HOUSTON TOAD
POPULATION & HABITAT VIABILITY ASSESSMENT

A contribution of the IUCN/SSC Conservation Breeding Specialist Group and the United States Fish and Wildlife Service in partial fulfillment of contract #94-172.

The primary sponsors of this workshop were: The National Fish & Wildlife Foundation, the Lower Colorado River Authority, Horizon Environmental Services, Inc., The Texas Organization for Endangered Species, Espey, Houston & Associations, The Bastrop County Environmental Network, The City of Bastrop, Bastrop County, The National Audubon Society, The Sierra Club State Chapter, The Nature Conservancy, The Texas Forest Service, Texas Parks & Wildlife Department, National Wildlife Federation and the United States Fish & Wildlife Service.

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Houston Toad Population & Habitat Viability Assessment Report. U.S. Seal (ed.). IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. 1994: 1-145.

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POPULATION AND HABITAT

VIABILITY ASSESSMENT

HOUSTON TOAD

Bufo houstonensis

U. S. Seal, Executive Editor

Report of Workshop conducted by CBSG in partial fulfillment of USFWS Contract #

23-25 May 1994

Austin, Texas

The work of the Conservation Breeding Specialist Group is made possible by generous contributions from the following members of the CBSG Institutional Conservation Council

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Bufo houstonensis

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POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 2

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Executive Summary

The Houston toad (*Bufo houstonensis* Sanders 1953) is endemic to southeast and central Texas. Six disjunct metapopulations of the Houston toad are currently extant in seven different counties, and a small population occurs in Lavaca County. The toad may occur in Lee, Caldwell and Waller counties. It probably has been extirpated from its historic localities in Harris, Liberty, and Fort Bend counties.

There is a strong correlation between occurrence of the Houston toad and two separate bands of geologic formations, on which the deepest sands in the region occur. Four populations occur on the band of geologic formations (Carrizo, Queen City, Sparta, Reclaw, Weches) that runs through Bastrop County northeast to Freestone County. Two metapopulations and the Lavaca County population occur on the other band (Willis and Goliad) that runs parallel to and southeast of the first band, through Lavaca, Austin, and Colorado counties.

The Bastrop County population is the most robust and appears to be stable at the present time. About 70-100 square miles of potential habitat based on geologic formations and native woodland occurs in this area. Public lands include Bastrop and Buescher State Parks and the Lower Colorado River Authority's land around Lake Bastrop totalling about 6,000 acres.

The size and status of the other populations is unknown. However, these populations occur within areas that appear to provide suitable habitat (based on relatively contiguous deep [>40 inches], sandy soils and native vegetation) in large enough blocks (20,000-50,000 acres) to support long-term viable populations. The amount of habitat at the Lavaca County site has not been estimated, but appears limited and marginal. Other than the Bastrop County metapopulation, no other population occurs on public land.

Little is known about the toad's activities during the non-breeding season, except that they aestivate/hibernate in sandy soils during some portion of this season. During the breeding season, many toads do not appear to be faithful to certain breeding sites, but rather move from one site to another. These movements between sites provide the basis for genetic and demographic exchange between what may appear to be isolated small populations or satellite populations to a large population. The risk of extinction and viability of this complex of populations (a metapopulation) will depend upon the size of these populations, the rate of exchange between them, the configuration of exchanging populations, and the threats impacting each of the individual units. Individual male toads have been known to move 1400 meters (1.4 km, 0.87 miles) or more between breeding sites (cumulative distance - including back and forth movements). Straight line distance was estimated at approximately 700 meters.

Fifty biologists, managers, government officials, professors, non-government organization representatives, interested private individuals and policy makers attended a Population Habitat Viability Assessment (PHVA) Workshop at the University of Texas, Austin, Texas on 23-25 May, 1994 to assess the current status and trends of the populations of the Houston

Toad. The Conservation (formerly Captive) Breeding Specialist Group, of the IUCN/Species Survival Commission was asked to conduct this PHVA workshop to assist in assessment and subsequent planning. One purpose was to review data from wild populations as a basis for developing stochastic population simulation models. These models estimate risk of extinction and rates of genetic loss from interactions of demographic, genetic, and environmental factors as a tool for ongoing management of the species. Other goals included review of the current state of knowledge about habitat requirements, population sizes, role of direct threats (including conflicting land use competition by people) as a factor in the decline of the species, potential role of other threats such as disease and pollution, and to discuss research needs and priorities.

The first morning and afternoon consisted of a series of presentations summarizing data on the distribution of populations, genetics, and threats to the Houston Toad. A brief presentation on population biology, the PHVA process, and the use of VORTEX was made as an introduction to the use of the models and the problems associated with small isolated populations. The participants formed four working groups (distribution, threats, habitat requirements and management, and modeling). In the subsequent days three additional groups (captive breeding & reintroduction, urban land use, and public education/outreach) were established to review in detail current information, to develop values for use in the simulation models, and to develop management scenarios and recommendations. Stochastic population simulation models were initialized with ranges of values for the key variables to estimate the viability of the population using the VORTEX software modeling package.

During the course of discussions by the working groups a number of recommendations were identified for consideration as research topics. No attempt was made to rank these recommendations in the working groups and support for them is located in the individual report sections. Due to lack of precise distribution and population status knowledge regarding the Houston toad, it is difficult to determine risk associated with each threat throughout the range. Working group consensus was that most of these threats occur throughout the range; however, intensity of each threat varies depending upon location.

Examination of the collective recommendations indicated that several threats inspired recommendations from the majority of the groups. The need for surveys to determine both the extent of the Houston toad range and the numbers of toads along with determination of what constitutes Houston toad habitat were two of the most repeated recommendations. Education and planning guidelines and a need for a process to work collaboratively on these issues were given high priority. Further investigation into all aspects of resource extraction within Houston Toad habitat was also identified as a high priority.

Recommendations

Population Characteristics Influencing Houston Toad Survival

1. **The largest population patches, which serve as the primary source of migrants**

available for recolonization of empty patches, need to be the primary target of metapopulation management efforts.
2. Houston toad population viability may be enhanced by maintaining populations with subpopulations of relatively large and equal sizes and migration rates of 2% per year or greater between patches. This rate was estimated by simulation iwith the model.

3. Gradual and sustained reduction (a deterministic threat resulting from land use practices and urbanization) in available habitat increases risk of population extinction.

4. Catastrophes (stochastic threats) reducing survival are a greater threat to population survival, than those reducing reproduction. Growth rate is reduced by more than 75% in scenarios where fire and drought are occurring independently, compared to those scenarios in which catastrophes are absent. In the absence of catastrophes, the metapopulation is at no risk of extinction under three migration scenarios.

Distribution, Habitat, and Threats

Distribution and mapping recommendations address the need for surveys, preparation of maps, and development of criteria for suitable habitat (using geologic, topographic, and plant community characteristics) which can be mapped . Substantial time was devoted by one of the working groups in assembling this information for Bastrop County on maps. Such information would assist the conduct of surveys on distribution of the toad and the continuing organization of the information as it is collected.

<u>Surveys</u>

1. Conduct additional standarized surveys to determine distribution within habitat patches and establish accuracy of mapping.

2. Conduct surveys in Lee County.

3. Survey priorities for Bastrop County:

a) Survey area within appropriate geologic formations and soil types north of the Colorado River. Recent Houston toad surveys in this area have been limited to public lands and power line rights of way. Most of the land outside of these areas that fall within the appropriate geologic formations have never been surveyed to determine the presence of toads. Surveys of these areas should be initiated during the 1995 breeding season.

b) Survey area within appropriate soil type, but outside geologic formations, north of the Colorado River.

c) Survey area within appropriate geologic formation south of the Colorado River.

Geographic Information System Database

4. Undertake mapping work on soil formations, initiated for Bastrop County at the meeting, for other counties occupied by the Houston toad.

5. Incorporate mapping information into a geographic information system database (GIS). Show land use on a regional scale and orient land use activities to areas outside of toad habitat. Information and cost-sharing between the multiple interested agencies and organizations would be useful.

6. Determine areas of suitable or potential habitat and degree of isolation and inter-connections between and within population patches.

Habitat

7. Characterize preferred toad habitat utilized during activities outside of the breeding season, and develop a habitat description including soils, vegetation, water quality, distance to water, topography, and patch size and shape.

8. Investigate size, shape, depth, location, etc. of pond construction conducive to Houston toad conservation.

9. Investigate restoration techniques for toad habitat in forested and savannah lands.

10. Investigate the role of travel corridors and barriers in the dispersal of toads between population patches and ephemeral habitats.

Threats

11. Estimate probabilities of occurrence, from historical records, of weather cycles, drought and fire. Estimate effects on survival and reproduction of Houston toads.

12. Identify pollutants, including agricultural chemicals, affecting life stages of the Houston Toad and its food resources.

13. Evaluate the effects of fire ants and fire ant control methods on toad populations.

14. Evaluate conditions favoring introductions of other toad species and their effects on Houston toad populations.

15. Monitor populations for disease outbreaks and endemic disease patterns.

16. Evaluate possible effects of UV radiation on Houston toad reproduction and survival.

Land Use Activities

Assessment of Impacts

17. Determine effects of fish stocking of ponds on toad populations.

18. Assess effects of current agricultural management practices including chemical applications, prescribed burns, fences, and soil compaction on toad populations.

19. Assess the impact of crop land and orchard operations, timber harvesting methods, and resource extraction on toads and toad habitat to allow evaluation of potential effects of planned land uses on toad habitat.

20. Study combination of prescribed burning with planned grazing systems and other management practices as related to Houston toad habitat.

21. Investigate land modification and urbanization activities that may be compatible with the Houston toad by monitoring known sites where the toad exists in proximity to developed areas.

Management Guidelines

22. Minimize disturbance of soil (including compaction) to prevent introductions and possible competition from other species of toad and impacts of exotic species invasions such as fire ants.

23. Minimize pesticide use and other chemical use in toad habitat.

24. Minimize habitat fragmentation by barriers such as fences and impervious cover.

25. Maximize maintenance and restoration of corridors (including stream side management zones) and use of native plants in landscaping.

26. Maximize use of non-toad habitat for urban development needs through comprehensive planning.

Public Outreach

27. Undertake communication and coalition-building with city and county officials.

28. Develop instructional documents detailing a description of the species, its habitat, and its range in user-friendly language, accompanied by an attractive and clear color photos of the toad. Distribute the documents to schools, chambers of commerce, county extension agents, conservation organizations and professional and civic groups throughout Houston toad range.

29. Develop and provide consistent technical assistance to land owners and planners through resource agency programs. Provide guidance to the public regarding the Houston toad, its ecological requirements, and compliance with the Endangered Species Act.

30. Media contacts should be established. Develop an organized public outreach effort to promote public awareness, understanding, appreciation, and support for the Houston toad recovery efforts. Utilize the public school system as an important component of the public base that is receptive to educational campaigns. A summary guide detailing the contacts and requirements of each educational program should be developed for distribution.

31. Compile and distribute information about economic incentives and assistance programs for landowners and planners to increase their use in assisting to conserve toad habitat. These include alternatives to resource extraction and livestock management systems compatible with Houston toads. Link recovery efforts to other benefits, such as protection of water quality, pine forest community (in Bastrop County), the deep sand ecosystem, ecotourism, and community planning.

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 3

HISTORICAL OVERVIEW OF THE ENDANGERED HOUSTON TOAD

Historical Overview of the Endangered Houston Toad and its Interactions with Humans.
Lauren E. Brown.

The Houston toad (*Bufo houstonensis*) is relatively small and unglamorous in appearance. Its most notable characteristic is its beautiful mating call which sounds like the tinkling of a small bell. The species was first discovered by John C. Wottring of southeastern Houston in the late 1940's. John was an aircraft mechanic and amateur herpetologist who found the toad in the then semi-rural neighborhood where he lived. To attract toads, John had constructed a system of canals in his backyard with pools and bridges at various locations. Two other amateur herpetologists (Walter J. Greer, Werner Gottsch) helped John collect the toad at other localities in southeastern Texas.

Wottring was not sure of the identity of the toad, and in his travels around the country he showed specimens to many herpetologists and played tapes of the toad's mating call which he had recorded. Most of the herpetologists thought that the toad might be related to the American toad (*Bufo americanus*). However, Ottys Sanders from Dallas became especially interested in the toad and described it as a new species (*Bufo houstonensis)* in 1953. Ottys was an odd person with unusual views (Smith, 1994). He earned his living by operating a small-time biological supply company, and he was also a published poet. In honor of John Wottring's contribution, Sanders suggested that the species be known as the Wottring toad--a practice that was not subsequently followed by others.

In his description of the Houston toad as a new species, Sanders designated the largest specimen he could find as the holotype or type specimen. Holotypes are supposed to be typical of the species, and the species description is based on the holotype. Larger toads usually have larger cranial crests (bony ridges on the top of the head), and unfortunately Sanders used the large size of these features (particularly the postorbital crests) on the holotype as a key character for distinguishing the entire species. This was subsequently followed by Conant (1958) in his famous Peterson field guide for reptiles and amphibians. Thus, many herpetologists unfortunately believed that this character was of prime importance in identifying Houston toads. However for most specimens, large crests are of little value for identification (Brown and Thomas, 1982) because they are variable in their occurrence. The Houston toad is most easily identified by its mating call.

During the late 1940's and early 1950's, there was considerable collecting of the Houston toad in the Houston area by both amateurs and professionals. It was a prize species that many individuals and museums desired for their collections. The 1950's were a time of severe drought in Texas and also a time of great expansion of the city of Houston. Thus, almost nothing was seen or heard of the Houston toad, and it was almost certainly in decline in the Houston area.

In 1962, when I was an M.S. graduate student researching toads at Southern Illinois University at Carbondale, I attended the American Institute of Biological Sciences meeting at Purdue. There I met Professor W. Frank Blair, world renowned toad researcher from the University of

Texas in Austin. At that meeting, Frank told me that he thought the Houston toad might be nearly extinct. Within a year I finished at Southern Illinois University and left for Austin to work on my Ph.D. degree under Blair.

While doing field work in the spring of 1965, I (along with fellow graduate students Bill Birkhead and Jack Pierce) inadvertently rediscovered the Houston toad at a new locality, far away from Houston, in the Lost Pines of Bastrop County, Texas. Further research on the toad made up part of my Ph.D. dissertation (Brown, 1967; 1971). Reinvestigation of the historical distribution at that time revealed that the species was extant at only three of the known localities. The toad was nearly extinct in Houston and only a small population occurred in Burleson County. By far the most individuals were found in the Lost Pines area, but it was still not common. Several other localities have more recently been located (Price, 1994; Yantis, 1994a,b).

One of the most interesting aspects about the biology of the Houston toad is that it forms natural hybrids with two other species, the Gulf Coast toad (*Bufo valliceps*) and Woodhouse's toad (*Bufo woodhousei*), in the Lost Pines. The hybrid *B. houstonensis* X *B. valliceps* can easily be identified by the round or oval shape of their parotid gland (poison gland behind the head) and intermediacy of other characters. This hybrid has a harsh ragged mating call that is quite abnormal and often not intermediate in pulse rate between the mating calls of the parental species. The hybrid *B. houstonensis* X *B. woodhousei* are visually quite difficult to distinguish morphologically from either parental species, but they can be identified by statistical analysis and the intermediate pulse rate of their mating call. Possible causes of the natural hybridization include incompletely developed reproductive isolating mechanisms, human-induced habitat modification, and low densities of Houston toads. Some writers thought that the natural hybridization was a major cause of the decline toward extinction. Although hybridization is a potential cause, it most likely is not an actual cause. Most probable causes are Holocene warming and drying up of the habitat, over-collecting, droughts in the 1950's and early 1960's, urbanization, and other types of human-induced habitat modification.

An important advocate of the Houston toad was Professor Clark Hubbs, famous ichthyologist, former Chair of the Zoology Department at the University of Texas in Austin, friend of graduate students, and former member of my Ph.D. dissertation committee. When I was finishing my dissertation in 1967, Clark attended a meeting of the American Society of Ichthyologists and Herpetologists where he strongly advocated the conservation of the Houston toad to Dr. James Peters, Curator at the National Museum of Natural History in Washington, D.C. In 1968, Peters officially entered the species as endangered in the "Redbook" of rare and endangered species.

In the 1960's, Lady Bird Johnson, wife of the President, became the advocate of a beautification/conservation drive. I wrote a letter to her in 1967, hoping to gain governmental support to save the Houston toad and Lost Pines. In a disappointing reply, Lady Bird's social secretary indicated that "these matters are not in her hands" and "she does hope that interested citizens will work with their officials to protect our natural heritage." In retrospect,

this was a sign of the times, and governmental agencies did not have the resources (or desire) to support many projects, regardless of how noble their cause.

With the passage of the Endangered Species Act of 1973, the Houston toad was listed as endangered. An important provision of this act is that the Secretary of the Interior is required to establish and implement a program to conserve each species designated as endangered or threatened. A little over a year later (Jan. 1975), I wrote a letter to Ronald Skoog (then Chief of the Office of Endangered Species, U.S. Fish and Wildlife Service, Washington, D.C.) and asked him what conservation plan they had in mind for the Houston toad. He replied that they had no plan but hoped to formulate one.

The Office of Endangered Species then decided to designate Critical Habitat for the Houston toad. Critical Habitat is the area necessary for the species to carry out its normal activities. Such areas are not preserves but the federal government cannot finance any programs in those areas if such programs harm the endangered species. The Office of Endangered Species was provided available information on the distribution of the Houston toad by a specialist on Texas endangered species. On that basis, the Office of Endangered Species proposed Critical Habitat for the Houston toad in the Federal Register in Bastrop and Burleson counties as well as large tracts of land in Houston (U.S. Fish and Wildlife Service, 1977). In Houston this created an unbelievable uproar--particularly among building contractors and land developers. This was because the proposed Critical Habitats were about to be developed into residential and commercial areas. The FHA or any other federal agency would be unable to guarantee mortgages in Critical Habitat and federally financed roads could not be built. Thus, the expansion of Houston would be dealt a critical blow. Several land developers had spent large sums of money to purchase the land which was later suggested as Critical Habitat. They thus envisioned considerable loss in profits if the proposed Critical Habitats were approved. Ironically, this didn't matter much so far as the Houston toad was concerned since it had been only rarely seen in the Houston area for many years. A particularly ludicrous problem was that the Sharpstown Shopping Center was located within proposed Critical Habitat.

