50 individuals with a growth potential of 2% and growth variance of .2 is shown in Figure 13. The mean persistence time is 57 years. However, since the distribution is exponential, there is a high probability that the time to extinction will occur before 57 years. In fact, there is a 33% chance that the time of extinction will be before 25 years.

Given that persistence times are approximately exponentially distributed, times to extinction can be estimated with various degrees of certainty. Again for the same population described in Figure 12, we can estimate the probability of extinction at different time periods (Figure 14). With growth rate variation at .2, mean time to extinction is 57 years; however, there is a 50% chance that the population will survive only to 40 years, only a 75% chance that the population will survive at least to 15 years, and a 95% chance that the population will survive at least to 4 years. In other words, there is a 5% chance that the population will go extinct in 4 years.

The Minimum Viable Population (MVP) Size concept is based on the premise that persistence times can only be defined with reference to degrees of certainty. Ideally, given a population's life history characteristics and management goal (a desired persistence time under a specified degree of certainty, e.g. 95% chance of surviving for 200 years), we could estimate the population size required to achieve the goal. This would be a Minimum Viable Population Size (MVP size) for the program (Shaffer 1981). However, since MVP size is a function of the specific management goals of the population, there is no one "magical" MVP size for any given population in any given circumstance.

Management Implications

The implication of exponentially distributed persistence time is that management strategies can not be based on the mean persistence time if a high degree of certainty is desirable. Although the mean persistence time of the modeled population is 57 years, management strategies should recognize that to be 95% certain that the population survives even 50 years would require a population size whose mean persistence time is 975 years. This would require well over 1000 individuals.

A second implication is that management strategies can only be fully evaluated if both degree of certainty and time frame for management are specified. For example, programs may be evaluated in terms of their potential for assuring a 95% chance of the managed population surviving for 200 years. It is critical that the management decision making process recognize that the process of extinction is a matter of probabilities, as are all its components (environmental and demographic variation, probability of catastrophe, etc.; Shaffer 1987).

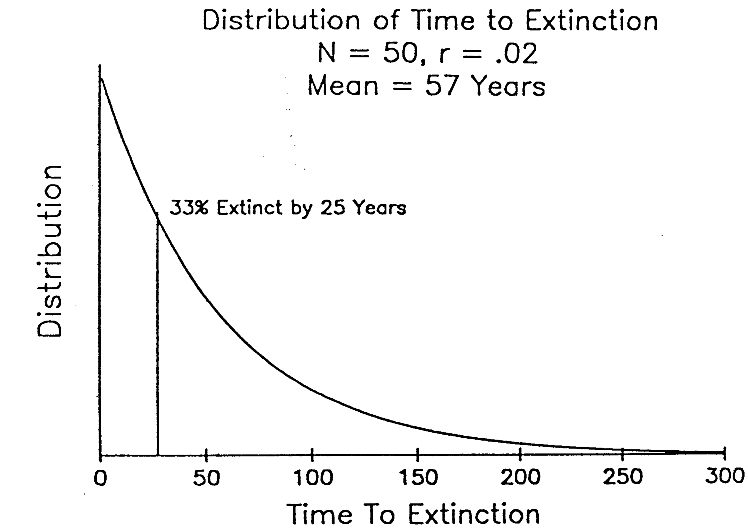

Figure 13. Exponentially distributed time for a population of 50 animals growing at an exponential rate of .02 with a variation in growth rate of 0.2. While the mean (expected) persistence time is 57 years, the exponential characteristic of the distribution shows that there is a high probability of extinction before this period (33% chance by 25 years).

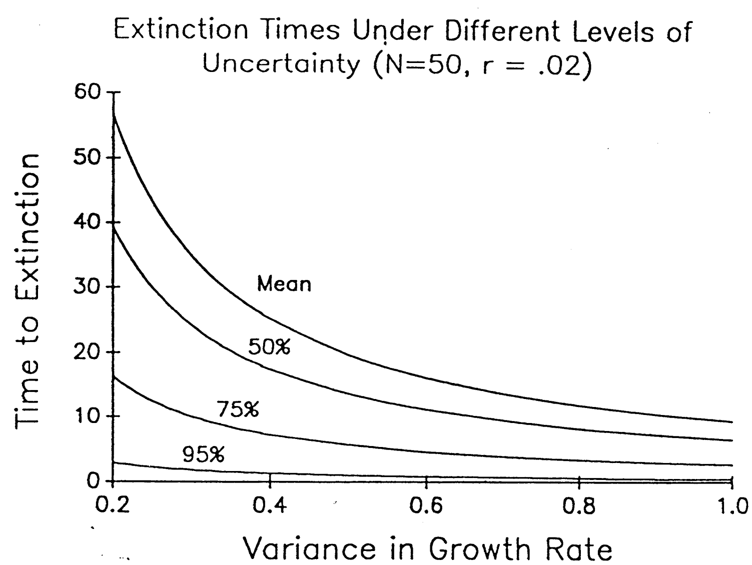

Figure 14. Extinction times under different levels of uncertainty. See text.

ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

REPORT
30 November 1992

SECTION 4

POPULATION AND HABITAT VIABILITY ANALYSIS

ARUBA ISLAND RATTLESNAKE POPULATION BIOLOGY

Biological Characteristics of the Population

A recurrent theme throughout the modeling session was the general lack of field data for the cascabel needed for the VORTEX model and for developing a long term management plan for the species. The data that are available have come from the field study conducted by Matthew Goode, from the captive population in North American zoos and aquariums, from local experts (Tom Barmes, Candido Ras and Harro Weustink), and by utilization of information available from studies on similar rattlesnakes throughout the world, primarily *C. horridus* and *C. viridis*.

The models were run for a period of 100 years. Based on a maximum rattlesnake generation time of 10 years this represents about 10 generations. For the VORTEX model, 10 generations is sufficient to indicate any demographic and genetic trends which may be occurring in this population. Based on the best estimates of the general biology for the cascabel, the generation time is probably closer to 7-8 years. This generation time will give an additional 2-4 generations in 100 years. Each simulation scenario was run 250 times to provide a reasonable sample size for stable statistics. Approximated 150 scenarios were examined.

The most critical factor for the survival of the cascabel is the limited habitat. The maximum present habitat is 45 square km as determined by mapping known capture locations for the cascabel on a topographical map of Aruba. At this time the habitat is contiguous and it is theoretically possible for a snake to move over the entire habitat. The cascabel has been shown to move an average of 90 meters per day for males and 30 meters per day for females (Goode). With contiguous habitat and the documented cascabel movement patterns the population can be modeled as one population. It is important that the habitat remain contiguous and does not become subdivided. Subdivision or fragmentation of the habitat preventing the cascabel from moving throughout the habitat will produce additional negative effects (e.g. smaller effective population sizes, increased edge effects, and increased rate of inbreeding) to operate on the population.

Inbreeding depression was not considered to be a problem for the cascabel population at the present time. The movement of the cascabel should give the population sufficient mixing to avoid inbreeding. Also, the population is relatively large and is not as subject to the rate of genetic loss by random drift and the inbreeding problems that can occur if the population is below approximately 100 animals. As a check on this assumption, the effect of inbreeding was modeled for several basic scenarios. Subdivision of the population would produce the negative effects of inbreeding.

Reproduction and survivability were not believed to be tightly correlated. An abundant year of resource availability may improve survival slightly and reproduction greatly. A poor resource year may reduce reproduction to near zero, but will have relatively little effect on the survival of adult animals. The ability to survive a poor resource year on stored reserves is typical of most snakes.

The primary catastrophe, for which there is historical evidence, which may affect the cascabel population is drought which will result in a reduction of resources. A reduction in resources results in the curtailment of breeding in most snakes. Droughts were modeled to occur under two scenarios once in 7 years and once in 15 years, on average. Each extreme drought was expected to reduce reproduction to zero for that year, but would not affect survival.

An additional catastrophe was modeled to occur on the average once in 100 years. This catastrophe may represent a severe hurricane, a fire in the cunucu, or some undetermined event. This catastrophe is modeled to decrease both reproduction and survival by 50 percent.

The cascabel was modeled to be polygynous. No snakes have been shown to be monogamous. While the cascabel will exhibit combat behavior in captivity, the low density on Aruba may reduce the actual contact between males during the breeding season. Males may find females and reproduce without contacting another male and therefore smaller males may have a better chance to reproduce than would be likely in a more dense population. The potential for sperm storage from one year to the next and with multiple sires possible for a single brood would also tend to equalize the number of males and females breeding per year.

In captivity the cascabel was shown to breed at 2 years of age on one occasion, but 3 years is a much more usual age (Odum and Peterson). Wild animals with resources more limited will grow more slowly and therefore will not breed at as young an age as well fed captive animals. It is likely that wild males and females reproduce for the first time at 5 years of age. A few females may reproduce at 4 years of age and a few may not reproduce until 6 years of age. The males probably do not reproduce until at least 5 years of age and possibly 6 due to female choice and the slight chance of combat possible between males. These age estimates are based on limited data on the correlation between body size and number of sheds. Small animals that are believed to be barely reproductive possessed up to 9 unbroken segments in their rattle which is estimated to be 4-5 years (Goode).

The maximum age for the cascabel is estimated to be 20 years. This is based upon captive records (Odum and Peterson). Data on the natural life span are needed.

The sex ratio of the 4 natural litters (Goode) and the captive litters (Odum and Peterson) was even, 1 male to 1 female.

The 4 natural litters produced 8, 8, 12, and 12 offspring for a mean of 10. The maximum litter size was determined to be 12 and the distribution of litter sizes possible in the model was selected to produce a mean of 10.

Mortality in the first year (0-1 age class) is expected to be at least 50 percent and not greater than 80 percent. There are a number of causes of juvenile mortality including the caracara, burrowing owl, kestrel, centipede, failure to shed, failure to feed, dehydration, *Bufo marinus* predation, and other factors. This does not include death due to humans.

Once an animal has survived to 1 year, the chances of survival are much better. Mortality for the 1-2 age class was estimated to be 10-25 percent. This is slightly higher than the older age classes because these individuals may still be vulnerable to the numerous predators which will take young snakes. Mortality for all other juvenile and adult age classes due to predators, disease, and senescence was estimated to be 5 percent annually. It should be noted that the adult annual mortality rate for *C. horridus* is 10 percent (Reinart). These mortality estimates do not include mortality caused directly by humans which is discussed later in the section under harvest. It is often believed that male snakes are more prone to predation because of their higher rates and distances of movement. However, the equal sex ratio found in the wild population (Goode) and the equal sex ratio at birth suggest that mortality is the same for males and females throughout their life.

It was estimated that 50 percent of the males would be in the breeding pool in any one year. Data to support this figure are absent. But in the absence of inbreeding, as discussed above, genetic effects due to this fraction is likely to be minimal. Also in a polygynous mating system, limited males do not affect the demographics of the population.

The initial population size is very difficult to estimate. Indeed snake populations in general are difficult to estimate (Reinert; Biology of Reptilia Vol. 7). This is primarily due to their secretive nature and relatively little movement. Based on the censuses which have been conducted in cascabel habitat, it is estimated that 1-2 adult snakes (10 snakes total), occur per 1 square km. It is felt that if the cascabel occurred in higher densities the censuses would have located more individuals. Based on the maximum of 45 square km of current habitat, the current population is estimated to be 350-550 animals of which 50-100 are breeding adults.

A 10 percent reduction in the habitat in the first 2 years was modeled based on increased building for which permits have already been issued. This is a minimum loss of habitat and the actual reduction may be much greater. If the only remaining habitat for the cascabel was in the proposed National Park (see habitat section) this would leave only 22 square km of habitat. This is too low to maintain a viable population of the cascabel. Reduction of habitat below 40 square km would put the cascabel's survival in serious jeopardy.

Carrying capacity was estimated at 350-450, the current population size estimate. It was noted that much higher densities of rattlesnakes have been observed in other populations. Anecdotal reports suggest that the snake may have been more numerous on Aruba 25 years ago, although there are no census data from that time.

Another, and perhaps the major threat is the killing of primarily adult animals by humans. This is associated with increased construction and activity within the cascabel's habitat. Killing may include road kills, joggers in the cunucu, and wandering snakes which enter the vicinity of a private residence. Up to 50 percent of translocated snakes may not survive due to stress and unfamiliarity with a new area. Therefore translocations may add to the human caused death rate. (Note: This is not to recommend that translocation of reported snakes be stopped, only to suggest collecting data in an effort to find the best ways in which to carry out translocations). It is estimated that 10-30 cascabel are killed by humans each year on Aruba. Any data that can be collected on the exact number of cascabel killed each year would be extremely valuable. The State of Pennsylvania, USA has initiated a permit system by which they can track the number of people hunting the rattlesnakes. In Aruba this may not work as it may encourage collection, however other programs to allow estimation of the current rate of death need to be explored.

Two harvest scenarios were examined. In one scenario, 2 males and females were removed every 10 years for placement into the captive population to maintain the level of genetic diversity of the captive population. Another scenario was constructed to simulate the loss of adult animals through human removals and killing of animals encountered by chance. There is no evidence for deliberate poaching or hunting of the snake. The estimates of the number of animals killed annually ranges from 10-30 which may represent 10 to 20% of the adult population.

Results of the Simulations

The base scenario formulated from the estimates of age of first reproduction as 5 years, interbirth interval of 3 years, adult mortality of 10%, and first year mortality of 50-70%, with no annual harvest yielded a probability of extinction of 0 over 100 years (shaded lines in Table 2). The stochastic growth rates of the populations were positive, ranging from 14 to 7% respectively. The population under these conditions should expand to carrying capacity if there are no other negative factors acting upon the population. These conditions yielded a generation time of about 9 years and a loss of about 8% of heterozygosity over 100 years at a population size of 300. This rate of loss would be reduced at larger population sizes. The scenarios with 70% first year mortality had a slight lower average population size and about double the standard deviation for population size indicating much variability in final population sizes at 100 years. The high population risk of extinction (Pe = .968 with mean time to extinction of 38 years), for first year mortalities of 90%, indicates that on average about 20% first year survival is necessary for these populations to replace themselves.

Changes in interbirth interval have minimal effect on the generation time, increase the annual rate of increase, and reduce the risk of population extinction to 0.908 for a first year mortality of 90% (Table 2). An increase in interbirth interval to 4 years has the opposite effect and results in a 0.020 probability of extinction for first year mortalities of 90%.

A decrease of age of first reproduction to 4 years results in slightly higher rates on population increase and a 1 year shorter generation time but does not overcome the effects of a high first year mortality rate (Table 1). An increase in age of first reproduction results in the occasional extinction of a population at a 70% first year mortality. An increase in age of first reproduction to 6 years has the opposite effect reducing the annual rates of population increase and larger variance in mean population sizes at 100 years.

Reduction of adult mortality rates to 85 (Tables 4-6) or 5%(Tables (7-9) increases the annual rates of population increase and generally reduces the probabilities of extinction at even the high rates of first year mortality. However an average 90% first year mortality is not sustainable with Pe greater than .80 or 80%. An increase in adult mortality rates to an average of 12%, (Tables 10-12) decreases the annual rates of increase and increases the risks of extinction in some scenarios. The variance in population size at 100 years is also increased indicating wider fluctuations in population sizes over the 250 runs.

The effects of removals of adult rattlesnakes (Table 13), as is thought to be occurring through the increased rates of human encounters at present, at a rate of 20 adults - 10 male and 10 females - per year for 50 years results in a dramatically increased risk of extinction for base adult mortality rates of 8, 10, and 12%. In the base scenario (shaded lines in Table 13) the risk of extinction was 0.172 in 100 years for a first year mortality of 50% and 0.844 (84%) for a first year mortality of 70%. The stochastic rates of increase were negative during the harvest years. The surviving populations built up to carrying capacity during the second 50 years of the simulation scenarios.

Summary

The general conclusion from these exploratory simulation models and scenarios for the Aruba Island Rattlesnake indicate a wide range of flexibility in the potential for response of this species to varying environmental conditions. It can easily survive years of poor resources, reproductive failure, and high losses of young animals. However, it is very vulnerable to the removal of adult breeding animals as appears to be occurring on the island as individual snakes are encountered by humans. The rate of removal required to produce severely detrimental effects on the population appears surprisingly small but the population is limited in distribution and cannot recruit new animals from some source population. These results emphasize the importance of human acceptance of this species and for the development of methods to assure the return of animals removed from the population or better the tolerance of the animals by the human population.

Table 1. Aruba Island Rattlesnake: Adult Mortality = 10%; Age First Reproduction = 4 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30													
2	50													
2	70													
2	90													
3	30													
3	50													
3	70													
3	90													
4	30													
4	50													
4	70													
4	90													

Table 1. Aruba Island Rattlesnake: Adult Mortality = 10%; Age First Reproduction = 4 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.307	7.3	28	18	0	297	18	.299	.21	.90	17		
2	50	.251	7.6	33	19	0	294	18	.244	.21	.91	20		
2	70	.173	8.0	45	22	0	267	46	.155	.31	.92	23		
2	90	.032	9.2	71	25	.890	86	89	-.042	.38	.75	8	43	21
3	30	.240	7.6	36	22	0	291	28	.232	.21	.90	18		
3	50	.189	8.0	42	25	0	293	24	.178	.20	.92	22		
3	70	.117	8.4	52	28	0	261	46	.098	.26	.92	23		
3	90	-.011	9.6	91	34	.964	59	71	-.077	.32	.84	6	40	19
4	30	.197	7.9	41	27	0	289	29	.189	.21	.90	19		
4	50	.149	8.2	48	30	0	288	27	.139	.20	.92	23		
4	70	.081	8.7	57	34	.004	241	64	.063	.24	.91	22	40	
4	90	-.039	9.9	100	40	.988	21	19	-.091	.30	.61	4	37	17

Table 2. Aruba Island Rattlesnake: Adult Mortality = 10%; Age First Reproduction = 5 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.248	8.5	24	16	0	292	19	.242	.19	.90	19		
2	50	.202	8.8	28	18	0	294	23	.194	.19	.92	22		
2	70	.138	9.2	37	20	0	270	46	.126	.28	.92	24		
2	90	.016	10.1	63	24	.908	76	74	-.047	.36	.75	9	45	23
3	30	.193	8.8	31	20	0	291	22	.186	.19	.91	21		
3	50	.151	9.1	36	22	0	288	28	.143	.18	.92	24		
3	70	.090	9.5	44	26	0	261	50	.076	.24	.92	25		
3	90	-.023	10.5	87	32	.968	31	29	-.081	.32	.60	5	38	18
4	30	.158	9.0	36	25	0	286	38	.151	.19	.92	22		
4	50	.117	9.3	39	27	0	280	39	.110	.18	.93	26		
4	70	.059	9.8	50	31	.020	229	73	.044	.23	.91	23	73	30
4	90	-.048	10.7		100	.996	16	0	-.100	.29	.71	4	37	16

Table 3. Aruba Island Rattlesnake: Adult Mortality = 10%; Age First Reproduction = 6 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.205	9.6	20	14	0	295	18	.198	.17	.91	20		
2	50	.166	9.9	24	16	0	288	29	.160	.17	.92	24		
2	70	.111	10.2	34	18	0	262	51	.097	.26	.93	26		
2	90	.003	11.0	31	24	.932	100	99	-.050	.36	.75	8	46	23
3	30	.159	9.9	26	18	0	294	29	.153	.17	.92	23		
3	50	.122	10.1	30	21	0	290	26	.117	.17	.93	27		
3	70	.069	10.5	40	24	.004	246	60	.057	.22	.92	26	74	0
3	90	-.033	11.3	55	31	.984	56	26	-.085	.30	.81	10	38	18
4	30	.128	10.1	31	22	0	287	32	.121	.18	.92	24		
4	50	.092	10.3	35	25	0	279	36	.085	.17	.93	28		
4	70	.042	10.7	44	29	.020	208	86	.029	.22	.90	23	80	12
4	90	-.057	11.5	100	37	.996	4	0	-.104	.29	.62	3	36	16

Table 4. Aruba Island Rattlesnake: Adult Mortality = 8%; Age First Reproduction = 4 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.325	7.5	27	16	0	297	14	.317	.21	.89	17		
2	50	.270	7.8	35	18	0	295	22	.261	.21	.91	20		
2	70	.192	8.3	47	21	0	275	34	.174	.30	.92	24		
2	90	.052	9.4	76	26	.856	110	79	-.017	.38	.84	13	43	20
3	30	.259	7.8	36	19	0	294	20	.252	.20	.90	19		
3	50	.207	8.2	41	25	0	294	24	.198	.20	.92	23		
3	70	.136	8.7	52	28	0	267	44	.123	.26	.93	25		
3	90	.008	9.9	66	34	.928	90	85	-.044	.32	.75	7	45	20
4	30	.216	8.1	41	27	0	292	24	.207	.21	.92	20		
4	50	.168	8.4	48	30	0	290	27	.158	.20	.92	24		
4	70	.101	9.0	59	34	0	256	55	.082	.24	.93	24		
4	90	-.019	10	89	40	.968	36	27	-.075	.30	.75	6	38	19

Table 5. Aruba Island Rattlesnake: Adult Mortality = 8%; Age First Reproduction = 5 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.267	8.7	24	16	0	295	24	.261	.18	.90	19		
2	50	.222	9.0	29	17	0	295	21	.216	.19	.92	23		
2	70	.157	9.4	40	20	0	273	41	.140	.27	.93	26		
2	90	.036	10.3	66	25	.844	132	86	-.016	.37	.85	12	48	23
3	30	.212	9.0	31	20	0	294	19	.207	.19	.91	22		
3	50	.170	9.3	37	23	0	290	30	.162	.18	.92	25		
3	70	.110	9.7	46	26	0	267	42	.099	.24	.93	27		
3	90	-.003	10.7	58	32	.916	77	65	-.052	.29	.78	10	46	21
4	30	.177	9.2	36	25	0	291	24	.170	.19	.92	23		
4	50	.136	9.5	40	28	0	286	31	.129	.18	.93	26		
4	70	.079	10.0	51	31	.004	254	58	.067	.22	.93	27	100	0
4	90	-.028	11.0	54	38	.984	98	78	-.070	.29	.86	11	41	20

Table 6. Aruba Island Rattlesnake: Adult Mortality = 8%; Age First Reproduction = 6 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.224	9.8	21	14	0	296	19	.219	.17	.91	21		
2	50	.186	10.0	25	16	0	294	22	.179	.17	.93	25		
2	70	.130	10.4	35	19	0	269	42	.118	.25	.93	27		
2	90	.023	11.2	49	33	.860	105	85	-.028	.35	.80	12	45	22
3	30	.178	10.1	26	18	0	292	24	.171	.18	.92	23		
3	50	.141	10.3	31	21	0	293	20	.135	.17	.93	27		
3	70	.089	10.7	41	25	0	261	51	.076	.22	.93	28		
3	90	-.013	11.5	73	31	.956	77	62	-.056	.31	.81	11	45	22
4	30	.148	10.3	30	22	0	289	28	.144	.18	.92	25		
4	50	.112	10.5	37	25	0	287	27	.106	.17	.93	29		
4	70	.061	10.9	45	29	.004	247	61	.050	.21	.93	27	100	0
4	90	-.037	11.7	83	37	.984	24	26	-.084	.29	.71	4	40	20

Table 7. Aruba Island Rattlesnake: Adult Mortality = 5%; Age First Reproduction = 4 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.352	7.8	29	18	0	297	21	.345	.20	.89	17		
2	50	.297	8.1	35	19	0	298	15	.287	.20	.91	21		
2	70	.220	8.6	46	22	0	282	33	.202	.29	.92	25		
2	90	.080	9.8	74	26	.832	156	85	.015	.37	.89	18	44	23
3	30	.287	8.1	38	23	0	295	21	.278	.20	.90	19		
3	50	.236	8.5	43	25	0	296	19	.228	.19	.92	23		
3	70	.165	9.0	53	28	0	280	33	.149	.25	.93	27		
3	90	.038	10.2	76	34	.864	121	83	-.022	.32	.85	13	43	21
4	30	.243	8.4	44	28	0	294	24	.234	.21	.91	21		
4	50	.195	8.8	48	30	0	293	23	.184	.20	.92	24		
4	70	.129	9.3	60	34	0	271	41	.114	.23	.93	27		
4	90	.010	10.6	69	40	.956	141	108	-.034	.29	.82	12	48	24

Table 8. Aruba Island Rattlesnake: Adult Mortality = 5%; Age First Reproduction = 5 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.294	9.0	24	16	0	298	17	.288	.18	.90	19		
2	50	.249	9.2	30	18	0	294	22	.243	.18	.92	23		
2	70	.185	9.7	40	20	0	283	28	.172	.27	.93	27		
2	90	.065	10.7	66	24	.800	163	90	.010	.36	.86	18	46	23
3	30	.242	9.3	31	20	0	296	21	.235	.18	.91	22		
3	50	.199	9.6	37	23	0	294	20	.191	.18	.93	26		
3	70	.139	10.0	48	26	0	274	40	.125	.24	.93	29		
3	90	.027	11.0	81	32	.884	125	73	-.023	.30	.82	12	44	23
4	30	.205	9.5	35	24	0	296	17	.198	.19	.92	23		
4	50	.165	9.8	43	28	0	291	27	.157	.18	.93	27		
4	70	.108	10.3	53	32	0	271	42	.093	.22	.94	30		
4	90	.001	11.3	66	39	.948	107	87	-.050	.27	.82	11	43	22

Table 9. Aruba Island Rattlesnake: Adult Mortality = 5%; Age First Reproduction = 6 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.253	10.1	21	14	0	295	21	.246	.17	.91	21		
2	50	.214	10.3	26	16	0	297	14	.208	.17	.93	25		
2	70	.159	10.7	35	19	0	280	36	.149	.25	.94	30		
2	90	.052	11.5	47	24	.848	185	88	-.001	.35	.88	17	45	23
3	30	.208	10.3	30	19	0	293	25	.202	.17	.92	24		
3	50	.171	10.6	32	22	0	290	28	.165	.17	.93	28		
3	70	.118	11.0	44	24	0	273	40	.106	.22	.94	31		
3	90	.017	11.8	71	32	.896	94	76	-.032	.29	.83	11	43	22
4	30	.176	10.6	32	23	0	292	28	.169	.18	.93	25		
4	50	.141	10.8	36	26	0	291	26	.135	.17	.94	29		
4	70	.090	11.2	46	30	0	274	37	.080	.20	.94	32		
4	90	-.007	12.0	88	37	.928	52	59	-.050	.28	.79	10	42	22

Table 10. Aruba Island Rattlesnake: Adult Mortality = 12%; Age First Reproduction = 4 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.288	7.2	29	17	0	294	23	.280	.21	.89	17		
2	50	.232	7.4	34	19	0	294	20	.224	.21	.90	20		
2	70	.154	7.8	51	20	0	264	44	.135	.31	.91	22		
2	90	.013	8.9	64	26	.932	97	93	-.057	.39	.68	8	40	20
3	30	.221	7.5	36	23	0	291	27	.214	.21	.90	18		
3	50	.170	7.8	40	25	0	290	30	.161	.20	.91	21		
3	70	.098	8.2	52	28	0	254	59	.082	.27	.91	22		
3	90	-.031	9.4	40	33	.980	67	106	-.090	.33	.68	6	38	20
4	30	.178	7.7	40	27	0	290	26	.168	.22	.90	19		
4	50	.129	8.0	48	30	0	282	32	.120	.20	.92	22		
4	70	.062	8.5	58	33	.024	218	75	.045	.25	.90	20	55	23
4	90	-.059	9.6	100	40	.996	11	0	-.110	.31	.61	4	35	15

Table 11. Aruba Island Rattlesnake: Adult Mortality = 12%; Age First Reproduction = 5 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.228	8.4	23	15	0	297	18	.220	.19	.90	19		
2	50	.183	8.6	29	17	0	290	28	.175	.19	.92	22		
2	70	.118	9.0	37	19	0	265	47	.103	.28	.92	23		
2	90	-.004	9.9	79	24	.976	47	71	-.070	.37	.66	6	43	20
3	30	.174	8.6	30	20	0	292	21	.167	.19	.91	21		
3	50	.131	8.9	35	23	0	287	27	.124	.19	.92	23		
3	70	.070	9.3	44	26	.012	239	69	.055	.25	.92	23	75	20
3	90	-.043	10.3	0	32	1.00	0	0	-.099	.32	0	0	37	16
4	30	.138	8.8	35	25	0	288	26	.128	.20	.92	22		
4	50	.097	9.1	40	27	0	278	38	.088	.19	.92	23		
4	70	.039	9.6	49	31	.044	201	81	.024	.23	.89	20	67	20
4	90	-.069	10.5	18	38	.996	11	0	-.124	.29	0	1	33	15

Table 12. Aruba Island Rattlesnake: Adult Mortality = 12%; Age First Reproduction = 6 Years

Birth	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Interv	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
2	30	.185	9.5	19	14	0	292	27	.179	.18	.90	20		
2	50	.146	9.7	24	15	0	290	28	.140	.18	.92	23		
2	70	.091	10.0	33	18	.004	258	52	.080	.26	.93	25	60	0
2	90	-.018	10.8	36	23	.964	66	74	-.076	.36	.65	6	40	20
3	30	.139	9.7	26	18	0	291	24	.132	.17	.92	22		
3	50	.102	10.0	31	20	0	281	40	.095	.18	.93	26		
3	70	.049	10.3	39	24	.004	223	71	.038	.23	.91	23	87	0
3	90	-.054	11.1	100	31	.992	35	40	-.098	.32	.81	8	38	17
4	30	.108	9.9	29	22	0	282	32	.102	.18	.92	23		
4	50	.072	10.2	34	25	0	277	34	.066	.18	.93	26		
4	70	.021	10.5	46	29	.144	160	91	.005	.23	.87	17	75	22
4	90	-.077	11.3	0	37	1.00	0	0	-.122	.29	0	0	33	14

Table 13. Aruba Island Rattlesnake: Effects of Removal of 20 Adults Per Year for 50 Years

Adult	Mortal.			% Adults			Population		$r_{stochas}$				T(Ext)	
Mortal.	0-1	r_{det}	G(Yrs)	Pre	Post	P(E)	X	SD	X	SD	Het	Allele	X	SD
8	30	.259	7.8	36	23	.060	296	20	.251	.21	.89	17	32	12
8	50	.207	8.2	42	25	.132	294	23	.199	.20	.90	20	27	10
8	70	.136	8.7	60	28	.720	277	44	.118	.25	.89	19	30	11
8	90	.008	9.9		34	1.00	0	0	-.322	.54	0	0	12	4
10	30	.240	7.6	37	23	.092	295	23	.232	.21	.89	17	32	11
10	50	.189	8.0	44	35	.172	292	29	.178	.20	.90	20	30	11
10	70	.117	8.4	52	28	.844	246	65	.097	.25	.88	17	26	11
10	90	-.011	9.6		34	1.00	0	0	-.345	.54	0	0	11	4
12	30	.221	7.5	37	23	.172	292	25	.214	.21	.88	16	32	11
12	50	.170	7.8	43	25	.304	290	24	.160	.20	.90	19	30	11
12	70	.098	8.2	54	28	.944	264	59	.094	.27	.87	16	23	9
12	90	-.031	9.4		33	1.00	0	0	-.386	.55	0	0	9.7	3.3

ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

REPORT
30 November 1992

SECTION 5

PHVA RECOMMENDATIONS

ARUBA ISLAND RATTLESNAKE (*Crotalus durissus unicolor*)
FINAL HABITAT REPORT

Prepared by
Howard Reinert, Robert Johnson, and Matthew Goode

The present geographic range of the Aruba Island rattlesnake consists of approximately 45 sq km in the southern portion of the island (see map). This range can be roughly circumscribed by a line that extends southwest from Sabania Abao through Balashi to Pos Chiquito, then eastward through Rooi Master to the vicinity of the Golf Club, northward to Guadirikiri, and then returning westward through Boca Prins and Arikok to Sabania Abao. Information on the historical range of the Aruba Island rattlesnake is sparse and based upon anecdotal accounts. However, the rapid increase of the human population has undoubtedly resulted in a restriction of the distribution of this species on the island.