The controversy received considerable coverage by the press in Texas and nationally (e.g., Anonymous, 1977a,b; Scarlett, 1977a,b,c). The toad was also ridiculed in newspaper cartoons (e.g., Houston Chronicle, June 25, 1977; Houston Post, June 19, 1977). One magazine article (Anonymous, 1978) not only demeaned the Houston toad, but also made fun of Texans as well by publishing a drawing of a homely-looking toad wearing a large cowboy hat. The high point came when NBC's widely-watched Weekend television show was devoted to the controversy. In retrospect, the Office of Endangered Species cannot really be blamed. They made the proposal based on historical distribution records and knew nothing about pending real estate development in Houston. Eventually, Critical Habitat was officially designated in Bastrop and Burleson counties (U.S. Fish and Wildlife Service, 1978) where there was no heavy real estate development at that time. No Critical Habitat was designated in the Houston area, which was justified since the species was probably nearly extinct there due to over-collecting, drought, and urbanization.

This controversy generated increasing interest in the Houston toad, and publicity of a more positive nature began to appear. For example, the Encyclopedia Britannica Educational Corporation came out with an attractive endangered species poster series which included the Houston toad. There was also the Houston toad beer can, part of the Endangered Species Series of Brickskeller Beer (Pittsburgh Brewing Company). On the front of the beer can there is a drawing of the Houston toad (which actually appears somewhat more similar to the Gulf Coast toad). On the back of the can there is a short write-up explaining the reason for endangerment, which reads like a short abstract of part of my Ph.D. dissertation (how many dissertations can claim such distinction?)

In 1978 the U.S. Fish and Wildlife Service decided to establish a Recovery Team for the Houston toad which consisted of: Floyd Potter, Leader, Texas Parks and Wildlife; Bill McClure, Texas Highway Department; Norm Scott, U.S. Fish and Wildlife Service; Bob Thomas, Louisiana Nature Center; and myself. After in-depth consideration of many controversial issues, a Recovery Plan was published (Brown et al., 1984). The Plan proposed a number of recovery efforts, some of which have been implemented.

Lastly, and most recently, there has been the rise of environmental activism in central Texas, especially among the membership of the BCEN (Bastrop County Environmental Network). These concerned citizens have worked hard to thwart lignite mining in Bastrop County, and have been outspoken in stressing the need for compatibility between humans and the Houston toad. It is my conviction that local defenders of the toad will now play the most important role in its conservation.

In conclusion, this small toad of unglamorous appearance has had a fascinating history in the short time it has been known to humans. It rose from its first discovery in a humble semi-rural neighborhood in southeastern Houston, to fame and notoriety in the hallowed governmental halls of Washington, D.C. Indeed, this once obscure amphibian has now become one of the most glamorous of endangered species which is known by conservationists throughout the world. Its plight has made it a symbol of endangered species that have suffered from unleashed expansion of urban areas.

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POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 4

POPULATION BIOLOGY AND MODELING

Houston Toad: Population Viability Analysis Data

Introduction

Species: *Bufo houstonensis*

Species Distribution: The Houston toad is endemic to southeast Texas. Seven disjunct populations of the Houston toad are currently known to exist in eight different counties. One small population has been located in Lavaca County. The toad is believed to occur in Lee County, since it contains suitable soils and lies between Bastrop and Burleson counties, which both support toad populations. The toad may also occur in Caldwell and Waller counties. It is not currently known or believed to occur in any other counties, nor does it occur east of the Trinity River (Yantis 1991, 1992; Price 1993).

All known toad populations occur within one of two separate bands of geologic formations. Four populations occur on the band that runs through Bastrop County northeast to Freestone County. Two populations and the Lavaca population occur on the other band that runs parallel to and southeast of the first band, through Lavaca, Austin, and Colorado counties (Yantis 1991).

Surveys conducted in 1989 did not locate toads south of the Colorado River in Bastrop County (Yantis 1989). However, toads have been found south of the Colorado River in Lavaca County, and additional survey efforts are warranted to verify absence of the toad from south of the Colorado River in Bastrop County.

Census and Changes During the Past 10-50 years: The Houston toad probably was extirpated from its former range in Harris, Liberty, and Fort Bend counties by the mid-1970's (Yantis 1992; Price 1993). Toads have not been found at the Woodrow Lake site in Burleson County in the last five years.

Of the six populations, the one in Bastrop County is the most robust and is the only one known to be viable and self-sustaining (based on nearly 30 years of periodic field investigations). The Bastrop County metapopulation is estimated to be a minimum of 2,000 adults at present (Yantis 1991; Price, TPWP, pers. comm., 1994).

Estimating toad population sizes is inherently difficult because toads can only be found reliably while calling during the breeding season which varies depending on weather conditions, and because of the difficulty of accessing much of the area inhabited by the toad.

The size and status of the other five populations is unknown. However, these populations occur within areas that appear to provide suitable habitat (i.e., areas supporting sandy soils

and native woodland/savannah) in large enough blocks (20,000-50,000 acres) to support a viable population. Habitat at the Lavaca County site appears to be limited and marginal (Yantis 1991, 1992, pers. comm. 1994).

Based on observations of the frequency of hearing Houston toads during the breeding season, Yantis has suggested that a rough estimate of the total number of adult Houston toads, <u>excluding the Bastrop County population</u>, is about 2,000 - 5,000 adults (Yantis 1991, 1992).

<u>Home Range/Territory Size</u>: Little is known about the toad's activities during the non-breeding season, except that they aestivate/hibernate in sandy soils during some portion of this season. During the breeding season, many toads do not appear to be faithful to certain breeding sites, but rather move randomly from one site to another. Individual male toads have been known to move a total of 1400 meters (0.87 miles) or more between breeding sites (cumulative distance - back and forth movements) (Price 1992, 1993).

Life History Characteristics

<u>Mating System</u>: Promiscuous (Price 1992, 1993).

<u>Breeding Season</u>: Usually February and March. However, males have been heard calling from December 22 - June 22 (varies depending on weather conditions) (Price 1992, 1993). Reported egg-laying dates range from January 24 to June 26 (Hillis et al. 1989).

<u>Average Age of First Reproduction (female and male)</u>: Females - 2 years. Males - 1 year (Price 1992, ,1993).

<u>All Males In Breeding Pool?</u>: Unknown, but due to the highly skewed sex ratio in favor of males (may be as high as 30:1 in a given chorus), it is believed that many do not breed (Price 1992, 1993, pers. comm. 1994).

<u>Proportion of Adult Females Reproducing Per Year</u>: Unknown, but estimated to be 100% (although some females probably do not breed successfully) for females that come to the breeding ponds. If habitat (i.e., foraging) conditions are poor, female reproduction may be limited (Price, pers. comm. 1994).

<u>Oldest Age (Senescence)</u>: Estimated average four years for both sexes (Price 1992, 1993, pers. comm. 1994); for the closely related American toad, estimated at 3-4 years for males and 4-5

years for females in one Virginia population (Kalo and Eng 1990).

<u>Inbreeding</u>: Unknown, but not believed to be a problem in Bastrop County (Price, pers. comm. 1994). The Houston toad may be adapted to short periods of drought, but longer periods may result in population reductions. During and after wet years, populations may re-expand provided there is sufficient habitat. However, habitat destruction and fragmentation may preclude expansion for some populations, so inbreeding may be a factor for those populations that are permanently prevented from exchanging individuals with neighboring populations (Dixon, Price and Yantis pers. comm. 1994).

<u>Number of Reproductions</u>: Females are generally believed to breed only once during a breeding season (although unlikely, it is possible that some females may breed twice if the habitat is highly productive). Individual males have been known to breed with more than one female during a given breeding season (Price 1992, 1993, pers. comm. 1994).

<u>Maximum Eggs Produced Per Female</u>: 512 - 6,199 (Quinn et al. 1987).

<u>Mortality</u>: Due largely to predation and drying of breeding sites, estimated that $<1\%$ of eggs laid survive to adulthood (Price pers comm. 1994).

Population Parameters

<u>Catastrophes and Threats</u>:

(1) Habitat destruction and fragmentation. Portions of the toad's range have been highly modified by residential and other urban development as well as certain agricultural practices, such as replacing native vegetation with Bermuda grass and St. Augustine grass or other exotic species. Other impacts from urban and agricultural activities include increased impervious cover; soil compaction; plowing; changes in drainage patterns; use of fertilizers and pesticides that impact the toad directly or impact its food supply; and destruction or degradation of wetlands used for breeding (such as from changes in water quality, draining/filling breeding sites, and/or predatory fish stockings). In some areas, fire prevention may result in increased growth of understory plants, such as yaupon or juniper thickets, which may limit Houston toad movement and decrease its food supply. Habitat fragmentation (e.g., power line ROW's and roadways) 'open up' toad habitat, leaving the toad more vulnerable to predation. Habitat fragmentation by roadways also disrupts migration routes and dispersal of individuals. Highway mortality of toads has been documented.

(2) Drought. This can result in reduction/loss of breeding sites. Mortality may be especially high in increasingly fragmented populations.

(3) Ultra-violet radiation (possible increases). UV radiation may result in increased egg mortality, which has been documented for other anuran species. Research is necessary to determine if this is a threat to the Houston toad.

(4) Catastrophic fire. The Lost Pines community in Bastrop County is historically a fire-maintained community and has been subject to periodic burning, and thus the Houston toad is likely adapted to fire regimes. However, frequent and/or severe burning may be detrimental to this species, particularly for small, fragmented populations. Increased fuel loads due to prolonged periods of fire prevention may result in catastrophic fire. Research is necessary to determine the effects of prescribed burning programs.

(5) Introduction of exotic parasites and disease. None are known at this time in these populations. Fish stockings may introduce parasitic fungi or other parasites/diseases.

(6) Fire ants. They are known to prey on toadlets. Unsuccessful attempts at reintroducing Houston toads into former parts of its range may in part have been due to fire ant predation on toadlets (Freed and Neitman 1988, Quinn 1991). Fire ants have also been known to have a devastating impact on arthropod communities, which may result in a severe reduction of the toad's food supply.

Frequency and Severity of Catastrophes: Unknown.

Starting Population Size of Adults (post-metamorphosis): See data for species distribution/census and changes during past 10-50 years. Based on capture-recapture data at two breeding sites in Bastrop State Park (Price 1992, 1993, pers. comm. 1994), assuming all first captures are 1 year old, the estimated age distribution of adult toads (male and female) during 1992 was:

1 year old	**75%**
2 years old	**23%**
3 years old	**2%**

For the American toad, estimated age distributions (based on skeletochronology) over a three-year period at two breeding sites in Virginia was (Kalb and Zug 1990):

1 year old	**21%**
2 years old	**51%**
3 years old	**23%**
4 years old	**4%**

Carrying Capacity and Projected Changes: This is unknown, but dependent largely on amount of rainfall and number of available breeding sites. Populations probably increase

following wet years and recede during dry periods. The Bastrop County population appears to be stable and not limited at this time by breeding habitat. The Bastrop population may also be larger than it was historically due primarily to the creation of water bodies used by the toad for breeding (Price pers. comm. 1994). The density of the populations in other counties might be further increased if additional breeding sites were provided. All populations are threatened by habitat modification, including destruction or modification of breeding sites.

Harvests: No commercial harvesting. However, highway mortality has been documented. About 67% (12 of 18) of the toads found along a five mile stretch of Highway 21 during a 1990 survey were road kills (Price 1990).

Supplementation: Reintroduction efforts have been unsuccessful (Quinn, Ferguson, and Mayo 1987; Freed and Neitman 1988).

Population Modeling

The need for and effects of intensive management strategies can be modeled to suggest which practices may be most effective in preserving individual toad populations. A simulation modeling package, VORTEX written by Robert Lacy and Kim Hughes was used as a tool to study the interaction of multiple variables treated stochastically to assist a better understanding of the effects of different management manipulations.

The VORTEX program is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on populations. VORTEX models population dynamics as discrete, sequential events (e.g., births, deaths, catastrophes, etc.) that occur according to defined probabilities. Probabilities of events are modeled as constants or as random variables that follow specified distributions. VORTEX simulates a population by stepping through series of events that describe the typical life cycle of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it projects stochastically the interactions of many parameters which enter into the model and because of random processes involved in nature. Interpretation of the output depends upon knowledge of the biology of the toad, the conditions affecting each individual population, and possible future changes. Output is limited by the input. Where needed input data are unavailable or questionable, data from other toad populations or best guesses by toad experts were provided as input. Results from simulations can be used to suggest the most critically needed data to provide more reliable results, and thus assist the design of needed research for population management.

Starting Population:

Introduction: The current version of VORTEX is limited in its capacity to handle realistic life-history parameters for r-selected species like the Houston Toad. We therefore took the

available data for the Bastrop County population (the only one for which such data are available), and adjusted parameters proportionately to fit limitations of the model.
<u>Carrying Capacity</u>: K defines an upper limit for population size, above which additional mortality is imposed in order to return the population to K. In other words, VORTEX uses K to impose a ceiling model of density-dependence on survival rates. We set K initially at 1000 toads with annual variation of 7.5% (minimum estimate of 3000 adult toads alive throughout the county at any given time, and actual variation of 10%). These populations may subdivided into smaller patches (subpopulations) with limited exchange of toads (5% or less per year) between the patches. We modeled declining trends in annual carrying capacity as 0.25% and 0.5% equally over all patches, and as 1% over patch 1-5 and 8 to mimic potential habitat loss on the periphery of the metapopulation.

<u>Age First Reproduction</u>: VORTEX defines breeding as the time when eggs are laid. VORTEX also assumes discrete intervals of years in the case of the Houston Toad. On average, the age of first reproduction for females is 2 years and for males 1 year. These values were used in the simulation scenarios (although unlikely, some females may breed at 1 year of age during times of high primary productivity).

<u>Clutch Size</u>: Reproductive characteristics of the Houston Toad are highly variable. Published clutch sizes range from 512 to 6199. Data from Bastrop breeding ponds suggest that mortality rates from egg stage to entrance into the breeding population exceed 99%, a figure not unusual for some groups of anurans. We therefore decided to model this effect by assuming that all females of reproductive age breed (which may be an over estimate) and produce 10 toads returning to the breeding site - the location and life history stage for which field data are collected. This provides the most optimistic scenario concerning female reproductive output; the following distribution was used in the simulations:

<u>Sex Ratio</u>: Sex ratio at birth is taken as equal (1:1) or 0.500.

<u>Age of Senescence</u>: VORTEX assumes that animals can breed (at species typical rates) throughout their adult life spans. Maximum life expectancy is not used if the species does not reproduce throughout its entire life. This maximum age was estimated as 4 years for the Houston toad based upon animals of known age, and this value was used in all scenarios.

<u>Mortalities</u>: Mortality prior to age 1 was incorporated into determination of number of toads returning to the breeding site (clutch size). Recapture data suggest an annual mortality of 80% for the Houston Toad, with male mortality of 80% after age 1 and female mortality of 90% after age 2. Mortality rates for females from age 1 to age 2 are unknown. Females are more cryptic than males during the breeding season, and their mortality rate of 90% is believed to be an overestimate; therefore we have modeled an annual mortality rate of 80% for each sex with a minimal variation of 1%.

<u>Threats</u>: A major potential threat to the Houston Toad is fragmentation of the habitat. We have modeled this threat as decreasing trends in carrying capacities, as described above.

<u>Catastrophes</u>: Catastrophes are singular events outside the bounds of normal environmental variation affecting reproduction (defined in VORTEX as recruitment of individuals into the breeding population) and survival (defined in VORTEX as mortality of adults) either singly or in combination. Catastrophes can be tornados, floods, fire, disease, fire ants, droughts, or some similar circumstance. Catastrophes are modeled by assigning a probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect).

Catastrophes in the Bastrop County Houston Toad metapopulation might include disease, fire, or drought. We modeled the effects of 2 catastrophes with a probability of occurrence of 0.1 (once every 10 years on average), each occurring in the absence of the other. One reduced reproductive output by 50% and the other adult survivorship by an equivalent amount. In addition, we modeled effects of both catastrophes occurring together, each with an independent probability of occurrence of 0.1 over the simulation run.

Results from Simulation Modeling

The following scenarios were simulated 500 times with projections for 100 years. Output results were summarized at 10-year intervals and used for the time series figures. All simulations were conducted using the Vortex 6.2 software package.

Deterministic Results

Growth rate (*r*): The deterministic growth rates calculated using Leslie matrix methods are shown at the bottom of the tables for each general scenario. Positive values indicate population growth, while a value of zero characterizes a population that is neither growing nor declining. Note that the imposition of catastrophes has significant effects on population growth rate. For example, growth rate is reduced by more than 75% in scenarios when fire and drought are occurring simultaneously, compared to those scenarios in which catastrophes are absent (Table 1).

Other deterministic values: Generation length for males and females was approximately 1.2 and 2.2 years, respectively. Thus a 100-year simulation includes about 45-50 generations for females and 70-80 generations for males. In addition, adult sex ratio of males to females was calculated to be about 5.5:1, consistent with field observations made in local breeding ponds. This provides a useful check on the internal consistency of the field

data and on the fitting of the simulation parameters with the available data.

Stochastic Simulation Results

Unstructured Populations:

Results from single population base scenarios, with K = 1000, 600, 300, and 100, are shown in Figures 2-5 and Table 1. In the absence of catastrophes, larger populations show 9-10% annual growth and no risk of extinction (Fig. 2a). Moreover, populations are maintained near carrying capacity throughout the duration of the simulation. In contrast, the small population, while showing 7% annual growth, has a 16% probability of extinction in 100 years with significant loss of genetic variation (Fig. 2). Mean time to extinction of these populations is 54 years, indicating considerable instability for small toad populations.

Addition of catastrophic events significantly influences stability of all populations modeled. When a catastrophe affecting survival, such as fire, is incorporated into the model, growth rates are reduced dramatically (Table 1) and risk of population extinction is similarly increased. Even populations of 1000 individuals face a 6% chance of extinction in 100 years. Smaller populations have high risks of extinction (Fig. 3a) over a short time period (Table 1). In addition to these extinction risks, population sizes after 100 years are considerably reduced below carrying capacity (Table 1), implying increased vulnerability beyond the 100-year period currently modeled.

When a catastrophe affecting reproduction, such as drought, is added to the model, the same qualitative effects are observed as with fire (Fig. 4, Table 1), but to a lesser degree. Both fire and drought operating on these populations pose severe threats to population viability (Fig. 5). It is clear from these results that catastrophes influencing survival are a greater threat, particularly to larger populations, than those influencing reproduction. For the remaining discussion, only those catastrophe scenarios combining both fire and drought will be considered.

Fine-Structured Metapopulations:

We modeled three different sets of conditions in a metapopulation composed of 10 patches, each with a carrying capacity of 100. The 'unequal migration' scenario (Fig. 1a) looks at a metapopulation in which four patches are more or less isolated from the remaining patches, which are themselves connected to varying degrees. This is an attempt to more realistically model the Bastrop County toad population. To investigate greater levels of patch connectivity, 'equal migration' scenarios were modeled in which adjacent patches experienced either 2% or 5% migration (Fig. 1b). Additionally, deterministic reductions in patch carrying capacity were included in each set of simulations according to the following

designs: No reduction, 0.25% annual reduction in each patch, 0.5% annual reduction in each patch, and 1.0% annual reduction only in peripheral patches 1-4, 5, and 8 (Fig. 1a).

Complex dynamics become evident in these scenarios (Figs. 6-13, Table 2). In the absence of catastrophes, the metapopulation is at no risk of extinction under all three migration scenarios (Fig. 6a). Likewise, retention of heterozygosity is relatively high under these conditions (Fig. 6b). Despite metapopulation stability, however, individual patches may go extinct in about 50 years, but can be relatively rapidly recolonized depending on patch connectivity (Table 2a). When 5% migration occurs between patches, individual patch extinction does not occur (Table 2a).

The entire metapopulation is at appreciable risk of extinction when fire and drought are included in the simple metapopulation model (Fig. 7a). Even when adjacent patches receive migrants at a rate of 5%, risk of extinction is 4%; this probability jumps to 19% under the unequal migration scenario (Table 2a). Considerable local extinction and recolonization takes place, with initial patch extinction occurring after about 50 years and recolonization occurring shortly thereafter. The metapopulation becomes extinct after approximately 80 years under these conditions. Additionally, while metapopulation sizes remain fairly high when catastrophes are absent, addition of fire and drought leads to a significant reduction in final metapopulation size (Table 2a) with associated losses in heterozygosity (Fig. 7b).

When deterministic reductions in patch carrying capacity are included, the metapopulation remains free of extinction risk over a 100 year period as long as catastrophes are not a threat (Figs. 8a, 10a, and 12a). However, as is expected, final metapopulation size declines as deterministic forces increasingly reduce metapopulation carrying capacity (Table 2b-d). Once again, metapopulation extinction is prevented largely through rapid recolonization of patches locally extinct after about 80 years. Inclusion of fire and drought poses a serious threat to metapopulation viability when deterministic forces act to reduce patch carrying capacity. The situation is at its worst when the peripheral populations experience a 1% annual reduction in K: metapopulation extinction probabilities range from 53% under 5% equal migration between adjacent patches to 66% under 2% equal migration (Fig. 13a, Table 2d). It is interesting to note that the 2% equal migration scenario, with greater overall patch connectivity, results in a slightly greater risk of extinction than the unequal migration scenario. This is because while some patches in the latter scenario are isolated, others have higher rates of between-patch migration.

Coarse-Structured Metapopulations:

The degree to which patch size and migration rates between patches influence metapopulation viability was studied by essentially repeating the above simulations on a metapopulation of 1000 individuals composed of only three patches. In one set of analyses, patches were of unequal size (K = 100, 300, and 600) while another set employed patches of

equal size (333 each). For each of these scenarios, inter-patch migration was either 2% or 5%, distributed equally among patches (Fig. 1c).

Results are qualitatively similar to the more finely-structured metapopulation models, but with considerably less risk of metapopulation extinction (Figs. 14-19, Table 3). In all scenarios where catastrophes were absent, neither patch nor metapopulation extinction occurred. Moreover, final population sizes were 80-90% of final carrying capacity after 100 years.

The inclusion of fire and drought produced interesting results. For all three levels (0, 0.2% and 0.5% per year) of deterministic carrying capacity reduction, probabilities of metapopulation extinction were greater when patch sizes were unequal. These probabilities ranged from about 14% (Fig. 14a, Table 3a) to nearly 25% (Fig. 18a, Table 3c), with population persistence again extending to about 80 years. When patch sizes were equal, risk of metapopulation extinction did not exceed 9% (Table 3). Note that when patch sizes are unequal, risk of extinction is essentially the same regardless of level of patch connectivity (Figs. 14a, 16a, and 18a), whereas extinction probability is consistently greater when migration is less frequent among patches of equal size (Figs. 15a, 17a, and 18a). This phenomenon results from the tight correlation between extinction of the K=600 patch and extinction of the metapopulation (data not shown). When the largest patch goes extinct, effective migration is not sufficient from adjacent smaller patches to make up for loss of the primary migrant source, and metapopulation extinction soon follows. When patch sizes are equal, no one patch dominates as a migrant source, and metapopulation viability is no longer influenced by any one patch. This is an important point for conservation biology as it relates to population management: the smallest local population, often the primary focus of management efforts, may be the least important factor governing metapopulation viability. These results indicate that the largest patch, serving as the primary source of migrants available for recolonization of empty habitats, may be the primary target of metapopulation management efforts.

These simulation models illustrate the severe consequences for population persistence of catastrophic events targeting adult survival of the Houston toad, and the interaction of these events with toad population substructure dynamics. The results suggest that Houston toad population viability may be enhanced by maintaining populations with some degree of substructure, as long as opportunity for migration between patches exists. This degree of substructure, however, should not be too fine; maintaining subpopulations of relatively large and equal sizes appears to largely ameliorate the effects of demographic and environmental uncertainties. Finally, gradual reduction in available habitat leads to considerably increased risk of population extinction. Consequently, local conservation planning efforts for the Houston toad must allow for maintenance of sufficient habitat necessary for sustained population viability.

Conclusions and Recommendations

1. **The adult sex ratio of males to females was calculated to be about 5.5:1, consistent with field observations made in local breeding ponds.**
2. **Generation length for males and females was estimated as approximately 1.2 and 2.2 years, respectively.**

3. **Catastrophes reducing survival are a greater threat to population survival, particularly to larger populations, than those reducing reproduction.**

4. **In the absence of catastrophes, the metapopulation is at no risk of extinction under three migration scenarios.**

5. **Growth rate is reduced by more than 75% in scenarios in which fire and drought are occurring independently, compared to those scenarios in which catastrophes are absent.**

6. **Houston toad population viability may be enhanced by maintaining populations with subpopulations of relatively large and equal sizes and migration rates of 2% or greater between patches.**

7. **Gradual and sustained reduction in available habitat increases risk of population extinction.**

8. **The largest population patches, which serve as the primary source of migrants available for recolonization of empty patches, need to be the primary target of metapopulation management efforts.**

Figure and Table Legends

Table Legends

Table 1. Modeling results for single populations with and without catastrophes (F, fire; D, drought; F & D, fire and drought). K is carrying capacity; stochastic r (SD) is growth rate with standard deviation resulting from the simulation; P(E) is probability of extinction after 100 years; N100 (SD) is the mean and standard deviation of final population size; H(E) is the expected heterozygosity after 100 years; and T(E) is mean time to extinction (in years).

Table 2. Modeling results for the 10-patch metapopulation under various scenarios. T(Ep) is mean time to patch extinction; T(Rp) is mean time to patch recolonization; and T(Ep*) is the mean time to patch re-extinction. All other measures are as defined in Table 1.

Table 3. Modeling results for the 3-patch metapopulation under various scenarios. All measures are as defined in Table 2.

Figure Legends

Figure 1. Metapopulations used in population modeling. (a) 10-patch metapopulation with the 'Unequal migration' scenario, with migration rates indicated. (b) 10-patch metapopulation with the 'Equal migration' scenario. Migration rates used in this case were 2% and 5% between patches. (c) 3-patch metapopulation. Diagram shown represents the case of unequal patch sizes, with size of patch corresponding to the approximate carrying capacity described in text.

Figure 2. Proportion of surviving populations (a) and proportional heterozygosity (b) in single populations of various sizes.

Figure 3. Proportion of surviving populations (a) and proportional heterozygosity (b) in single populations of various sizes subjected to periodic fires.

Figure 4. Proportion of surviving populations (a) and proportional heterozygosity (b) in single populations of various sizes subjected to periodic drought.

Figure 5. Proportion of surviving populations (a) and proportional heterozygosity (b) in single populations of various sizes subjected to both fire and drought.

Figure 6. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations under various migration conditions.

Figure 7. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations subjected to periodic fire and drought under various migration conditions.

Figure 8. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations experiencing 0.25% annual reductions in patch size under various migration conditions.

Figure 9. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations experiencing 0.25% annual reductions in patch size and periodic fire and drought under various migration conditions.

Figure 10. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations experiencing 0.5% annual reductions in patch size under various migration conditions.

Figure 11. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations experiencing 0.5% annual reductions in patch size and periodic fire and drought under various migration conditions.

Figure 12. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations experiencing 1.0% annual reductions in peripheral patch size under various migration conditions.

Figure 13. Proportion of surviving populations (a) and proportional heterozygosity (b) in 10-patch metapopulations experiencing 1.0% annual reductions in peripheral patch size and periodic fire and drought under various migration conditions.

Figure 14. Proportion of surviving populations (a) and proportional heterozygosity (b) in 3-patch metapopulations of unequal patch size under various migration conditions with and without catastrophes.

Figure 15. Proportion of surviving populations (a) and proportional heterozygosity (b) in 3-patch metapopulations of equal patch size under various migration conditions with and without catastrophes.

Figure 16. Proportion of surviving populations (a) and proportional heterozygosity (b) in 3-patch metapopulations of unequal patch size experiencing 0.25% annual reductions in patch size under various migration conditions with and without catastrophes.

Figure 17. Proportion of surviving populations (a) and proportional heterozygosity (b) in 3-patch metapopulations of equal patch size experiencing 0.25% annual reductions in patch size under various migration conditions with and without catastrophes.

Figure 18. Proportion of surviving populations (a) and proportional heterozygosity (b) in 3-patch metapopulations of unequal patch size experiencing 0.5% annual reductions in patch size under various migration conditions with and without catastrophes.

Figure 19. Proportion of surviving populations (a) and proportional heterozygosity (b) in 3-patch metapopulations of equal patch size experiencing 0.5% annual reductions in patch size under various migration conditions with and without catastrophes.

Table 1. Single populations

Catastrophe	K	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)
None	1000	0.095 (0.140)	0.0	965 (72)	0.884	--
	600	0.094 (0.171)	0.0	578 (43)	0.819	--
	300	0.090 (0.244)	0.0	281 (31)	0.659	--
	100	0.074 (0.505)	0.16	80 (24)	0.228	54
F	1000	0.024 (0.306)	0.06	603 (318)	0.768	66
	600	0.019 (0.355)	0.12	351 (195)	0.646	68
	300	0.011 (0.460)	0.32	172 (98)	0.448	62
	100	-0.016 (0.690)	0.83	58 (34)	0.170	44
D	1000	0.069 (0.310)	0.0	895 (150)	0.870	--
	600	0.067 (0.328)	0.0	524 (100)	0.791	--
	300	0.064 (0.377)	0.01	251 (60)	0.605	67
	100	0.041 (0.619)	0.39	71 (29)	0.162	55
F & D	1000	-0.009 (0.471)	0.25	392 (307)	0.642	66
	600	0.0004 (0.407)	0.20	266 (202)	0.569	75
	300	-0.024 (0.586)	0.61	128 (93)	0.359	54
	100	-0.053 (0.789)	0.94	48 (30)	0.102	37

Note: Deterministic growth rate *r* (from life table): 0.097 (none), 0.046 (fire), 0.074 (drought), 0.023 (fire & drought).

Table 2. 10-Patch Metapopulation (total K = 1000)

a. Constant K

Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	None	0.105 (0.131)	0.0	805 (76)	0.881	--	56	12	2
	F & D	0.008 (0.318)	0.19	228 (126)	0.544	80	50	7	5
Equal (2%)	None	0.105 (0.130)	0.0	834 (68)	0.873	--	55	1	2
	F & D	0.007 (0.304)	0.17	240 (155)	0.571	79	51	4	6
Equal (5%)	None	0.103 (0.126)	0.0	877 (63)	0.875	--	--	--	--
	F & D	0.017 (0.221)	0.04	459 (173)	0.741	83	63	2	6

Note: Deterministic growth rate *r* (from life table): 0.097 (none), 0.023 (fire & drought)

b. 0.25% Annual Reduction in K

Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	None	0.106 (0.141)	0.0	546 (75)	0.852	--	64	6	2
	F & D	0.005 (0.345)	0.27	155 (94)	0.492	80	50	8	5
Equal (2%)	None	0.106 (0.141)	0.0	585 (65)	0.855	--	75	1	3
	F & D	0.0002 (0.354)	0.30	143 (94)	0.481	79	51	4	6
Equal (5%)	None	0.104 (0.138)	0.0	627 (56)	0.857	--	74	1	--
	F & D	0.016 (0.233)	0.06	309 (138)	0.694	83	69	2	6

c. 0.5% Annual Reduction in K

Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	None	0.106 (0.162)	0.0	313 (56)	0.809	--	80	4	2
	F & D	-0.0002 (0.385)	0.38	80 (54)	0.382	82	51	7	5
Equal (2%)	None	0.107 (0.155)	0.0	373 (58)	0.823	--	83	2	3
	F & D	-0.009 (0.396)	0.52	71 (52)	0.379	81	50	4	6
Equal (5%)	None	0.105 (0.153)	0.0	383 (49)	0.823	--	93	1	4
	F & D	0.011 (0.274)	0.14	172 (90)	0.624	83	68	3	6

d. 1% Annual Reduction in K from Peripheral Patches

Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	None	0.103 (0.171)	0.0	292 (56)	0.732	--	77	4	4
	F & D	-0.004 (0.401)	0.56	75 (59)	0.387	81	51	7	6
Equal (2%)	None	0.105 (0.167)	0.0	303 (57)	0.757	--	80	2	4
	F & D	-0.011 (0.412)	0.66	83 (61)	0.399	79	49	4	6
Equal (5%)	None	0.102 (0.169)	0.0	262 (63)	0.770	--	91	2	3
	F & D	-0.002 (0.341)	0.53	68 (51)	0.482	86	68	3	6

Table 3. 3-Patch Metapopulation with Unequal (100, 300, 600) or equal (333, 333, 333) Patch Sizes

a. Constant K

Patch Size	Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	(2%)	None	0.100 (0.130)	0.0	947 (61)	0.871	--	--	--	--
		F & D	0.007 (0.340)	0.13	313 (221)	0.650	74	68	3	4
	(5%)	None	0.098 (0.134)	0.0	930 (71)	0.870	--	--	--	--
		F & D	0.007 (0.332)	0.15	303 (193)	0.641	72	68	2	5
Equal	(2%)	None	0.099 (0.128)	0.0	947 (53)	0.885	--	--	--	--
		F & D	0.010 (0.300)	0.07	440 (231)	0.715	76	70	3	4
	(5%)	None	0.098 (0.126)	0.0	958 (49)	0.884	--	--	--	--
		F & D	0.013 (0.264)	0.03	542 (242)	0.771	82	75	2	4