The rattlesnake has been found from sea level to 189 m and reportedly inhabits rocky arroyos, canyons, and limestone plateaus (baranca). The habitat within the current range includes thorny woodland derived from seasonal formation, thorny woodland derived from dry evergreen formation, and *Croton-Lantana* thicket. These plant associations occur on diabase formations with outcrops of exposed limestone. Aruba is thought to have been more densely forested in pre-Columbian times. The forest was apparently cut for a wide variety of uses including charcoal production and wood products. Regeneration of this pre-Columbian forest has obviously been retarded and existing trees are widely scattered and cacti predominate in most areas. The vegetation on the island has apparently been subjected to constant, uncontrolled grazing by goats and donkeys for several hundred years.

The existence of suitable habitat is a necessary prerequisite for the survival of the Aruba Island rattlesnake. Suitable habitat is defined by a complex composition of structural, climatic, and biotic features that supply the necessary environment for the survival and maintenance of a sustainable wild population. The fact that a wild rattlesnake population of unknown size currently exists on Aruba indicates that at least marginally suitable habitat also exists. However, without additional information concerning patterns of habitat use by this species, we are incapable of assessing the quality of the existing habitat.

Information provided by the Director of the Department of Land Development (Mr. Adonis) confirmed an immediate need for 5000 new homes islandwide. Approximately 1300 of these dwellings are scheduled to be constructed at no less than four locations within the existing range of the rattlesnake. The construction of new homes will undoubtedly necessitate the expansion of existing limestone quarrying activity (for construction material) which is also currently located within the range of this species. The Department of Land Development has expressed a commendable willingness to consider recommendations with regard to the location of future development, the size and direction of quarry expansions, and the eventual reclamation of quarried land.

Arikok National Park presently protects approximately 3 sq km of existing rattlesnake habitat. The Director of the Department of Land Development indicated that preservation status is being considered for a triangular area that can roughly be defined by a line extending from Daimari southwest to Pos Chiquito and east to Guadirikiri. This area includes an additional 19 sq km, or nearly 50% of the existing range of the Aruba Island rattlesnake. However, the Director also indicated that new developments may occur anywhere on the island, and that each application for development is evaluated on a case by case basis.

The most common cause for the decline of populations of wildlife species is the destruction, fragmentation, and/or degradation of their habitats. Human population growth and the subsequent requirement of more land for homes, farms, business, and recreation directly conflict with the needs of many wildlife species. Although the factors responsible for the scarcity of the Aruba Island rattlesnake remain elusive, it is obvious that the loss or degradation of additional rattlesnake habitat will only serve to exacerbate an already perilous situation.

Aruba is experiencing tremendous economic growth and increases in both resident and transient (tourist) human populations. However, a relatively large portion of the island presently exists in a natural, undeveloped condition. These areas maintain a wealth of interesting and unique plants and animals, several of which, like the Aruba Island rattlesnake, are found nowhere else in the world. Now is the time to act to assure that future generations of Arubans and island visitors can continue to enjoy this unique natural heritage.

Recommendations:

1. **Official designation of National Park status for the area that is currently unofficially defined as a preservation zone.** This represents a triangular area that can roughly be defined by a line extending from Daimari southwest to Pos Chiquito and east to Guadirikiri. This area should be protected from mining, quarrying, vehicular traffic (except on primary roadways), and over-grazing by domestic and feral animals.

   Rationale: Arikok National Park presently protects only 3 sq km of apparent rattlesnake habitat. This is clearly insufficient to guarantee the long-term survival of the Aruba Island rattlesnake. Preliminary data indicates that a single snake is capable of traversing more than 3 sq km during its seasonal movements. The preservation zone suggested is presently sparsely inhabitated by humans, and it would protect an additional 19 sq km of existing rattlesnake habitat. It should also be noted that this area would serve as a preserve for all of the unique fauna and flora of Aruba.

2. **Official designation of an approximately 23 sq km Conservation Management Area which would include all of the existing range of the Aruba Island rattlesnake occurring outside of the two protected National Park areas (Arikok and newly designated).** Trails and non-essential secondary roads in this area should be gated to reduce the impact of vehicles. Further development within this Conservation Management Area would be strictly regulated and permitted only in consultation with the Department of Agriculture.

   Rationale: The designation of a Conservation Mangement Area would allow a limited amount of carefully regulated development in an area presently subject to unrestrained development. Future, well-planned development could be restricted to insensitive or already altered areas. Approvals for development would be based upon an evaluation of the potential impact of the development upon rattlesnake populations and habitat. In areas defined as critical habitat, restitution or mitigation for such impacts would be a required part of approved development plans.

3. Establishment of a Conservation Officer to oversee the protection of the Aruba Island rattlesnake and all Aruban flora and fauna within the National Parks (Arikok and newly designated park) and Conservation Management Area. The Officer would respond to calls concerning rattlesnake encounters and would be actively involved in public education efforts concerning rattlesnakes and Aruban wildlife in general. We do not visualize this to be an administrative position. Our recommendation is that the bulk of the Officer's working time be spent in the field and in contact with the public and the environment under his jurisdiction.

Rationale: The establishment of parks, conservation areas, and conservation regulations requires visible, on-site personal for the purpose of education and regulation enforcement.

4. Initiation of an intensive, large-scale, ecological study of the Aruba Island rattlesnake to determine its preferred habitat, patterns of habitat use, extent of movements, daily and seasonal activity regimes, prey preferences, and foraging behavior.

Rationale: Basic, unbiased information concerning the behavior and natural history of the Aruba Island rattlesnake is currently lacking. Such information is of paramount importance for the continued survival of this species. The results of a recent pilot project indicate that a large-scale research program is feasible and necessary to define habitat critical to the continued survival of the Aruba Island rattlesnake. Such a study is required to produce the quantitative data necessary for the design of meaningful conservation and management programs for the Aruba Island rattlesnake. In particular, such information is necessary for guiding the regulation of development within the Conservation Management Area and for improving habitat quality within the Conservation Management Area and the National Parks.

5. Initiation of research to assess the impact of grazing upon the vegetation and wildlife on Aruba.

Rationale: Grazing by domestic and feral animals is often implicated in the alteration and degradation of wildlife habitat. Goats and donkeys have been an integral part of the Aruban landscape for centuries. Carefully designed studies would allow an unbiased assessment of the impact of grazing upon rattlesnake habitat, behavior, and potential prey populations of rabbits, mice, lizards, and birds.

6. Initiation of research to assess the impact of translocation on the survival and behavior of the Aruba Island rattlesnake.

Rationale: Moving rattlesnakes from areas populated by humans to wilder regions has been, and may continue to be, a common practice. The impact of such translocations upon the survival and behavior of the snakes involved needs to be evaluated to determine if this is a viable conservation measure. Such research would produce guidelines for the relocation and release of rattlesnakes.

Disease Impact on Aruba Island Rattlesnakes

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INTRODUCTION OF DISEASE ORGANISMS

Aruba Island rattlesnakes appear to be very susceptible to viral and bacterial disease processes evident in captive collections. During viral epizootics affecting diverse reptile collections, Aruban rattlesnakes appear early in the list of mortalities. The study of infectious disease processes in reptiles is relatively new. Only in the last 15 to 20 years has any attempt been made to describe the pathogens, and only in the past ten years or so have the disease processes been worked with. Without a doubt, there are many reptilian disease organisms and processes yet to be discovered.

Work has been done with a few reptile pathogens seen most commonly in captive situations. This work has been largely opportunistic in nature and has followed on the heels of a disease outbreak. Captivity often enhances the transmission of disease organisms due to the close proximity of animals originating from a diversity of geographical and environmental conditions.

Although there has been relatively little work done with infectious diseases in captive reptiles, even less has been done to study disease impacts on wild populations. Assessment of risk of disease introduction to an insular population of rattlesnakes is largely theoretical, but is based on what is known about the biology of rattlesnakes, local environmental conditions, and the knowledge gained about diseases introduced into island ecosystems involving other species.

Rattlesnakes are solitary except during the breeding season and during denning (in those species which have to endure seasonally adverse environmental conditions). Throughout most of the year contact with congeners would only occur sporadically as paths crossed. Contact with other reptile species would be, however, much more probable. The high numbers of lizards (<u>Cnemidophorous</u> and <u>Ameiva spp.</u>) present on the island could maintain and transmit a pathogen quite easily. These lizards may constitute a portion of the natural diet for Aruban rattlesnakes during at least part of their lifespan and would therefore easily transmit any exotic pathogen introduced into their population.

Environmentally, Aruba has a very harsh, dry windy climate. However, the microenvironment utilized by the snakes is somewhat tempered from the overall conditions. The snakes have been observed in arroyos, under vegetation, rocks, and in hollow stumps, where there is a moderation of temperature, and a relatively increased humidity. Most pathogens would be destroyed when exposed to full sunlight and the hot, dessicating conditions normal for the island. However, the conditions existing in the microenvironment utilized by the snakes would be more conducive to the survival of pathogens.

In recent years humans have invaded many areas of the world (especially islands) which were either uninhabited or sparsely inhabited by indigenous people. These "invaders" have brought a variety of domestic species and in some cases, wild animals to their new homes. The Hawaiian islands for example have been populated by both North American and Asian peoples who have introduced species of birds native to their homelands (and others). While seemingly innocent, these birds brought with them a piroplasm (malaria causing organisms) previously absent from the islands. With the accidental introduction of mosquito vectors, many native birds of Hawaii are declining rapidly in numbers. Hawaiian birds evolved without the challenge of this malaria causing organism and appear to be unable to mount an effective immune response in order to survive the infection. The extinction of several species has already occurred and many more are sure to follow. The elimination of mosquitos and exotic birds would be impossible.

Few reptiles are deliberately kept or transported by humans. However, a small subunit of the public exists which keeps a number of reptile species as pets. Additionally, reptile and amphibian species can be easily transported through the transfer of plant materials used in landscaping. Exotic reptiles and amphibians have already been introduced to Aruba by these means and will likely play a role in its future ecology. From a disease standpoint, the pet trade in reptiles exerts the greatest risk of infection to the reptiles of Aruba. Pets are frequently purchased from dealers which group a number of animal species in suboptimal conditions prior to their sale to retailers. Once purchased by a private individual, the pet reptile may already have been exposed to a number of pathogenic organisms. Exotic pet owners are often poorly prepared to handle disease in their pets and have been known to release specimens into foreign habitats. It would be very easy for exotic diseases to be introduced to Aruba in this manner.

A number of arboviral diseases of livestock have been serologically identified in reptiles. These diseases are transmitted by ectoparasites which may feed off of either domestic or wild animals. The importation of reptiles infested with exotic ticks could easily impact the health of the livestock kept on Aruba through the introduction of exotic diseases. These same diseases and/or vectors may have little impact on Aruba's native wildlife.

In the captive environment, the specific organisms which are known to be associated with morbidity and mortality in Aruban rattlesnakes are ophidian Paramyxovirus and <u>Salmonella</u> <u>arizona</u>. Paramyxovirus is found in a number of different serpent families including boids, colubrids, elapids, as well as viperids. A sample of captive snakes on Aruba was assayed for detectable antibody to Paramyxovirus in 1989. These animals were found tobe negative for antibody, indicating no exposure to the disease at that time in the population.

No surveys have been done on the island to detect the presence of <u>Salmonella</u> <u>arizona</u>, but since this is a ubiquitous organism, there is little doubt that it already exists in the environment. However, future work on the island should include a survey for this organism to detect it's prevelence. Parasitic organisms which are associated with morbidity, and occassionally mortality in Aruban rattlesnakes are <u>Entamoeba</u> <u>spp.</u> and <u>Cryptosporidium</u> <u>spp.</u> These organisms have a wide host range and are potentially zoonotic. Mortality caused by these organisms is usually related to concomittant infection with other pathogens.

REINTRODUCTION OF CAPTIVE BORN ANIMALS

One of the purposes of maintaining wild animals in captivity is for the possible reintroduction to the natural habitat in the event the species becomes extinct in the wild. This can be done when the original causes for the extinction have been mitigated and the environment is determined to be suitable for the species to survive.

Augmentation programs are considered when the wild population has reached a low level due to overcollection or because of an extraordinary disaster. Population levels must be determined to be so low that without augmentation, the population would continue to decline for genetic reasons as well as low population density causing a failure of reproductive encounters. The augmentation of wild populations using captive born animals has been done with other species, but is not without risk. Disease factors must be considered relative to the genetic benefit inherent in a reintroduction or augmentation program. These factors must not only consider the species in question, but must also address sympatric species susceptible to the disease organism(s) present within the habitat.

Reintroduction or augmentation programs should utilize animals "donated" from a healthy population. Breeding age adults should be isolated from other species prior to the breeding season. They should be monitored for the presence of known pathogens through the use of physical examination, routine bacteriology of feces, parasite examination, and serology for viral organisms such as Paramyxovirus. Breeding and gestation should be done under isolation, preferrably in a separate building and utilizing a separate keeper staff. Offspring produced in isolation should be fed once and released as quickly as possible into suitable habitat.

MONITORING THE WILD POPULATION

The wild population can currently be assumed to be as healthy as it will ever be. Habitat loss and destruction due to human activities are unlikely to be reversed and will undoubtedly increase somewhat in the near future. Therefore the current wild population should be assessed from a health standpoint as soon as possible to determine a "baseline" of information which can be compared to future values. Field studies to further elucidate the biology of wild Aruban rattlesnakes should include the collection of a number of biological specimens in addition to the usual biometric and behavioral data normally collected. Full post mortem examination including histopathology should be performed on any dead specimen encountered.

As soon as possible after capture, all wild animals should be physically examined under proper restraint. Evaluation of over-all condition and vitality should be followed by close examination for ectoparasites. If present, a count should be made and some specimens collected and preserved for identification in ethyl alcohol.

Blood collection from the ventral caudal vein is relatively easy in specimens as small as 100 grams. Blood smears should be made onto microscope slides using fresh or heparin anticoagulated blood. Packed cell volume and plasma protein values can be easily performed with minimal equipment either in the field or at a veterinary clinic. If possible, complete blood counts and a "routine" serum chemistry screen should be performed. Where this is not possible, estimations can be made off the blood smear and serum chemistries can be performed at a later time using frozen serum. The remaining blood should be separated into serum or plasma and red cell components. These should be frozen separately at -40 C for future genetic analysis.

Feces should be collected and evaluated for bacteria and parasite organisms. Bacteriology should describe the prevalence of gram negative and gram positive organisms, and survey for known pathogenic organisms such as Salmonella. Parasite evaluation should include the species present and their relative numbers quantified. Remaining feces should be preserved in 10% neutral buffered formalin at a rate of 1:10. This can later be used to further the parasite evaluation as well as serve to identify the types of prey fed upon by the wild animal.

Sporadic encounters with humans or their pets will result in the occasional encounter with a freshly killed specimen. A thorough post mortem examination should be performed by a veterinarian familiar with reptile anatomy and pathology. In the absence of a veterinarian, the carcass should still be evaluated and any abnormalities recorded. Samples of each major organ should be collected and preserved in 10% neutral buffered formalin. The tissues collected should include: esophagus, stomach, duodenum, jejunum, ileum, colon, liver, gall bladder, pancreas, spleen, gonad, uterus, kidney, lung, trachea, brain, heart, skin, muscle, and bone. Specific areas which appear abnormal should be saved in addition to the routine specimens. Records should be kept of all findings.

Determination of the population status may be indicated through data collected opportunistically due to the inevitable interaction with humans. Records of all specimens encountered by humans should be maintained. The data collected should minimally include the location of the encounter, date, time of day, size of specimen (weight and/or length), and if possible, sex. Although encounters are infrequent, trends in the population may be noticed after several years of data collection.

Determination of the "normal" is critical to the understanding of the species in its habitat. Should the population decline for any reason, measured parameters could be helpful in identifying the specific cause of the decline. An increasing prevalence of disease organisms may signal that the population is undergoing stress even before a significant population decline is detected.

CONSERVATION EDUCATION ON ARUBA

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INTRODUCTION

Although the Aruban school system has recently begun a conservation education program in its schools, historically there have been few environmental/conservation education opportunities available on Aruba. Typically these opportunities are made available through not-for-profit organizations such as zoos, nature centers, park systems, preserve systems, or natural history museums, and more recently, through schools. To my knowledge, none of these types of organizations (except schools, of course) exist on Aruba. As a result, the burden of conservation education falls on schools and on groups such as STIMARUBA, a conservation organization similar to a chapter of the Audubon Society.

With growing awareness of the fragility of island ecosystems, there is a greater sense of urgency for teaching Aruban children about their island. A teachers' workshop was held in February of 1992, as part of the International Symposium and Workshop on the Conservation and Research of the Aruba Island Rattlesnake, to introduce teachers to local ecological concerns. In general, the people of Aruba are surprisingly unfamiliar with their native wildlife. Recently, STIMARUBA has begun providing nature walks, birding trips and lectures for anyone interested in learning about Aruban wildlife. This has been a small but growing program with increasing interest and attendance.

The only way to assure the future preservation of Aruban wildlife is to educate the people. No one is willing to save something they don't know about, misunderstand, or fear -- like the Aruba Island rattlesnake, Crotalus durissus unicolor. People need to realize that islands are very fragile places and that damage occurs quickly and easily. They need to gain a sense of pride and ownership for the island's wildlife. Only then will they be willing to take the steps necessary to preserve it.

RECOMMENDATIONS

The following recommendations are intended to increase awareness, increase understanding, and inspire action. Although the people and government of Aruba must do the majority of the work necessary, the following are ways in which U.S. zoos and the conservation community can help support their efforts and some ideas that may encourage their participation.

Networking

Develop teacher or staff exchange programs. Teachers and/or school administration staff could visit American schools, zoos, nature centers, etc. and gain experience in using a variety of techniques for teaching environmental and conservation education.

Work with the school system to develop a series of workshops and in-services that will give teachers and teachers in training background information on conservation and island ecology, as well as Aruban ecology. We can also provide activities and materials that can be used in the classroom to teach about conservation and wildlife. Eventually, teachers who have participated in these workshops should be encouraged to develop their own materials and share their experiences with other teachers in teacher-led workshops.

Encourage and provide assistance in having teachers organize sharing sessions (such as teacher-led workshops) so they work together and develop a strong network for ideas, activities, and information.

Provide information on interpretive organizations, such as NIA (National Interpreters' Association) and other conservation education associations, for building a network of people in the field of interpretation and conservation education from which to draw advice and assistance.

Information

Assist in providing information on native and transient endangered and threatened species and on the threat of introduced species.

Assist in preparing background information (fact sheets, books, slides, videos, etc.) for teachers on native species of plants and animals. This is especially important for organisms considered unnecessary or dangerous (e.g. bats, snakes, spiders, etc.)

Encourage the teaching of energy and water conservation through training and in-services.

Encourage recycling and minimal packaging efforts.

Assist in providing information on native species through research. This information should be passed on in lectures and programs at meetings of STIMARUBA and other organizations as well as programs to which teachers (e.g. in-services/workshops) and the general public are invited.

Materials

Provide current literature on appropriate topics and on what has been successful on other islands. (e.g. current publications)

Provide materials to support curriculum studies, such as books, games, activities. Also catalogs from which teachers may acquire these materials directly. This will also encourage the integration of science throughout the curriculum.

Work with school system in providing loan boxes for use on particular topics (for example, endangered species, desert plants, etc.). Loan boxes are "kits" that contain activities, bulletin board displays, games, posters, photos, books, biofacts, experiments, etc. and a teacher instruction manual and background information. Encourage the school system to continue the development of loan boxes with teachers developing boxes to suit their particular needs. These boxes could be distributed through a central office for use by other teachers and other schools.

Make videos of teacher workshops and on-going field work available for classroom use. Special videos could be produced that cover the wildlife of Aruba. Like the loan boxes, these could be made available for use by all teachers.

Programs

Provide incentives for teachers to participate in conservation and conservation education. For example, something equivalent to Continuing Education Unit (CEU) credits, inexpensive awards, or other inexpensive recognition.

Encourage contests (such as poster competitions, essay competitions, conservation project awards, etc.) by providing prizes or inexpensive recognition for student efforts.

Mentorship programs in schools where older students learn about a subject/topic and then give talks and lead activities with younger students.

Develop adult education programs that entice, not only those already interested, but also those who probably wouldn't normally care (for example, economic gains from conservation).

Incentive program to encourage use of native species in planting, landscapes, etc.

Intern education program with teachers working with researchers in the field. For example, a teacher would be selected to work for a summer on radio tracking C. d. unicolor, or whatever studies may be going on at the time. It would probably be helpful if the teacher were paid a small stipend or given college credits.

Develop a traveling "museum" or exhibit that would visit all the schools. A unit of study should be developed to go along with the exhibit.

Someone should begin to offer classes similar to the Toledo Zoo's Saturday Class program. These are programs that are offered to the general public on a regular basis (at a small fee to cover the expenses of the class) and teach the basics for young children on a variety of natural history topics. These classes are usually inexpensive but include activities, crafts and lessons. For example, "Their Blood Runs Cold" was a program that taught kids 9-10 years old about reptiles. They learned about how reptiles differ from other animals, about the different groups of reptiles, what "cold blooded" means, what reptiles eat and the natural histories of a few species. They toured the reptile house and met a reptile keeper, met and touched some live reptiles, enjoyed a snack, and participated in a craft activity (e.g. made a "pet lizard" out of foam rubber, or "draft snakes" from old neckties to keep cold drafts from coming under doors.)

Public Relations

Articles should be placed in journals, magazines and newspapers, for example, giving information about native wildlife ("The Truth About the Aruban Island Rattlesnake") and about on-going conservation projects in the schools ("Our Children are Saving Our Island's Wildlife"). The more people hear about the success of any project, the more proud and supportive they'll be of the efforts that went into it. An example of this success is the bat colony that lives under the Ambassador Bridge in Austin, Texas. The people of Austin wanted to have the bats exterminated until there was a huge effort to educate them of the importance of the animals and dispel the myths about bats. Now the Ambassador Bridge bats are a major city attraction, almost like Carlsbad Cavern!

SOME SUGGESTED REFERENCE BOOKS

Activity Resources and Books for Children

Blake Publishing's Nature Series, 2222 Beebee Street, San Luis Obispo, CA 93401. phone (805) 543-7311 or 1-800-727-8558. (This series contains books with bright photos and illustrations covering a number of topics. A few topics include tidepools, tropical rainforests, coral reefs, seals and sea lions, sharks, birds of prey)

Conservation At Home, by Jane Mainwaring and Alison Whyman, British Museum of Natural History. 1989. (Activities stressing simple, reasonable conservation steps for the home)

Earth Book For Kids, by Linda Schwartz. The Learning Works, Inc. P.O. Box 6187, Santa Barbara, CA 93160. 1990 (Activities to help heal the environement) Ecology, by Linda Quick. Creative Teaching Press, Inc., Cypress, CA 90630. 1987. (Part of their Investigating Science series. Includes blackline student worksheets in binder-ready formats)

Educator's Activity Book About Bats, Bat Conservation International, P.O. Box 162603, Austin, TX 78716. 1991 (Contains activities that help dispell myths and reinforce positive information about bats.)

Endangered Animals, teaching units for grades 3-5 and 6-8. Developed by Leigh Childs, Lois Schwartz, and Jeff Swenerton. Leigh Childs, P.O. Box 9856, San Diego, CA 92109. 1984. (Contains activities, background information, and guidelines for teaching about endangered animals)

Get Growing!, by Candace Savage. Firefly Books Inc., P.O. Box 1325, Ellicott Station, Buffalo, NY 14205. 1991. (Agricultural ecology, conservation, and pollution. Organic agriculture)

Going Green: A Kid's Handbook to Saving the Planet, by John Elkington. Puffin Books, published by Viking Penguin, 375 Hudson Street, New York, NY 10014. 1990. (Things children can do toward living a minimal impact life)

How Green Are You?, by David Bellamy. Clarkson N. Potter, Inc., 201 East 50th Street, New York, NY, 10022. 1991. (Provides informatin and projects about ecology and environmental concerns that teach children how to conserve energy, protect wildlife, and reduce pollution)

Kid's Earth Book, by Rozanne Williams. Cretive Teaching Press, Inc., Cypress, CA 90630. 1991. (Interdisciplinary activities that incorporate language arts, math, social studies, music, and art)

The Kids' Environment Book: What's Awry and Why, by Anne Pedersen. John Muir Publications, P.O. Box 613, Santa Fe, NM 87504. 1991. (Examines our environmental problems, our historic relationship with the earth, how industrialization has changed our planet, and what must be done to repair the damage)

The Lorax, by Dr. Seuss. Random House, Inc. New York, NY. 1971. (A typical Dr. Seuss book with wonderful fictional characters and a strong lesson to learn about the environment and taught in an entertaining style.)

Litter Pevention and Recycling: An Ohio Science Workbook, edited by Lynn Edward Elfner. Ohio Academy of Science, 445 King Avenue, Columbus, OH 43201. phone (614) 424-6045. 1987. (A how-to book on litter and recycling) NatureScope, National Wildlife Federation, 1400 16th St. NW, Washington D.C. 20036-2266. (Series of activity books, each dealing with a different nature related topic. Some examples include: endangered species, rocks and minerals, insects, dinosaurs, weather, birds, trees, mammals, astronomy, wetlands, oceans, rainforests, pollution, reptiles and amphibians).

OBIS , Outdoor Biology Instructional Strategies, Delta Education, Box M, Nashua, NH 03061-6012. (An OBIS library includes 97 individual activities on easy-to-use, laminated cards. This collection covers a variety of topics including adaptations, animal behavior, breakwaters and bays, deserts, forests, human impact, schoolyard studies, seashores.)

Project Learning Tree, American Forest Council, 1250 Connecticut Avenue, NW, Washington, D.C. 20036. 1988. (Two versions, one for elementary students and one for junior and senior high students. These activity books were produced by the Western Regional Environmental Education Council and the American Forest Foundation to be distributed to environmental educators who participate in a Project Learning Tree workshop.)