Note: Deterministic growth rate *r* (from life table): 0.097 (none), 0.023 (fire & drought)

b. 0.25% Annual Reduction in K

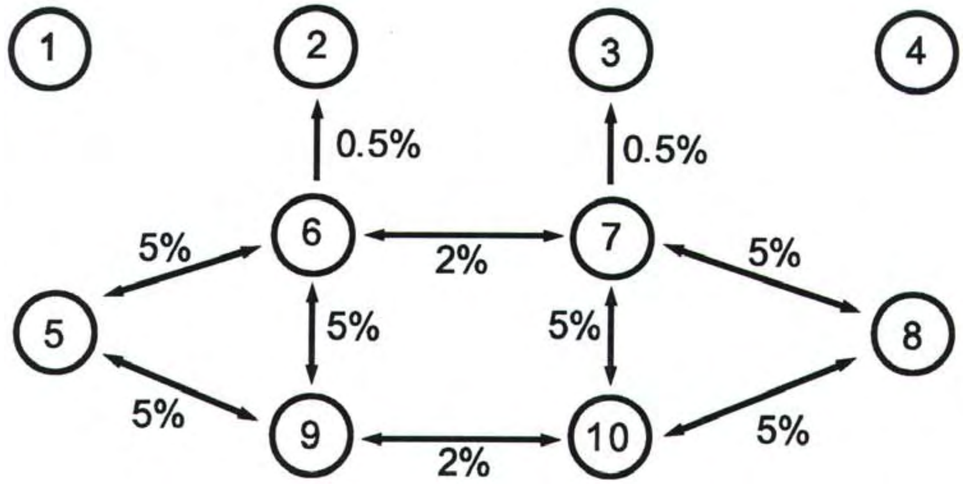
Patch Size	Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	(2%)	None	0.099 (0.140)	0.0	708 (50)	0.854	--	--	--	--
		F & D	0.007 (0.352)	0.16	269 (177)	0.611	79	71	3	4
	(5%)	None	0.098 (0.142)	0.0	685 (65)	0.850	--	--	--	--
		F & D	0.007 (0.345)	0.15	232 (145)	0.586	77	74	2	4
Equal	(2%)	None	0.100 (0.136)	0.0	701 (50)	0.868	--	--	--	--
		F & D	0.009 (0.305)	0.08	341 (166)	0.688	78	72	3	4
	(5%)	None	0.098 (0.136)	0.0	705 (49)	0.866	--	--	--	--
		F & D	0.012 (0.273)	0.03	408 (195)	0.737	76	76	2	4

c. 0.5% Annual Reduction in K

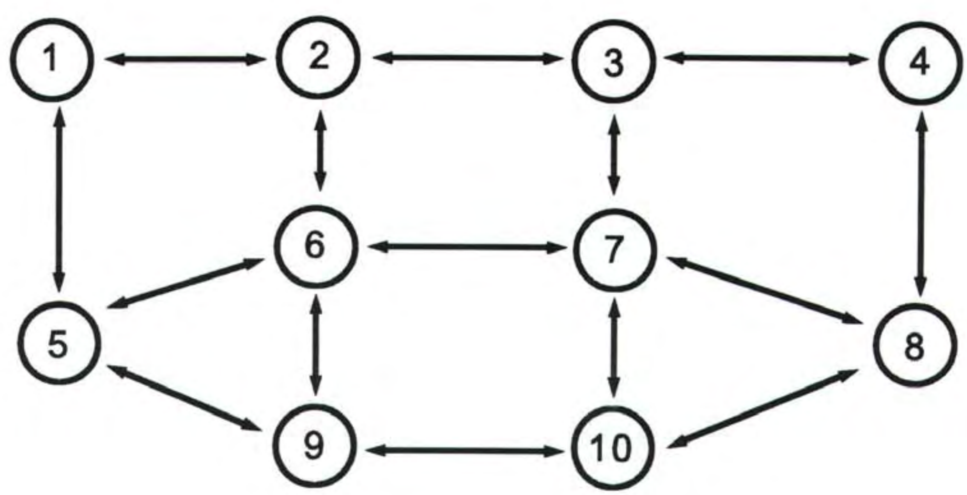
Patch Size	Migration	Catastrophe	Stochastic *r* (SD)	P(E)	N_{100} (SD)	H(E)	T(E)	T(Ep)	T(Rp)	T(Ep*)
Unequal	(2%)	None	0.099 (0.154)	0.0	458 (44)	0.828	--	--	--	--
		F & D	0.004 (0.379)	0.22	189 (125)	0.563	75	68	3	5
	(5%)	None	0.098 (0.154)	0.0	448 (51)	0.821	--	--	--	--
		F & D	0.003 (0.368)	0.24	177 (130)	0.564	76	73	2	4
Equal	(2%)	None	0.100 (0.150)	0.0	455 (43)	0.843	--	--	--	--
		F & D	0.008 (0.319)	0.09	225 (117)	0.632	78	73	3	5
	(5%)	None	0.098 (0.150)	0.0	465 (42)	0.843	--	--	--	--
		F & D	0.012 (0.288)	0.04	283 (122)	0.703	82	78	2	4

Figure 1.

(a)



(b)



(c)