Protecting Our World: A Beginner's Guide to Conservation, by Felicity Brooks. EDC Publishing, 10302 E. 55th Place, Tulsa, OK 74146. 1991. (Outlines the various threats to species and their habitats and explains how and why we must act now to stop further destruction)

Rads, Ergs, and Cheeseburgers: The Kid's guide to Energy and the Environment, by Bill Yanda. John Muir Publicatins, P.O. Box 613, Santa Fe, NM 8750a4. 1991. (A magical being discusses the generation of various forms of energy, its transportation, uses in everyday life, conservation, and development of alternative sources)

Sharing Nature With Children, by Cornell, Joseph, Ananda Publications, 14618 Tyler Foote Road, Nevada City, CA 95959. 1979. (A book of outdoor games and activies designed to increase awareness of nature and reinforces basic concepts.)

The Ocean Book: Aquarium and Seaside Activities and Ideas for all Ages, by The Center for Marine Conservation, 1725 DeSales Street, Suite 500, Washington, D.C. 20036. 1989. (Full of activities dealing with marine life and oceanography)

Tomorrow's Earth, A Squeaky-green Guide, by David Bellamy. Running Press Book Publishers, 125 South Twenty-second Street, Philadelphia, PA 19103. 1992. (A guide to living gently on the earth)

Trash Attack!, by Candace Savage. Douglas & McIntyre Ltd., 585 Bloor Street West, Toronto, Ontario M6G 1K5. 1990. (A guide to reducing solid waste)

Waste Away, A Curriculum on Solid Waste, by the Vermont Institute of Natural Science, P.O. Box 86, Woodstock, VT 05091 phone (802) 457-2779. (A school curriculum for upper elementary and junior high school students, families, and communities)

ZooBooks, Wildlife Education Ltd., 930 W. Washington St., San Diego, CA 92103. (A series of books devoted to giving basic information in a short, clear, interesting format. Illustrations, photos, and texts are usually quite good. Some examples include: Rattlesnakes, Giraffes, Bears, Endangered Species, Elephants, Bats, Hummingbirds, Eagles, Snakes, Big Cats, Seals, Sea Lions, and Walruses)

General Reference

And Then There Was One: The Mysteries of Extinction, by Margery Facklam. Little, Brown & Company Limited, Canada and US. 1990. (Examines the many reasons for the extinction and near extinction of animal species and how some animals can be save through special programs.)

Atlas of Environmental Issues, by Nick Middleton. Facts on File, Inc. 460 Park Avenue South, New York, NY 10016. 1989. (Describes and explains major environmental issues including soil erosion, deforestation, oil pollution, and overfishing.)

Balancing on the Brink of Extinction: The Endangered Species Act and Lessons for the Future, edited by Kathryn A. Kohm. Island Press, Suite 300, 1718 Connecticut Ave. NW, Washington, D.C. 20009. 1991. (A collection of articles dealing with endangered species.)

Biodiversity and Conservatin in the Caribbean, by Timothy H. Johnson. International Council for Bird Preservation, 32, Cambridge Road, Girton, Cambridge CB3 OPJ, UK. 1988. (Maintaining biodiversity in the Caribbean)

Caring for the Earth. A Strategy for Sustainable Living, IUCN/UNEP/WWF (The World Conservation Union, United Nations Environment Programme, World Wide Fund For Nature). 1991 (Discusses principles and actions for sustainable living) There is also a summary available for this volume.

Conservation Directory, 1992, published annually by the National Wildlife Federation, 1400 Sixteenth Street, N. W., Washington, D.C. 20036-226. phone (202) 797-6800. (A list of organizations, agencies, adn officials concerned with natural resource use and management)

A Crowded Ark, by Jon R. Luoma. Houghton Mifflin Company, 2 Park Street, Boston, MA 02108. 1987

Discover Aruba's Wildlife, STINAPA No. 26, avialable through STIMARUBA. (A guide to plants and animals on the island) 1982

Endangered Species, edited by John Strohm. National Wildlife Federation, 1412 Sixteenth Street, N.W., Washington, D.C. 20036. (A series of articles on endangered species and habitats)

Environmental Vacations: Volunteer Vacations to Save the Planet, by Stephanie Ocko. John Muir Publications, P.O. Box 613, Santa Fe, NM 87504. 1990. (A listing and descriptions of ways you can spend your vacation doing volunteer work with scientists from around the world. Includes information on travel and health tips andwhat to expect)

A Field Guide to Coral Reefs of the Caribbean and Florida, by Eugene H. Kaplan. Houghton, Mifflin Company, Boston. 1982. (A guide to the common invertebrates and fishes)

The Green Pages: Your Everyday Shopping Guide to Environmentally Safe Products, by Bennett Information Group. Random House, Inc., 201 East 50th Street, New York, NY 10022. 1990. (Environmentally safe products are listed. Listing is based on product labels, information from manufacturers, and catalog descriptions)

The Living Ocean: Understanding and Protecting Marine Biodiversity, by Boyce L. Thorne-Miller and John G. Catena. Island Press, Suite 300, 1718 Connecticut Avenue, N.W., Washington, D.C. 20009. 1991.

The Rainforest Book, by Scott Lewis and the Natural Resources Defense Council. Living Planet Press, 558 Rose Avenue, Venice, CA 90291. 1990. (General information about rainforests, how they are being destroyed, why we should preserve them and what you can do to help save them)

Research Priorities for Conservation Biology, edited by Michael E. Soule and Kathryn Kohm. Published in cooperation with The Society for Conservation Biology. Island Press, Critical Issues Series, Suite 300, 1718 Connecticut Avenue, N.W., Washington, D.C. 1989.

The Recycler's Handbook. Simple Things You Can Do, by The EarthWorks Group. The EarthWorks Press, 1400 Shattuck Ave., #25, Berkeley, CA 94709. phone (510) 652-8533. 1990.

State of the Ark, by Lee Durrell, John May, Chris Madsen, and Gaia Books, Ltd. Doubleday & Company, Inc., Garden City, New York. 1986. (A global perspective on conservation problems. Uses lots of diagrams, charts, and maps)

Treat The Earth Gently, An Environmental Resource Guide, by Sherrill B. Flora. T.S. Dennison and Company, Inc. Minneapolis, MN 55431. 1991. (Reproducible worksheets and activity sheets for use in the classroom)

Viable Populations for Conservation, by Michael E. Soule. Press Syndicate of the University of Cambridge, 40 West 20th Street, New York, NY 10011, USA. 1987. (A technical publication on small population biology)

Magazines

Buzzworm: The Environmental Journal, published bimonthly. Subscription rates: $21 per year for US and Possessions, $26 per year for Canada, all other countries $31 per year surface mail, $39 air mail. Call (800) 825-0061 for subscription information. Buzzworm also annually produces the Earth Journal - Environmental Almanac and Resource Directory

Conservation Biology, published four times a year. Blackwell Scientific Publications, Inc., 238 Main Street, Cambridge, MA 02142. Subscription rates: with membership to the Society for Conservation Biology, $41 per year for US and Mexico, $44 for Canada, $56 overseas. Without membership: $80 US, $83 Canada, $95 overseas. Student and institution rataes are also available. (A technical journal)

International Wildlife, published bimonthly. For subscription information, contact Membership Services, National Wildlife Federation, 8925 Leesburg Pike, Vienna, VA 22184. Subscription rates: $16 per year. Add $6 for addresses outside US. (National Wildlife magazine is also available through National Wildlife Federation)

ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

REPORT
30 November 1992

SECTION 6

CAPTIVE POPULATION

ARUBA ISLAND RATTLESNAKE
SPECIES SURVIVAL PLAN
MASTERPLAN

1992-93

R. Andrew Odum, Species Coordinator - Toledo Zoo

Karl H. Peterson, Studbook Keeper - Houston Zoo

Crotalus durissus unicolor
ARUBA ISLAND RATTLESNAKE
SSP PROPAGATION GROUP

1992-93

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Dennis Herman, Zoo Atlanta (94)

James Murphy, Dallas Zoo (94)

Karl Peterson, Houston Zoo (93)

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Susan Schafer, San Diego Zoo (94)

Frank Slavens, Woodland Park Zoo (93)

Advisers

Karl Peterson, International Studbook Keeper, Houston Zoo

Joseph Flanagan, D.V.M. Advising Veterinarian, Houston Zoo

James Gerholdt, Minnesota Zoo

Introduction

This MASTER PLAN marks a new phase for the AAZPA Aruba Island Rattlesnake Species Survival Plan. For the first time, this program has sufficient potential founders to meet its long term genetic goals. In February 1992, a Population and Habitat Viability Assessment (PHVA) workshop was conducted on Aruba. From these meetings, a long range Conservation Action Plan (CAP) was created that integrates the captive and wild populations in a unified conservation strategy. The creation of this CAP is the most significant event that has yet occurred in this SSP program.

In this CAP, new goals have been outlined for the captive SSP population. In the past, the overall genetic goal for captive population was to maintain 90% of the expected wild genetic diversity (WGD) in the captivity for a period of two hundred years. During the PHVA, this goal was increased to maintain 95% WGD indefinitely. To accomplish this new and higher goal, it will be necessary to add additional founders to the population in four or five generations. This will be probably occur around 2030, if the wild population is still available for additional recruitment. If it appears that the wild population is in difficulty prior to the this time, the captive population would be available for reintroducing and bolstering wild numbers. This close relationship where the captive population is always available as a resource for the supporting the wild population if necessary, and the wild population helps preserve the genetic diversity in the captive population, is the foundation of the CAP and the basis for this Master Plan.

The following section gives a brief outline of the *Crotalus durissus unicolor* SSP program's goals and objectives.

Master Plan Goals and Objectives

1. The overall genetic goal of captive population - preserve 95% of average heterozygosity indefinitely

2. Establish a carrying capacity of 150 animals.

3. Publish studbook with husbandry section.

4. Designate animals with unknown lineages or inbreeding coefficients greater than 0.25 as surplus to breeding program.

5. Increase population to carrying capacity by breeding potential founders and living founders.

6. Remove surplus animals from AAZPA institutions according to the following priorities:
   - A. Zoological institutions outside the United States. (Coordinate European Zoos through Rotterdam)
   - B. Research
     1. Disease (i.e. Paramyxovirus)
     2. Stress induced problems
     3. Behavioral
     4. Artificial insemination
   - C. Venom research institutions
   - D. Euthanasia

7. Breed 9.10 wild caught animals to each other at nine separate institutions. Produce equal numbers of offspring from each pairing (refer to table below).

8. Attempt to extend generation time to 10 years.

9. Maintain policy for random selection of animals that will be recruited in the SSP from the large litters produced by *C. d. unicolor.*

10. Regulate family size to maximize Ne.

11. Initiate all non-founding breedings according to lowest mean kinship coefficient as follows:

OFFSPRING OBJECTIVES

Kind of Individual	Offspring Surviving To Reproduce	Births *
Founder	12	20
Non-Founders	2	4

* Derive number of births by dividing desired number of offspring that will survive to reproduce by 0.66 the average Lx from birth to age 10, the generation time (i.e. the average age at which offspring are produced). Produce 12 offspring to survive to reproduce for each founder. Using an age specific survivorship (Lx) of 0.60 at age class ten will require 20 births. The number of offspring needed may be reduced if the survival rates increase in the future.

12. After reaching carrying capacity, select surplus animals using mean kinship (highest).

13. Insert transponders in all U.S. captive *C. d. unicolor* greater than 50 grams in weight. Site of insertion should be dorso-lateral just anterior to the vent (IUCN-CBSG standard).

14. Continue monitoring for the occurrence of sperm retention in females.

15. Test new Paramyxovirus vaccines on surplus animals. Work scheduled for 1993-94.

16. Request that all medical and necropsy records be entered into Med-ARKS.

17. Present Conservation Action Plan to Aruba government in 1992.

18. Import additional blood samples from Aruba for establishing a genetic reference point.

19. Initiate field research program as outlined in CAP.

20. Incorporate additional founders in future generations to maintain 95% of expected genetic diversity.

Breeding Recommendations

Male		Female	Location
102	X	111	SEATTLE
160	X	165	ALBUQUERQUE
161	X	166	FRESNO
163	X	168	CINCINNATI
169	X	167	HOUSTON
218	X	(221 or 222)	RIVERBANKS
219	X	220	ATLANTA
226	X	224	KNOXVILLE
227	X	(221 or 222)	TOLEDO

Living Population at: CHAFFEE ZOOLOGICAL GARDEN OF FRESNO FRESNO

Stud #	Sex	Birth Date Arrival	Sire Dam	Loc ID Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All GU-CB	Vx	Live Sibs Live Offspr Repro Offspr	Founder Representation
161	M	~ 1987 27 Feb 1990	WILD WILD	10009	1.0000	.0000 .0000	. .0431	. .0418	.0300 .0000	0.880	. . 0. 0. 5 . .	
166	F	~ 1988 27 Feb 1990	WILD WILD	10010	1.0000	.0000 .0000	. .0431	. .0418	.0305 .0000	1.540	. . 0. 0. 5 . .	
231	?	28 May 1992 28 May 1992	161 166	______	1.0000	.0000 .0000	. .0517	. .0502	.0000 .0645	1.070	0. 0. 4	166=50% 161=50%
232	?	28 May 1992 28 May 1992	161 166	______	1.0000	.0000 .0000	. .0517	. .0502	.0000 .0575	1.070	0. 0. 4	166=50% 161=50%
233	?	28 May 1992 28 May 1992	161 166	______	1.0000	.0000 .0000	. .0517	. .0502	.0000 .0585	1.070	0. 0. 4	166=50% 161=50%
234	?	28 May 1992 28 May 1992	161 166	______	1.0000	.0000 .0000	. .0517	. .0502	.0000 .0600	1.070	0. 0. 4	166=50% 161=50%
235	?	28 May 1992 28 May 1992	161 166	______	1.0000	.0000 .0000	. .0517	. .0502	.0000 .0625	1.070	0. 0. 4	166=50% 161=50%

1) Sex newborns and report to studbbok keeper as soon as possible.
2) Send two offspring (of same sex) to Sedgwick County Zoo
3) Send two offspring (of same sex) to Los Angeles
4) Additional offspring from 161 x 166 breedings will be distributed to other SSP institutions.

Living Population at: LOS ANGELES ZOO

LOSANGELE

	Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Global: Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S	31	F	25 Jan 1981	19	000534	.	.0000	.	.	.	.	14. 8. 0	2=75.0% 1=25%
			25 Jan 1981	20			.3750	.	.	.		. .	
												. .	
S	70	M	29 Feb 1984	19	002887	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			29 Feb 1984	22			.3750	.	.	.		. .	
												. .	
S	71	M	29 Feb 1984	19	002996	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			29 Feb 1984	22			.3750	.	.	.		. .	
												. .	
S	72	F	29 Feb 1984	19	002996	.	.0000	.	.	.	.	14. 8. 0	2=75.0% 1=25%
			29 Feb 1984	22			.3750	.	.	.		. .	
												. .	
S	140	F	27 Apr 1987	23	004121	.	.0000	.	.	.	.	8. 6. 0	2=37.6% 1=12.6%
			14 Apr 1992	57			.	.	.	.		2. 0. 3	
												. .	
S	184	M	19 Jun 1991	157	004125	.	.0000	.	.	.	.	1. 0. 3	2=37.6% 1=12.4%
			14 Apr 1992	140			.6875	.	.	.		. .	
												. .	
S	185	M	19 Jun 1991	157	004126	.	.0000	.	.	.	.	1. 0. 3	2=37.6% 1=12.4%
			14 Apr 1992	140			.6875	.	.	.		. .	
												. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Receive two offspring (of same sex - 161 x 166) from Fresno.
3) Additional animals for breeding will be provided from founder x founder breedings.

Living Population at: THE LIVING DESERT PALM DES

	Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr		Founder Representation
S	80	F	28 Jul 1984	40	58736	.	.0000	.	.	.	.	7.	17.	0 2=37.6% 14=25% 13=25% 1=12.6%
			15 Apr 1987	42			.0000	.	.	.		.	.	
												.	.	
	82	F	13 May 1985	40	58738	1.0000	.0000	.	.	.0280	1.210	7.	17.	0 2=37.6% 14=25% 13=25% 1=12.6%
			15 Apr 1987	42			.0000	.0992	.0893	.0280		.	.	
												.	.	
S	83	F	13 May 1985	40	58737	.	.0000	.	.	.	.	7.	17.	0 2=37.6% 14=25% 13=25% 1=12.6%
			15 Apr 1987	42			.0000	.	.	.		.	.	
												.	.	

1) Hold 82 for future pairing.
2) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
3) Verify information with studbook keeper.
4) Replacement animals will be provided from founder x founder breedings.

Living Population at: SAN DIEGO ZOOLOGICAL GARDEN SANDIEGOZ

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr (Global)	Founder Representation
S 65	F	21 Aug 1983	27	783716	.	.0000	.	.	.	.	1. 1. 0	14=50%
		21 Aug 1983	14			.	.	.	.		. .	
											. .	
S 66	F	21 Aug 1983	27	783717	.	.0000	.	.	.	.	1. 1. 0	14=50%
		21 Aug 1983	14			.	.	.	.		. .	
											. .	
S 123	F	30 Mar 1987	40	187089	.	.0000	.	.	.	.	7. 17. 0	5=25% 1=25% 14=25% 13=25%
		14 Apr 1987	17			.	.	.	.		. .	
											. .	
S 124	F	30 Mar 1987	40	187090	.	.0000	.	.	.	.	7. 17. 0	5=25% 1=25% 14=25% 13=25%
		15 Apr 1987	17			.	.	.	.		. .	
											. .	
S 125	F	30 Mar 1987	40	187091	.	.0000	.	.	.	.	7. 17. 0	5=25% 1=25% 14=25% 13=25%
		15 Apr 1987	17			.	.	.	.		. .	
											. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.
3) Receive 120 from Crutchfield. This animal will be surplus.

Living Population at: CENTRAL FLORIDA ZOO SANFORD

Stud #	Sex	Birth Date Arrival	Sire Dam	Loc ID Social	Genome Known	F	MK	KV	GU-All GU-CB	Vx	Live Sibs Live Offspr Repro Offspr	Founder Representation
						[unks -> founders] [unknowns removed]						
S 180	M	25 May 1990	103	______	.	.0000	.	.	.	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5%
		10 Oct 1991	115			.0625	.	.	.		. .	1=12.5%
											. .	
188	M	26 Apr 1991	103	______	1.0000	.0000	.	.	.0050	1.390	9. 4. 3	3=25% 14=25% 13=25% 5=12.5%
		10 Oct 1991	115			.0625	.1153	.1300	.0050		. .	1=12.5%
											. .	
190	M	26 Apr 1991	103	______	1.0000	.0000	.	.	.0065	1.390	9. 4. 3	3=25% 14=25% 13=25% 5=12.5%
		10 Oct 1991	115			.0625	.1153	.1300	.0065		. .	1=12.5%
											. .	
S 191	M	26 Apr 1991	103	______	.	.0000	.	.	.	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5%
		10 Oct 1991	115			.0625	.	.	.		. .	1=12.5%
											. .	
S 201	M	27 May 1991	102	______	.	.0000	.	.	.	.	2. 8. 1	3=25% 14=25% 13=25% 5=12.5%
		10 Oct 1991	111			.0625	.	.	.		. .	1=12.5%
											. .	
S 208	M	27 May 1991	102	______	.	.0000	.	.	.	.	2. 8. 1	3=25% 14=25% 13=25% 5=12.5%
		10 Oct 1991	111			.0625	.	.	.		. .	1=12.5%
											. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Hold 188 and 190 for future breeding.
3) Additional animals for breeding will be provided from founder x founder breedings.

Living Population at: HERPETOFAUNA INC. HERPEFAUN

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 48	F	7 Feb 1982	19	_____	.	.0000	.	.	.	.	14. 8. 0	2=75.0% 1=25%
		1 Apr 1987	22			.3750	.	.	.		. .	
											. .	
S 120	M	30 Mar 1987	40	_____	.	.0000	.	.	.	.	6. 18. 0	5=25% 1=25% 14=25% 13=25%
		11 Apr 1991	17			.0000	.	.	.		. .	
											. .	

1) Return San Diego animal (120) to San Diego. Directions for surplus animals will be decided according to priorities in Master Plan Outline.

Living Population at: ZOO ATLANTA ATLANTA

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
						[unks -> founders] / [unknowns removed]						
219	M	~ 1987	WILD	______	1.0000	.0000	.	.	1.000	1.310	. .	
		20 Jul 1992	WILD			.0000	.0000	.0000	.0000		. .	
											. .	
220	F	~ 1987	WILD	______	1.0000	.0000	.	.	1.000	1.540	. .	
		20 Jul 1992	WILD			.0000	.0000	.0000	.0000		. .	
											. .	

1) Breed 219 to 220. Produce 20 offspring (13 to reproduce)
2) Offspring from 219 x 220 breedings will be distributed to other SSP institutions.

Living Population at: LOUISVILLE ZOOLOGICAL GARDEN LOUISVILL

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr (Global)			Founder Representation
S 136	F	27 Apr 1987	23	300312	.	.0000	.	.	.	.	8.	6.	0	2=37.6% 1=12.6%
		12 May 1989	57			.0000	.	.	.		.	.		
											.	.		
S 137	M	27 Apr 1987	23	300313	.	.0000	.	.	.	.	7.	7.	0	2=37.6% 1=12.6%
		17 May 1989	57			.0000	.	.	.		.	.		
											.	.		
S 138	M	27 Apr 1987	23	300314	.	.0000	.	.	.	.	7.	7.	0	2=37.6% 1=12.6%
		17 May 1989	57			.0000	.	.	.		.	.		
											.	.		
S 139	M	27 Apr 1987	23	300315	.	.0000	.	.	.	.	7.	7.	0	2=37.6% 1=12.6%
		17 May 1989	57			.0000	.	.	.		.	.		
											.	.		

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: DETROIT ZOOLOGICAL PARK DETROIT

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr		Founder Representation
						[unks -> founders] [unknowns removed]					< Global >		
S 132	M	27 Apr 1987	23	2437	.	.0000	.	.	.	.	7.	7. 0	2=37.6% 1=12.6%
		6 Nov 1987	57			.0000	.	.	.		.	.	
											.	.	
S 133	M	27 Apr 1987	23	2438	.	.0000	.	.	.	.	7.	7. 0	2=37.6% 1=12.6%
		6 Nov 1987	57			.0000	.	.	.		.	.	
											.	.	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: ST. LOUIS ZOOLOGICAL PARK

ST LOUIS

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr			Founder Representation
S 170	M	8 Feb 1983	19	383025	.	.0000	.	.	.	.	13.	9.	0	2=75.0% 1=25%
		27 Apr 1983	22			.3750	.	.	.		.	.		
											.	.		
S 171	F	8 Feb 1983	19	383026	.	.0000	.	.	.	.	14.	8.	0	2=75.0% 1=25%
		27 Apr 1983	22			.3750	.	.	.		.	.		
											.	.		

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.1) Direc
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: RIO GRANDE ZOOLOGICAL PARK

RIO GRAND

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Global: Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 54	M	8 Feb 1983	19	R87042	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
		3 Sep 1987	22			.3750	.	.	.		. .	
											. .	
S 60	M	11 Apr 1983	19	R87043	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
		3 Sep 1987	20			.3750	.	.	.		. .	
											. .	
S 76	M	28 Jul 1984	40	R87044	.	.0000	.	.	.	.	6. 18. 0	2=37.6% 14=25% 13=25% 1=12.6%
		3 Sep 1987	42			.	.	.	.		. .	
											. .	
S 79	M	28 Jul 1984	40	R87045	.	.0000	.	.	.	.	6. 18. 0	2=37.6% 14=25% 13=25% 1=12.6%
		3 Sep 1987	42			.	.	.	.		. .	
											. .	
160	M	~ 1988	WILD	R90084	1.0000	.0000	.	.	.1325	1.310	. .	
		1 Nov 1990	WILD			.0000	.0259	.0251	.0000		0. 0. 3	
											. .	
165	F	~ 1988	WILD	R90085	1.0000	.0000	.	.	.1270	1.540	. .	
		1 Nov 1990	WILD			.0000	.0259	.0251	.0000		0. 0. 3	
											. .	
229	?	29 Jun 1992	160	R92020	1.0000	.0000	.	.	.0000	1.070	0. 0. 2	165=50% 160=50%
		29 Jun 1992	165			.0000	.0345	.0335	.2415		. .	
											. .	
230	?	29 Jun 1992	160	R92021	1.0000	.0000	.	.	.0000	1.070	0. 0. 2	165=50% 160=50%
		29 Jun 1992	165			.0000	.0345	.0335	.2390		. .	
											. .	

1) Continue to breed 160 to 165. Produce 20 offspring (13 to reproduce)
2) Transfer males 76 and 79 to Dr. Eliot Jacobson for Paramyxovirus work.
3) Report sex of 229 and 230 to studbook keeper as soon as possible.
4) Transfer two animals (229 and 230) to Milwaukee County Zoo..
5) Directions for surplus animals will be decided according to priorities in Master Plan Outline.

Living Population at: STATEN ISLAND ZOOL. SOCIETY INC. STATEN IS

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	<< Global >> Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 30	M	25 Jan 1981	19	10057	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
		3 Sep 1987	20			.3750	.	.	.		. .	
											. .	
S 47	M	7 Feb 1982	19	10058	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
		3 Sep 1987	22			.3750	.	.	.		1. 1. 0	
											. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: GERALD MARZEC (IHR)

MARZEC

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr			Founder Representation
S 41	F	6 Feb 1982	19	_____	.	.0000	.	.	.	.	14.	8.	0	2=75.0% 1=25%
		15 Mar 1988	20			.3750	.	.	.		.	.		
											.	.		
S 58	F	11 Apr 1983	19	_____	.	.0000	.	.	.	.	14.	8.	0	2=75.0% 1=25%
		15 Mar 1988	20			.3750	.	.	.		1.	1.	0	
											.	.		
S 68	M	29 Feb 1984	19	_____	.	.0000	.	.	.	.	13.	9.	0	2=75.0% 1=25%
		15 Mar 1988	22			.3750	.	.	.		.	.		
											.	.		
S 73	M	5 May 1984	19	_____	.	.0000	.	.	.	.	13.	9.	0	2=75.0% 1=25%
		15 Mar 1988	20			.3750	.	.	.		.	.		
											.	.		

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: CINCINNATI ZOOLOGICAL SOCIETY CINCINNAT

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
163	M	~ 1986	WILD	______	1.0000	.0000	.	.	1.000	0.680	. .	
		1 Nov 1990	WILD			.0000	.0000	.0000	.0000		. .	
											. .	
168	F	~ 1986	WILD	______	1.0000	.0000	.	.	1.000	1.210	. .	
		1 Nov 1990	WILD			.0000	.0000	.0000	.0000		. .	
											. .	

1) Breed 163 to 168. Produce 20 offspring (13 to reproduce)
2) Offspring from 163 x 168 breedings will be distributed to other SSP institutions.

Living Population at: TOLEDO ZOOLOGICAL GARDENS TOLEDO

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr (Global)			Founder Representation
129	F	30 Mar 1987	40	873039	1.0000	.0000	.	.	.0205	1.540	7.	17.	0	5=25% 1=25% 14=25% 13=25%
		18 May 1987	17			.0000	.1056	.1101	.0205		.	.		
											.	.		
130	F	30 Mar 1987	40	873040	1.0000	.0000	.	.	.0180	1.540	7.	17.	0	5=25% 1=25% 14=25% 13=25%
		18 May 1987	17			.0000	.1056	.1101	.0180		.	.		
											.	.		

1) Receive one wild caught female from Riverbanks Zoo (221 or 222).
2) Receive one wild caught male from Houston (227).
3) Breed 227 to (221 or 222). Produce 20 offspring (13 to reproduce)

Living Population at: RIVERBANKS ZOOLOGICAL PARK

RIVERBANK

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr			Founder Representation
						[unks -> founders] / [unknowns removed]					Global			
S 157	M	9 May 1988	23	345	.	.0000	.	.	.	.	7.	7.	0	2=37.6% 1=12.6%
		1 Oct 1989	57			.6875	.	.	.		2.	0.	3	
											.	.		
218	M	~ 1987	WILD	733	1.0000	.0000	.	.	1.000	1.310	.	.		
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		
221	F	~ 1987	WILD	736	1.0000	.0000	.	.	1.000	1.540	.	.		
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		
222	F	~ 1989	WILD	737	1.0000	.0000	.	.	1.000	1.630	.	.		
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		

1) Transfer (221 or 222) to Toledo for breeding (Late November 1992).
2) Breed 218 to 221 or 222. Produce 20 offspring (13 to reproduce)
3) Offspring from 218 x (221 or 222) breedings will be distributed to other SSP institutions.