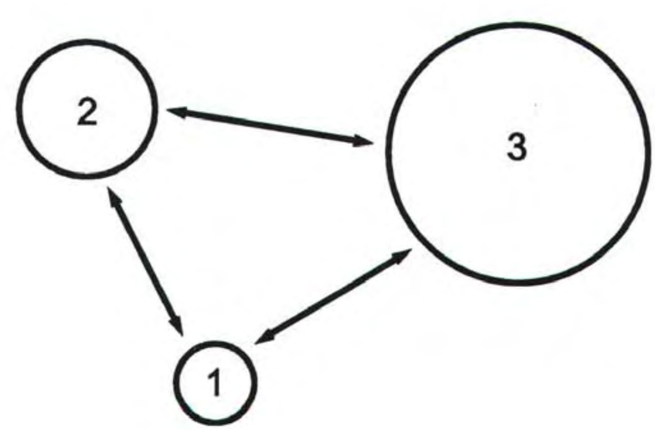


Fig. 2. Single Populations
No migration, No catastrophes

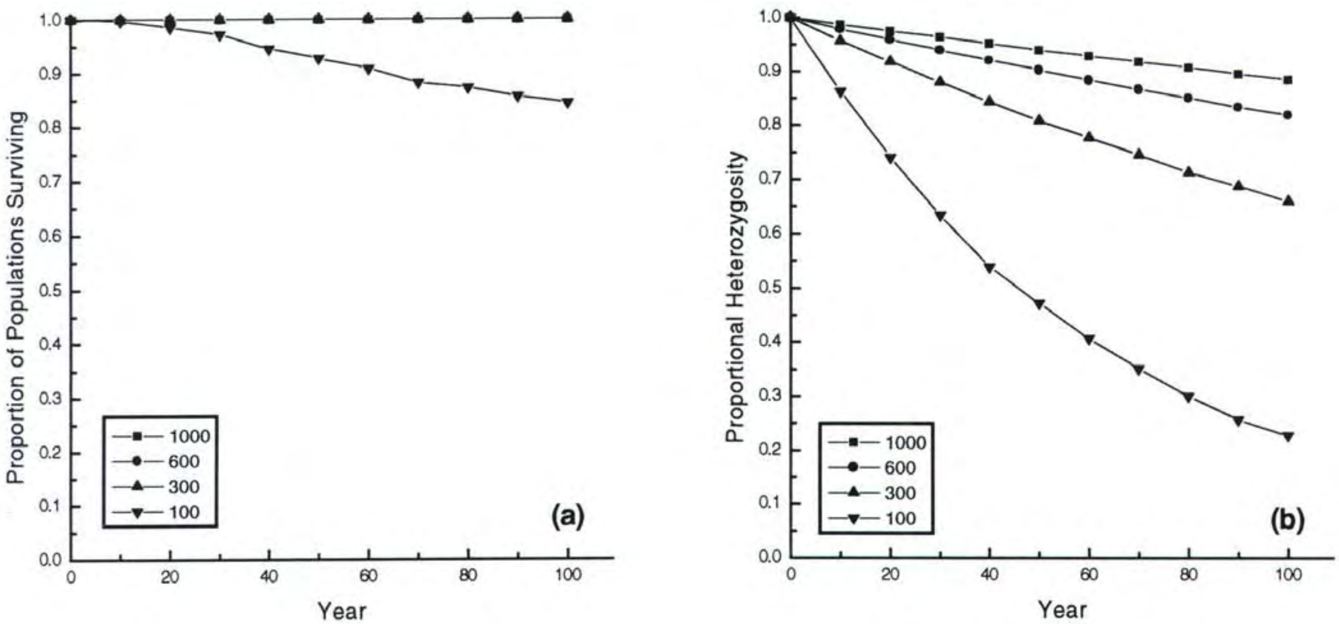


Fig. 3. Single Populations
No migration, Fire

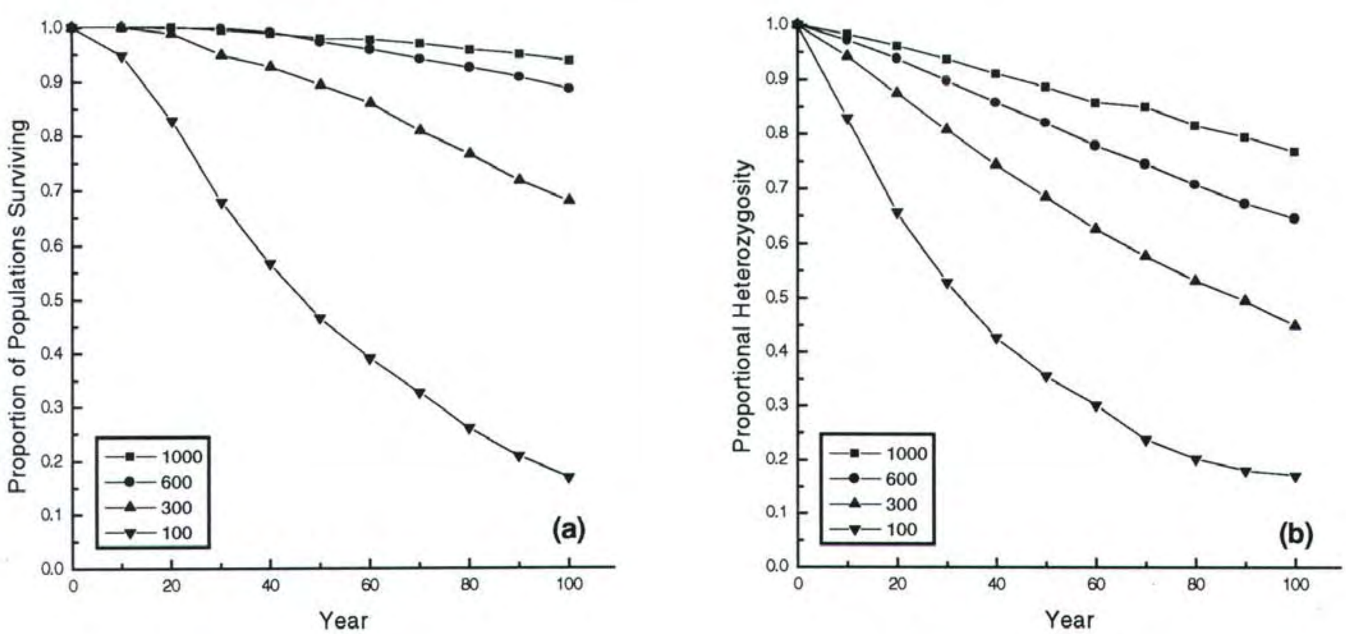


Fig. 4. Single Populations
No migration, Drought

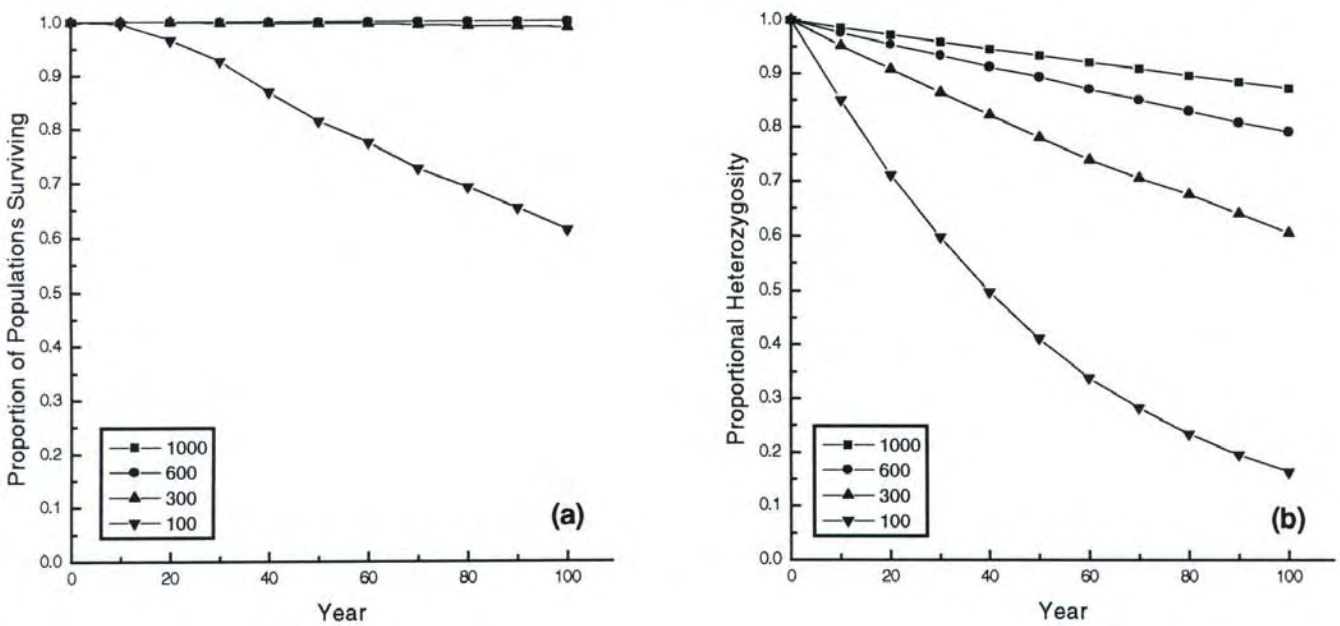


Fig. 5. Single Populations
No migration, Fire and Drought

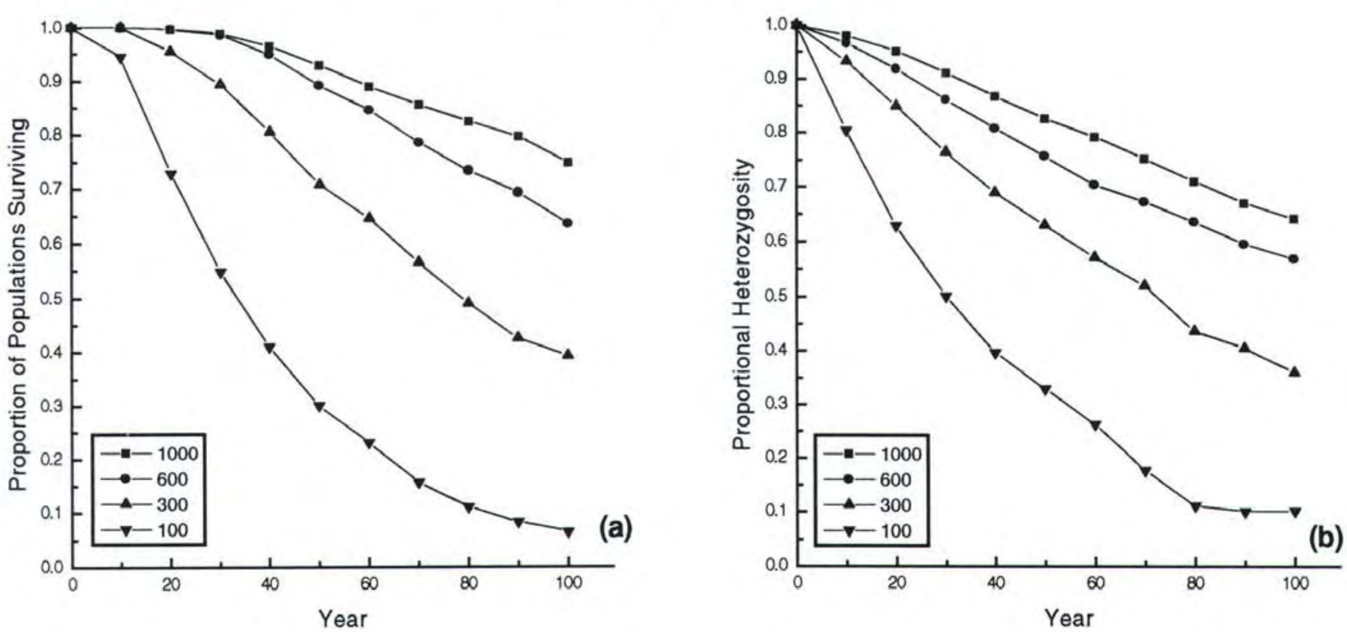


Fig. 6. 10-Patch Metapopulation (K=1000)
No catastrophes

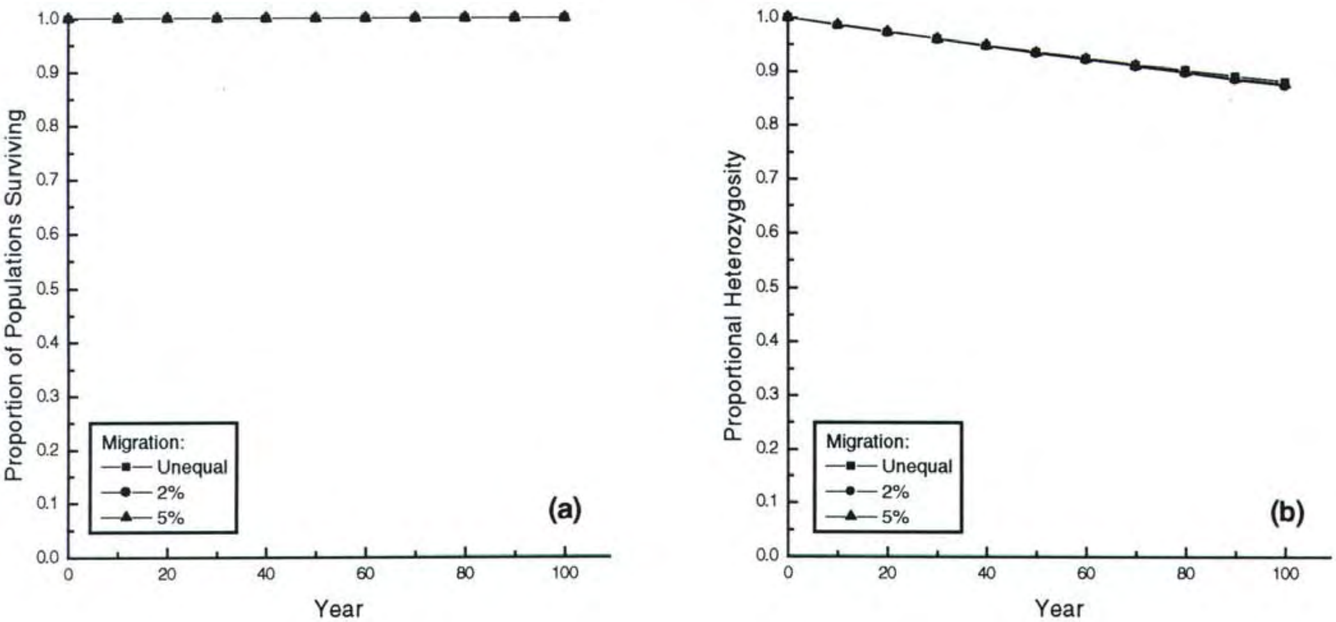


Fig. 7. 10-Patch metapopulation (K=1000)
Fire and Drought

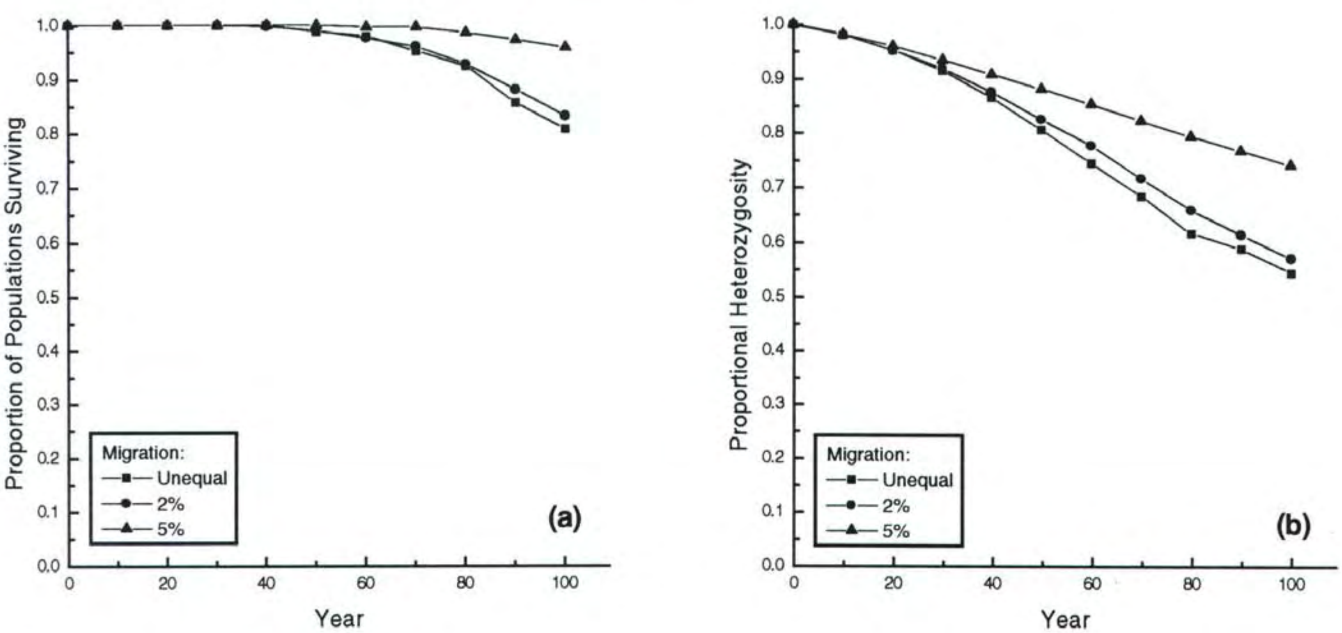


Fig. 8. 10-Patch Metapopulation (K=1000)
0.25% Annual Reduction in K

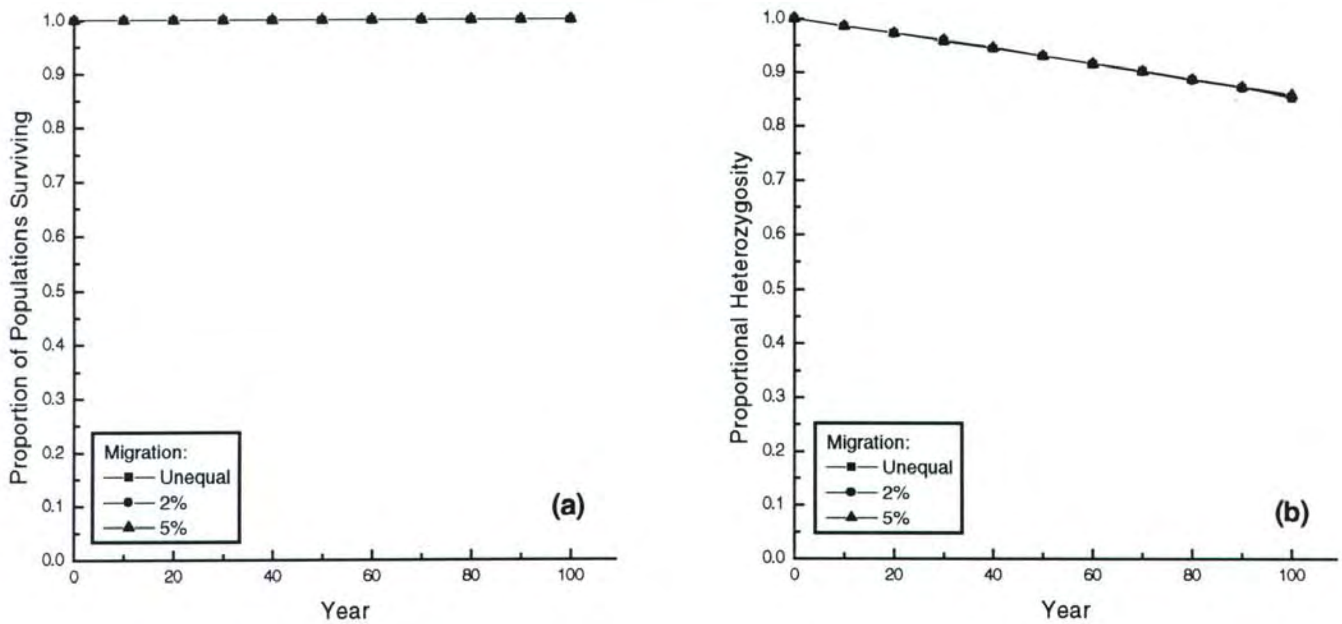


Fig. 9. 10-Patch Metapopulation (K=1000)
0.25% Annual Reduction in K, Fire and Drought

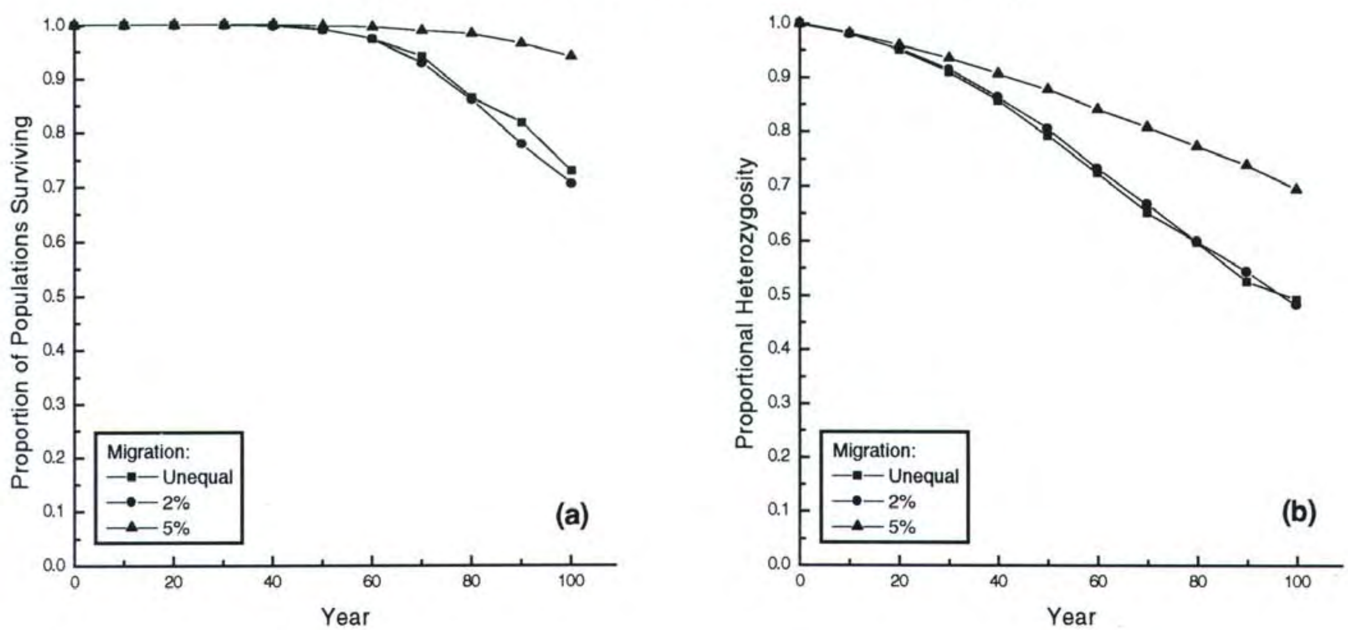


Fig. 10. 10-Patch Metapopulation (K=1000)
0.5% Annual Reduction in K

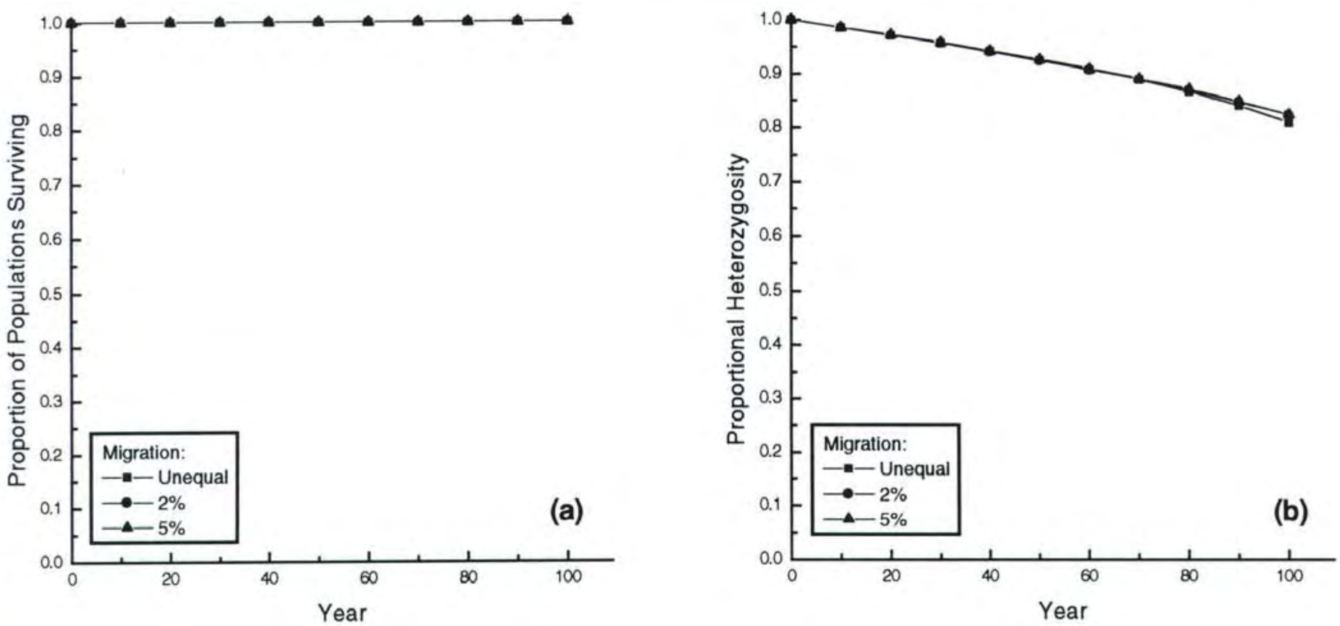


Fig. 11. 10-Patch Metapopulation (K=1000)
0.5% Annual Reduction in K, Fire and Drought

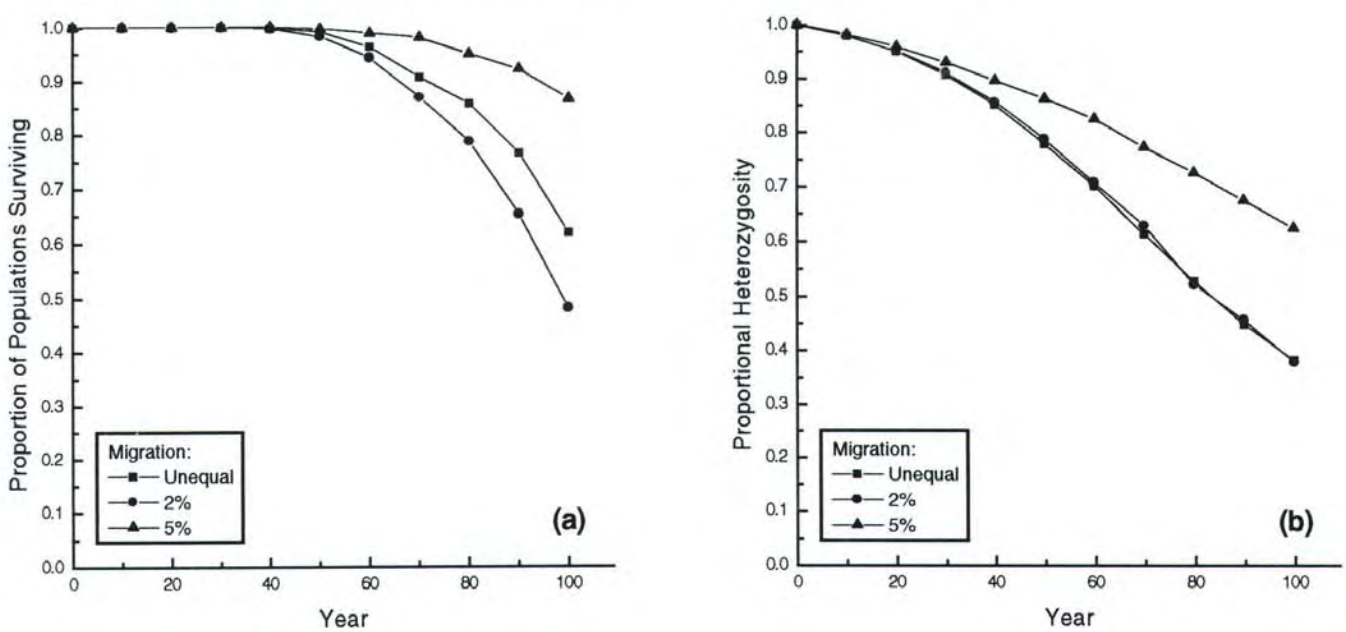


Fig. 12. 10-Patch Metapopulation (K=1000)
1.0% Peripheral Reduction in K

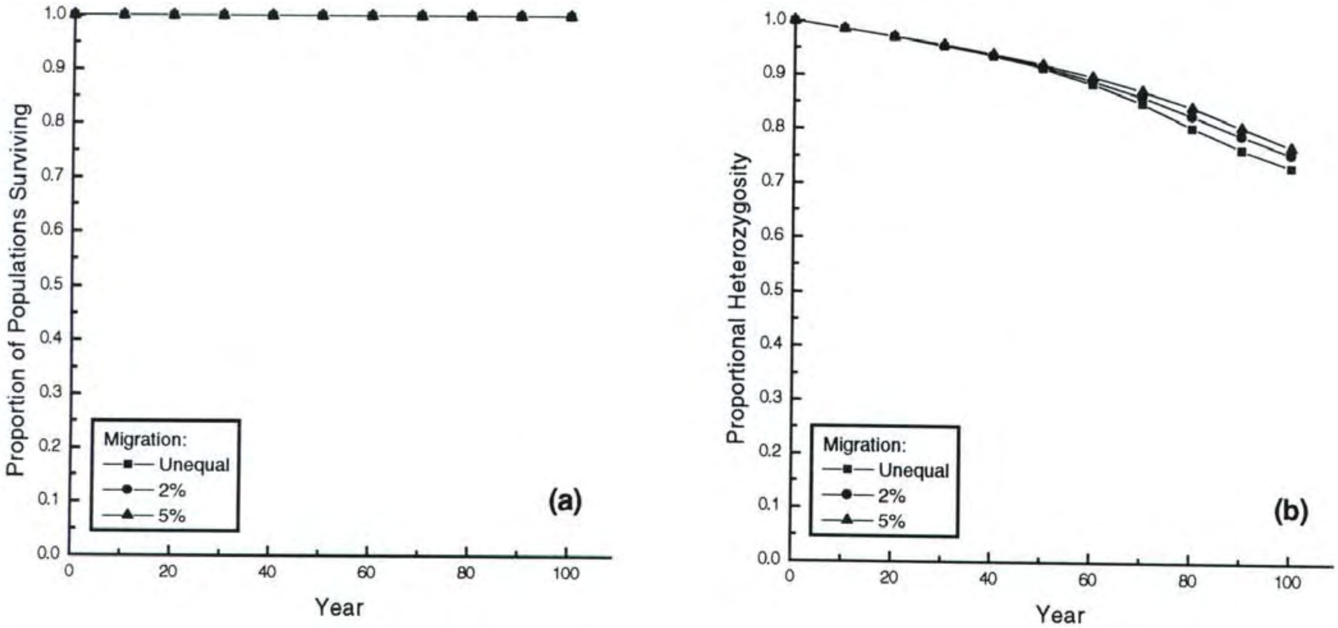


Fig. 13. 10-Patch Metapopulation (K=1000)
1.0% Peripheral Reduction in K, Fire and Drought

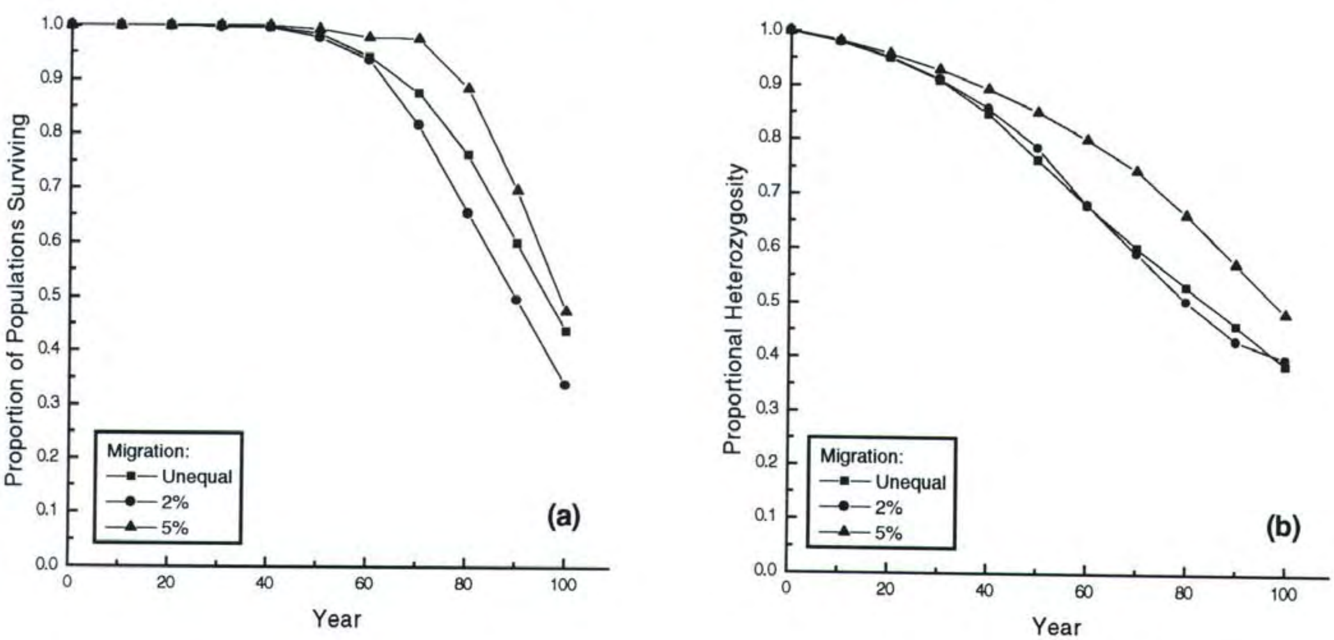
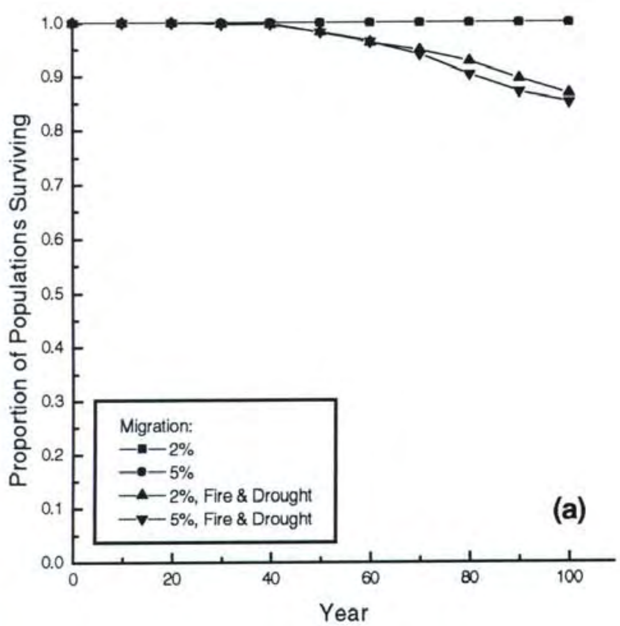


Fig. 14. 3-Patch Metapopulation (K=1000)
Unequal Patch Size



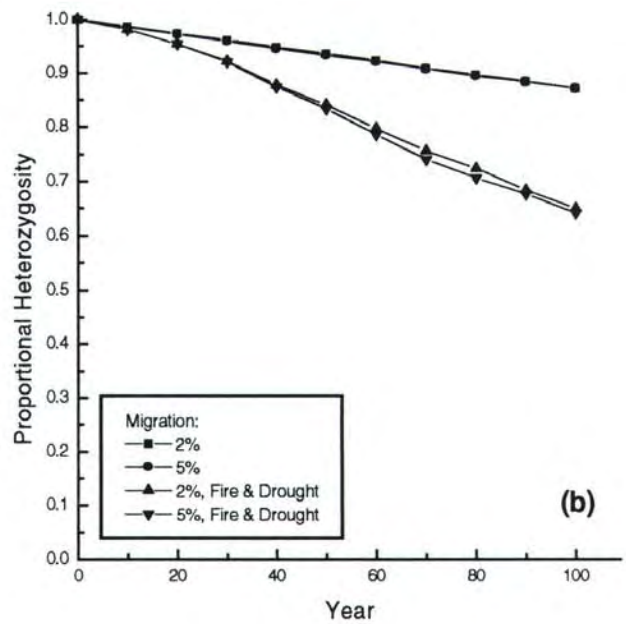
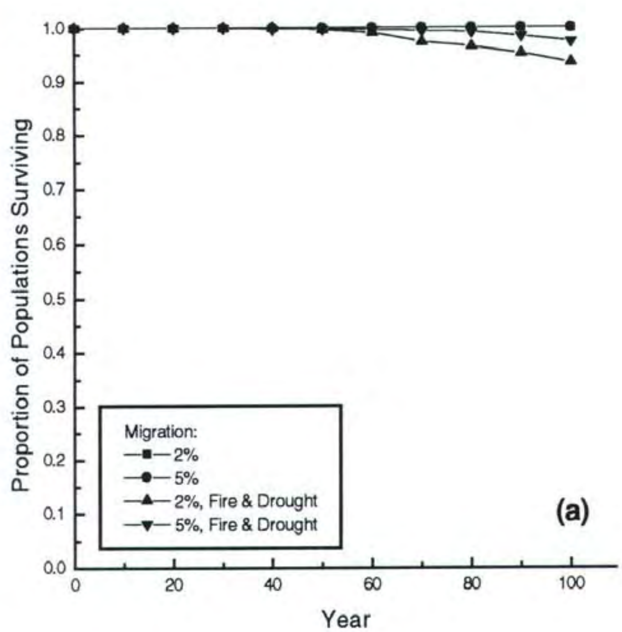


Fig. 15. 3-Patch Metapopulation (K=1000)
Equal Patch Size



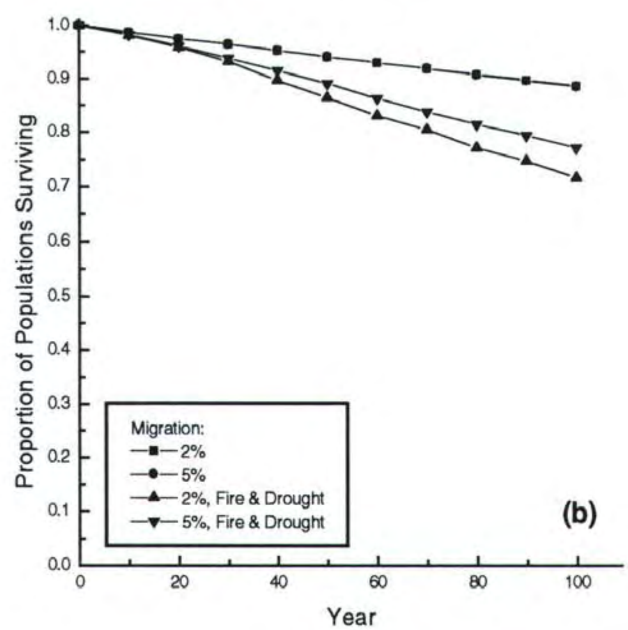


Fig. 16. 3-Patch Metapopulation (K=1000)
Unequal Patch Size; 0.25% Annual Reduction in K

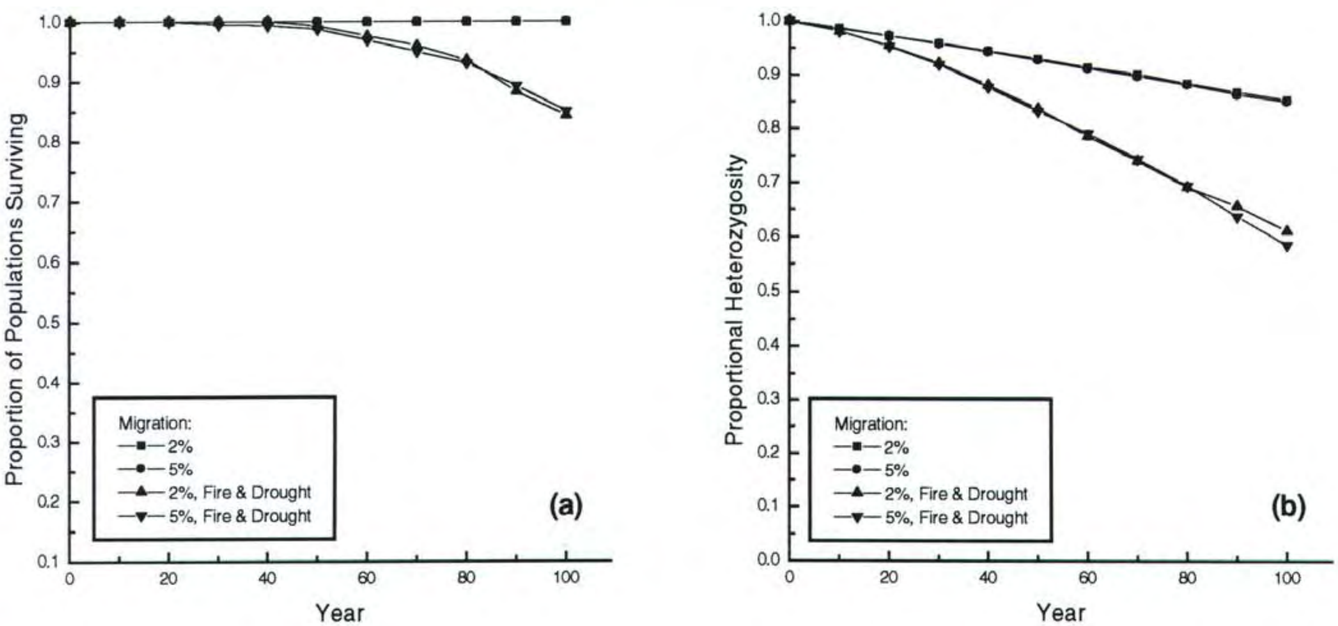


Fig. 17. 3-Patch Metapopulation (K=1000)
Equal Patch Size; 0.25% Annual Reduction in K

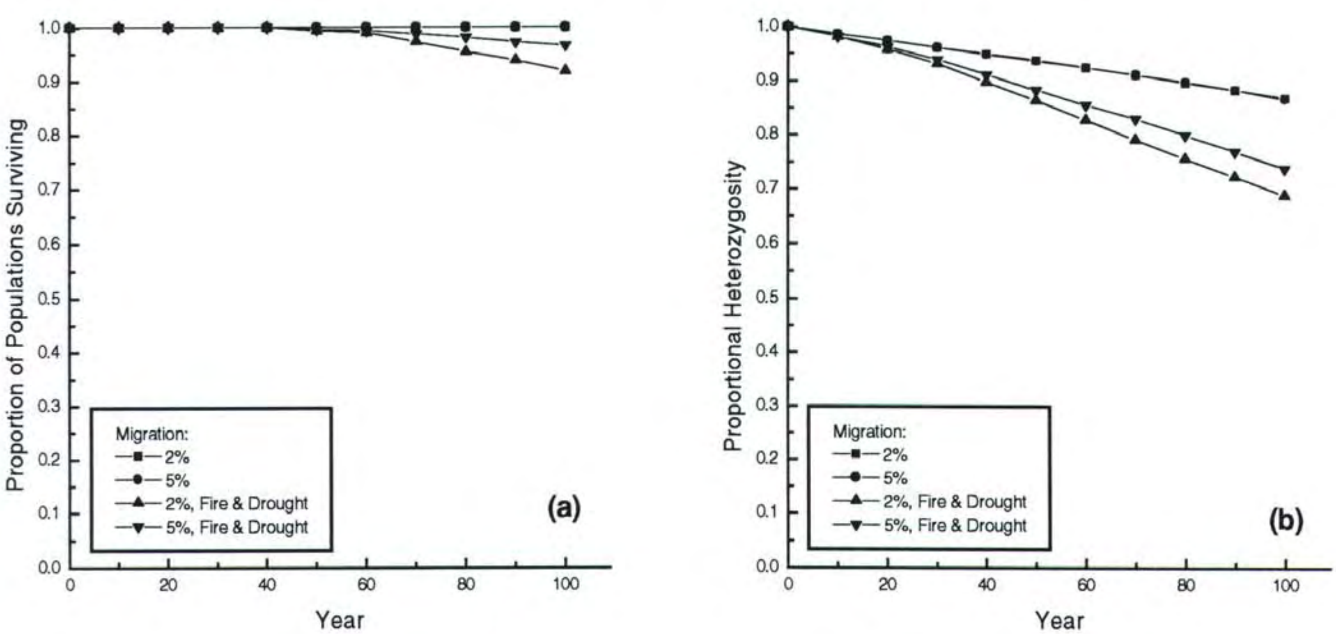


Fig. 18. 3-Patch Metapopulation (K=1000)
Unequal Patch Size; 0.5% Annual Reduction in K

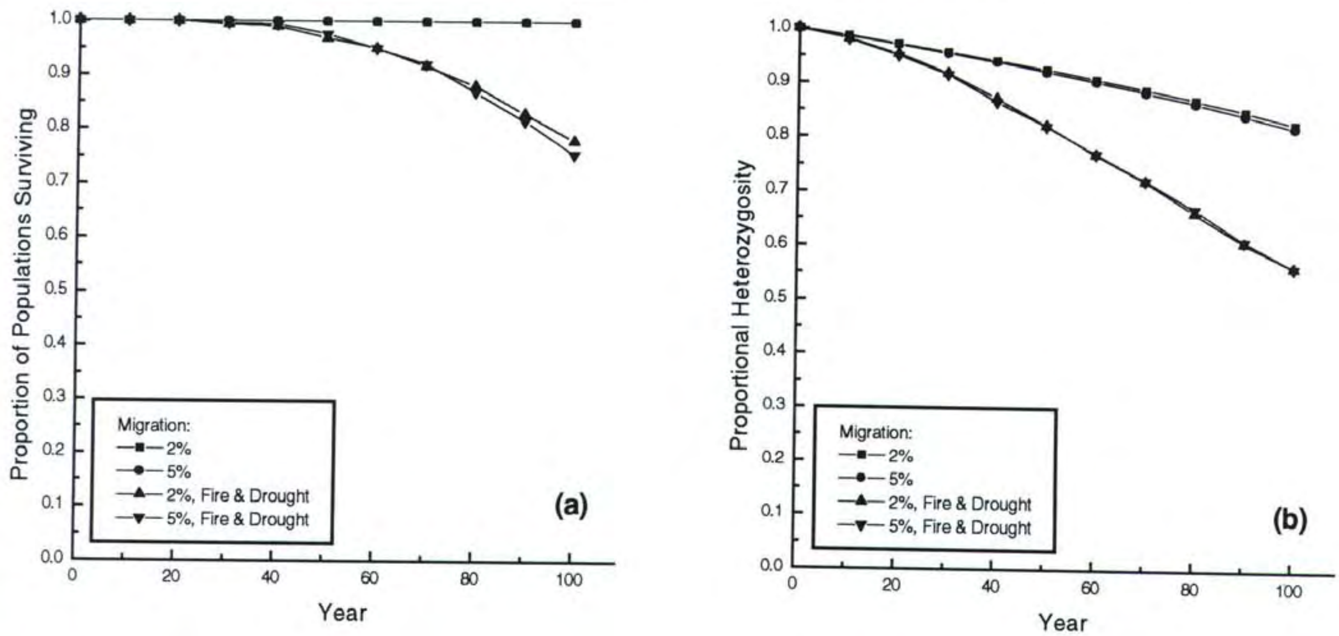
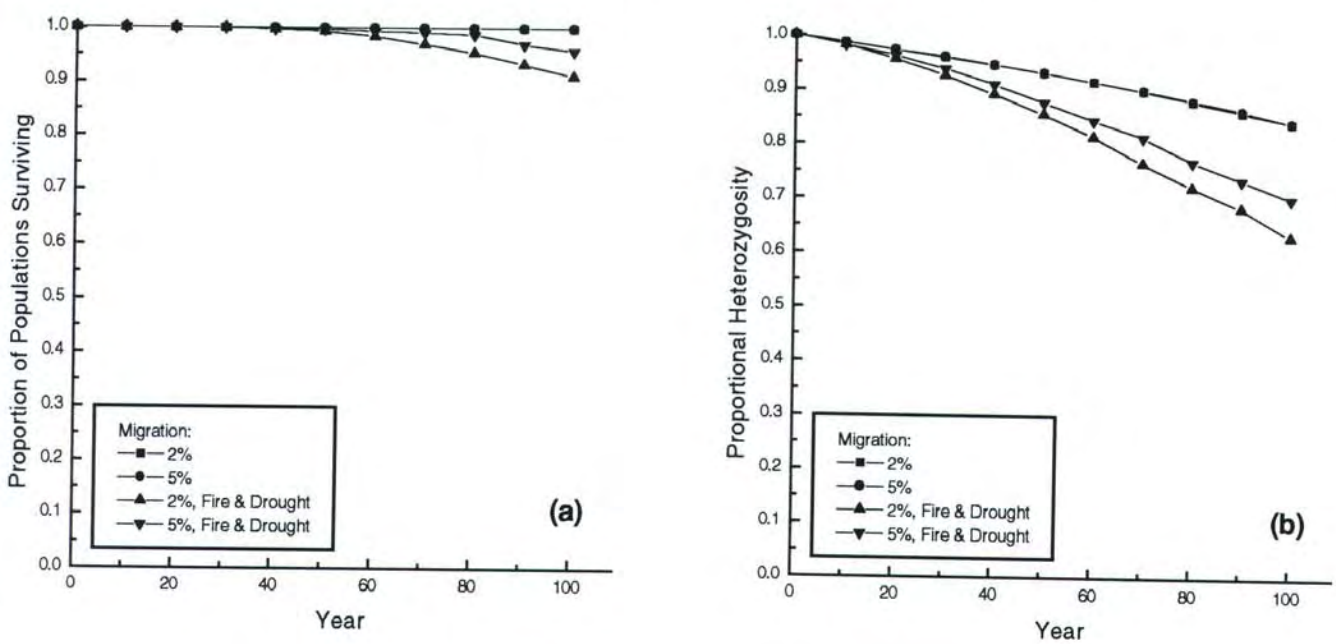


Fig. 19. 3-Patch Metapopulation (K=1000)
Equal Patch Size; 0.5% Annual Reduction in K



POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 5

DISTRIBUTION

Distribution

The Houston toad is endemic to southeast Texas. Six disjunct populations of the Houston toad are currently known to exist in seven different counties, and a small population of Houston toads has also been located in Lavaca County. The toad likely occurs in Lee county as well, and may occur in Caldwell and Waller counties. It probably has been extirpated from its former range in Harris, Liberty, and Forth Bend counties.