Living Population at: BLACK HILL REPTILE GARDENS RAPIDCITY

<< Global >>

Stud #	Sex	Birth Date Arrival	Sire Dam	Loc ID Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All GU-CB	Vx	Live Sibs Live Offspr Repro Offspr	Founder Representation
S 172	F	25 May 1990 10 Oct 1991	103 115	913038	.	.0000 .0625	. .	. .	. .	.	10. 3. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 176	F	25 May 1990 10 Oct 1991	103 115	913039	.	.0000 .0625	. .	. .	. .	.	10. 3. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 179	F	25 May 1990 10 Oct 1991	103 115	913040	.	.0000 .0625	. .	. .	. .	.	10. 3. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 181	F	25 May 1990 10 Oct 1991	103 115	913041	.	.0000 .0625	. .	. .	. .	.	10. 3. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 198	F	27 May 1991 10 Oct 1991	102 111	913042	.	.0000 .0625	. .	. .	. .	.	3. 7. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 199	F	27 May 1991 10 Oct 1991	102 111	913043	.	.0000 .0625	. .	. .	. .	.	3. 7. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 200	F	27 May 1991 10 Oct 1991	102 111	913044	.	.0000 .0625	. .	. .	. .	.	3. 7. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 202	F	27 May 1991 10 Oct 1991	102 111	913045	.	.0000 .0625	. .	. .	. .	.	3. 7. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 203	F	27 May 1991 10 Oct 1991	102 111	913046	.	.0000 .0625	. .	. .	. .	.	3. 7. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 204	F	27 May 1991 10 Oct 1991	102 111	913047	.	.0000 .0625	. .	. .	. .	.	3. 7. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: KNOXVILLE MUNICIPAL ZOO KNOXVILLE

Stud #	Sex	Birth Date Arrival	Sire Dam	Loc ID Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All GU-CB	Vx	Live Sibs Live Offspr Repro Offspr	Founder Representation
90	F	20 Jul 1985 20 Jul 1985	38 16	CR 154	1.0000	.0000 .0000	. .1013	. .1088	.0525 .0525	1.210	2. 5. 0 0. 0. 4 . .	5=25% 1=25% 14=25% 13=25%
91	F	20 Jul 1985 20 Jul 1985	38 16	CR 155	1.0000	.0000 .0000	. .1013	. .1088	.0625 .0625	1.210	2. 5. 0	5=25% 1=25% 14=25% 13=25%
S 106	F	28 Apr 1986 28 Apr 1986	38 16	CR-165	.	.0000 .	. .	. .	. .	.	2. 5. 0	5=25% 1=25% 14=25% 13=25%
S 175	M	25 May 1990 10 Oct 1991	103 115	______	.	.0000 .0625	. .	. .	. .	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 192	M	26 Apr 1991 10 Oct 1991	103 115	______	.	.0000 .0625	. .	. .	. .	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 193	M	26 Apr 1991 10 Oct 1991	103 115	______	.	.0000 .0625	. .	. .	. .	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 194	M	26 Apr 1991 10 Oct 1991	103 115	______	.	.0000 .0625	. .	. .	. .	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
205	M	27 May 1991 10 Oct 1991	102 111	______	1.0000	.0000 .0625	. .1110	. .1246	.0065 .0065	1.390	2. 8. 1	3=25% 14=25% 13=25% 5=12.5% 1=12.5%
S 236	?	17 May 1992 17 May 1992	39 90	______	.	.0000 .1250	. .	. .	. .	.	0. 2. 3	14=37.5% 13=37.5% 5=12.5% 1=12.5%
S 237	?	17 May 1992 17 May 1992	39 90	______	.	.0000 .1250	. .	. .	. .	.	0. 2. 3	14=37.5% 13=37.5% 5=12.5% 1=12.5%
S 238	?	17 May 1992 17 May 1992	39 90	______	.	.0000 .1250	. .	. .	. .	.	0. 2. 3	14=37.5% 13=37.5% 5=12.5% 1=12.5%

Living Population at: KNOXVILLE MUNICIPAL ZOO (Coninued) KNOXVILLE

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 239	?	17 May 1992	39	_____	.	.0000 .	.	.	.	.	0. 2. 3	14=37.5% 13=37.5% 5=12.5%
		17 May 1992	90			.1250 .	.	.			. .	1=12.5%
											. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Transfer 90 and 91 to Lincoln Park.
3) Receive 226 and 224 from Houston.
4) Breed 226 to 224. Produce 20 offspring (13 to reproduce).
5) Offspring from 226 x 224 breedings will be distributed to other SSP institutions.

Living Population at: MEMPHIS ZOOLOGICAL GARDEN

MEMPHIS

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 101	F	28 Apr 1986	38	8436	.	.0000 .	.	.		.	2. 5. 0	5=25% 1=25% 14=25% 13=25%
		24 Oct 1986	16			.0000 .	.	.			. .	
											. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: GLADYS PORTER ZOO BROWNSVIL

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
24	F	27 Apr 1978	7	S-0067	1.0000	.0000	.	.	.0670	0.020	0. 2. 0	2=50% 1=50%
		~ 1979	6			.2500	.0754	.0557	.0670		1. 0. 0	
											. .	
93	M	14 Mar 1986	40	-01030	1.0000	.0000	.	.	.0090	0.880	6. 18. 0	5=25% 1=25% 14=25% 13=25%
		8 Oct 1986	17			.0000	.1099	.1121	.0090		1. 0. 6	
											. .	
S 94	F	14 Mar 1986	40	-01031	.	.0000	.	.	.	.	7. 17. 0	5=25% 1=25% 14=25% 13=25%
		8 Oct 1986	17			.0000	.	.	.		. .	
											. .	
S 95	F	14 Mar 1986	40	-01032	.	.0000	.	.	.	.	7. 17. 0	5=25% 1=25% 14=25% 13=25%
		8 Oct 1986	17			.0000	.	.	.		0. 0. 6	
											. .	
182	M	10 Sep 1989	93	-01170	1.0000	.0000	.	.	.0000	1.820	0. 0. 6	1=37.5% 2=25% 5=12.5%
		10 Sep 1989	24			.0625	.1002	.0964	.0000		. .	14=12.5% 13=12.5%
											. .	
S 212	?	16 Apr 1991	93	-01335	.	.0000	.	.	.	.	1. 0. 5	5=25% 1=25% 14=25% 13=25%
		16 Apr 1991	95			.2500	.	.	.		. .	
											. .	
S 213	?	16 Apr 1991	93	-01336	.	.0000	.	.	.	.	1. 0. 5	5=25% 1=25% 14=25% 13=25%
		16 Apr 1991	95			.2500	.	.	.		. .	
											. .	
S 214	?	16 Apr 1991	93	-01337	.	.0000	.	.	.	.	1. 0. 5	5=25% 1=25% 14=25% 13=25%
		16 Apr 1991	95			.2500	.	.	.		. .	
											. .	
S 215	?	16 Apr 1991	93	-01338	.	.0000	.	.	.	.	1. 0. 5	5=25% 1=25% 14=25% 13=25%
		16 Apr 1991	95			.2500	.	.	.		. .	
											. .	
S 216	?	16 Apr 1991	93	-01339	.	.0000	.	.	.	.	1. 0. 5	5=25% 1=25% 14=25% 13=25%
		16 Apr 1991	95			.2500	.	.	.		. .	
											. .	
S 217	?	16 Apr 1991	93	-01340	.	.0000	.	.	.	.	1. 0. 5	5=25% 1=25% 14=25% 13=25%
		16 Apr 1991	95			.2500	.	.	.		. .	
											. .	

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Hold 24, 93, 182 for future pairings.

Living Population at: DALLAS ZOO

DALLAS

	Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Global: Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S	23	M	~ 1978	______	DAL-5	.	.UNK	.	.	.	.	. .	
			23 Oct 1985	______			.UNK	.	.	.		8. 7. 0	
												2. 2. 0	
S	43	M	6 Feb 1982	19	DAL-1	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			30 Jun 1983	20			.3750	.	.	.		. .	
												. .	
S	55	M	8 Feb 1983	19	DAL-3	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			30 Jun 1983	22			.3750	.	.	.		. .	
												. .	
S	56	F	8 Feb 1983	19	DAL-2	.	.0000	.	.	.	.	14. 8. 0	2=75.0% 1=25%
			30 Jun 1983	22			.3750	.	.	.		0. 1. 0	
												. .	

1) Transfer surplus animals to Audubon Park Zoo for Paramyxovirus research.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: FORT WORTH ZOOLOGICAL PARK & AQUARIUM FORTWORTH

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr (Global)			Founder Representation
40	M	22 Jul 1981	13	827401	1.0000	.0000	.	.	.0025	0.080	0.	2.	0	14=50% 13=50%
		8 Apr 1982	14			.0000	.1207	.1174	.0025		7.	18.	0	
											2.	1.	0	
S 42	F	6 Feb 1982	19	837401	.	.0000	.	.	.	.	14.	8.	0	2=75.0% 1=25%
		6 Mar 1983	20			.3750	.	.	.		4.	8.	0	
											1.	0.	0	
S 77	M	28 Jul 1984	40	847404	.	.0000	.	.	.	.	6.	18.	0	2=37.6% 14=25% 13=25% 1=12.6%
		28 Jul 1984	42			.0000	.	.	.		.	.		
											.	.		
92	M	14 Mar 1986	40	867401	1.0000	.0000	.	.	.0215	0.880	6.	18.	0	5=25% 1=25% 14=25% 13=25%
		14 Mar 1986	17			.0000	.1056	.1050	.0215		.	.		
											.	.		
S 97	F	14 Mar 1986	40	867402	.	.0000	.	.	.	.	7.	17.	0	5=25% 1=25% 14=25% 13=25%
		14 Mar 1986	17			.0000	.	.	.		.	.		
											.	.		
S 98	F	14 Mar 1986	40	867403	.	.0000	.	.	.	.	7.	17.	0	5=25% 1=25% 14=25% 13=25%
		14 Mar 1986	17			.0000	.	.	.		.	.		
											.	.		
S 99	F	14 Mar 1986	40	867404	.	.0000	.	.	.	.	7.	17.	0	5=25% 1=25% 14=25% 13=25%
		14 Mar 1986	17			.0000	.	.	.		.	.		
											.	.		

1) Transfer 77, 97, 98, and 99 to Audubon Zoo for Paramyxovirus research.
2) Directions for other surplus animal (42) will be decided according to priorities in Master Plan Outline.
3) Hold 40 and 92 for future pairings to offspring from founder x founder breedings.
4) Replacement animals will be provided from founder x founder breedings.

Living Population at: HOUSTON ZOOLOGICAL GARDENS HOUSTON

	Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F / [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S	36	F	23 May 1981	7	8125	.	.0000	.	.	.	.	0. 2. 0	2=62.5% 1=37.5%
			23 May 1981	25			.3750	.	.	.		. .	
												. .	
	37	F	30 May 1981	7	8126	1.0000	.0000	.	.	.1800	0.330	0. 2. 0	2=75.0% 1=25%
			30 Nov 1984	2			.2500	.0614	.0392	.1800		. .	
												. .	
S	45	M	7 Feb 1982	19	8150	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			9 Jun 1982	22			.3750	.	.	.		. .	
												. .	
S	46	M	7 Feb 1982	19	8128	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			9 Jun 1982	22			.3750	.	.	.		. .	
												. .	
S	69	F	29 Feb 1984	19	8135	.	.0000	.	.	.	.	14. 8. 0	2=75.0% 1=25%
			13 Jun 1984	22			.3750	.	.	.		. .	
												. .	
S	74	M	5 May 1984	19	8137	.	.0000	.	.	.	.	13. 9. 0	2=75.0% 1=25%
			13 Jun 1984	20			.3750	.	.	.		. .	
												. .	
	81	M	13 May 1985	40	8143	1.0000	.0000	.	.	.0265	0.680	6. 18. 0	2=37.6% 14=25% 13=25% 1=12.6%
			17 Aug 1985	42			.0000	.0992	.0860	.0265		. .	
												. .	
S	84	F	13 May 1985	40	8144	.	.0000	.	.	.	.	7. 17. 0	2=37.6% 14=25% 13=25% 1=12.6%
			17 Aug 1985	42			.0000	.	.	.		. .	
												. .	
S	85	F	13 May 1985	40	8145	.	.0000	.	.	.	.	7. 17. 0	2=37.6% 14=25% 13=25% 1=12.6%
			17 Aug 1985	42			.0000	.	.	.		. .	
												. .	
S	86	F	13 May 1985	40	8146	.	.0000	.	.	.	.	7. 17. 0	2=37.6% 14=25% 13=25% 1=12.6%
			17 Aug 1985	42			.0000	.	.	.		. .	
												. .	
S	87	F	13 May 1985	40	8147	.	.0000	.	.	.	.	7. 17. 0	2=37.6% 14=25% 13=25% 1=12.6%
			17 Aug 1985	42			.0000	.	.	.		. .	
												. .	

Living Population at: HOUSTON ZOOLOGICAL GARDENS (Continued) HOUSTON

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr			Founder Representation
						[unks -> founders] / [unknowns removed]								
S 88	F	13 May 1985	40	8148	.	.0000	.	.	.	.	7.	17.	0	2=37.6% 14=25% 13=25% 1=12.6%
		17 Aug 1985	42			.0000	.	.	.		.	.		
											.	.		
S 135	F	26 Apr 1987	23	13486	.	.0000	.	.	.	.	8.	6.	0	2=37.6% 1=12.6%
		25 Mar 1992	56			.0000	.	.	.		.	.		
											.	.		
S 144	F	26 May 1987	47	8422	.	.0000	.	.	.	.	1.	0.	0	2=75.2% 1=25%
		26 May 1987	58			.0000	.	.	.		.	.		
											.	.		
S 154	F	9 May 1988	23	13487	.	.0000	.	.	.	.	8.	6.	0	2=37.6% 1=12.6%
		25 Mar 1992	57			.0000	.	.	.		.	.		
											.	.		
S 156	F	9 May 1988	23	13488	.	.0000	.	.	.	.	8.	6.	0	2=37.6% 1=12.6%
		25 Mar 1992	57			.0000	.	.	.		.	.		
											.	.		
S 158	F	9 May 1988	23	13485	.	.0000	.	.	.	.	8.	6.	0	2=37.6% 1=12.6%
		25 Mar 1992	57			.0000	.	.	.		.	.		
											.	.		
S 159	M	9 May 1988	23	13484	.	.0000	.	.	.	.	7.	7.	0	2=37.6% 1=12.6%
		25 Mar 1992	57			.0000	.	.	.		.	.		
											.	.		
164	M	~ 1987	WILD	11641	1.0000	.0000	.	.	1.000	0.880	.	.		
		27 Jul 1989	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		
167	F	~ 1979	WILD	11644	1.0000	.0000	.	.	1.000	0.020	.	.		
		27 Jul 1989	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		
169	M	~ 1987	WILD	11646	1.0000	.0000	.	.	1.000	0.880	.	.		
		27 Jul 1989	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		
223	F	~ 1987	WILD	13225	1.0000	.0000	.	.	1.000	1.540	.	.		
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		.	.		
											.	.		

Living Population at: HOUSTON ZOOLOGICAL GARDENS (Continued) HOUSTON

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	<< Global >> Live Sibs / Live Offspr / Repro Offspr	Founder Representation
224	F	~ 1987	WILD	13226	1.0000	.0000	.	.	1.000	1.540	. .	
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		. .	
											. .	
225	F	~ 1987	WILD	13227	1.0000	.0000	.	.	1.000	1.540	. .	
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		. .	
											. .	
226	M	~ 1987	WILD	13228	1.0000	.0000	.	.	1.000	1.310	. .	
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		. .	
											. .	
227	M	~ 1987	WILD	13229	1.0000	.0000	.	.	1.000	1.310	. .	
		2 Nov 1991	WILD			.0000	.0000	.0000	.0000		. .	
											. .	

1) Breed 169 to 167. Produce 20 offspring (13 to reproduce)
2) Offspring from 169 x 167 breedings will be distributed to other SSP institutions.
3) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
4) Transfer 227 to Toledo in late fall.
5) Transfer 224 and 226 to Knoxville.
6) Transfer 164 and 223 to San Antonio.

Living Population at: ELLEN TROUT PARK ZOO LUFKIN

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F / MK / KV [unks -> founders] [unknowns removed]	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation

1) Replacement animals will be provided from founder x founder breedings.

Living Population at: SAN ANTONIO ZOOL. GARDEN & AQUARIUM SAN ANTON

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Global: Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 153	F	9 May 1988	23	______	.	.0000	.	.	.	.	8. 6. 0	2=37.6% 1=12.6%
		4 Nov 1990	57			.0000	.	.	.		0. 0. 5	
											. .	
S 155	M	9 May 1988	23	______	.	.0000	.	.	.	.	7. 7. 0	2=37.6% 1=12.6%
		4 Nov 1990	57			.0000	.	.	.		0. 0. 5	
											. .	
S 240	?	4 Jun 1992	155	920686	.	.0000	.	.	.	.	0. 0. 4	2=37.6% 1=12.4%
		4 Jun 1992	153			.6875	.	.	.		. .	
											. .	
S 241	?	4 Jun 1992	155	920687	.	.0000	.	.	.	.	0. 0. 4	2=37.6% 1=12.4%
		4 Jun 1992	153			.6875	.	.	.		. .	
											. .	
S 242	?	4 Jun 1992	155	920688	.	.0000	.	.	.	.	0. 0. 4	2=37.6% 1=12.4%
		4 Jun 1992	153			.6875	.	.	.		. .	
											. .	
S 243	?	4 Jun 1992	155	920689	.	.0000	.	.	.	.	0. 0. 4	2=37.6% 1=12.4%
		4 Jun 1992	153			.6875	.	.	.		. .	
											. .	
S 244	?	4 Jun 1992	155	920690	.	.0000	.	.	.	.	0. 0. 4	2=37.6% 1=12.4%
		4 Jun 1992	153			.6875	.	.	.		. .	
											. .	

1) Receive 164 and 223 from Houston.
2) Breed 164 to 223. Produce 20 offspring (13 to reproduce)
3) Offspring from 164 x 223 breedings will be distributed to other SSP institutions.
4) Directions for surplus animals will be decided according to priorities in Master Plan Outline.

Living Population at: AUDUBON PARK ZOO

AUDUBON

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F / MK / KV [unks -> founders] [unknowns removed]	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation

1) Receive 23, 43, 55, and 56 from Dallas Zoo
2) Receive 77, 97, 98, and 99 from Fort Worth Zoo
3) Perform Paramyxovirus research to develop new methods for virus detection.
4) Additional SSP animals will be provided from founder x founder breedings in the future.

Living Population at: WOODLAND PARK ZOOLOGICAL GARDENS SEATTLE

<< Global >>

	Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S	102	M	28 Apr 1986	38	880497	.	.0000	.	.	.	.	1. 6. 0	5=25% 1=25% 14=25% 13=25%
			12 Nov 1988	16			.0000	.	.	.		3. 8. 1	
												. .	
S	103	M	28 Apr 1986	38	880498	.	.0000	.	.	.	.	1. 6. 0	5=25% 1=25% 14=25% 13=25%
			17 Nov 1988	16			.0000	.	.	.		10. 4. 3	
												. .	
	111	F	10 May 1986	39	880073	1.0000	.0000	.	.	.0310	1.340	0. 1. 4	3=50% 14=25% 13=25%
			1 Mar 1988	3			.0000	.0991	.1125	.0310		3. 8. 1	
												. .	
	115	F	10 May 1986	39	880074	1.0000	.0000	.	.	.0220	1.340	0. 1. 4	3=50% 14=25% 13=25%
			1 Mar 1988	3			.0000	.1034	.1180	.0220		10. 4. 3	
												. .	
S	173	M	25 May 1990	103	900126	.	.0000	.	.	.	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5%
			25 May 1990	115			.0000	.	.	.		. .	1=12.5%
												. .	
S	178	M	25 May 1990	103	900131	.	.0000	.	.	.	.	9. 4. 3	3=25% 14=25% 13=25% 5=12.5%
			25 May 1990	115			.0000	.	.	.		. .	1=12.5%
												. .	
	195	?	26 Apr 1991	103	910135	1.0000	.0000	.	:	.0040	1.290	10. 4. 2	3=25% 14=25% 13=25% 5=12.5%
			26 Apr 1991	115			.0625	.1153	.1292	.0040		. .	1=12.5%
												. .	
	196	?	26 Apr 1991	103	910136	1.0000	.0000	.	.	.0010	1.290	10. 4. 2	3=25% 14=25% 13=25% 5=12.5%
			26 Apr 1991	115			.0625	.1153	.1292	.0010		. .	1=12.5%
												. .	
S	197	?	26 Apr 1991	103	910137	.	.0000	.	.	.	.	10. 4. 2	3=25% 14=25% 13=25% 5=12.5%
			26 Apr 1991	115			.0000	.	.	.		. .	1=12.5%
												. .	
	206	F	27 May 1991	102	910232	1.0000	.0000	.	.	.0060	1.290	3. 7. 1	3=25% 14=25% 13=25% 5=12.5%
			27 May 1991	111			.0625	.1110	.1238	.0060		. .	1=12.5%
												. .	
	207	F	27 May 1991	102	910233	1.0000	.0000	.	.	.0050	1.290	3. 7. 1	3=25% 14=25% 13=25% 5=12.5%
			27 May 1991	111			.0625	.1110	.1238	.0050		. .	1=12.5%
												. .	

Living Population at: WOODLAND PARK ZOOLOGICAL GARDENS (Continued) SEATTLE

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 209	?	27 May 1991	102	910235	.	.0000 .	.	.		.	3. 8. 0	3=25% 14=25% 13=25% 5=12.5%
		27 May 1991	111			.0625 .	.	.			. .	1=12.5%
											. .	

1) Transfer 173, 178, 197, and 209 to University of Florida for Paramyxovirus research.
2) Report sexes of 195 and 196 to studbook keeper.
3) Hold 111, 115, 206, and 207.

Living Population at: LINCOLN PARK ZOO CHICAGOLP

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F / MK / KV [unks -> founders] [unknowns removed]	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr (<< Global >>)	Founder Representation

1) Receive 90 and 91 from Knoxville.
2) Other animals will be transferred from founder x founder breedings in the future.

Living Population at: MILWAUKEE COUNTY ZOO **MILWAUKEE**

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F / MK / KV [unks -> founders] [unknowns removed]	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation

1) Receive two animals of same sex (either 228, 229, or 230) from Rio Grande
2) Other animals will be transferred from founder x founder breedings in the future.

Living Population at: POINT DEFIANCE ZOO

POINT DEF

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 118	F	25 Mar 1987 5 Apr 1990	38 16	90R001	.	.0000 .0000	. .	. .	. .	.	2. 5. 0	5=25% 1=25% 14=25% 13=25%
S 119	F	25 Mar 1987 5 Apr 1990	38 16	90R002	.	.0000 .0000	. .	. .	. .	.	2. 5. 0	5=25% 1=25% 14=25% 13=25%

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline.
2) Replacement animals will be provided from founder x founder breedings.

Living Population at: SEDGWICK COUNTY ZOO WICHITA

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F / MK / KV [unks -> founders] [unknowns removed]	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation

1) Receive two animals of same sex (161 x 166 offspring) from Fresno.
2) Other animals will be transferred from founder x founder breedings in the future.

Living Population at: PITTSBURG ZOO

PITTSBURG

Stud #	Sex	Birth Date / Arrival	Sire / Dam	Loc ID / Social	Genome Known	F [unks -> founders] [unknowns removed]	MK	KV	GU-All / GU-CB	Vx	Live Sibs / Live Offspr / Repro Offspr	Founder Representation
S 186	?	19 Jun 1991 19 Jun 1991	157 140	578	.	.0000 .6875	. .	. .	. .	.	2. 0. 2	2=37.6% 1=12.4%
S 187	?	19 Jun 1991 19 Jun 1991	157 140	579	.	.0000 .6875	. .	. .	. .	.	2. 0. 2	2=37.6% 1=12.4%

1) Directions for surplus animals will be decided according to priorities in Master Plan Outline. These animals will be transferred in several years when replacements are available.
2) Replacement animals will be provided from founder x founder breedings.

DEFINITIONS

Animals that identified with an S before the studbook number are designated surplus.

Stud # -- Studbook ID number
Sex -- '~' indicates the animal is sterilized or contracepted
Birth/Hatch Date
Arrival -- Arrival date at the curent institution
Sire/Dam -- Sire/Dam IDs
Loc ID -- Current institution ID number
Social -- Current social group at the current institution

Genome Known: Proportion of animal's genome known

F -- Inbreeding Coefficient
First value assumes animals of unknown origin are founders.
Second value omits animals of unknown origin.

MK -- mean kinship
First value is mean kinship. Second value is mean kinship if animals of unknown origin are omitted.

K V -- kinship value
A weighted mean kinship where the weights are the other animals' reproductive values. Second value omits animals of unknown origin.

GU-All -- Genome Uniqueness
Proportion of genes in an animal that are not found in the rest of the population.

GU-CB -- Genome Uniqueness of Captive-Born Animals
Proportion of genes in an animal that are not found in the rest of the captive-born population.

Vx -- Expected future lifetime reproduction by an animal of age x.

G L O B A L vs. Restricted -- Following values may be calculated using all animals in the studbook or using the population specified by the view set for the report.

Live sibs -- Half siblings are counted as complete siblings.
Live offspr -- Living offspring
Repro offspr -- Reproducing offspring

Founder representation -- Percent of this animal's genes that descended from each founder.

Demographic Analysis

Crotalus durissus unicolor Species Survival Plan

Parameters of Demographic Analysis:

Because of the small sample size of the database contained in the International Studbook, all available data were used to establish demographic parameters. Also, to produce a more realistic analysis, the *C. d. unicolor* database was slightly altered. These alterations include assigning specimens with multiple possible sires to a single individual sire and estimating founder ages. Almost all cases of multiple possible sires have involved sibling males from the same litter. This adjustment is considered a "worst possible scenario" for demographic calculations. With exception of a few sub-adults that were assigned to the second year age class, all founding animals were assumed to be young adults of approximately 3-5 years of age when they entered the captive population.

Demographic analysis was performed using DEMOG3_0.WK1 (Bingaman and Ballou, 1992).

Summary:

As of August 1982, the total living captive population of *C. d. unicolor* listed in the studbook database is 159 animals (95.70.30). The current SSP population is 17.21.10 (48). The number of SSP institutions presently housing *C. d. unicolor* has increased to 28 from 14 in 1988.

It should be noted that the resulting demographic projections are based upon the available studbook data set and produce results that show a slower population growth than would be realized if more animals were in a breeding situation. For the past five years the SSP program had been anticipating the importation of new founders. Only a few breedings were scheduled to bolster the representation of greatly underrepresented founder lineages. Therefore, the yearly population growth rate (lambda) has been deliberately lowered.

The analysis shows that both male and female *C. d. unicolor* become sexually mature in 3 to 5 years and can remain reproductive into their teens (see age specific fertility graphs). The cessation of breeding of the males depicted in the male age specific fertility graph at age class 12 is probably inaccurate and a fecundity curve corresponding more closely to the females is felt to be a more realistic approximation for this species. To minimize the genetic variation that will be lost in each successive generation of progeny, attempts to increase generation time from the minimum of 3-5 years to 10 years will be made. At eight to ten years there is a sharp decrease in male survivorship. Similar to the situation mentioned above, this is probably an error resulting from the small sample size, thus male survivorship, as well as fecundity, should probably be considered similar to that of the females.

With its possible short generation time of 3-4 years and large litter size (5-12), the *C. d. unicolor* population can potentially increase very rapidly. In this program, the proposed ten year extended generation time will limit the population growth rate per year. No model has been created to calculate the exact yearly rate of growth for the captive population at this extended generation time. A yearly growth rate (Lambda) of *ca.* 111% has been used in the Ballou Demographic/Genetic software model (Capacity 2.11) for projecting genetic variability in future generations (output included in this section). This is based on the current data set, and as mentioned earlier, may not be a realistic value for the population. When the SSP population has reached carrying capacity and the sample size has increased, further demographic estimates will have to be calculated.

The carrying capacity for *C. d. unicolor* in American collections has been established at 150 specimens. This value was derived from polling zoos with large reptile collections and limiting the size of the SSP population to minimize the impact on available space needed for similar taxa. Considering this carrying capacity limitation, and its large litter size, it will be necessary to cull some of the *C. d. unicolor* to maintain a stable age distribution without exceeding this carrying capacity.

Genetic Analysis

Crotalus durissus unicolor Species Survival Plan

Parameters of Genetic Analysis

Animals included in the genetic analysis are those contained within the current breeding scheme for this SSP program. These animals are denoted in the studbook with an "SSP" in the PROGRAM field (right column). In the Master Plan report, animals identified with an "S" proceeding the studbook number are surplus to the breeding program. Animals without any designation are included in the breeding scheme. These animals can also be identified in the Master Plan report with a value for mean kinship.

Analysis was performed using GENES (version 10.12) included with SPARKS (version 1.11).

Summary

The current captive population is descended from ten founders. Four of these founders were imported from Aruba in 1989 and have bred for the first time this year. There are an additional 15 wild caught animals that have not yet reproduced (potential founders). Ten of these potential founders were imported in 1991.

The current descendant population represents 91.2% of the expected wild genetic diversity. If the additional potential founders breed, and the population is managed to maximize the retention of genetic diversity, it could be possible to produce a descendant population that represents 97.9% of the wild genetic diversity. The current Founder Genome Equivalents is 5.699 (potential 23.864).

All animals with inbreeding coefficients greater than 0.25 have been surplused from the SSP breeding program. With the additional founders and potential founders that have been added to the SSP in the last few years, inbreeding should be avoidable for the foreseeable future. The descendant population mean kinship is 0.0877.

To achieve the current captive population genetic goal of retaining 95% of the wild genetic diversity indefinitely, it will be necessary to add additional unrelated founders in about four generations. This will be approximately 40 years (2030) if the current generation time (T) goal of 10 years can be realized.

Inbreeding coefficients and mean kinships

SSP BREEDING ANIMALS SELECTED

INBREEDING AND KINSHIP CALCULATIONS OMIT GENES FROM UNKNOWN ANCESTORS.

STUDBOOK	SEX	SIRE	DAM	F	PROP. OF GENOME KNOWN
5	F	WILD	WILD	0.0000	1.0000
1	M	WILD	WILD	0.0000	1.0000
2	F	WILD	WILD	0.0000	1.0000
3	F	WILD	WILD	0.0000	1.0000
4	F	WILD	WILD	0.0000	1.0000
6	F	1	2	0.0000	1.0000
7	M	1	2	0.0000	1.0000
11	F	WILD	WILD	0.0000	1.0000
12	F	WILD	WILD	0.0000	1.0000
13	M	WILD	WILD	0.0000	1.0000
14	F	WILD	WILD	0.0000	1.0000
8	M	1	2	0.0000	1.0000
9	M	1	2	0.0000	1.0000
10	M	1	2	0.0000	1.0000
15	F	1	2	0.0000	1.0000
16	F	1	5	0.0000	1.0000
17	F	1	5	0.0000	1.0000
18	F	1	5	0.0000	1.0000
19	M	7	2	0.2500	1.0000
20	F	7	2	0.2500	1.0000
21	M	7	2	0.2500	1.0000
22	F	7	2	0.2500	1.0000
23	M	UNK	UNK		0.0000
24	F	7	6	0.2500	1.0000
25	F	7	2	0.2500	1.0000
26	M	UNK	UNK		0.0000
27	M	UNK	UNK		0.0000
28	F	UNK	UNK		0.0000
167	F	WILD	WILD	0.0000	1.0000
29	M	19	20	0.3750	1.0000
30	M	19	20	0.3750	1.0000
31	F	19	20	0.3750	1.0000
32	M	19	20	0.3750	1.0000
33	F	7	2	0.2500	1.0000
34	M	7	25	0.3750	1.0000
35	F	7	25	0.3750	1.0000
36	F	7	25	0.3750	1.0000
37	F	7	2	0.2500	1.0000
38	M	13	14	0.0000	1.0000
39	M	13	14	0.0000	1.0000
40	M	13	14	0.0000	1.0000
41	F	19	20	0.3750	1.0000
42	F	19	20	0.3750	1.0000
43	M	19	20	0.3750	1.0000
44	M	19	20	0.3750	1.0000
45	M	19	22	0.3750	1.0000
46	M	19	22	0.3750	1.0000
47	M	19	22	0.3750	1.0000

Inbreeding coefficients and mean kinships

STUDBOOK	SEX	SIRE	DAM	F	PROP. OF GENOME KNOWN
48	F	19	22	0.3750	1.0000
49	F	19	22	0.3750	1.0000
50	M	19	22	0.3750	1.0000
P14	M	UNK	UNK		0.0000
51	F	P14	14	0.0000	0.5000
52	F	P14	14	0.0000	0.5000
53	M	19	22	0.3750	1.0000
54	M	19	22	0.3750	1.0000
55	M	19	22	0.3750	1.0000
56	F	19	22	0.3750	1.0000
57	F	19	22	0.3750	1.0000
170	M	19	22	0.3750	1.0000
171	F	19	22	0.3750	1.0000
58	F	19	20	0.3750	1.0000
59	F	19	20	0.3750	1.0000
60	M	19	20	0.3750	1.0000
61	F	26	11	0.0000	0.5000
62	F	26	11	0.0000	0.5000
P28	M	UNK	UNK		0.0000
63	F	P28	28		0.0000
64	U	27	14	0.0000	0.5000
65	F	27	14	0.0000	0.5000
66	F	27	14	0.0000	0.5000
67	U	27	14	0.0000	0.5000
68	M	19	22	0.3750	1.0000
69	F	19	22	0.3750	1.0000
70	M	19	22	0.3750	1.0000
71	M	19	22	0.3750	1.0000
72	F	19	22	0.3750	1.0000
73	M	19	20	0.3750	1.0000
74	M	19	20	0.3750	1.0000
75	M	19	20	0.3750	1.0000
76	M	40	42	0.0000	1.0000
77	M	40	42	0.0000	1.0000
78	M	40	42	0.0000	1.0000
79	M	40	42	0.0000	1.0000
80	F	40	42	0.0000	1.0000
81	M	40	42	0.0000	1.0000
82	F	40	42	0.0000	1.0000
83	F	40	42	0.0000	1.0000
84	F	40	42	0.0000	1.0000
85	F	40	42	0.0000	1.0000
86	F	40	42	0.0000	1.0000
87	F	40	42	0.0000	1.0000
88	F	40	42	0.0000	1.0000
89	M	40	42	0.0000	1.0000
90	F	38	16	0.0000	1.0000
91	F	38	16	0.0000	1.0000
163	M	WILD	WILD	0.0000	1.0000
168	F	WILD	WILD	0.0000	1.0000
92	M	40	17	0.0000	1.0000
93	M	40	17	0.0000	1.0000
94	F	40	17	0.0000	1.0000
95	F	40	17	0.0000	1.0000
96	F	40	17	0.0000	1.0000

Inbreeding coefficients and mean kinships

STUDBOOK	SEX	SIRE	DAM	F	PROP. OF GENOME KNOWN
97	F	40	17	0.0000	1.0000
98	F	40	17	0.0000	1.0000
99	F	40	17	0.0000	1.0000
116	U	40	17	0.0000	1.0000
100	F	38	16	0.0000	1.0000
101	F	38	16	0.0000	1.0000
102	M	38	16	0.0000	1.0000
103	M	38	16	0.0000	1.0000
104	M	38	16	0.0000	1.0000
105	M	38	16	0.0000	1.0000
106	F	38	16	0.0000	1.0000
107	M	38	16	0.0000	1.0000
108	M	39	3	0.0000	1.0000
109	M	39	3	0.0000	1.0000
110	M	39	3	0.0000	1.0000
111	F	39	3	0.0000	1.0000
112	F	39	3	0.0000	1.0000
113	F	39	3	0.0000	1.0000
114	F	39	3	0.0000	1.0000
115	F	39	3	0.0000	1.0000
161	M	WILD	WILD	0.0000	1.0000
162	M	WILD	WILD	0.0000	1.0000
164	M	WILD	WILD	0.0000	1.0000
169	M	WILD	WILD	0.0000	1.0000
117	M	38	16	0.0000	1.0000
118	F	38	16	0.0000	1.0000
119	F	38	16	0.0000	1.0000
120	M	40	17	0.0000	1.0000
121	M	40	17	0.0000	1.0000
122	M	40	17	0.0000	1.0000
123	F	40	17	0.0000	1.0000
124	F	40	17	0.0000	1.0000
125	F	40	17	0.0000	1.0000
126	F	40	17	0.0000	1.0000
127	F	40	17	0.0000	1.0000
128	F	40	17	0.0000	1.0000
129	F	40	17	0.0000	1.0000
130	F	40	17	0.0000	1.0000
135	F	23	56	0.0000	0.5000
131	M	23	57	0.0000	0.5000
132	M	23	57	0.0000	0.5000
133	M	23	57	0.0000	0.5000
134	M	23	57	0.0000	0.5000
136	F	23	57	0.0000	0.5000
137	M	23	57	0.0000	0.5000
138	M	23	57	0.0000	0.5000
139	M	23	57	0.0000	0.5000
140	F	23	57	0.0000	0.5000
141	F	47	58	0.4375	1.0000
142	M	47	58	0.4375	1.0000
143	M	47	58	0.4375	1.0000
144	F	47	58	0.4375	1.0000
145	U	47	58	0.4375	1.0000
146	U	76	37	0.1875	1.0000
147	U	76	37	0.1875	1.0000

Inbreeding coefficients and mean kinships

STUDBOOK	SEX	SIRE	DAM	F	PROP. OF GENOME KNOWN
148	U	76	37	0.1875	1.0000
149	U	76	37	0.1875	1.0000
150	U	76	37	0.1875	1.0000
151	U	76	37	0.1875	1.0000
152	U	76	37	0.1875	1.0000
218	M	WILD	WILD	0.0000	1.0000
219	M	WILD	WILD	0.0000	1.0000
220	F	WILD	WILD	0.0000	1.0000
221	F	WILD	WILD	0.0000	1.0000
223	F	WILD	WILD	0.0000	1.0000
224	F	WILD	WILD	0.0000	1.0000
225	F	WILD	WILD	0.0000	1.0000
226	M	WILD	WILD	0.0000	1.0000
227	M	WILD	WILD	0.0000	1.0000
160	M	WILD	WILD	0.0000	1.0000
165	F	WILD	WILD	0.0000	1.0000
166	F	WILD	WILD	0.0000	1.0000
153	F	23	57	0.0000	0.5000
154	F	23	57	0.0000	0.5000
155	M	23	57	0.0000	0.5000
156	F	23	57	0.0000	0.5000
157	M	23	57	0.0000	0.5000
158	F	23	57	0.0000	0.5000
159	M	23	57	0.0000	0.5000
182	M	93	24	0.0625	1.0000
222	F	WILD	WILD	0.0000	1.0000
172	F	103	115	0.0625	1.0000
173	M	103	115	0.0625	1.0000
174	U	103	115	0.0625	1.0000
175	M	103	115	0.0625	1.0000
176	F	103	115	0.0625	1.0000
177	M	103	115	0.0625	1.0000
178	M	103	115	0.0625	1.0000
179	F	103	115	0.0625	1.0000
180	M	103	115	0.0625	1.0000
181	F	103	115	0.0625	1.0000
210	U	93	95	0.2500	1.0000
211	U	93	95	0.2500	1.0000
212	U	93	95	0.2500	1.0000
213	U	93	95	0.2500	1.0000
214	U	93	95	0.2500	1.0000
215	U	93	95	0.2500	1.0000
216	U	93	95	0.2500	1.0000
217	U	93	95	0.2500	1.0000
188	M	103	115	0.0625	1.0000
189	U	103	115	0.0625	1.0000
190	M	103	115	0.0625	1.0000
191	M	103	115	0.0625	1.0000
192	M	103	115	0.0625	1.0000
193	M	103	115	0.0625	1.0000
194	M	103	115	0.0625	1.0000
195	U	103	115	0.0625	1.0000
196	U	103	115	0.0625	1.0000

Inbreeding coefficients and mean kinships

STUDBOOK	SEX	SIRE	DAM	F	PROP. OF GENOME KNOWN
197	U	103	115	0.0625	1.0000
198	F	102	111	0.0625	1.0000
199	F	102	111	0.0625	1.0000
200	F	102	111	0.0625	1.0000
201	M	102	111	0.0625	1.0000
202	F	102	111	0.0625	1.0000
203	F	102	111	0.0625	1.0000
204	F	102	111	0.0625	1.0000
205	M	102	111	0.0625	1.0000
206	F	102	111	0.0625	1.0000
207	F	102	111	0.0625	1.0000
208	M	102	111	0.0625	1.0000
209	U	102	111	0.0625	1.0000
183	U	157	140	0.6875	0.5000
184	M	157	140	0.6875	0.5000
185	M	157	140	0.6875	0.5000
186	U	157	140	0.6875	0.5000
187	U	157	140	0.6875	0.5000
236	U	39	90	0.1250	1.0000
237	U	39	90	0.1250	1.0000
238	U	39	90	0.1250	1.0000
239	U	39	90	0.1250	1.0000
231	U	161	166	0.0000	1.0000
232	U	161	166	0.0000	1.0000
233	U	161	166	0.0000	1.0000
234	U	161	166	0.0000	1.0000
235	U	161	166	0.0000	1.0000
240	U	155	153	0.6875	0.5000
241	U	155	153	0.6875	0.5000
242	U	155	153	0.6875	0.5000
243	U	155	153	0.6875	0.5000
244	U	155	153	0.6875	0.5000
228	U	160	165	0.0000	1.0000
229	U	160	165	0.0000	1.0000
230	U	160	165	0.0000	1.0000

Inbreeding coefficients and mean kinships

MEAN KINSHIP OF LIVING ANIMALS TO LIVING NON-FOUNDERS

STUDBOOK		SIRE	DAM	INBREEDING	MEAN KINSHIP	GENOME KNOWN
24	F	7	6	F = 0.2500	mk = 0.0754	1.0000
167	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
37	F	7	2	F = 0.2500	mk = 0.0614	1.0000
40	M	13	14	F = 0.0000	mk = 0.1207	1.0000
81	M	40	42	F = 0.0000	mk = 0.0992	1.0000
82	F	40	42	F = 0.0000	mk = 0.0992	1.0000
90	F	38	16	F = 0.0000	mk = 0.1013	1.0000
91	F	38	16	F = 0.0000	mk = 0.1013	1.0000
163	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
168	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
92	M	40	17	F = 0.0000	mk = 0.1056	1.0000
93	M	40	17	F = 0.0000	mk = 0.1099	1.0000
111	F	39	3	F = 0.0000	mk = 0.0991	1.0000
115	F	39	3	F = 0.0000	mk = 0.1034	1.0000
161	M	WILD	WILD	F = 0.0000	mk = 0.0431	1.0000
164	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
169	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
129	F	40	17	F = 0.0000	mk = 0.1056	1.0000
130	F	40	17	F = 0.0000	mk = 0.1056	1.0000
218	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
219	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
220	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
221	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
223	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
224	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
225	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
226	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
227	M	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
160	M	WILD	WILD	F = 0.0000	mk = 0.0259	1.0000
165	F	WILD	WILD	F = 0.0000	mk = 0.0259	1.0000
166	F	WILD	WILD	F = 0.0000	mk = 0.0431	1.0000
182	M	93	24	F = 0.0625	mk = 0.1002	1.0000
222	F	WILD	WILD	F = 0.0000	mk = 0.0000	1.0000
188	M	103	115	F = 0.0625	mk = 0.1153	1.0000
190	M	103	115	F = 0.0625	mk = 0.1153	1.0000
195	U	103	115	F = 0.0625	mk = 0.1153	1.0000
196	U	103	115	F = 0.0625	mk = 0.1153	1.0000
205	M	102	111	F = 0.0625	mk = 0.1110	1.0000
206	F	102	111	F = 0.0625	mk = 0.1110	1.0000
207	F	102	111	F = 0.0625	mk = 0.1110	1.0000
231	U	161	166	F = 0.0000	mk = 0.0517	1.0000
232	U	161	166	F = 0.0000	mk = 0.0517	1.0000
233	U	161	166	F = 0.0000	mk = 0.0517	1.0000
234	U	161	166	F = 0.0000	mk = 0.0517	1.0000
235	U	161	166	F = 0.0000	mk = 0.0517	1.0000
228	U	160	165	F = 0.0000	mk = 0.0345	1.0000
229	U	160	165	F = 0.0000	mk = 0.0345	1.0000
230	U	160	165	F = 0.0000	mk = 0.0345	1.0000

ORDERED LISTS OF MEAN KINSHIP BY SEX:

Rank	MALES	MK	Known	FEMALES	MK	Known	UNKNOWNS	MK	Known
1	163	0.0000	1.0000	167	0.0000	1.0000	228	0.0345	1.0000
2	164	0.0000	1.0000	168	0.0000	1.0000	229	0.0345	1.0000
3	169	0.0000	1.0000	220	0.0000	1.0000	230	0.0345	1.0000
4	218	0.0000	1.0000	221	0.0000	1.0000	231	0.0517	1.0000
5	219	0.0000	1.0000	223	0.0000	1.0000	232	0.0517	1.0000
6	226	0.0000	1.0000	224	0.0000	1.0000	233	0.0517	1.0000
7	227	0.0000	1.0000	225	0.0000	1.0000	234	0.0517	1.0000
8	160	0.0259	1.0000	222	0.0000	1.0000	235	0.0517	1.0000
9	161	0.0431	1.0000	165	0.0259	1.0000	195	0.1153	1.0000
10	81	0.0992	1.0000	166	0.0431	1.0000	196	0.1153	1.0000
11	182	0.1002	1.0000	37	0.0614	1.0000			
12	92	0.1056	1.0000	24	0.0754	1.0000			
13	93	0.1099	1.0000	111	0.0991	1.0000			
14	205	0.1110	1.0000	82	0.0992	1.0000			
15	188	0.1153	1.0000	90	0.1013	1.0000			
16	190	0.1153	1.0000	91	0.1013	1.0000			
17	40	0.1207	1.0000	115	0.1034	1.0000			
18				129	0.1056	1.0000			
19				130	0.1056	1.0000			
20				206	0.1110	1.0000			
21				207	0.1110	1.0000			

GENETIC SUMMARY OF POPULATION

Descendant population mean kinship: 0.0877
Gene diversity: 0.9123
Founder Genome Equivalents: 5.6991

Studbook	Sex	Sire	Dam	Status (cap=alive)	Prop. Genome living desc.	unique among all living
5	F	WILD	WILD	f		
1	M	WILD	WILD	f		
2	F	WILD	WILD	f		
3	F	WILD	WILD	f		
6	F	1	2	d		
7	M	1	2	d		
13	M	WILD	WILD	f		
14	F	WILD	WILD	f		
16	F	1	5	d		
17	F	1	5	d		
19	M	7	2	d		
20	F	7	2	d		
24	F	7	6	A	0.0617	0.0617
167	F	WILD	WILD	F		1.0000
37	F	7	2	A	0.1734	0.1734
38	M	13	14	d		
39	M	13	14	d		
40	M	13	14	A	0.0052	0.0052
42	F	19	20	d		
81	M	40	42	A	0.0239	0.0239
82	F	40	42	A	0.0274	0.0274
90	F	38	16	A	0.0520	0.0520
91	F	38	16	A	0.0512	0.0512
163	M	WILD	WILD	F		1.0000
168	F	WILD	WILD	F		1.0000
92	M	40	17	A	0.0246	0.0246
93	M	40	17	A	0.0119	0.0119
102	M	38	16	d		
103	M	38	16	d		
111	F	39	3	A	0.0401	0.0401
115	F	39	3	A	0.0188	0.0188
161	M	WILD	WILD	F		0.0307
164	M	WILD	WILD	F		1.0000
169	M	WILD	WILD	F		1.0000
129	F	40	17	A	0.0242	0.0242
130	F	40	17	A	0.0266	0.0266
218	M	WILD	WILD	F		1.0000
219	M	WILD	WILD	F		1.0000
220	F	WILD	WILD	F		1.0000
221	F	WILD	WILD	F		1.0000
223	F	WILD	WILD	F		1.0000
224	F	WILD	WILD	F		1.0000
225	F	WILD	WILD	F		1.0000
226	M	WILD	WILD	F		1.0000
227	M	WILD	WILD	F		1.0000
160	M	WILD	WILD	F		0.1254
165	F	WILD	WILD	F		0.1242
166	F	WILD	WILD	F		0.0293
182	M	93	24	A	0.0000	0.0000
222	F	WILD	WILD	F		1.0000
188	M	103	115	A	0.0032	0.0032

Studbook	Sire	Dam	Status (cap=alive)	Prop. genome living desc.	unique among all living
190 M	103	115	A	0.0028	0.0028
195 U	103	115	A	0.0032	0.0032
196 U	103	115	A	0.0033	0.0033
205 M	102	111	A	0.0054	0.0054
206 F	102	111	A	0.0056	0.0056
207 F	102	111	A	0.0054	0.0054
231 U	161	166	A	0.0632	0.0000
232 U	161	166	A	0.0617	0.0000
233 U	161	166	A	0.0609	0.0000
234 U	161	166	A	0.0632	0.0000
235 U	161	166	A	0.0623	0.0000
228 U	160	165	A	0.2495	0.0000
229 U	160	165	A	0.2508	0.0000
230 U	160	165	A	0.2501	0.0000

25 Founders 29 Living descendants 65 In total pedigree

FOUNDER ALLELE REPRESENTATION

Founder	Retention	%Representation	Target	Difference
5 F	0.717	8.640	3.005	-5.635
1 M	0.874	12.880	3.663	-9.217
2 F	0.857	7.755	3.592	-4.162
3 F	0.754	9.475	3.158	-6.317
13 M	0.827	16.818	3.463	-13.355
14 F	0.835	16.843	3.499	-13.345
167 FL	0.000	0.000	4.191	4.191
163 ML	0.000	0.000	4.191	4.191
168 FL	0.000	0.000	4.191	4.191
161 ML	0.969	8.620	4.191	-4.430
164 ML	0.000	0.000	4.191	4.191
169 ML	0.000	0.000	4.191	4.191
218 ML	0.000	0.000	4.191	4.191
219 ML	0.000	0.000	4.191	4.191
220 FL	0.000	0.000	4.191	4.191
221 FL	0.000	0.000	4.191	4.191
223 FL	0.000	0.000	4.191	4.191
224 FL	0.000	0.000	4.191	4.191
225 FL	0.000	0.000	4.191	4.191
226 ML	0.000	0.000	4.191	4.191
227 ML	0.000	0.000	4.191	4.191
160 ML	0.875	5.172	4.191	-0.982
165 FL	0.876	5.172	4.191	-0.982
166 FL	0.971	8.621	4.191	-4.430
222 FL	0.000	0.000	4.191	4.191

Genetic Summary	Living Descendant Population	Potential
Number of founders:	10	25
Mean retention:	0.855	0.955
Founder genomes surviving:	8.554	23.864
Founder Equivalents:	8.627	24.801
Founder Genome Equivalents:	5.699	23.864
Fraction of wild gene diversity retained:	0.912	0.979
Fraction of wild gene diversity lost:	0.088	0.021
Mean inbreeding coefficient:	0.064	

ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

REPORT
30 November 1992

SECTION 7

EPIDEMIOLOGY & TREATMENT ASPECTS OF ENVENOMATION

THE ARUBA ISLAND RATTLESNAKE OR CASCABEL (*Crotalus durissus unicolor*): EPIDEMIOLOGY AND TREATMENT ASPECTS OF ENVENOMATION

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Introduction

The neotropical rattlesnake (*Crotalus durissus*) has the widest distribution of any of the 29 species of rattlesnake, having a range which extends from southern Mexico to northern Argentina (Campbell and Lamar, 1989). Reports on the toxinology of venom and human envenomation have been primarily concerned with two of the 14 subspecies of *C. durissus*: the Central American neotropical rattlesnake (*C. d. durissus*) and the South American neotropical rattlesnake (*C. d. terrificus*). No reports in the literature could be found concerning either venom characteristics, including toxicity, or the effects of clinical human envenomation of the Aruba Island rattlesnake (*C. d. unicolor*). This Symposium afforded the opportunity to access the incidence and severity of envenomations by *C. d. unicolor* which have occurred in recent years. Based on this information and an extensive review of the literature, recommendations are made for reduction of the risk of being bitten, and for treatment should envenomation occur. On Aruba, *C. d. unicolor* is known as the "cascabel."

Risk of Venomous Snakebite on Aruba

In general, the neotropical rattlesnake is a species which is not easily threatened or prone to bite, as compared to other rattlesnake species, e.g., western diamondback (*C. atrox*) and western rattlesnake (*C. viridis*). By most accounts, the cascabel seems almost docile. Being an insular form, it may not have been exposed to predators prior to man's arrival.

My own studies in Arizona (Hardy, 1988) and those of Curry et al. (1989) indicate that classifying bites as to their "legitimacy" can be important in terms of risk management. A "legitimate" bite occurs when an individual is bitten by an unseen snake and did not intend to be near the snake. An "illegitimate" bite occurs as a result of willful interaction with a snake known to be venomous, e.g., killing, capturing, restraining, photographing, etc. In Arizona, more than 60% of bites by rattlesnakes are illegitimate, and nearly all involve men, usually in the age group 12 to 40. Illegitimate bites are important because they are both common and preventable. Through education of that segment of the population which is most at risk, namely young men and teenage boys, the number of bites can be reduced.

Method of Study

Number, sex and age of recent snakebite hospital admissions were made available by Dr. J. Van Veen, Director, Department of Public Health, Aruba. Medical records were not available. Information concerning additional cases of cascabel bite were obtained from several other persons in attendance at the Symposium.

Results

Information was obtained on 12 bites by cascabels in four individuals which had occurred in the past seven years. This information is given below in the form of case histories in chronological order:

Cases 1-9. In 1985, a 26 year old male was bitten on the distal middle finger while holding a captive adult cascabel by the tail. There was an immediate burning sensation locally which spread rapidly up the arm. He noted blurred vision within an hour which lasted for 24 hours. The arm could not be elevated for one week due to muscle weakness. Paresthesias and hyperesthesia of the extremity persisted for one month post-envenomation. There was no local tissue injury.

From 1985 to 1989, the same individual suffered eight additional bites from captive cascabels which are free handled because of their usual tendency not to bite. All bites were on the fingers or hands. A juvenile snake inflicted a bite described as the most painful and debilitating. Dark urine or generalized weakness was never noted, but other details are lacking. With all bites, he remained at home and recovered without hospital treatment. There is no evidence of any lasting venom effect and his hands are normal in appearance and function.

Case 10. In 1988, a 24 year old male encountered a cascabel in the Canucu and attempted to kill it with a rock. Thinking the snake to be dead, it was manipulated and he was bitten on the hand. The victim was hospitalized and treated with an unknown type and amount of antivenom. He has experienced residual weakness and spastic movements of the affected extremity which continue to the present.

Case 11. In 1989, a 14 year old male was bitten by a cascabel, but information as to circumstances and severity were not available. He was said to have made a complete recovery.

Case 12. In 1990, a 28 year old male was one of two men collecting garbage when a cascabel was found in a collection can and taken to the local newspaper to be photographed. The victim manipulated the snake and was bitten. The severity is not known, but recovery was complete.

Discussion

All four individuals were young males. In at least three cases, they were interacting with the snakes involved and sustained illegitimate bites. Detailed information was lacking in all cases. Case 10 was described as severe, and is also of interest because of the long term and persistent neurologic sequelae of the involved upper extremity. A similar case in Sweden has been reported for *C. d. terrificus* in captivity (Ekenback et al., 1985).

Crotoxin

Crotoxin, a phospholipase A2, is the primary venom component of the South American neotropical rattlesnake (*C. d. terrificus*) and can make up to 60% of its composition (Hawgood, 1982). Subspecies of *C. durissus* at the northern end of its range in Middle America either lack or contain only small amounts of crotoxin in their venom (Bolanos et al., 1981; Gutierrez et al., 1991). Venom from specimens of *C. d. unicolor* at the Houston Zoo were found to have 30% crotoxin in their venom and thus appear to be intermediate in this regard (J.L. Glenn, Salt Lake City, January, 1992, pers. comm.). For a summary of neurotoxic snake venoms and envenomation see Minton (1990).

The clinical picture following envenomation by *C. d. terrificus* in Brazil results from the effects of the primary venom component, crotoxin. Local effects are mild with pain and occasional swelling, but without necrosis (Rosenfeld, 1971). Systemic symptoms and signs are hypotension (shock) (Da Silva et al., 1979), progressive skeletal paralysis (Rosenfeld, 1971), hypofibrinogenemia (Amaral et al., 1980), gastrointestinal hemorrhage (Azevedo-Marques et al., 1985) and acute renal failure (Azevedo-Marques et al., 1982, 1985). With the possible exception of paralysis, none of the other problems have been documented for *C. d. unicolor*. Any treatment regime should attempt to prevent or alleviate these effects.

First aid measures

No specific first aid measures are recommended for cascabel bite on Aruba. Anyone bitten should proceed to the nearest medical facility as soon as possible and as quickly as is consistent with safe travel. The victim and anyone in attendance should remain calm and not take any rash action. If possible, the bitten extremity should be immobilized (splinting is best), so as to passively reduce absorption. One should not wait to see if signs or symptoms of envenomation appear before seeking medical treatment. Invasive measures are not recommended because they have not been shown to be effective in the field and may themselves do harm. The following measures should not be used: incision with suction, tourniquet application or constriction band, application of ice, and stun gun electroshock. Although "The Extractor" suction devise and the compression/immobilization method of Australia would probably not do harm, their effectiveness for crotoxin is not clear and no recommendation is make for their use on Aruba.

For a more exhaustive discussion on first aid measures for pitviper bite see Hardy (1992).

Treatment Recommendations

Since local findings may be minimal, they cannot be used to judge severity of envenomation. Early and aggressive treatment is required for anyone bitten by a cascabel.

Hypotension is the result of direct venom action to dilate veins with peripheral pooling of blood and decreased return to the heart. Treatment is expansion of intravascular volume with intravenous (i.v.) crystalloid solutions (Ringer's lactate or normal saline) in addition to i.v. antivenom.

Progressive muscle paralysis is first recognized by ptosis, double vision, lack of facial expression, dysphagia, dysphonia and a generalized feeling of weakness. If there is progression of paralysis, respiratory muscles become involved and respiratory insufficiency or failure results (Amaral et al., 1986). Definitive treatment is oral or nasal endotracheal intubation and artificial ventilation until muscle strength returns. Patients have been ventilated for up to two weeks or more with full recovery (DaSilva et al., 1979). Antivenom may prevent further paralysis, but will not reverse the neuro-blockade already in effect. Since crotoxin produces a presynaptic rather than a postsynaptic block at the myoneural junction (Chiung Chang and Dong Lee, 1977), neostigmine will not reverse its effect (Watt et al., 1986).