There is a strong correlation between the occurrence of Houston toad sightings and two separate bands of geologic formations, on which the deepest sands in the region occur. Four populations occur on the band of geologic formations (Carrizo, Queen City, Sparta, Reclaw, Weches) that runs through Bastrop County northeast to Freestone County. Three populations occur on the other band that runs parallel to and southeast of the first band, through Lavaca, Austin, and Colorado counties.

Of the six populations, the one in Bastrop County is the most robust. About 70-100 square miles of suitable/potential habitat (based on geologic formation and native woodland/savannah) occurs in this area. Public lands include Bastrop and Buescher State Parks and LCRA's land around Lake Bastrop (about 6,000 acres).

The size and status of the other populations is unknown. However, these populations occur within areas that appear to provide suitable habitat (based on relatively contiguous deep (>40 inches), sandy soils and native vegetation) in large enough blocks (20,000-50,000 acres) to support viable populations. The amount of habitat at the Lavaca County site has not been estimated, but appears to be limited and marginal. Other than the Bastrop County metapopulation, no other population occurs on public land.

Mapping exercise for Bastrop County

The best available distribution information outside Bastrop County is from Jim Yantis's (Texas Parks and Wildlife Department) studies. He has found that there is a strong correlation between Houston toad sightings and the occurrence of deep (>40 inches) sandy soils in more or less contiguous zones of greater than 20,000 acres. Jim never found a toad more than 200 meters from these soil formations.

Since a significant amount of sighting information exists for Bastrop County, we highlighted the deep sandy soils (Patilo series) and plotted the known sighting records to verify if there was a correlation with deep sands. The purpose of this exercise was to attempt to develop a predictive mechanism with which potential Houston toad habitat could be identified outside of areas of known occurrence. This could be utilized to focus recovery efforts. The appropriate geologic formations and public lands were also plotted.

Results

The mapping effort indicated three primary areas where deep sandy soils (Patilo series) occur in Bastrop County. The main area, comprising approximately 29,500 acres, includes Bastrop State Park and runs northward in a nearly contiguous band to the Lee County line. This band contained a number of sightings, primarily around Bastrop State Park and along SH 21. A second, smaller area (about 11,000 acres) is present in the northwest portion of the county. The third area is located south of the Colorado River and slightly west of Bastrop. This area comprises about 18,000 acres, but is somewhat less densely covered by deep sandy soil. The main band and southwest band are located in the geologic formations indicated as potential for occurrence of the Houston toad. The northwest band is outside these geologic formations.

Correlation of Houston toad sightings with geology indicate a 100% association with the occurrence of the Carrizo, Queen City, Sparta, Reclaw and Weches geologic formations. These formations produce the deepest and sandiest soils in the region.

Plotting of known sighting information in Bastrop County shows a weak positive correlation with the deep sands. A number of sightings were east of Bastrop State Park within the Axtell-Tabor soil association which includes shallower sands and sandy loams. While the occurrence of the toad outside of the mapped deep sandy soil complex can not be discounted, significant sampling bias has occurred in Bastrop County focusing on public lands, along major roadways, and power line corridors. More uniform and unbiased sampling throughout the county will allow evaluation of the significance of the sightings outside of the deep sandy soil complex.

Vegetation

In Bastrop County, Houston toads are found almost entirely on native pine-oak woodland and savannah which, thus, is another important component of toad habitat. Clearing of this habitat and replacement with non-native vegetation appears to promote the invasion of Woodhouse's toad.

Soils

The mapping effort found that for the Bastrop County population, there is a strong correlation between Houston toad sightings and two soil formations, the Patilo and Axtell-Tabor series. Jim Dixon (Texas A & M University) noted during surveys conducted in Bastrop County in 1990 that both the Patilo and Axtell-Tabor complexes appear to be the most important to the toad (Dixon et al. 1990). The Axtell Series has 0 to 8 inches fine sandy loam; and the Patilo Series has 0 to 52 inches fine sand, underlain by sandy clay loam
These soil formations also correspond to the occurrence of forested areas. Other possible soil types where the toad may occur include the Lincoln Series with 0 to 60 inches fine sand

and the Sayers Series with 0 to 60 inches fine sandy loam.
The Patilo soil series overlays the aquifer's major recharge zones (Carrizo, Simsborough, Queen City, and Sparta). This has important management implications to the protection of ground water quality, and the toad would also benefit from this management.

Summary Considerations

Primary considerations for determining the long-term viability of the Houston Toad include population size, habitat patch size and configuration, and migration between habitat patches. Additional research needs to be conducted to formulate possible answers to the following questions associated with those considerations.

Population

The current estimate of 2,000 toads in Bastrop County is explicitly related to the survey work primarily conducted in Bastrop State Park around Ponds 9 and 10 and utility right-of-way in the east-central part of the county. This area represents approximately one-third of the total area that could be considered viable toad habitat based on soil formations, geologic formations, and vegetation. Questions: 1) What is a reasonable estimate for a Bastrop County metapopulation for the entire habitat area; and 2) How are these toads distributed in the county in terms of patch sizes and configurations?

Area

The mapping work done by the Distribution working group identified three broad-based geographic regions that have soil formations that might support toad populations. These regions are the east-central region, which is where the principal survey work has been done and where the toad populations are verified. The southern region, all of which lies south of the Colorado River fits the basic profile in terms of soil, geology, and vegetation; however, no toads were sighted in this area during the survey conducted in 1989. The other region is in the northwest quadrant of the county and it fits the soil and vegetation criteria but it lies outside the geologic parameter. Question: Do toads occur in each of the southern or northwestern regions?

Fragmentation

The map prepared by the group indicates that clusters of toad sightings along Highway 21, Park Road 1, and various points associated with LCRA right-of-way. If the toad also occurs in other parts of the habitat range, fragmentation between toad patches becomes a serious consideration for the long-term viability of the species. Question: To what extent are the toad patches fragmented (migration rates) from one another, and how does this fragmentation affect recovery planning for the toad?

Recommendations

1. Repeat mapping effort for other counties occupied by the Houston Toad.

2. Incorporate mapping information into a geographic information system database; look into cost-sharing with other agencies/organizations.

3. Determine areas of potential habitat and degree of interconnectedness between and within patches.

4. Conduct additional surveys to determine distribution within habitat patches and verify accuracy of mapping effort.

5. Conduct surveys in Lee County.

6. Survey priorities for Bastrop County:

> **a) Survey area within appropriate geologic formations north of the Colorado River. Houston toad surveys in this area have been limited to public lands and road and power line rights-of-way. Most of the land outside of these areas within the appropriate geologic formations have never been surveyed to determine the presence/absence of toads. We recommend that surveys of these areas be initiated during the 1995 breeding season.**
>
> **b) Survey area within appropriate soil type, but outside geologic formations, north of the Colorado River.**
>
> **c) Survey area within appropriate geologic formations south of the Colorado River.**

7. Develop volunteer groups to help conduct surveys. Volunteers would need to be trained by Houston toad biologists.

8. Look at genetic relationship between toads occupying the two different bands of geologic formations.

Houston Toad Survey Methods

Hillis 1984 **Each site was visited Jan.1 through June 4 (1981); chorusing assembled each time minimum air temperature of preceding 24-hour period did not fall below 14 degrees C (57 degrees F); [Findings: chorusing not directly correlated with rain; no gravid females seen after May 2; initiation of chorusing January 22; initiation of spawning February 18; latest date for initiation of chorusing and spawning February 23].**

Potter 1984 **First late-winter night following 24-hour period where air temperature does not fall below 14 degrees C; same ponds should be visited each year.**

Jacobson 1989
Fifty visits made between January 20 (1982) and June 2; nightly during breeding choruses, otherwise every 2-3 nights in February-March and every 2-10 nights in January, April, and May; [Findings: first calling heard on January 22 and last on May 15; first major night of calling activity February 19; main breeding chorus 19 to 24 February (85 percent of males and 64% of females); prior to March 29, initiation of calling occurred in absence of rain but when low of previous night did not drop below 14 degrees C.].

Dixon 1990 **Most ponds monitored during late March (peak period of toad activity); two ponds monitored beginning in late January on nights with favorable weather (minimum air temperature greater or equal to 14 degrees C during previous 24-hour period); [Findings: moon visibility inhibits Houston toad activity; suitable minimum air temperature for prior 24-hour period may be lower than 14 degrees C.].**

Price 1990 **Survey mid-February through end of April; nightly searches under conditions known to be favorable to Houston toad activity; searches to begin at dark.**

Yantis 1990 **Surveys to be conducted within 48 hours after first heavy (more than 3"), widespread rain in March that is accompanied by night-time temperatures in the mid-60's or above and previous night minimum temperature has not fallen below 55 degrees F (but survey may begin as early as dark on the day of the rain); do not survey if the wind is too strong (inhibits hearing ability); begin survey 30 minutes after sundown and continue to at least midnight, but no later than 2 AM; stop every 0.2 miles and listen 20 seconds for breeding**

call (keep windows down and turn engine off).

Horizon 1993

Surveys to be conducted in conjunction with Dr. Jim Dixon of TAMU; listening stations at potential Houston toad breeding sites to be visited on 20 different occasions between February and April; all toads to be identified to species; audio-taped recordings of male Houston toad calls to be used.

Hicks and Company 1994

Two surveyors familiar with anuran calls and taxonomy to visit 20-30 wetlands on 20 nights in March and April; survey when weather and lunar conditions are prime for Houston toad breeding colonies; prime conditions are warm (above 52 degrees F. for prior 24-hour period), humid (greater than 20% humidity), nights when moon is not full.

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POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 6

HABITAT REQUIREMENTS AND MANAGEMENT

Habitat

The Houston toad appears to be associated with sandy soils found within five geologic formations running northeast-southwest from south of Bastrop County to Freestone County and from Lavaca County to Austin County. These areas usually have fairly deep friable sands with subsurface moisture.

Suitable breeding sites are also essential. This does not appear to be a limiting factor for the western portion of the Bastrop population, but may be in the eastern portion. The toad appears to prefer ephemeral breeding pools but also regularly breeds in smaller permanent ponds or sheltered waters having minimal predation. The breeding pools must provide sufficient water quality and quantity, food sources for tadpoles, and protection from predators. The water must persist long enough (about 30-60 days) for tadpoles to metamorphose into juvenile toads.

Habitat contains varying degrees of an overstory of woody vegetation, and a ground cover that permits relatively easy travel, sufficient insect supplies, cover from predators and relatively little disturbance. Toads have been located in the Lost Pines (*Pinus taeda* and associated species) in Bastrop County and in the post oak (*Quercus stellata*) savannah (little blue stem and other native grasses) northeast of Bastrop County. Both the pine and post oak savannah are fire climax communities. There is a need to further identify preferred toad habitat used during activities outside the breeding season. A need also exists to obtain a habitat description including study of soils, vegetation, water quality, distance to water, topography, and patch size.

Land Uses

Land use in the area consists of commercial and non-commercial forests, native range, improved pasture, intensive agricultural activities such as row crops, both rural and urban development for homes, and recreational and park lands. Establishment of a geographic information system could show land use on a regional scale and assist planning of land use activities in relation to toad habitat. Assessment of current management practices, herbicide application, prescribed burning, etc. for determination of impacts to Houston toads needs to be conducted. Establishment and maintenance of stream side management zones for improved water quality and migration of toads is also encouraged along with restoration and reclamation activities to reestablish appropriate native vegetation.

<u>Commercial Pine Timber</u>

The "Lost Pines" pine forests have commercial timber value, especially during the wetter months when East Texas timber is less accessible, and cutting timber is common. Some areas that have been selectively cut several times still have toads, and it is believed that this method may be compatible with toad populations. Catastrophic events, such as insect outbreaks and fires can cause extensive pine mortality. For example, southern pine beetles

have periodically caused fairly extensive pine mortality and sometimes reach epidemic populations necessitating control efforts. Pine forests are also a fire climax community. Fire has been and probably should be a part of habitat management in these pine forests. Pine forests have been removed and the land converted to other uses, primarily improved pasture and residential development. Work is needed to further identify the beneficial and detrimental impacts of timber harvesting methods on toad populations and restoration techniques for toad habitat in forested lands. Practices to avoid impacts on the toad should be integrated into forest land management plans.

Native Range

Native range is found over a large portion of the area that contains habitat which is believed to be suitable for Houston toads. When associated with some type of overstory, as in the Post Oak Savannah type, native range appears to be compatible with the Houston toad. This cover type is also a fire climax type. Native range is usually a bunch grass type which permits relatively easy travel by the toad and provides a suitable prey substrate and cover. Normal native range maintenance procedures, including shredding, herbicide application, etc., are fairly common and may be detrimental to toads. Native pastures are also sometimes burned. Conversion of ephemeral ponds into deeper stock ponds and clearing of the overstory may lead to an increase in the presence of Woodhouse's toads which compete with and may displace the Houston toad. Clearing vegetation and disturbing the soil may also lead to the invasion or increase of fire ants which may prey on the toadlets. The maintenance or restoration of native range lands to conditions favorable for the Houston toad is desirable . Options including providing technical guidance, economic incentives, stewardship programs, etc. should be evaluated.

Improved Pasture

Improved pasture is also found over a large portion of the area suitable for Houston toads. Often introduced pasture grasses, such as coastal Bermuda, are planted and cultivated for grazing or hay production. Improved pastures usually have little or no woody species. These grasses are dense and may inhibit travel by the toad. Often improved pastures have been topographically altered, which fills ephemeral pools and may alter the depth of sands. Fertilizers and pesticides are common management tools. Improved pastures are usually grazed heavily or mowed and baled for hay. Improved pastures often run through creek courses or up to banks of streams. Further research is needed to examine the potential for eliminating barriers and maintaining or creating travel corridors for toads. Technical assistance and incentives are needed to encourage conversion of improved pasture to native range.

Crop Land

Intensive row crop and orchard operations occurring near toad habitat area are generally located on heavier soils and less frequently on deep sands. Soils are often turned on a

regular basis by plowing or discing. Intensive use of fertilizers and pesticides is the rule, which may impact breeding ponds in surrounding areas. Often the land lies fallow throughout winter. Usually land has been leveled or terraced. Assessment as to the extent and impacts of these operations in the range of the toad would prove helpful to determine impacts on the populations or future habitat planning.

Urban and Rural Housing Development

Urban and rural housing development associated with the expansion of towns or the development of subdivisions is often intensive and concentrated. Streets and utility rights-of-way are prevalent. Creeks may be rechanneled or filled. Leveling often occurs on lots. Often native vegetation is replaced with lawn and cultivated plants, but overstory trees are retained when possible. Usually there is much use and misuse of chemical fertilizers and pesticides. Rural development is generally scattered and only intensive on the house-yard-barn area. The lawn area may be developed as in the city, but often native vegetation is used.

Recreation and Park Lands

Recreational activities on public and private land can have positive and negative impacts on the Houston toad. On a positive note, dedication of lands for recreation can increase public interest in toad preservation and encourage education about the species. Negative impacts on toads and their habitat may result from planning, facilities construction, maintenance activities, and heavy human use. Integration of toad management needs into park management and master planning strategies is essential.

Resource Extraction

Resource extraction activities including strip mining, soil and gravel mining, petro-chemical extraction, and their associated activities can negatively impact toads and are known to occur within the toad's range. Research regarding the effects of resource extraction and reclamation activities on toads and toad habitat need to be evaluated.

Recommendations

1. Minimize disturbance of soil (including compaction) to prevent introductions and competition from other species of toad and impacts of exotic species invasions (such as fire ants).

2. Minimize activities that increase predation on the toad and destruction and conversion of ephemeral pools.

3. Minimize topographical alteration.

4. Minimize pesticide and other chemical use.

5. Minimize habitat fragmentation including barriers and impervious cover (such as fences and non-native grasses like coastal Bermuda and St. Augustine).