Coagulopathy with a drastic fall in fibrinogen, but without signs of hemorrhage, has been reported (Amaral et al., 1980). Significant gastrointestinal bleeding is well documented (Azevedo-Marques et al., 1985). Although its cause has not been determined, it is likely secondary to the coagulopathy. Antivenom will return laboratory values to the normal range, and cryoprecipitates should not be used unless hypofibrinogenemia is <100 mg/dL and there are signs of significant hemorrhage (Burgess and Dart, 1991).

Acute renal failure results from generalized rabdomyolysis by crotoxin (Azevedo-Marques et al., 1982, 1985) and release of myoglobin into the general circulation (Azevedo-Marques et al., 1987; Cupo et al., 1988; Magalhaes et al. 1986). Myoglobin toxicity is increased by the presence of dehydration, hypotension and acidosis, all of which are associated with crotoxin toxicity. Expansion of intravascular volume with crystalloid solution and i.v. antivenom will protect major organ systems, including the kidneys. In additions, an active diuresis should be instituted using i.v. mannitol or furosemide (Brezis et al.,1991). Alkalinization of the urine by addition of sodium bicarbonate to i.v. solutions has also been suggested.

Antivenom

The following antivenom is stated to be effective against *C. d. cumanensis* of Venezuela, the closest relative of the cascabel (Theakston and Warrell, 1991):

- Suero antiophidico polyvalente UCV. University Central of Venezuela, Caracas, Venezuela (telephone 582719450). (Each vial neutralizes 15 mg of venom.)

The following antivenoms are stated to be effective against *C. d. terrificus*:

- Suero antiophidico polyvalente. Instituto Nacional de Salud, Av. Eldorado con Carrera, Zona, G, Bogota D.E., Colombia (telephone 5712220577).
- Soro anticrotalico. Instituto Butantan, Av. Vital Brazil, Caixa Postal 65, Sao Paulo-SP, Brazil.
- Wyeth antivenin (Crotalidae) polyvalent. Wyeth Laboratories Inc., Marietta, PA 17547 (telephone 215-688-4400).

The effectiveness of Wyeth's antivenin against *C. d. terrificus* has recently been questioned by Schaeffer, Jr. et al. (1988). It was postulated that low molecular mass proteins (<16,000 mol. wt.), such as crotoxin, are poor antigens and resulting antibody levels in antivenom are low.

It is recommended that at least 10 vials of antivenom be stocked in the hospital pharmacy at all times. It should be administered early, in adequate amounts (10 vials or 100 ml) and by the i.v. route. Antivenom is composed of equine globulins and anaphylaxis occurs in 1-3 % of patients (Jurkovich et al., 1988; Malasit et al., 1986). Epinephrine and the ability to institute artificial ventilation must be at the bedside before antivenom is administered. Skin testing for allergy to horse serum is the standard of practice for the United States, but its high incidence of false negative reactions has hindered its usefulness (Jurkovick et al., 1988). It is used less in other countries. Late serum reactions are common and best treated with gradually decreasing doses of oral steroids.

When stocks of antivenom are used or become outdated, they should be replaced as soon as possible. For treatment of *C. d. unicolor* envenomation, "Suero antiophidico polyvalente UCV" from Venezuela may be a better choice than Wyeth antivenin (Crotalidae) polyvalent since it utilizes *C. d. cumanensis* venom during production. Its availability is unknown.

Summary

The cascabel (*C. d. unicolor*) is a race of neotropical rattlesnake with venom which has intermediate levels of crotoxin and is capable of inflicting severe envenomation. However, recent experience indicates it is reluctant to bite and those

bitten were interacting with the rattlesnake. The cascabel should not be considered a significant public health hazard because the number of bites it inflicts is low and, for the most part, preventable. However, medical personnel and hospitals on Aruba must be prepared to treat victims of envenomation. Since the venom contains significant amounts of crotoxin, aggressive treatment with intravenous crystalloid fluids and antivenom should be instituted in anyone bitten. Adequate stocks of antivenom must be maintained and replaced quickly when used or outdated.

The public risk of bites can be reduced through education of the local populace and visitors to the island. They should know that when rattlesnakes are encountered, they should be observed at a distance, and any urge for interaction be resisted. If this attitude were instilled in the majority of people on Aruba, the incidence of venomous snakebite would be reduced to near zero.

It is possible, and certainly desirable, for *Homo sapiens* and *C. d. unicolor* to live together without endangering the existence of one another.

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Literature cited

AMARAL, C.F.S., O.A. DASILVA, M. LOPEZ and E.R.P. PEDROSO. 1980. Afibrinogenemia following snake bite (*Crotalus durissus terrificus*). Am. J. Trop. Med. Hyg. 29: 1453-1455.

AMARAL, C.F.S., N.A. REZENDE, O.A. DA SILVA, M.M.F. RIBEIRO, R.A. MAGALHAES, R.J. DOS REIS, J.G. CARNEIRO and J.R.S. CASTRO. 1986. Insuficiencia renal aguda secundaria a acidentes ofidicos bothropicos e crotalico. Analise de 63 casos. Rev. Inst. Trop. Sao Paulo 28: 220-227.

AZEVEDO-MARQUES, M.M., P. CUPO, T.M. COIMBRA, S.E. HERING, M.A. ROSSI and J.A. OLIVEIRA. 1982. Mionecrose e insuficiencia renal aguda mioglobinurica apos acidente crotalico. Livro de Programa e Resumos de XVIII Congresso da Sociedade Brasileira de Medicina Tropical, J2.

_____, _____, _____, _____, _____ and C.J. LAURE. 1985. Myonecrosis, myoglobinuria and acute renal failure induced by South American rattlesnake (*Crotalus durissus terrificus*) envenomation in Brazil. Toxicon 23:631-636.

_____, S.E. HERING andP. CUPO. 1987. Evidence that *Crotalus durissus terrificus* (South American rattlesnake) envenomation in humans causes myolysis rather than hemolysis. Toxicon 25: 1163-1168.

BOLANOS, R., O. MARIN, E.M. MEDINA and E.A. ALFARO. 1981. El accidente ofidico por cascabela (*Crotalus durissus durissus*) en Costa Rica. Act. Med. Costarric. 24:211-214.

BREZIS, M., S. ROSEN and F.H. EPSTEIN. 1991. Acute renal failure. In: The Kidney, B.M. Brenner and F.C. Rector, Jr., eds. W.B. Saunders Company, Philadelphia. pp. 993-1061.

BURGESS, J.L., and R.C. DART. 1991. Snake venom coagulopathy: use and abuse of blood products in the treatment of pit viper envenomation. Ann. Emerg. Med. 20: 795-801.

CAMPBELL, J.A., and W.W. LAMAR. 1989. *The Venomous Reptiles of Latin.* America. Cornell Press, Ithaca, New York. pp. 425.

CHIUNG CHANG, C., and J. DONG LEE. 1977. Crotoxin, the neurotoxin of South American rattlesnake venom, is a presynaptic toxin acting like b-bungarotoxin. Naunyn Schmiedeberg's Arch. Pharmacol. 296: 159-168.

CUPO, P., M.M. AZEVEDO-MARQUES, and S.E. HERING. 1988. Clinical and laboratory features of South American rattlesnake (*Crotalus durissus terrificus*) envenomation in children. Trans. Royal Soc. Trop. Med. Hyg. 82:924-929.

CURRY, S.C., D. HORNING, P. BRADY, R. REQUA, D.B. KUNKEL and M.V. VANCE. 1989. The legitimacy of rattlesnake bites in central Arizona. Ann. Emerg. Med. 18: 658-663.

DASILVA, O.A., M. LOPEZ and P. GODOY. 1979. Intensive care unit treatment of acute renal failure following snake bite. Am. Jour. Trop. Med. Hyg. 28:401-407.

EKENBACK, K., J. HULTING, H. PERSSON and I. WERNELL. 1985. Unusual neurological symptoms in a case of severe crotalid envenomation. Clin. Toxicol. 23:357-364.

GUTIERREZ, J.M., M.C. DOS SANTOS, M. DE FATIMA FURTADO and G. ROJAS. 1991. Biochemical and pharmacological similarities between the venoms of newborn *Crotalus durissus durissus* and adult *Crotalus durissus terrificus* rattlesnakes. Toxicon 29: 1273-1277.

HARDY, D.L. 1988. The Epidemiology of rattlesnake envenomation in Tucson, Arizona: 1973-1980. A preliminary report. Tucson Herpetological Society Newsletter 1: 33-36.

_____, Sr. 1992. A Review of First Aid Measures for _____, Sr. 1992. A Review of F with an Appraisal of Extractor™ Suction and Stun Gun Electroshock. In: Jonathan A. Campbell and William S. Lamar, eds., *Biology of the Pitvipers*, Selva, Tyler, Texas, pp. 405-414.

HAWGOOD, B.J. 1982. Physiological and pharmacological effects of rattlesnake venoms. In. A.T. Tu, ed. *Rattlesnakes Venoms*, Their Actions and Treatment. Marcel Dekker, Inc., New York. pp. 121-162.

JURKOVICK, G.J., A. LUTERMAN, K. MCCULLAR, M.L. RAMENOFSKY and P.W. CURRERI. 1988. Complications of Crotalidae antivenin therapy. J. Trauma 28:1032-1037.

MAGALHAES, R.A., M.M.F. REBEIRO, N.A. REZENDE and C.F.S. AMARAL. 1986. Rabdomiolise secundaria a acidente ofidico crotalico (*Crotalus durissus terrificus*). Rev. Inst. Med. Trop. Sao Paulo 28:228-233.

MALASIT, P., D.A. WARRELL, P. CHANTHAVANICH, C. VIRAVAN, J. MONGKOLSAPAYA, B. SINGHTHONG, and C. SUPICH. 1986. Prediction, prevention, mechanism of early (anaphylactic) antivenom reactions in victims of snake bites. British Med. J. 292:17-20.

MINTON, S.A. 1990. Neurotoxic snake envemoning. Sem. Neurol. 10: 52-61.

ROSENFELD, G. 1971. Symptomology, pathology, and treatment of snake bites in South America. In W. Bucherl, E.E. Buckley and V. Deulofeu, eds. *Venomous Animals and Their Venoms*. Volume II. Venomous Vertebrates. Academic Press, New York. pp. 345-384.

SCHAEFFER, JR., R.C., H. RANDALL, J. RESK and R.W. CARLSON. 1988. Enzyme-linked immunosorbant assay (ELISA) of size-selected crotalid venom antigens by Wyeth's polyvalent antivenom. Toxicon 26: 67-76.

THEAKSTON, R.D.G., and D.A. WARRELL. 1991. Antivenoms: a list of hyperimmune sera currently available for the treatment of envenoming by bites and stings. Toxicon 29: 1419-1468.

WATT, G., R.D.G. THEAKSTON, C.G. HAYES, M.L. YAMBAO, R. SANGALANG, C.P. RANOA, E. ALQUIZALAS, and D.A. WARRELL. 1986. Positive response to edrophonium in patients with neurotoxic envenoming by cobras (*Naja naja philippinensis*). New England Jour. Med. 315:1444-1449.

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ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

REPORT
30 November 1992

SECTION 8

SYMPOSIUM PROCEEDINGS

THE *Crotalus durissus unicolor* SSP, A MULTIFACETED APPROACH

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ABSTRACT

A multifaceted approach to the long term conservation of the Aruba Island rattlesnake was employed in this Species Survival Plan. First, the captive population was managed through selective breeding to increase the wild gene diversity retained (WGDR) from 67.5% in 1982 to 86.2% in 1991. With the acquisition of nineteen additional potential founders in 1989 and 1991, the potential WGDR was increased to 97.9%. Secondly, research was initiated into the development of a vaccine for reptilian Paramyxovirus, a disease that has been a primary cause of death for this species in captivity and also prevents any future release programs. Thirdly, a research project was initiated to ascertain the status and obtain life history data for this species in the wild. This project included the collection of blood samples from wild specimens to establish a genetic reference for future captive population monitoring. Finally, an education and public relations campaign was initiated on Aruba to help promote conservation of endemic species.

INTRODUCTION

The American Association of Zoological Parks and Aquariums (AAZPA) Species Survival Plan (SSP) program for the Aruba Island Rattlesnake, *Crotalus durissus unicolor*, was initiated in 1982. Since that time, the SSP program has evolved from a captive-based propagation effort to a broad approach to the many issues that are involved in the conservation of this insular form. The ultimate goal of the SSP is the conservation of the animal in its natural environment. Captive populations are maintained to support wild populations, not as a replacement for wild populations. As reservoirs of genetic and demographic material, captive populations can be used to reinforce, revitalize, or re-establish wild populations (Foose, 1983; Ballou and Foose, 1991).

The success of any SSP program requires overcoming problems associated with the numerous issues involving the conservation of the organisms. Many of the issues encountered in managing an SSP program are not apparent at its initiation. For this reason, SSP programs must be responsive to new situations and challenges that arise through the term of the program and appropriate actions must be implemented. In some cases, the original program goals may be altered or abandoned, and new goals may be established for the SSP.

Occasionally, opportunities arise that allow significant advances in the taxon's conservation. Such opportunities may include political changes, proprietorship changes of critical habitat, economic changes, release and relocation opportunities, and specimen availability for captive propagation programs. SSP conservation programs must be adaptable to these situations as they arise in an attempt to exploit, when possible, any opportunity that may improve the prospects of survival of the endangered taxon.

This paper is an overview of the efforts to conserve *C. d. unicolor* through the AAZPA SSP. The problems and issues that have been addressed include the limited number of founders for the captive population, ophidian Paramyxovirus epidemics, a lack of information about the status and life history of the wild population, inadequate references to monitor the genetic status of the captive population through successive generations, and the future of this endemic form on Aruba.

This paper is divided into two distinct parts. The first section describes *ex situ* efforts to manage the captive population in the United States so as to maximize the wild genetic diversity retained. It also includes an overview of work completed to overcome the problem of ophidian Paramyxovirus, a pathogen that has had a substantial negative impact on the demographics of the captive population and complicates any attempt for future release of animals into Aruba. The second section describes *in situ* work on Aruba that includes field research and a public relations/education campaign for *C. d. unicolor* on Aruba.

CAPTIVE POPULATION

Genetic and Demographic Management

As with individual SSP programs themselves, the science used for the management of SSP propagation schemes has also evolved. In the early 1980s, founder contribution was seen as the dominant basis for genetic management. By the mid-1980s, retention of founder genomes became the principal emphasis. This was later refined with the concept of founder genome equivalents (FGE) (Lacy, 1989). Methods for selecting breeding pairs included maximum avoidance of inbreeding (Flesness, 1977), equalization of founder contribution (Foose et.al., 1986), Founder Importance Coefficient (FIC) (Ballou, 1989, Pers. Comm.), and Mean Kinship (MK) (Ballou, 1991). The management of the *C. d. unicolor* SSP program has followed these developments and refinements in propagation schemes and is currently using MK and inbreeding as the foundation for selecting breeding pairs.

A more detailed methodology of the demographic and genetic analysis of an SSP population has been omitted from this paper. For a more detailed explanation of these management techniques, see Foose, 1983; Foose, et al., 1986; and Ballou and Foose, 1992.

An overall genetic goal for captive population of the *C. d. unicolor* SSP has been established to maintain 90% of the expected genetic diversity of the wild population (measured by average heterozygosity) for a period of 200 years (Soule, et al. 1986). A captive carrying capacity of 250 animals was established. The genetic retention goal and carrying capacity is based upon a compromise between minimizing loss of genetic diversity and maintaining a manageable captive population size that is not at high risk of extinction from deterministic and stochastic events. Limitations on the SSP carrying capacity were made to minimize the impact on other species competing for captive space. SSP population size for any single taxon must be limited so that a maximum number of forms can be accommodated in the limited captive space available.

Since 1982, a captive population database has been maintained in the form of the International Studbook for the Aruba Island Rattlesnake (Peterson, 1992). This database was computerized using software specifically developed for the *C. d. unicolor* SSP program in a Dbase III language for IBM compatible personal computers (Odum, 1990). A Dbase language was selected because it allowed the easy data manipulation and translation into other formats for genetic and demographic analysis.

Initial genetic analysis (using Lacy, 1991; Mace, 1986) of the captive population in 1982 established the effects of unmanaged breeding of the captive population. Founder contribution was heavily skewed (c.a. 60%) for one individual (Fig. 1) and a large portion of the captive population was inbred ($F > 0.25$). Only 67.5% of the expected wild genetic diversity retained (WGDR) was in the captive population. This is far below the 90% goal for the program which would require a minimum of 20 founders (WGDR=97.5%) at program initiation (computer model used, Ballou, 1989). The actual number of founder genome equivalents (FGE) for the population in 1982 equaled 1.537.

To correct this problem, actions were taken to improve the skewed founder contributions and maximize FGE. Through selective breeding, as well as surplusing animals from over represented founders, with unknown pedigrees, or with inbreeding coefficient greater than 0.25, the FGE were increased to 3.165 by 1991 (Fig. 2). This is reflected in an increase in the WGDR to 86.2%. Although this was a substantial improvement over the WGDR at the program's initiation, additional unrelated founding stock would be required to achieve the overall genetic goals.

To support the AAZPA conservation efforts, ten additional unrelated potential founders were imported into the United States in 1989. With the inclusion of these new wild caught animals in the SSP program, the potential WGDR in the captive population increased to 96.5%. In 1991, another ten potential founders were imported bringing the potential WGDR to 97.9%. The inclusion of these new animals has made the 90%/200 year WGDR goal feasible.

A method to compare the actual WGDR to the calculated WGDR in future captive generation of *C. d. unicolor* was needed. As part of the field research project mentioned below, blood was collected from 25 wild-born individuals as a genetic reference. In the future, the amount of heterozygosity in the captive population can be compared to the amount of heterozygosity in this base sample. This will determine the effectiveness of the breeding schemes used by the SSP program.

Paramyxovirus

Preliminary demographic analysis of the captive population in 1983 identified ophidian Paramyxovirus (OPV) as a significant factor affecting the longevity of *C. d. unicolor* in American zoos. Epidemics had occurred at several institutions which resulted in considerable mortality. Although no statistical evaluation has been performed, *C. d. unicolor* appears to be especially susceptible to this disease. For this reason, a program was initiated to explore a means to protect the captive population from this virulent pathogen.

Ophidian Paramyxovirus was first identified as the cause of death of a group of *Bothrops moojeni* in Switzerland in the 1970s (Folsch and Leloup, 1976). Since that time, OPV has been implicated in many epidemic events throughout the world. It has been identified in most major zoo herpetology collections in the United States at some point in time. Reptiles are easily transportable, which is reflected in the huge numbers imported into the United States. This ease of transport has resulted in the establishment of OPV as a pandemic pathogen in captive collections.

An approach to protect the captive population of *C. d. unicolor* from OPV was established. This pathogen is a virus that is not directly eliminated through antibiotic therapy and no antiviral drugs have yet been tested. Little is known of the long term pathology of this disease and once an animal has been exposed, it may die or perhaps harbor the virus for an indefinite period of time. For this reason, the approach to protect the captive population first focused on immunization by vaccination prior to exposure rather than a post-exposure management.

Prior to 1988, no vaccination studies had ever been performed on a snake. Killed OPV vaccine trials were performed at the Houston Zoo in a cooperative effort with the University of Florida, Gainesville, during 1988 and 1989 (Jacobson, et al., 1991). Twenty-three *Crotalus atrox* were used as a model for viperid snakes. The products tested included three killed virus preparations, one without and two with adjuvants, and a control inoculant. The test animals were bled at two week intervals and antibody response to the vaccine was measured by hemoglutination inhibition. This study established that snakes can respond to a killed virus vaccine by producing antibodies, although these responses were not identified in all test animals and when it did occur, was minimal and transient. No live virus challenges were made on this study group.

The development of an effective vaccine will probably be a long term effort that will require many additional product trials. Because the effectiveness of any preparation may be species-specific, it will ultimately be necessary to test vaccines on *C. d. unicolor*. SSP surplus *C. d. unicolor* have been set aside for future vaccine trials. One trial has already been performed. This was a preliminary study that tested a modified live vaccine (J. Flanagan, pers. comm.). The trials resulted in the mortality of one *C. d. unicolor* which received the test product. Additional product tests are scheduled.

Other studies to determine the incubation period of OPV disease were performed at the Toledo Zoo in 1990-91. The results of this study (Odum and Lloyd, in prep.) determined an incubation period of 70 days from exposure to morbidity. A carrier state was also identified in which animals showed some clinical signs of disease and were infectious. One animal remained infectious for approximately one year before its death. Future studies will include the testing of several other vaccine products and the development of a new test for direct identification of OPV in tissue samples.

IN SITU CONSERVATION

Field work

In 1982 a literature search revealed that there was little published data about the wild population of *C. d. unicolor* on Aruba. The most recent information available was from several zoo herpetologists that had visited the island and did not find any *C. d. unicolor* after substantial searching. To learn more about the status of the wild population and to obtain life history data for this taxon, a one year field project was initiated in late 1988. It is not the intent of this paper to publish detailed findings of this field work. Instead, this information will be published elsewhere (Goode and Odum, in prep.). The following is a brief overview of this field project.

The field work employed a variety of techniques to collect data. Study animals were obtained by physically searching as well as receiving specimens collected by Arubans. Radio telemetry was used to monitor individual specimens for movements, intraspecific interactions, and habitat utilization. Several gravid females were also held in captivity to obtain brood size, neonate size, and neonate sex ratio information. Data was also collected from wild caught animals being held in captivity on Aruba.

During this project, observations of free ranging *C. d. unicolor* included courtships ($N > 10$) and copulations ($N = 4$). Data were obtained from approximately 40 *C. d. unicolor*.

Through interviews, information was also collected from Aruban citizens about sightings and incidental take of *C. d. unicolor*. This information proved invaluable in determining the current range. This research did established that *C. d. unicolor* is still found on Aruba and that the wild population is breeding. It will be the basis of future field efforts.

Public relations and education

Public relations (PR) and education programs were initiated on Aruba in conjunction with the field research project in 1988-89. The focus of this campaign was to increase the awareness of the Aruban people to their native fauna with particular emphasis on *C. d. unicolor*. Adult Arubans were the target group for the PR campaign and school age children were the target group for the education program.

The PR campaign was initiated by establishing contacts with local media. Through these contacts, numerous stories were published in newspapers and magazines (Dutch; Papiamentu, the local Aruban language; and English), and radio and television interviews were broadcast. Lectures were also given to social groups on the island. A great deal of interest was shown by Arubans in the "American snake experts" working on the island. The researchers became well known to the general public and were frequently recognized by local people who were usually happy to express their opinions with regard to the rattlesnake.

Although no formal study was performed, there appeared to be an increased awareness by Arubans of the existence of the rattlesnake through the course of this PR campaign. This awareness seemed to be accompanied by a generally positive attitude towards the snake. Most people did not perceive the snakes as a threat and many people felt that the animal had a right to exist. A great deal of time was spent talking to people to establish and reinforce positive points of view about the natural environment of Aruba.

In addition to this public relations campaign were efforts to contact and talk to school groups on Aruba. This education program focused on grade school and middle school students. Understanding that ultimately the fate of the Aruban ecosystem lies in future generations of citizens and leaders of Aruba, it was felt that these groups could have a significant impact on the long term conservation of *C. d. unicolor*. These age groups are usually more receptive to new ideas. Through the numerous talks, it is hoped that the seeds have been laid to improve the probability that *C. d. unicolor* will survive on Aruba through the next century.

CONCLUSION

The Aruba Island rattlesnake Species Survival Plan is an ongoing effort to advance the conservation of this insular form and protect its critical habitat. Since this presentation in August 1991, significant advances have been made toward the long term conservation of *C. d. unicolor* on Aruba. In February of 1992, an International Symposium and a Population and Habitat Viability Assessment (PHVA) workshop were conducted on Aruba. These meetings were a cooperative effort of the American Association of Zoological Parks and Aquariums SSP, the IUCN - World Conservation Union - Captive Breeding Specialist Group, and the Aruba Department of Agriculture, Husbandry, and Fishes.

The meetings were a continuation of the multifaceted approach to the many conservation issues regarding *C. d. unicolor*. They included a general symposium to review the available data on *C. d. unicolor*, a snake envenomation workshop for medical professionals, a teachers workshop to demonstrate techniques for teaching conservation issues to students, and the PHVA. The location (Aruba) for the meetings was specifically chosen to involve as many Arubans as possible. Attending the meetings were members of Aruba government agencies, FINAPA (national parks), STIMARUBA (an active conservation organization on Aruba), and Arubans with an interest in conservation, as well as American conservation workers with expertise in a variety of biological disciplines.

The PHVA has resulted in the formulation of a Conservation Action Plan (CAP) that was prepared by the workshop attendees (Aruban, Dutch, and American). The CAP includes both the captive and wild population and will address habitat utilization and species management. The goal for the captive population has been changed to maintain 95% of the WGDR indefinitely as a backup for the wild population. This will require the importation of several additional animals (founders) from Aruba each generation. The goal for the wild population was established to reduce the probability of extinction of *C. d. unicolor* on Aruba during the next 100 years to less than 5%. This will be accomplished by setting aside sufficient habitat on the Island for a viable population, initiating legal protection to reduce incidental take, and using the captive population as a backup.

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LITERATURE CITED

BALLOU, J.D. 1989. CAPACITY Version 2.11: Wordtech Quicksilver Dbase compiler, Computer software to calculate carrying capacity from N_e, generation time, population growth rate, and program duration and goals. National Zoological Park: Washington, D.C.

BALLOU, J.D. 1991. Management of genetic variation in captive populations. In E. Dudley (Ed.): *The unity of Evolutionary Biology*. pp. 602-610. Dioscorides Press: Portland.

BALLOU, J.D. and T. FOOSE. (in press) 1992. Demographic and genetic management of captive populations. In Kleiman, D and S. Lumpkin (Eds.): *Wild Mammals in Captivity*. University of Chicago Press: Chicago.

BINGAMAN, L. and J.D. BALLOU. 1991. DEMOG2_2, Version 2.2: Lotus 123 Spreadsheet Demographic Model. National Zoological Park: Washington, D.C..

FLESNESS, N. 1977. Gene pool conservation and computer analysis. *Inter. Zoo. Yearb.* 17:77-81. Zoological Society of London: London.

FOLSCH, D.W. and P. LEOUP. 1976. Über eine uerlustreich verlaufene infektion in einon schlangenbestand. Verhandlungsgericht des XVII. Internationalen Symposiums uber die Erkrankungen der Zootiere. Akademie-Verlang, Berlin, 18:159-166.

FOOSE, T.J. 1983. The relevance of captive propagation to the conservation of biotic diversity. Pp.374-401. In C.M Schonewald - Cox, S.M. Chambers, B. Macbride, and L. Thomas (eds): *Genetics and Conservation.* Benjamin/Cummings: Menlo Parks, CA.

FOOSE, T.J., R. LANDE, N. FLESNESS, G. RABB, and B. READ. 1986. Propagation Plans. Zoo Biology 5:139-146.

JACOBSON, E., J.M GASKIN, J.P. FLANAGAN, and R.A. ODUM. 1991. Antibody responses to western diamondback rattlesnake, *Crotalus atrox*, to

inactivated ophidian Paramyxovirus vaccines. Journal of zoo Wildlife Medicine. (22) 2:184-190.
LACY, R.C. 1989. Analysis of founder representation in a pedigree: founder equivalents and founder genome equivalents. Zoo Biology 8:111-124.
LACY, R.C. 1991. GENES: C program to perform genetic analysis on single taxon databases, Version 9.2. Brookfield Zoological Society: Chicago.
MACE, G. 1986. GENEDROP: Computer software for Gene Drop Analysis. Zoological Society of London: London.
ODUM, R. A. 1990. *Studbook Management System, Version 3.0* Software. Toledo Ohio: Toledo Zoological Society and Houston Zoological Gardens.
PETERSON, KARL. H. 1992. International Studbook for the Aruba Island Rattlesnake, 1992 Edition. Houston Texas: Houston Zoological Gardens
SOULE, M.E., M. GILPIN, W. CONWAY, and T. FOOSE. 1986. The Millenium Ark: How long a voyage, how many staterooms, how many passengers?. Zoo Biology 5:101-113.

GUIDELINES FOR RADIOTELEMETRIC STUDIES OF RATTLESNAKES

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ABSTRACT

The use of radiotelemetry offers the opportunity to gain insights into snake behavior that cannot be obtained through the more traditional methods of search and survey or mark and recapture. This paper presents guidelines for designing, beginning, and evaluating a telemetric study of snakes. It includes information on transmitter package design, attachment, and tracking; suggestions for methods of analysis of movements, habitat use, population parameters, physiological responses, and conservation programs; and a discussion of some of the limitations and potential biases of telemetric studies.

The use of telemetry to study the ecology and physiology of snakes under field conditions is increasing rapidly. Rattlesnakes (*Crotalus* and *Sistrurus*) have been especially well represented in recent telemetric studies (Landreth, 1973; Means, 1977; Moore, 1978; Galligan and Dunson, 1979; Jacob and Painter, 1980; Brown, 1982; Brown et al., 1982; Reinert and Kodrich, 1982; Reinert, 1984a, 1984b; Reinert et al, 1984; Duvall et al, 1985, 1990; Reinert and Zappalorti, 1988a, 1988b). In addition, several telemetry projects involving rattlesnakes are currently in progress.

However, researchers wishing to begin radiotelemetric studies of snakes are often met with many inherent technical and methodological problems and pitfalls. This paper presents guidelines and suggestions for avoiding some of the disappointments and disasters. The contents of this paper were largely extracted from an earlier, more extensive review of the subject (Reinert, 1992) which appeared in the "Biology of the Pitvipers" (Campbell and Brodie, 1992).

Transmitters

Most researchers purchase commercially available transmitters. There are several reputable transmitter manufacturers who sell units that are suitable, or can be modified, for use with snakes. Manufacturers sell transmitters as "bare units" or as complete, potted packages with batteries and antenna wires installed. In many instances, the complete packages are designed incorrectly for use with snakes, and it is often best to purchase "bare units" and assemble your own package.

Packages should be designed to be as unobtrusive as possible. If the package is being placed in the coelomic cavity, it should be designed so as not to obstruct the intestinal tract or apply undue pressure to internal organs or blood vessels. A long, flat package is preferable to a short, cylindrical one. A transmitter that makes a highly discernible distention of the body is too large or incorrectly shaped. Transmitters to be implanted in the coelomic cavity should probably not exceed 5% of the snake's body mass.

The greatest transmission distances will be obtained from a transmitter equipped with a whip antenna. Transmitters with internal, tuned loop antennas are generally unsuitable because of their limited range.

A 1:1 mixture of beeswax and paraffin is recommended for potting transmitters destined for either intragastric or intraperitoneal insertion. This mixture produces a workable coating that is both easily applied and removed by the researcher when battery replacement is required. The assembled transmitter unit can be dipped to produce several water and abrasion resistant layers. The wax surface can be shaped to produce a non-abrasive, indigestible, tissue inert final package.

Receivers and Accessories

The receiver is the most important piece of telemetry equipment. Most transmitters produce very weak signals that require sensitive receiving equipment. A multichannel unit that covers a broad band width and is sensitive enough to monitor several transmitters with slightly different (0.005 - 0.010 MHz) frequencies is best. The receiver should produce both an audible signal and a visual display of signal strength. It should also have a gain control, battery indicator, and a jack for headphones. At current prices, an adequate receiver will cost close to $1000.

Tracking antennas come in several options. A hand-held, 3 element Yagi is probably most suitable for use in field location of snakes. The Yagi antenna can be moved in an arc in front of the investigator as he or she walks, making location of cryptic animals in dense vegetation easier and safer.

Transmitter Attachment

Three locations are available for attaching a transmitter to a snake: in the stomach (Fitch and Shirer, 1971; Fitch, 1987), under the skin (Weatherhead and Anderka, 1984), or in the coelomic cavity (Reinert and Cundall, 1982). Coelomic implantation is strongly preferred in almost all situations. A simple method for surgical implantation of long range transmitters with external whip antennas has been described by Reinert and Cundall (1982) with additional details given in Reinert (1992).

Radio Tracking

Field radio tracking is an art that requires practice. Transmission signals are influenced by the body position and location of the snake, intervening topography, and canopy structure. In most cases, the best signal will be obtained from the highest, most open vantage point. In certain situations such as valleys and canyons, reflected signals (back signals) may appear stronger than signals coming from the actual direction of the animal. To avoid long-distance treks in the wrong direction, listen frequently (or constantly) to the signal as you travel, take advantage of all high spots in the topography, and frequently check the actual direction of the signal by turning the tracking antenna through 360 degrees.

When attached to snakes, the transmitting antenna is usually horizontal and at ground level. This horizontal positioning of the transmitting antenna results in the best signal being obtaining when the receiving antenna is also held with its elements in a horizontal position.

Movements and Activity Ranges

Many studies have been undertaken to assess movements and activity ranges of snakes (reviewed in Gregory et al., 1987; Macartney et al., 1988), and many telemetry studies have this as their primary goal (e.g., Fitch and Shirer, 1971; Reinert and Kodrich, 1982; Tiebout and Carey, 1987). Extensive variation in the movement behavior among specimens, however, requires that a large number of individuals be monitored for extensive time periods (often complete seasons) for an adequate assessment of movement parameters (Reinert and Zappalorti, 1988a).

If assessment of activity ranges is the goal, the telemetry study must be designed to include a large number of specimens that represent adequate samples of the different subgroups within the population (i.e. males and females, gravid and non-gravid, adults and subadults). Five snakes per subgroup is probably the minimum number needed to obtain any statistical validity in the resulting comparisons. The frequency of location will depend upon the activity level of the specimens. Daily monitoring may be necessary; however, an adequate assessment of activity ranges can often be obtained for less active specimens with locations three to four times per week. Because many snakes appear to demonstrate shifting activity range centers (Tiebout and Cary, 1987; Reinert and Zappalorti, 1988a), monitoring movements throughout the entire active season is often necessary.

There are numerous methods available for calculating activity ranges (Jennrich and Turner, 1969). Of these, the convex polygon is the simplest and most commonly used method. However, the harmonic mean method of estimating activity ranges (Dixon and Chapman, 1980) has several advantages. It allows for the description of activity ranges of any shape, the determination of realistic activity centers (areas within the activity range with the greatest number of locational observations), the identification of multiple core areas of high activity, and requires fewer assumptions concerning the structure of the data.

Other measures of spatial activity include: total distance moved (the sum of all linear distances between locations), range length (linear distance between the two most distant locations), mean distance moved per day (total distance moved divided by the total number of days monitored), and mean distance per move (average of all distances between locations). Of these, total distance moved and mean distance moved per day are probably the most useful in evaluating spatial utilization.

Habitat Use

Perhaps one of the most useful aspects of telemetry is that it allows the researcher to make a more accurate assessment of preferred habitat (Reinert, 1993). For many cryptic animals our concept of their behavior and habitat preference may be strongly biased by our own prejudices and observational limitations. For example, the preferred habitat of *Crotalus horridus* was described incorrectly as rocky, open sites on the basis of many years of search and survey observations by numerous, experienced field biologists and naturalists. Only a short period of telemetric monitoring was necessary to reveal that these habitat descriptions were not representative of the habitat selected most frequently by this widespread and fairly common species (Reinert, 1984a). The error was the result of observational limitations imposed by chance encounter.

The habitat of an organism is a multidimensional resource requiring a multivariate approach for realistic evaluation (Carey, 1981). For such an analysis, the investigator must select a set of quantitative variables that are suspected to influence habitat use. These variables are then measured at each snake selected location and at a large series of randomly selected sites within the study area. A comparison between snake selected sites and random sites allows for an evaluation of both habitat selection and preferred habitat availability.

Several multivariate statistical methods are available for the analysis of such data (James and McCulloch, 1990). The overall purpose of these methods is to unravel correlations among variables and to reduce the dimensionality to understandable levels (preferably two or three meaningful dimensions). Most mainframe and many microcomputer statistical packages (e.g., SPSS, SPSSX, SAS, BMDP) contain programs that perform these basic multivariate analyses.

Population Parameters

There are several inherent problems in using radiotelemetry to estimate snake population parameters. The most serious drawback is that size and weight limitations usually restrict the tagging to the largest members of the population. Consequently, it may be possible only to include adults in the evaluation. For most snake species it would be imprudent to extrapolate such information to the remainder of the population. However, population estimates determined through more classical mark and recapture regimes have implicit assumptions concerning the sampled population such as equal catchability of marked and unmarked animals, permanence of marks, observability of marks, closed populations, or equal survivorship (Krebs, 1989). Telemetry can be used to check for violation of such assumptions and to assess the efficacy of sampling regimes (White and Garrott, 1990) such as drift fences and various trapping methods (Campbell and Christman, 1982; Vogt and Hine, 1982).

Radiotelemetry has also been used successfully to esitmate survival rates in various wildlife populations (Trent and Rongstad, 1974; Heisey and Fuller, 1985; Bunck, 1987). General techniques for survival analysis using telemetric data are described by Krebs (1989) and White and Garrott (1990). Plummer (1990) used telemtric data to estimate survival rates of gravid green snakes (*Opheodrys aestivus*) and was able to compare this data with survivorship estimates obtained from a prior mark and recapture study (Plummer, 1985).

Physiological Data

Telemetry opens new avenues for the study of the physiology of free-ranging snakes that have only begun to be explored. The thermal biology of reptiles has been a focal point in ecological studies, and many temperature sensitive transmitters which allow for the remote monitoring of deep body temperature are now commercially available. Transmitters are also available that can relate such additional pertinent physiological data as heart rate, blood pressure, blood flow rates, EEG, ECG, EMG, P_{CO_2}, P_{O_2}, and pH (Mackay, 1970, Smith, 1980).

The use of telemetry in the study of the field energetics of snakes holds great promise. Field metabolic rates of monitored animals over certain time periods can be determined by using isotopically labeled water (Nagy, 1975). By combining this information with body temperature profiles, activity patterns, and feeding frequency data gained from telemetric observation during the same time period, an accurate picture of energy requirements and expenditures may be achieved.

Conservation Programs

Conservation and management programs for wildlife species must be based upon sound ecological information (Giles, 1971). Programs conceived and designed without adequate or accurate data have little hope of success. Indeed, such programs may even have a negative impact upon the wildlife populations which they were designed to assist. For rare and secretive species, such as many rattlesnakes, telemetry offers the only viable option for obtaining accurate, unbiased behavioral and ecological data upon which to build useful conservation programs.

Radiotelemetric studies of threatened or endangered snake species should initially concentrate upon defining preferred habitat and methods for delineating optimal from sub-optimal sites (Reinert, 1993). Such information can then be used to define the extent of existing habitat and to design programs for habitat improvement.

The second most useful set of information that can be gained through telemetry pertains to the character and extent of movements. This information is necessary to determine the physical space required by individual snakes and the size of conservation zones. Data on movement patterns (seasonal, daily, age and sexual variations) are also helpful in designing programs to reduce human and snake interactions.

As predators, snakes are high trophic level components of their respective ecosystems. Important insight into the role of a snake species in the larger community and its interactions with other faunal elements can usually be gained from careful observation during radiotelemetric monitoring. Information concerning prey, predators, and competitors should be vigorously pursued during a telemetric study. It is obvious that such data may have important management implications.

Once the basic, required information is gathered, radiotelemetric monitoring can continue to be an invaluable tool for evaluating the utility and efficacy of implemented conservation and management programs. For example, studies may be performed to evaluate the response of monitored snakes to habitat improvement programs (G.

Johnson, pers. comm.), the impact of the translocation of individuals from undesirable areas to protected zones (Reinert, 1991), or the behavior and success of captive-reared specimens following their release into wild populations.

SUMMARY

It would be difficult to overstate the value of telemetry as a tool for the study of snake biology. It allows for repeated observation of the same specimen, remote data acquisition, and the reduction of observer induced locational bias. Already we have gained insights that were formerly unattainable, and certainly much of what we will learn in the future about snakes will be directly attributable to this technology. However, telemetry does have several drawbacks of which researchers should be aware.

First is the relatively high cost of the equipment and the high cost in terms of time and effort. For all but the most sedentary snakes, frequent location of specimens is required to avoid loss. Consequently, the information gained from telemetry studies tends to be based upon a large body of data obtained from a rather small sample size of individuals. An important consideration is that such data often lack the statistical independence assumed for numerous types of statistical analyses (Mathur and Silver, 1980; Reinert, 1984a).

Telemetry also imparts restrictions on the physical size of specimens monitored. The combined limitations of small sample size and large body size produce the fairly great potential for biased results. Currently, transmitters are too large for use in many of the smaller snake species or young individuals of larger species. The increasing availability of smaller transmitters and alternate monitoring methods (e.g., passive transponders [Mackay, 1970; Van Dyke, 1974; Mascanzoni and Wallin, 1986]) may help to alleviate this problem in the near future. However, the data base that we are presently accumulating is strongly biased toward larger snakes.

Finally, handling, surgery, constant disturbance through frequent observation, and the burden of the transmitters themselves may all tend to alter the behavior of snakes. This is certainly true for some ingested transmitters (Lutterschmidt and Reinert, 1990), and the effect of surgically implanted transmitters has not been experimentally evaluated. Using the smallest possible transmitters (3-5% or less of the body mass), returning the animals to the field as soon as possible (preferably within 24 hrs), and a conscious effort to be as unobtrusive as possible when locating and observing telemetered snakes will all aid in reducing bias associated with radio telemetry.

Clearly, telemetry is not without limitations, and the aforementioned factors need to be considered before beginning a telemetric study. However, with the aid of telemetry the dedicated researcher can gain insights concerning the biology of free-ranging snakes that cannot be obtained by any other method. During the past two decades, telemetric studies have contributed signficantly to our understanding of snakes. Undoubtedly, much of what will be learned during the next two decades will also be directly attributable to the use of this technology.

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LITERATURE CITED

BROWN, W.S. 1982. Overwintering body temperatures of timber rattlesnakes (*Crotalus horridus*) in northeastern New York. J. Herpetol. 16:145-150.

BROWN, W.S., D.W. Pyle, K.R. GREENE and J.B. FREIDLAENDER. 1982. Movements and temperature relationships of timber rattlesnakes (*Crotalus horridus*) in northeastern New York. J. Herpetol. 16:151-161.

BUNCK, C.M. 1987. Analysis of survival data from telemetry projects. J. Raptor Res. 21:132-134.

CAMPBELL, H.W., and S.P. CHRISTMAN. 1982. Field techniques for herpetofaunal community analysis. Pages 193-200 in N.J. Scott, Jr., editor. Herptological communities. U.S. Fish Wild. Res. Rep. 13.

CAMPBELL, J.A. and E.D. BRODIE, JR. 1992. Biology of the Pitvipers. Selva Publ. Co., Tyler, Texas, USA.

CAREY, A.B. 1981. Multivariate analysis of niche, habitat, and ecotope. Pages 104-113 in D.E. Capen, editor. The use of multivariate statistics in studies of wildlife habitat. United States Forest Service General Technical Report RM-87.

DIXON, K.R., and J.A. CHAPMAN. 1980. Harmonic mean measure of animal activity areas. Ecology 61:1040-1044.

DUVALL, D., M.J. GOODE, W.K. HAYES, J.K. LEONHARDT and D.G BROWN. 1990. Prairie rattlesnake vernal migrations: field experimental analysis and survival value. Nat. Geogr. Res. 6:457-469.

DUVALL, D., M.B. KING and K.J. GUTZWILLER. 1985. Behavioral ecology and ethology of the prairie rattlesnake. Nat. Geogr. Res. 1:80-111.

FITCH, H.S. 1987. Collecting and life-history techniques. Pages 143-164 in R.A. Seigel, J.T. Collins and S.S. Novak, editors. Snakes: ecology and evolutionary biology. Macmillan, New York, New York, USA.

FITCH, H.S., and H.W. SHIRER. 1971. A radiotelemetric study of spatial relationships in some common snakes. Copeia 1971:118-128.

GALLIGAN, J.H., and W.A. DUNSON. 1979. Biology and status of timber rattlesnake (*Crotalus horridus*) populations in Pennsylvania. Biol. Conserv. 15:13-58.

GILES, R.H., JR. 1971. Research to meet future management needs. Pages 156-160 *in* R.D. Teague, editor. A Manual of Wildlife Conservation, Wild. Soc., Washington, D.C., USA.

GREGORY, P.T., J.M. MACARTNEY and K.W. LARSEN. 1987. Spatial patterns and movements. Pages 366-395 in R.A. Seigel, J.T. Collins and S.S. Novak, editors. Snakes: ecology and evolutionary biology. Macmillan, New York, New York, USA.

HEISEY, D.M, and T.K. FULLER. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49:668-674.

JAMES, F.C., and C.E. McCULLOCH. 1990. Multivariate analysis in ecology and systematics: panacea or Pandora's box? Ann. Rev. Ecol. Syst. 21:129-166.

JENNRICH, R.I., and F.B. TURNER. 1969. Measurement of non-circular home range. J. Theor. Biol. 22:227-237.

KREBS, C.J. 1989. Ecological methodology. Harper & Row, New York, New York, USA.

LANDRETH, H.F. 1973. Orientation and behavior of the rattlesnake, *Crotalus atrox*. Copeia 1973:26-31.

LUTTERSCHMIDT, W.I. and H.K. REINERT. 1990. The effect of ingested transmitters upon the temperature preference of the northern water snake, *Nerodia s. sipedon*. Herpetologica 46:39-42.
MACARTNEY, J.M., P.T. GREGORY and K.W. LARSEN. 1988. A tabular survey of data on movements and home ranges of snakes. J. Herpetol. 22:61-73.
MACKAY, R.S. 1970. Bio-medical telemetry. J. Wiley and Sons, New York, New York, USA.
MASCONSONI, D., and H. WALLIN. 1986. The harmonic radar: a new method of tracing insects in the field. Ecol. Entomol. 11:387-390.
MATHUR, D., and C.A. SILVER. 1980. Statistical problems in studies of temperature preference of fishes. Can. J. Fish. Aquat. Sci. 37:733-737.
MEANS, D.B. 1977. Radio-tracking the eastern diamondback rattlesnake. Nat. Geogr. Soc. Res. Reports, 1977 Projects, pages 529-536.
MOORE, R.G. 1978. Seasonal and daily activity patterns and thermoregulation in the southwestern speckled rattlesnake (*Crotalus mitchelli pyrrhus*) and the Colorado desert sidewinder (*Crotalus cerastes laterorepens*). Copeia 1978:439-442.
NAGY, K. 1975. Water and energy budgets of free-living reptiles: measurement using isotopically labeled water. Pages 227-245 in N.F. Hadley, editor. Environmental physiology of desert organisms. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, USA.
PLUMMER, M.V. 1985. Demography of green snakes (*Opheodrys aestivus*). Herpetologica 41:373-381.
PLUMMER, M.V. 1990. High predation on green snakes, *Opheodrys aestivus*. J. Herpetol. 24:327-328.
REINERT, H.K. 1984a. Habitat separation between sympatric snake populations. Ecology 65:478-486.
REINERT, H.K. 1984b. Habitat variation within sympatric snake populations. Ecology 65:1673-1682.
REINERT, H.K. 1991. Translocation as a conservation strategy for amphibians and reptiles: some comments, conerns, and observations. Herpetologica 47:356-363.
REINERT, H.K. 1992. Radiotelemetric field studies of pitvipers: data acquisition and analysis. Pp. 185-197 *in* J.A. Campbell and E.D. Brodie, Jr., editors. Biology of the Pitvipers, Selva Publ. Co., Tyler, Texas, USA.
REINERT, H.K. 1993. Habitat selection in snakes. *In* R.A. Seigel and J.T. Collins, editors. Snakes: Ecology and Behavior. McGraw Hill, New York, NY. (in press)
REINERT, H.K., and D. CUNDALL. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia 1982:702-705.
REINERT, H.K., and W.R. KODRICH. 1982. Movements and habitat utilization by the massasauga, *Sistrurus catenatus catenatus*. J. Herpetol. 16:162-171.
REINERT, H.K., and R.T. ZAPPALORTI. 1988a. The timber rattlesnake (*Crotalus horridus*) of the Pine Barrens: its movement patterns and habitat preference. Copeia 1988:964-978.
REINERT, H.K., and R.T. ZAPPALORTI. 1988b. Field observation of the association of adult and neonatal timber rattlesnakes, *Crotalus horridus*, with possible evidence for conspecific trailing. Copeia 1988:1057-1059.
REINERT, H.K., D. CUNDALL and L.M. BUSHAR. 1984. Foraging behavior of the timber rattlesnake, *Crotalus horridus*. Copeia 1984:976-981.
SMITH, E.N. 1980. Physiological radio telemetry of vertebrates. Pages 45-55 in C.J. Amlaner and D.W. MacDonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford, England.
TIEBOUT, H.M., and J.R. CAREY. 1987. Dynamic spatial ecology of the water snake, *Nerodia sipedon*. Copeia 1987:1-18.

TRENT, T.T, and O.J. RONGSTAD. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. J. Wildl. Manage. 38:459-472.

VAN DYKE, D.L. 1974. A low cost very high frequency animal transponder tracking system. Biotelemetry 1:110.

VOGT, R.C., and R.L. HINE. 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. Pages 201-217 *in* N.J. Scott, Jr., editor. Herptological communities. U.S. Fish Wild. Res. Rep. 13.

WEATHERHEAD, P.J., and F.W. ANDERKA. 1984. An improved radio transmitter and implantation technique for snakes. J. Herpetol. 18:264-269.

WHITE, G.C., and R.A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

THE CONSERVATION OF THE EASTERN MASSASAUGA, *Sistrurus c. catenatus*, IN ONTARIO, CANADA

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Metro Toronto Zoo's massasauga rattlesnake conservation strategy began in 1988. At that time, the zoo began receiving an increasing number of requests for assistance with rattlesnakes. Most of the concerns were the result of young children playing in the areas where rattlesnake encounters had occurred. A significant shift in public attitudes was demonstrated by the fact that the callers did not want rattlesnakes killed. The zoo wanted to reinforce this new attitude and provide assistance in dealing with the snakes.

Because encounters with rattlesnakes often resulted in persecution, habitat protection alone would not be sufficient to ensure the snake's long term survival in Canada. This was particularly true where boaters or campers were concerned. These transient visitors had only occasional encounters with snakes, so there was no need to remove resident animals. Data on the dramatic decline of the eastern massasauga rattlesnake in Canada focussed our attention on the need for public education.

Of special concern was the recent division of one population into four separate populations. This genetic isolation in itself could threaten the viability of small outlying populations. But, in addition to this was the loss of relic populations and the fragmentation of the Great Lakes population into two genetically isolated groups with gene flow barriers between them. Not only were we concerned about the separation of populations, but also the speed of the population decline. The process of decline was happening at a rate that would compromise the demographic and genetic structure of the smaller populations. In effect, the reduction of a contiguous population into several small isolated populations increased the impact of development along the boundary of the rattlesnake's range. We were fortunate in recognizing these warning signals in advance of the loss of self sustaining populations and had the luxury of being able to develop experimental management protocols and an educational programme to slow the rate of decline until tolerance for this species could be established.

Because of the good habitat already available to the snake, public education was identified as the strategy most likely to reverse the decline of this species. Given the shy nature of this and most rattlesnake species, we argued for tolerance. As well, we decided to take our education programme directly to those living with the rattlesnake. Workshops at the zoo and in the areas where people and rattlesnakes had frequent contact focussed on the biology of the rattlesnake, the reasons why snake bite was unlikely to occur, how to avoid snakebite, how to treat snakebite, and, finally, the likelihood of full recovery even if snakebite and envenomation was to occur. This was placed in perspective with the number of deaths that occur each year from driving cars into deer, bee stings, dog maulings, or falling out of a boat and drowning. Few would recommend the extirpation of bees, bears, or dogs that kill people. We explained that snake bites would probably not result in death with proper hospital treatment, and that ecologically important snakes should be tolerated. In fact, we went further and suggested that, just like the conucu, rattlesnakes come as part of a package that includes the desirable aspects of the wilderness experience. It is not up to us to pick and choose which aspect of the experience we would preserve. The ecosystem itself, with all its functioning components, was integral to the snake's preservation.

Identifying those in the community who had the respect of their neighbours and who had some degree of understanding of the mythology or falsehoods that contributed to the fear of rattlesnakes was essential to our programme.

Two rattlesnake conservation and identification posters were distributed throughout the range of the rattlesnake. These made an appeal for tolerance and proper identification of snakes that might be encountered. They were designed to be attractive and recognizable from a distance. It was our intention that the posters become collectors items and be posted on homes as a reference for both factual information and conservation messages for many years. We also hoped the zoo would be contacted for more information or when snakes were encountered (The phone number was indicated on the poster). In fact, this is exactly what happened. We received many calls for assistance after people saw our posters. We anticipate that initially we will be consulted as a resource agency and then can distribute other factual information. With time, this role will be passed on to a local contact who has attended our workshop and is willing to act on behalf of the snake.

We also sent a newsletter," Rattlesnake Tales", to 280 Cottager Associations, conservation organizations, U.S. and Canadian government wildlife agencies, and all zoos within the range of the rattlesnake. The newsletter includes articles from the zoo, landowners, conservationists, children, and scientists. We wanted people to know that it wasn't just one person or one institution involved - this was a broad effort in conservation. Cottagers were invited to tell stories of their encounters with rattlesnakes, confirming that the snakes were usually quite shy and easily relocated away from areas frequented by people.

We took trips into rattlesnake habitat. I thought it was essential to take cottagers and other interested people to see where the snake lived and of course it was a very popular event.

As a continuing part of this programme, the Zoo holds Cottage workshops during which we bring 20 people into the zoo. This is done twice a year. We also take our workshop to areas where the rattlesnake is found and give presentations at annual meetings or in local libraries. These seminars last about four hours and detail snake biology, what venoms do, how antivenin is made and why it is effective in the treatment of bites, avoiding snakebite, snakebite treatment, how to live with rattlesnakes, and, if necessary, the safe removal and translocation of rattlesnakes. We allow people to have close contact with snakes. We bring out a massasauga rattlesnake and rattlesnake look-alikes so people can learn to identify them. We want them to focus on identification and see what is often mistaken for a massasauga. I think this is essential for developing a tolerance for all species that are unfamiliar or that come with a lot of mythology that generates misunderstanding and fear. Everyone who participates in these conservation education programmes receives a rattlesnake conservation certificate in appreciation of his/her contribution to the conservation of the massasauga rattlesnake.

A teacher education kit has been developed by the zoo's education unit for use in schools within the range of the rattlesnake. We also train workers whose jobs take them into areas where rattlesnakes may be encountered. This includes road construction crews, loggers, hydro transmission line workers, telephone cable workers, and local police departments.

A video detailing the above biological and conservation education information is loaned to people living in rattlesnake country and to agencies dealing with rattlesnakes.

We make sure that every cottager has an opportunity to identify and practise moving a snake to a safe container so that it can be moved to a designated area where it is less likely to come into contact with people. We also ask them to become delegates for their association. We want every lake to have a resident who is willing to volunteer to train other people for his/her association and come to the assistance of fellow cottagers if there is a snake found in someone's back yard. There is now an alternative to a cottager killing a snake. We recommend the use of brooms or shovels as good tools for carefully sweeping a snake into a garbage bucket for pick-up and relocation.

If necessary, we will translocate a snake. However, we will not release a snake unless the residents have identified a designated release site. For example, let's say there was an official request to remove a snake from a residence on a lake. We don't want to relocate the animal immediately because a cottager that lives two miles from the release site may panic at the thought of a venomous snake being two miles nearer. Instead, we'll wait for a letter from the cottager association with a designated release date and site. The snake will be released at that site.

We are working on a translocation programme to provide data on the survival of translocated snakes. If a high proportion of translocated snakes die, then we will re-examine our translocation strategy. To date, ten snakes translocated outside their home range have not only survived, but all the females have either given birth or been bred by resident males.

Finally, the number of people contacted through programmes that take people to see snake habitat and that bring people to the zoo for snake workshops is small when compared to the three million residents of Ontario. In order to reach more people, we designed an exhibit that is both attractive and representative of Georgian Bay habitat. This allows those who might not normally see snake habitat an opportunity to learn about the massasauga. It allows zoo visitors to hear how the rattle sounds so they know what the warning is and can explain what it means when they hear it. Graphic panels compare the relative dangers of other animals and other hazards: forty people die each year in the United States from dog interactions, eight people die each year in Canada from bee stings, one person dies each year in Ontario from black bear attacks, and many people die each year while driving to their cottages. In the past twenty-five years, no one has died from a snake bite in the Province of Ontario. We also give specific information about snake bite treatment and explain what a victim might expect at the hospital. The danger of the medical emergency of snake bite is not underplayed, but is kept in perspective with other hazards.

The Metro Toronto Zoo is committed to teaching people how to live with all wildlife. It is only through providing correct information to displace traditional misconceptions that a positive attitude change can be facilitated towards misunderstood animals.

SUMMARY AND RECOMMENDATIONS FOR THE ARUBA ISLAND RATTLESNAKE

Metro Toronto Zoo's eastern massasauga rattlesnake conservation and education programme has the following objectives:

* Public education
* Training in rattlesnake removal
* Research into translocation strategies and defining suitable release sites
* Fostering international co-operation in conservation programmes.

Possible application for the Aruba Island rattlesnake:

1. Public education
    * Interdependence of conucu and rattlesnake populations
    * Rattlesnake behaviour
    * First aid and hospital treatment for snakebite
    * Ways of living with rattlesnakes (take the program to residents)
  * Distribution of conservation posters
  * Education units for schools

Education programmes might include school teachers; local conservationists; police; agricultural workers; those who work on roads, quarries, electrical transmission, and water lines; and residents who live near rattlesnake habitat. All those who participate or contribute to the conservation of the Aruba Island rattlesnake should receive an Aruba Island Rattlesnake certificate of appreciation.

2. Relocating snakes from urban areas.

3. Perform research to establish the survivorship, movements, and behavioral alterations of translocated Aruba Island rattlesnakes.

A CHECKLIST OF THE AMPHIBIANS AND REPTILES OF ARUBA

Compiled by: R. Andrew Odum

AMPHIBIA

Anura - Frogs and Toads

Leptodactylidae

Pleurodema (Tschudi, 1838): Ten species in South America.

Pleurodema brachyops (Cope, 1884): Dori.
Identification: A small frog (<65mm) with conspicuous spots on the body under each thigh. These spots, which resemble eyes, are displayed by elevating the posterior part of the body.
Comments: Breeding usually coincides with sufficient rain (usually October through December) to produce temporary pools. Eggs are laid in white foam nests that float on the water. The rump spots may be used as a display to confuse predators or for sexual selection of males by females.

Bufonidae

Bufo (Laurenti, 1789): A large genus that is found almost worldwide in temperate and tropical climates.

Bufo marinus (Linnaeus, 1758): Giant toad, cane toad, marine toad, sapo.
Identification: A large species that exceeds 150mm. Large, pitted parotoid glands extend behind the head. The skin of this animal has a typical warty appearance that is common for many toad species.
Comments: *Bufo marinus* is an introduced species that has had a negative impact on native fauna. The secretions of the skin glands are very toxic and ingestion of this poison can be fatal. Symptoms of poisoning include profuse salivation and convulsions.

REPTILIA

Squamata - Sauria - Lizards

Gekkonidae

Gonatodes (Fitzinger, 1843): This genus includes approximately 18 species of small terrestrial and semi-arboreal lizards. Three species occur on Aruba.

Gonatodes a. albogularis (Dumeril and Bibron, 1836)
Identification: No stripe down center of back, round pupil, dark back.

Gonatodes antillensis (Van Lidth, 1887)
Identification: Vertical pupil.

Gonatodes v. vittatus (Lichtenstein, 1856)
Identification: Stripe down center of back in males, less defined as a series of dots on females, round pupil.

Phyllodactylus (Gray, 1828): Leaf-Finger Geckos. A large genus of gecko that contains over 60 species. The species found on Aruba is endemic.

*Phyllodactylus julieni** (Cope, 1885): Pega pega, house gecko.
Identification:
This gecko can be identified by its light and dark bands across the back and tail. The toe pads are smaller than those of *Thecadactylus rapicaudus*. At night, this animal loses most of it pigmentation and appears almost translucent.
Comments: A nocturnal gecko that may be encountered around human dwellings, in the leaf litter around trees, and in rock crevices.

Thecadactylus (Goldfuss, 1820): A monotypic genus of the gekkonidae which is distributed throughout Mexico, Central and South America, and the Caribbean Islands. Because this animal is commonly found in cohabitation with people, it has been frequently transported in cargo on ships and planes, and has been introduced to many locations.

Thecadactylus rapicaudus (Houttuyn, 1782): Pega pega, house gecko.
Identification: Large toe pads allow this species to climb walls and glass. The spotted pattern makes the identification of this species easy. At night, this animal loses most of its pigmentation and appears almost translucent.
Comments: A nocturnal lizard common throughout Aruba; especially common around human dwellings where they catch insects that are attracted to light sources. *Thecadactylus* is more common than the endemic *Phyllodactylus julieni*.

Iguanidae

Iguana (Laurenti, 1768): Two species of *Iguana* are recognized. The more widely distributed *I. iguana* is found on Aruba.

* Indicates endemics

Iguana iguana (Linnaeus, 1758): Common iguana, green iguana.
Identification: A large species that reaches two meters in total length. The young may be bright green or green/brown. Adults are generally darker in color and have a conspicuous spine . Iguana meat is considered a delicacy, and is commonly eaten by people throughout its range.

Polychridae

Anolis (Daudin, 1802): This is the largest genus of lizards in the world, comprising over 250 species.

Anolis lineatus (Daubin, 1804): Anole.
Identification: This is a greenish brown lizard with a light stripe down each side of the body. Like most anoles, this animal spends most of its time in bushes and trees. The male can be easily identified by its throat dewlap that is used in territorial and courtship displays.

Teiidae

Ameiva (Linnaeus, 1758): Fifteen species are included in this genus that is distributed from Panama southward through tropical South America and the Caribbean.

Ameiva b. bifrontata (Cope, 1862): Ameiva.
Identification: This is a khaki green lizard that resembles the Aruba whiptail in body form. The larger size of adults and the absence of the bright blue coloration differentiates this animal from the Aruba whiptail lizard.
Comments: There appears to be some dispute as to whether this lizard is native to Aruba. Schall (1973) has said that this animal was introduced around 1940, while Ruthven (1923) refers to this animal originally being collected by Cope in the late 1800's. A substantial portion of the Ameiva's diet is young *Cnemidophorus arubensis*. If this animal has been introduced in recent times, it may ultimately displace the native whiptail.

Cnemidophorus (Wagler, 1830): Thirty-six species distributed in the temperate and tropical Americas.

*Cnemidophorus arubensis** (Van Lidth, 1887): Aruba whiptail lizard.
Identification: This is the bright cobalt blue lizard (this color is particularly pronounced in males) that is found throughout the island. Females are less colorful, but can be differentiated from *Ameiva bifrontata* with green-blue spots laterally.
Comments: The Aruba whiptail lizard is an opportunistic feeder, eating a variety of plants. When available, insects and carrion are also consumed.
Cnemidophorus l. lemniscatus (Linnaeus, 1758): Venezuela whiptail lizard
Comments: An introduced species that was probably carried from the mainland on oil tankers.

* Indicates endemics

Tretioscincus (Cope, 1862): Two species comprise this small genus. This animal is commonly associated with human dwellings and has been introduced into many locations.

Tretioscincus bifasciatus kugleri (Dumeril, 1851):

Identification: A small terrestrial and semi-arboreal lizard that is identified with its keeled scales. Length less than 15 cm.

Squamata - Serpentes - Snakes

Colubridae

Leptodira (Fitzinger, 1843): Nine species distributed from southern Texas, through Central and South America, to Northern Argentina and Paraguay.

*Leptodira bakeri** (Van Lidth, 1887): Aruba cat-eyed snake.

Identification: Small thin snake with brown blotches on back. No rattle.

Comments: This animal is found throughout the island and may be common near homes. Its diet includes lizards and the dori frog, which it actively hunts at night.

Viperidae

Crotalus (Linnaeus, 1758): Twenty-six species distributed in North, Central, and South America.

*Crotalus durissus unicolor** (=*C. unicolor*) (Van Lidth, 1887): Aruba cascabel, Aruba Island Rattlesnake.

Identification: This animal is clearly identified by its rattle.

Comments: The population has been dwindling and its current status may be critical. The scientific name *unicolor* refers to the uniform dusty coloration that is prevalent in adults.

* Indicates endemics

Problem of "Non-Specific Stress"
Aruba Island Rattlesnake PHVA Workshop

David Chizar

The concept of stress can be divided into two components. Specific stressors include extreme climatic conditions, extreme exertion or energy utilization, severe reductions in critical resources, and the consequences of social domination, intra- and inter-specific competition. Frequent harassment by predators can also be placed into this category. Although these stimulus factors vary considerably, they have several common features. For example, they are all naturally occurring phenomena with which the species have probably coped during their evolutionary histories. Consequently, animals possess evolved physiological and behavioral mechanisms that contribute to survival in times of natural distress.

On the other hand, we must recognize that human intrusions into ecosystems can sometimes create disturbances that are more-or-less novel (or supra-ecological) for affected organisms. War games, motorcycles, and jeeps not only kill some animals and destroy vegetation and soil, they also generate various stimuli that disturb surviving animals (See Table 1 for details regarding types of disturbances and their intensities in the habitat of *C. d. unicolor* on Aruba).

In some species, escape behaviors are activated by serious disturbances, in some other species, animals remain in hiding places until the disturbance subsides. Both types of response can interfere with feeding and reproduction. Frequent disturbance, therefore, can have profound consequences, particularly if animals do not habituate to them. In the extreme, we might expect to see something akin to Selye's "General Adaptation Syndrome" (a set of physiological responses arising from chronic activation of the pituitary adrenal axis). This research area has developed considerably in recent years, producing insights and empirical laws that are far more refined than Selye's original findings. Numerous stimuli that are uncontrollable and unmitigatable by animals can generate this state of affairs. Hence, the term "non-specific stress" is frequently used as a label for the effects of these stimuli. Moreover, uncontrollable aversive events lead to profound neuropharmacological effects, to immunosuppression, and to inhibition of reproductive events.

Here are the reasons why we consider non-specific stress to be relevant to the *C. d. unicolor* SSP. First, the habitat is small (approximately 44 square kilometers) and bordered by impenetrable or suboptimal areas. This means that the snakes cannot migrate to other areas consequent to serious disturbance in the prime habitat. Second, the smallness of the habitat means that some human activities (e.g. war games, limestone blasting) might very well disturb most of the snake population. This is an important point because we are no longer talking about isolated individuals (as is the case in all experimental and clinical work on the effects of uncontrollable aversive events), rather we are talking about a population phenomenon (indeed, an entire taxon is involved). Third, there is reason to suspect that the effects of non-specific stress will interact with the effects of climatic exigencies and with effects of environmental insults. For example, the human occupied borders around *C. d. unicolor* habitat probably contains some pollution (from several sources), and the ability of the snakes to tolerate this insult may very well depend upon their physiological condition. Likewise, animals possessing mechanisms that permit toleration of drought or prolonged fasts may be less able to deploy these mechanisms if they have endured a period of uncontrollable aversive events. Although evidence for such assertions is sketchy in reptiles, there is no question these interactions occur in mammals.

These thoughts lead to the following recommendations. Most important, we need to conduct research on the effects of uncontrollable aversive events on reptiles. This will tell us whether or not the mammal literature is generalizable to the problems at hand. In the absence of this information, it is reasonable to assume that reptiles suffer from human intrusion. For *C. d. unicolor*, this is a serious matter because of the smallness of the habitat. Hence, the habitat ought to be protected as much as possible.

Research on the effects of non-specific stress should concentrate on several big questions. Do rattlesnakes habituate to disturbance? How long, following disturbance, do the effects persist? Do the effects of stress include increased vulnerability to infection and inhibition of reproduction? Care must be taken to distinguish between short-term (acute and reversible) and long-term effects of stressful stimuli. Although acute effects can be dramatic, they do not necessarily produce lasting consequences of importance for the *C. d. unicolor* SSP. Our focus must be on the long-term effects.

The Competence of Captive-Raised Animals

In recent years it has become abundantly clear that captive-raised animals are not equivalent to wild conspecifics. We have an indication of this difference from the fact that translocations involving captive animals are less often successful than are translocations of wild ones. The difference between captive and wild animals is not a simple matter, and there are doubtless many factors contributing to it. Recent research, mainly with birds and mammals, has revealed that anatomical, physiological, and behavioral variables are influenced by the conditions of captive rearing. Also, when big differences between captive and wild animals have been identified, it has been possible to institute programs of therapy to rehabilitate the captive animals.

Although this research area is still in its infancy, the results so far have been promising. Consequently, we are encouraged to apply these techniques to *C. d. unicolor*. The first step must be to study the development of captive specimens, measuring a wide variety of dependent variables, (e.g. predatory skill, avoidance of predators, locomotory performance, digestive efficiency, growth, anatomical dimensions, microhabitat preferences, and reproductive factors). An ideal strategy would involve systematic comparison of each measure of captive animals with the same measure taken in wild conspecifics. This approach, however, is contra-indicated by the undesirability of removing wild animals from the extant population. So, we must make use of a fall-back option that has been used by other researchers who have faced similar problems. This plan calls for comparison of captive-raised *C. d. unicolor* with wild congeners. No serious loss in experimental resolution should result from this technique.

It is proposed that a sample of at least 10 SSP surplus animals be devoted to this effort. A reasonable procedure would be for the animals to be placed under the control of a principle investigator (P.I.) who will take primary responsibility for data gathering. At intervals of six months, this investigator should report progress to the SSP co-ordinator. These reports should be made both in writing and orally. Further, the oral exchanges should be made in meetings attended by other members of the *C. d. unicolor* SSP, so that the P.I. and the SSP co-ordinator can benefit frequently from constructive criticism and suggestions by these knowledgeable people.

Another important element should be added to this research effort. The SSP co-ordinator should encourage some institutions to raise and maintain specimens of *C. d. unicolor* in quasi-natural habitats (as naturalistic and spacious as possible, with rocks, plants and other appropriate materials in the habitats). Behavioral and other measures taken from these animals can be compared with the same measures taken on specimens in standard cages. This data set will be interesting for its own sake, and it likely will contribute to our understanding of competence. For example, it is conceivable that certain features of quasi-natural habitats will be identified as critical for the appearance of desirable behaviors. In this way, we shall be developing therapy programs at the same time as we are identifying the deficits of traditionally-housed captive animals. This approach is of sufficient importance that it should be regarded as an integral component of this proposal.

A Need for Literature Synthesis

Inasmuch as the discipline of restoration biology is in a rapidly developing phase of growth, it is vital for this SSP to remain tuned to important conceptual and empirical findings. Persons attending this meeting are experts in different aspects of the discipline, and the sharing of perspectives and expertise has been incredibly beneficial. Here, we are advocating and intensification and continuation of this activity. The SSP co-ordinator should name an individual (or a small committee) to prepare reviews or annotated bibliographies that summarize literature pertinent to the SSP mission. These documents are not necessarily to be polished pieces of scholarship. Rather, they should be more like newsletters, designed to familiarize the SSP participants with diverse published and unpublished projects of potential use to our collective goals vis a vis *C. d. unicolor*. The multidisciplinary nature of our goals demands the difficult background work of familiarizing ourselves with diverse findings, made all the more difficult because of the rapidly expanding nature of the discipline of restoration biology. It is to this end that the present proposal is directed. The newsletter should be prepared periodically (say twice per year), submitted to the SSP co-ordinator, and eventually distributed by the co-ordinator to all SSP participants.

Table 1

Disturbances Known to Influence *C. d. unicolor*

Activity	**Quantification**
War Games*	100-150 people, 4 day exercises; twice/year
Sheep and Goats*	10,000
Feral cats*	4821
Feral dogs*	8,621
Donkeys	25
Pigs	Probably forage only at the edge of the habitat
Limestone quarrying* (includes blasting and trucking)	Weekly blasting, daily trucking
Recreational vehicles (motorcycles and jeeps)	Occasional (habitat not easily penetrated
Organized tourist trips	Two companies operating, but in ecologically sound ways

* Most significant disturbances

ARUBA ISLAND RATTLESNAKE

(*Crotalus durissus unicolor*)

REPORT
30 November 1992

SECTION 9

BIBLIOGRAPHY

Crotalus d. unicolor

Bibliography

Amaral, A. 1929. Estudos sobre ophidios neotropicos XVIII. Lista remissiva dos ophidios da regio neotropica. Mem. Inst. Butantan, 4:viii + 129-271.

_______. 1929. Key to the rattlesnakes of the genus *Crotalus* Linne, 1758. Bull. Antiven. Inst. Amer., 3(1):4-6.

Armstrong, B.L. and J.B. Murphy. 1979. The Natural History of Mexican Rattlesnakes. Univ. Kansas Mus. Nat. Hist. Spec. Publ. no. 5.

Banta, B.H. 1957. A simple trap for collecting desert reptiles. Herpetologica, 13:174-176.

Boulenger, G.A. 1896. Catalogue of the snakes in the British Museum (Natural History). Vol. 3, London. xiv + 727 p.

Bowler, J.K. 1977. Longevity of reptiles and amphibians in North American collections as of 1 November,1975. Soc. Stud. Amphib. Rept. Misc. Publ. Herpetol. Circ., (6):iv + 32 p.

Brattstrom, B.H. 1964. Evolution of the pit vipers. Trans. San Diego Soc. Nat. Hist., 13(11):185-268.

Brongersma, L.D. 1940. Snakes of the Leeward group, Venezuela and eastern Colombia. Studies on the fauna of Curacao, Aruba, Bonaire, and the Venezuelan Islands, 2(8):115-137.

_______. 1959. Some snakes from the Lesser Antilles. In P.W. Humerelink (Ed.) Studies on the fauna of Curacao, Aruba, Bonaire, and the Venezuelan Islands, 9(37):50-60.

Brower, J., J. Zar, and C. von Ende. 1990. Field and Laboratory Methods for General Ecology. W.C. Brown, Dubuque, IA.

Brown, J.H. 1973. Toxicology and pharmacology of venom from poisonous snakes. Charles C. Thomas Publ., Springfield, Illinois, xiv + 184pp.

Campbell, H.W., and S.P.Christman. 1982. Field techniques for herpetofaunal community analysis. In N.J. Scott, Jr., (ed.) Herpetofaunal Communities. U.S. Fish and Wildl. Ser. Wildl. Res. Rep. no. 13. pp. 193-200.

Campbell, J.A., and W.W. Lamar 1989. The Venomous Reptiles of Latin America. Cornell Univ. Press, Ithica, New York.

Carl, G., K.H. Peterson, and R. Hubbard. 1982. Reproduction in captive Aruba Island rattlesnakes, *Crotalus unicolor*. Herpetol. Rev., 13(3):89-90.

Chiszar, D., O'Connell, B., Greenlee, R., Demeter, B., Walsh, T., Chiszar, J., Moran, K., and Smith, H.M. 1985. Duration of strike-induced chemosensory searching in long-term captive rattlesnakes at National Zoo, Audobon Zoo, and San Diego Zoo. Zoo Biol., 4(4):291-294.

Cochran, G.A., and H.J. Stains. 1961. Deposition and decomposition of fecal pellets by cottontails. J. Wildl. Manage. 25:432-435.

Davis, D.E., and R.L. Winstead. 1980. Estimating the numbers of wildlife populations. Pp. 221-245 In S.D. Schemnitz (ed.) Wildlife Management Techniques Manual. The Wildlife Society, Washington, DC.

Ditmars, R.L., 1905. A new species of rattlesnake. Ninth Ann. Rep. New York Zool. Soc., (1904):197-200.

_______. 1941. Reptiles of the world. MacMillan Co., New York, xx + 321pp., 89 pl.

Ellison, L. 1960. Influence of grazing on plant succession of rangeland. Bot. Review 261-78.

Fischman, H.K., J. Mitra, and H. Dowling. (1972). Chromosome characteristics of 13 species in the order Serpentes. Mammalian Chromosomes Newsletter 13(1):7-9.

Glenn, J.L., and Straight, R.C., 1982. The rattlesnakes and their venom yield and lethal toxicity. In A. Tu (ed.) Rattlesnake venom; their actions and treatment. Marcel Dekker Inc., New York. pp. 3-120.

Gloyd, H.K. 1936. The status of *Crotalus unicolor* Van Lidth de Jeude and *Crotalus pulvis* Ditmars. Herpetologica, 1(2):65-68.

_______. 1940. The Rattlesnakes Genera *Sistrurus* and *Crotalus*. A study in zoogeography and evolution. Spec. Publ. Chicago Acad. Sci., (4) vii + 266 + 4.

Goode, M., C.W. Radcliffe, K. Estep, A. Odum and D. Chizar. 1990. Field observations on feeding behavior in an Aruba Island rattlesnake: Strike-induced chemosensory searching and trail following. Bull. of the Psych. Soc., 28(4):312-314.

Harding, K.A., and K. Welch, 1980. Venomous snakes of the world, a checklist. Permagon Press, Oxford, England, x + 188pp.

Harris, H.S., and R.S. Simmons. 1972. A checklist of the rattlesnakes (*Crotalus durissus* group) of South America. Bull. Maryland Herp. Soc., 8(1):27-32.

_______. 1972. Keys to the neotropical species and subspecies of the *Crotalus durissus* group. Bull. Maryland Herp. Soc., 8(2):33-40.

_______. 1977. A preliminary account of insular rattlesnake populations, with special reference to those occurring in the Gulf of California and off the Pacific coast. Bull. Maryland Herp. Soc., 13(2):92-110.

_______. 1978. A preliminary account of the rattlesnakes with the description of four new subspecies. Bull. Maryland Herp. Soc., 14(3):105-211.

Hayne, D.W. 1949. An example of the strip census method for estimating animal populations. J. Wildl. Manage., 13:145-157.

Hoge, A.R. 1966. Preliminary account on neotropical Crotalinae (Serpentes, Viperidae). Mem. Inst. Butantan, 32:109-184 (1965).

_______, and R. Hoge, S.A.R.W.L., 1981. Poisonous snakes of the world. Part 1. Checklist of the pit vipers (Viperoidea, Viperidae, Crotallnae). Mem. Inst. Butantan, 42/43:179-309.

Hudson, R. 1984. The species survival plan (SSP) and its application to reptiles, pp.1-9. In Peter J. Tolson (ed.), Proc. 7th annual reptile symposium on captive propagation and husbandry, Zool. Consortium Inc., Thurmont, Maryland, 149pp.

Hummelinck, P.W. 1940. Studies on the Fauna of Curacao, Aruba, Bonaire and the Venezuelan Islands: No. 3. Zoogeographical Remarks. In P.W. Hummelinck (ed.) Studies on the fauna of Curacao and other Caribbean islands. Foundation for the Scientific Research in Surinam and the Netherlands Antilles, Netherlands.

IUCN. 1990. 1990 IUCN Red List of Threatened Animals. Cambridge, United Kingdom. 228pp.

Kauffeld, C.F. 1937. Relative Rattlesnakes. News Bull. of the Staten Is. Zoo. Soc., 4(5):3.

_______. 1969. Snakes: The Keeper and the Kept. Doubleday and Co., Garden City, New York.

_______, C.F., and Gloyd, H.K., 1939. Notes on the Aruba rattlesnake. Herpetologica, 1(6):156-160.

Klauber, L.M. 1936a. A statistical study of the rattlesnakes. I. Introduction. Occ. Pap. San Diego Soc. Nat. His., (1):2-7.

_______. 1936b. A key to the rattlesnakes with summary of characteristics. Trans. San Diego Soc. Nat. Hist., 8(20):185- 276.

_______. 1937. A statistical study of the rattlesnakes. IV. The growth of the rattlesnake. Occ. Pap. San Diego Soc. Nat. Hist., (3):1-56.

_______. 1941. Four papers on the application of statistical methods to herpetological problems. Part IV. The rattlesnakes listed by Linnaeus in 1758. Bull. Zool. Soc. San Diego, (17):81-95.

_______. 1972. Rattlesnakes: Their Habits, Life Histories, and Influence On Mankind. 2 vols. Univ. Calif. Press., Berkeley, California.

Krebs, C.J. 1989. Ecology Methodology. Harper and Row, New York.

Kristensen, I. 1982. Amphibians and Reptiles. In (Eds. E.Jansen, I Kristensen, J. Maduro, V. Rooze, R. Stanley) Discover Aruba's Wildlife. STINAPA (26).

MacLean, W.P., R. Kellner, and H. Dennis. 1977. Island Lists of West Indian Amphibians and Reptiles. Smithsonian Herpetological Information Service (40). Smithsonian, Washington, D.C.

McCranie, J.R., 1986. *Crotalus unicolor* Van Lidth de Jeude, Aruba Island rattlesnake. In William J. Reimer (ed.) Cat. Amer. Amph. Rept., Soc. for St. Amp. Rep., pp. 389.1-389.2.

Meek, S.E. 1910. Notes on batrachians and reptiles from the islands north of Venezuela. Field Mus. Nat. Hist. Zool. Ser., 7(12):415-418.

Moore, G.M., S.A. Minton, H.G. Dowling, and F.E. Russell. 1968. Poisonous Snakes of the World. A manual for use by U.S. amphibious forces. Gov. Printing Office, Washington, D.C., viii + 212pp.

O'Connell, B.R., J. Bacon, and D. Chiszar. 1982. Strike-induced chemosensory in Old World vipers and New World pit vipers at the San Diego Zoo. Zoo Biol. 1(4):287-294.

Odum, R.A. 1987. Funding proposal, *Crotalus unicolor* Species Survival Plan. Houston Zoo, Houston, Texas.

_______. 1987. *Crotalus unicolor* Species Survival Plan, Master Plan, Status and Recommendations, 1987-88. Houston Zoo, Houton, Texas.

_______. 1989. *Crotalus unicolor* Species Survival Plan, Master Plan, Status and Recommendations, 1989-90. Houston Zoo, Houton, Texas.

_______. 1990. *Crotalus durissus unicolor* Species Survival Plan, Master Plan, Status and Recommendations, 1990-91. Toledo Zoo, Toledo, Ohio.

_______. 1991. On the Hunt in Aruba. Safari. Toledo Zoo. 7:1 12-13.

_______. 1992. *Crotalus durissus unicolor* Species Survival Plan, Master Plan, Status and Recommendations, 1992-93. Toledo Zoo, Toledo, Ohio.

_______, and M. Goode. In press. *Crotalus durissus unicolor* SSP: A multifaceted approach. In. (Ed. J. Murphy) The Proceeedings of the Roger Conant Symposium, State College, Penn. SSAR.

O'Connell, B., R. Greenlee, J. Bacon, and D. Chiszar. 1982. Strike-induced chemosensory searching in Old World vipers and New World pit vipers at San Diego Zoo. Zoo. Biol., 1(4):287-294.

Pfaff, S. 1992. Aruba. Riverbanks, 10(3) 20-21.

Perkins, C.B. 1951. Hybrid rattlesnakes. Herpetologica, 7:146.

Peters, J.A., and B. Orejas-Miranda. 1970. Catalogue of the neotropical squamata: Part 1. Snakes. Bull. United States Natl. Bus., 297:1-347.

_______. 1986. Catalogue of the neotropical squamata: Part 1. Snakes. Revised ed. Smithsonian Inst. Press, Washington, D.C., 293pp.

Peterson, C.R. 1987. Daily variation in the body temperature of free ranging garter snakes. Ecology, 68:160-169.

Peterson, K.H. 1992. Aruba Island Rattlesnake Studbook *Crotalus durissus unicolor*. Houston Zoo, Houston, Texas.

Phelps, T., 1984. Poisonous snakes. Blanford Press, Poole, Dorset, United Kingdom, viii v + 237pp.

Pope, C.H., 1944. The poisonous snakes of the New World. New York Zool. Soc., viii + 47pp.

Reinert, H.K. 1984. Habitat variation within sympatric snake populations. Ecology, 65:1673-1682.

_______. 1992. Radiotelemetric field studies of pitvipers: data acquisition and analysis. Pp. 185-197 In J.A. Campbell and E.D. Brodie (eds.) The Biology of Pitvipers, Selva Publ. Co., Tyler, TX.

_______, and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia, 1982:702-705.

_______, and R.T. Zappalorti. 1988. Timber rattlesnakes (*Crotalus horridus*) of the pine barrens: their movement patterns and habitat preference. Copeia, 1988:964-978.

_______, R. Johnson, and M. Goode. 1992. Final habitat report. Report and recommendations for the Population and Habitat Viability Assessment Workshop, 5-7 February, Palm Beach, Aruba. IUCN/SSC/CBSG, Apple Valley, MN.

Rosenberg, P., 1987. Common names index: poisonous animals, plants and bacteria. Toxicon, 25(8):799-890.

Ruthven, A.G. 1923. The reptiles of the Dutch Leeward Islands. Occ. Pap. Mus. Zool. Univ. Mich., (143):1-10.

Sarmiento, G. 1976. Evolution of and vegetation in tropical America. pp. 65-99. In D.W. Goodall (ed.) Evolution of desert biota. Univ. Texas Arling. Press., Austin.

Snider, A.T., and J.K. Bowler. 1992. Longevity of reptiles and amphibians in North American collections. Soc. Stud. Amphib. Rept. Misc. Publ. Herpetol. Circ., (21):iv + 40.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman and Co., San Francisco, CA.

Stille, B., 1987. Dorsal scale microdermatoglyphics and rattlesnake (*Crotalus* and *Sistrurus*) phylogeny (Reptilia: Viperidae: Crotalinae). Herpetologica, 43(1):98-104.

_______. 1987. *Crotalus vegrandis* Klauber, (Uracoan Rattlesnake). Forked Tongue, (Newsl. Great. Cinti. Herp. Soc.), 12(8):7-12.

Strimple, P.D. 1987. *Crotalus unicolor* Van Lidth de Jeude,(Aruba Island Rattlesnake). Forked Tongue, (Newsl. Great. Cinti. Herp. Soc.), 12(12):3-15.

Tryon, B.W. 1986. The Island, The Rattlesnake, and The Species Survival Plan. Brit. Herp. Soc. Bull. 16:20-24

Tu, A. 1982. Rattlesnake venoms; their actions and treatment. Marcel Dekker Inc., New York, ix + 393pp.

U.S. Government. 1987. Endangered and threatened wildlife and plants. Pp. 176-196 in Title 50 - Wildl. and Fish. U.S. Gov. Print. Offi., Washington, DC.

Van Lidth de Jeude. 1887. On a collection of reptiles and fishes from the West Indies. Notes Leyden Mus., 9:129-139.

Voous, K.H. 1983. Birds of the Netherlands Antilles. Van Dorp-Eddine N.V., Curacao.