6. Maximize use of current and innovative incentives to accomplish recovery.

7. Maximize maintenance and restoration of native vegetation.

8. Maximize maintenance and restoration of corridors (including stream side management zones).

9. Maximize use of native plants in landscaping.

10. Maximize use of non-toad habitat for urban development needs through comprehensive planning.

11. Maximize toad recovery by developing and providing consistent technical assistance to land owners and planners through resource agency programs.

12. Maximize education and interpretation of toad ecology and recovery

13. Further identify preferred toad habitat used during activities outside of the breeding season, and obtain a habitat description including a study of soils, vegetation, water quality, distance to water, topography, and patch size and shape.

14. Establish a geographic information system to show land use on a regional scale and orient land use activities to areas outside of toad habitat.

15. Assess current agricultural management practices, herbicide and pesticide application, prescribed burning, etc. for impacts on Houston toads.

16. Identify beneficial and detrimental impacts of timber harvesting methods on toad populations.

17. Examine restoration techniques for toad habitat in forested and savannah lands.

18. Further research is needed to examine the potential for eliminating barriers (including fences) and maintaining or creating travel corridors for toads.

19. Assess extent and impacts of cropland operations in the range of the toad to determine impacts on populations or future habitat planning.

20. Assess extent of resource extraction activities on toads and toad habitat.

POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 7

THREATS

Threats

Fish stocking

Fish stocking poses a widespread threat to Houston toad populations. The toad's reproductive habitats include ephemeral and permanent water bodies. These range from a few square meters to the shallow littoral habitat of Lake Bastrop. In contrast to the other toads in its range (Gulf Coast toad, Woodhouse's toad), the Houston toad appears to have evolved in small ephemeral ponds and watercourses. Much land use in the range of the Houston toad is primarily agricultural (pasture, hay, row crops) and a large number of ranch ponds have been constructed in the past century. Some of these were built in areas that had ephemeral depression wetlands suitable for Houston toad breeding. Once these ponds fill, landowners, or managers typically stock these ponds with a variety of fishes. Fishes stocked into these ponds (stock tanks) can include: ictalurids (channel catfish, blue catfish, possibly bullheads), centrarchids (sunfishes, and "black basses" including largemouth bass, smallmouth bass, crappie, bluegill, and others), cyprinids (minnows including fathead minnows) and salmonids (rainbow trout).

Within Bastrop State Park, a number of Houston toad breeding ponds currently are without fish. A ten-acre pond known as the fishing pond is stocked with largemouth bass, channel catfish, and rainbow trout. Rainbow trout, a non-native, are stocked in winter for a put-and-take fishery. The persistence of rainbow trout in this pond through February and March is not known but is inferred, given water temperatures less than 75^{o} F. If game fish were introduced into ponds #9 and #10, the expected effect would be reduction or elimination of tadpoles and hence toad recruitment. Large predacious fish could prey on eggs, tadpoles, and possibly interfere with breeding. A large number of fishing lures are modeled after tadpoles. Natural colonization of these habitats may be infrequent (1 in 100 years), but occasional drying would eliminate these fish. However, purposeful introductions and inadvertent stockings (either included in the sport fish stockings or through bait bucket releases) are expected to continue for the foreseeable future throughout the range of the Houston toad. Potentially, some fishes may compete with tadpoles which graze on algae.

In the Hilltop area of Burleson County (the second largest Houston toad population) Jim Yantis (Texas Parks and Wildlife Department) reported Houston toad breeding as occurring only in a shallow area behind a cattail stand apparently inaccessable to fishes in the lake. Changes in the lake level would affect suitability of this area for rearing. Low levels would result in drying of the area whereas high levels would allow fish to gain access.

Assignment of permanent ponds for toad breeding (without special engineering or management for fish and toad habitat segregation) appears to be incompatible with a sport fishery. While data on fish predation on Houston toads are not available, volumes of information are available on the broad food habits of basses and catfish. Placement of

brushpiles, dead trees or other structures in these ponds will attract bass. Toad tadpoles may be in some of these same areas.
Stocking of fishes would increase predation on egg and tadpole stages and may increase predation on adults by attracting predators such as snakes, birds, and small mammals to the ponds. This pond then would provide reduced or no recruitment of toads into the local population complex. New diseases may also be brought into the toad habitat with fish stocking.

Livestock Production

Livestock production initially involves the conversion of native prairie to "improved" pasture, introducing exotic sod-forming grasses (e.g. Bermuda, bahia), which inhibit toad mobility. Management-related activities that impact Houston toads include mowing, pesticide spraying for weed and insect control, discing, hay production, application of fertilizers, and over-grazing. These activities may result in direct mortality of toads, increased exposure of toads to predators and weather conditions, and loss of habitat. The problem is wide-spread outside of Bastrop County.

Timber Harvest/Soil Compaction

Impacts from pine timber harvesting in occupied Houston toad habitat are currently limited to Bastrop and Leon counties. Timber harvesting impacts include direct mortality of adult toads from vehicular traffic and machinery, soil compaction, alteration of habitat, rutting, erosion, damaged stream crossings, damage to ephemeral breeding ponds, and disturbances to breeding activities. Timber removal may alter the prey base, increase fire ant invasion and establishment, and facilitate development and/or alteration of habitat to uses incompatible with Houston toads. Clearing associated with timber harvest may open up habitat and facilitate colonization by Woodhouse's toads. Research is needed to determine methods for harvesting timber that will avoid or minimize impacts to toads. These include the type of harvest, time of the year of harvest, size of the cutting unit, and the type of machinery used.

Fire Ants

Fire ants are widespread throughout central Texas and may be a major threat to Houston toads throughout much of its range. Fire ants may not be as significant a threat in relatively undisturbed areas such as Bastrop State Park. Fire ant infestations may be facilitated by disturbance and modification of native vegetation and habitat in either urban or rural/agricultural settings.

Fire ants can impact Houston toads through direct mortality on emerging toadlets and adults or through indirect impacts on the toad's arthropod prey base. The impact of fire ants on the toad populations may be increased during dry periods when ants concentrate activity around water sources and damp depressions where toadlets are emerging.

Mortality caused by fire ants may decrease the size of Houston toad subpopulations, eliminate toads from certain parts of its current range, or prevent successful reintroduction of toads into otherwise suitable habitat.
The threat posed by fire ants is likely to persist and may even increase in absence of safe, effective control methods. Commonly used chemical methods of fire ant control may harm Houston toads directly via runoff and water pollution or indirectly through eliminating non-target invertebrates that may serve as toad prey. Proper, carefully controlled use of chemicals should help to alleviate the fire ant threat.

Research and information needs relevant to the fire ant threat include gathering information on the effect (positive or negative) of fire ant control methods on toad populations. In both urban and agricultural settings, public education on fire ant control and proper use of chemical control methods may help alleviate the threat. Education should also include discussion of efforts that can be undertaken to prevent introduction and spread of fire ants. Research into developing new, alternative methods of fire ant control should be encouraged and supported.

Pollution

Pollutants may include pesticides, fertilizers, waste water effluent, and petroleum products. Diffuse sources include run-off from highways, utility rights-of-ways, agricultural fields and residential lawns. Point source pollutants include pesticides or other pollutants applied directly to toad habitat and adjacent areas. Use of pesticides (herbicides, insecticides, rodenticides, fungicides) should be avoided if property or land area occurs within toad habitat. If fire ants are present, however, individual mound treatment with appropriate control procedures should be employed instead of broadcasting. Chemical residues can cause direct mortality to all phases of the toad's life cycle (egg, tadpoles, toadlets, adult) particularly the aquatic phase, and could also cause sublethal effects and indirect impacts such as reducing reproductive output by affecting physiological development, modifying behavior, and decreasing the prey base. Because of the nature of the life cycle in three separate stages, they are exposed to several media (air, water, soil) at some point in their life. Each of these life phases has different food requirements which are differentially affected by pollutants.

While pollution can occur throughout the entire range of the Houston toad, it will have localized impacts depending on type and source of pollutant. Research needs to be conducted to quantify lethal and sublethal effects of the particular pollutants affecting each life phase of the toad through air, water, and soil sampling and trying to determine the source(s) of the pollutants. Research to determine methods and timing of pesticide application might provide insight into reducing exposure. The impact of UV radiation also needs to be considered.

Pond Construction

Historically, Houston toads bred primarily in natural ephemeral ponds and low lying depressions. As a result of landscape modifications, the majority of Houston toad breeding sites at present are stock ponds and similar permanent impoundments.
Houston toads can be impacted by various factors of pond construction in addition to actual physical construction. Loss of ephemeral ponds can result from filling by humans or sedimentation from erosion. Conversion to permanent ponds poses another threat. Further impacts from construction or conversion include increase and/or introduction of competitors (e.g. Woodhouse and Gulf Coast toads), exotics, and aquatic predators (such as snakes, turtles and predatory fish). Concentration of cattle and feral hogs in a localized area could possibly result in direct mortality, soil compaction, nitrite pollution, and shoreline sedimentation due to loss of vegetative cover.

Although these threats are somewhat limited within the Bastrop State Park area, their occurrence in other rural areas within the range may be more widespread. Additional research regarding size, shape, depth, location, etc. of ponds should be conducted.

Suppressed Fire/Fire Control

The Lost Pines community that serves as the core of Houston toad habitat is historically a fire-maintained community. Nonetheless, fire may be both a threat and a management tool. Fire suppression poses a threat to the toad in prairie-like or savannah situations. Resulting thicketization may limit the available food supply and restrict mobility. Long term suppression increases probability of outbreak of damaging wildfire, specifically in pine areas.

Prescribed burning, on the other hand, when used properly can both manage existing habitat and help restore suitable toad habitat to grasses and forbs that grow after a controlled burn. Research should be conducted that includes study plots that record pre- and post-burning vegetation structure, invertebrate fauna before and after, and conditions of the burns including appropriate size, timing, frequency, and intensity of burning. Further studies of combining prescribed burning with planned grazing systems as related to Houston toad habitat should also be addressed.

Urbanization

Urbanization causes direct habitat loss from land clearing for infrastructure and actual construction. Permanent changes destroy habitat components, including small ephemeral ponds, existing vegetative communities, prey species and small depressions that hold water which may be used for breeding.

Traditional urban development levels property and replaces native habitat with

impervious cover and introduced plants that may lead to thicketization and/or alter the prey base. Furthermore, this may include management practices, such as mowing, that have further adverse effects.

Roadways and utility corridors may also have direct impacts. In addition to causing direct kills, large roadways may also disturb historic dispersal patterns and may affect drainage, eliminating some ephemeral ponds and attracting toads to ditches too near the roadway. Utility corridors that are cleared, sprayed or mowed may also adversely affect movement.

Indirect impacts associated with urbanization include introduction of domestic and feral predators (dogs, cats), increased numbers some native predators (raccoons), and destruction by uninformed humans. Also, urban landscapes are frequently treated with chemicals that may be lethal or sublethal and interfere with reproductive development or impact the food supply of tadpoles and adults. In addition, disturbance and openings in native vegetation provide habitat for the red imported fire ant, which competes with toads for food and can cause mortality in all development stages. Fence construction may also impede toad movement in some areas.

Urbanization is localized within the range of the Houston toad and the probability of this threat occurring and the intensity of the threat varies throughout the range. There is current urbanization in Bastrop, Burleson, and Leon counties (Hilltop Lakes), and more is projected to occur in Austin County. The probability of urbanization is increasing throughout the range.

Suggested research includes investigation of land use modification and urbanization activities that might be compatible with the Houston toad, and monitoring known sites where the toad is known to exist near urbanized areas. Acceptable chemical alternatives and pest management protocols need to be developed, along with planned development procedures which include toad friendly engineering (regarding roadways, housing density, mowing, fencing, etc.).

Weather Related Threats

Weather-related threats, although outside of our control, may pose a serious threat throughout the range of the toad. Droughts pose an immediate threat by reducing important breeding areas during extreme dry periods, floods can transport pathogens leading to disease and may also introduce exotics, pollutant and sediment loads into breeding areas. Reviewing historic weather patterns to determine flood and drought cycles as a tool to predict future patterns is recommended. Development of a contingency plan during extended drought periods is also suggested.

Disease

While the working group's current knowledge of the Houston toad does not include known diseases and parasites specific to the species, other amphibians are declining from bacterial and fungal infections. Further, immune systems of amphibians may be suppressed by environmental stresses which may lead to population decline. These speculations suggest that disease as an potential threat is a much needed area of research.

Resource Extraction

Because of the soil types common in Houston toad habitat, mining for coal, sand, gravel, or clay constitutes a potentially serious threat. Toads could possibly be killed by machines and vehicular traffic, and habitat destruction. These activities may also disturb breeding activities if they occur during the breeding season. Oil and gas exploration and production and electrical power transmission constitute the same threats with possibly even greater ramifications from extensive construction and maintenance of rights-of-way associated with these activities. Economic impact to private landowners involved with extraction need to be considered, and ways to develop incentives encouraging landowners to forego sand mining and other extraction should be explored.

Other

Another major factor posing a threat to the Houston toad is the widespread lack of public awareness about where toad habitat occurs and other habitat requirements and general information about the species. Many people in Bastrop County, as well as residents throughout the habitat range, may be interested in conservation efforts and measures to avoid indirectly impacting the species. However, there is a significant lack of information and awareness of Houston toad biology and habitat, both among the scientific community and the general public. Efforts are needed to compile and distribute information to schools, chambers of commerce, county extension agents, conservation organizations, professional and civic groups, throughout the Houston toad's range.

A rapid increase in existence of feral animals also poses a potential problem. Feral hogs are increasing both in number and distribution throughout Texas. Their activities within Houston toad habitat may include some predation since hogs are opportunistic feeders, but habitat destruction resulting from rooting around and pollution of permanent ponds and within ephemeral pond sites will most adversely impact the species.

Proposed expansion of the existing nine hole golf course in Bastrop County is an imminent threat. Specific threats pertaining to golf course, i.e., pollution, habitat destruction, and various factors related to urbanization, have been described in detail in previous sections.

Urban Land Use Planning

A small group of interested parties, led by Susan Crowe of the Bastrop Chamber of Commerce, was convened to identify problems related to urban land use planning within Houston Toad habitat. The group identified a number of basic problems that were posed

to the rest of the workshop participants.

The problems identified fell into two major categories. The first category concerned the lack of knowledge of the number of toads and the definition of what constituted suitable toad habitat. The second category consisted of problems resulting from the lack of a formal set of criteria regarding development. At the present time there appears to be inconsistent interpretation of governmental policies, rules, and regulations regarding development activities within areas inhabited by the Houston toad.

Recommendations

During the course of the discussion by the working group, a number of recommendations were identified for consideration as research topics. No attempt was made to rank these recommendations. Due to lack of precise knowledge regarding the specific soil types, geologic formations and vegetation structure associated with the Houston toad, it is extremely difficult to accurately determine overall risk associated with each threat throughout the range. Working group consensus was that most of these threats occur throughout the range; however intensity of each threat varies depending upon location.

1. Compile existing information regarding known Houston toad biology and habitat range and requirements and distribute to schools, chambers of commerce, county extension agents, conservation organizations and professional and civic groups throughout Houston toad range.

2. Identify and implement financial incentive programs that encourage livestock management systems and other management practices compatible with Houston toads.

3. Identify pollutants affecting all life history stages of the Houston Toad and its food source including pesticide application.

4. Determine methods for harvesting timber that will avoid or minimize impacts to toads.

5. Gather information on the effect (positive or negative) of fire ant control methods on toad populations.

6. Quantify and qualify both natural and artificially induced predation such as fish stocking and competition by Woodhouse's toad.

7. Investigate size, shape, depth, location, etc. of pond construction conducive to Houston toad conservation.

8. Study combination of prescribed burning with planned grazing systems and other

management practices as related to Houston toad habitat.

9. Investigate land modification and urbanization activities (Toad Friendly Engineering) that may be compatible with the Houston toad and monitor known sites where toad exists in proximity to developed areas.

10. Review historic weather cycles to assist prediction of potentially catastrophic events.
11. Begin preliminary investigation of disease threats.

12. Evaluate the impact of UV radiation.

13. Economic incentives for private landowners as alternatives to resource extractions (such as sand mining) need to be explored.

14. Further surveys conducted using consistent sampling methods to determine the number of Houston toads that are currently in areas of possible conflict with human development. Definition and description of suitable toad habitat would facilitate decision making by governmental agencies. The workshop participants all felt that more participation in surveys would allow for a more accurate appraisal of both issues.

15. Develop consistent policies assisted by a task force or committee which includes representatives from appropriate regulatory agencies, the development community, financial institutions, and other interested non-government agencies. Comments fielded from the group included a strong concern that consideration of requests on a case-by-case basis led to inconsistency in the opinions rendered by the various agencies involved. It should be noted, however, that compliance with the Endangered Species Act varies depending on the complexity of specific development projects. In the absence of a regional habitat conservation plan, this necessitates reviewing each action individually. Members from the U.S. Fish and Wildlife Service invited those interested to participate in the Bastrop County Steering Committee, which was formed to discuss the feasibility of developing a regional habitat conservation plan, under the guidelines of section 10(a)(1)(B) of the Endangered Species Act.

POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 8

PUBLIC EDUCATION

Public Outreach

A public outreach campaign for the Houston toad can be a crucial factor in the future protection of the species and its habitat. One of the most important initial needs of such a campaign is development of instructional documents detailing a description of the species, its habitat, and its range in user-friendly language, accompanied by several attractive and clear color photos of the toad. The use of the Houston toad's call may be particularly effective and impressive to people unfamiliar with the diversity and behavior of toads and other amphibians and reptiles.

The public school system has long been recognized as an important component of the public base that is receptive to educational campaigns. Targeting elementary grades can be particularly effective. Such an effort should be launched by contact with the president and members of local school boards. An efficient method of facilitating distribution may include the assignment of a contact at each school.

Education of and coalition-building with city and county officials is of extreme importance to a successful effort. Targeted contacts should include mayors, city managers, county judges, county commissioners, and members of the city council. Local economic development authorities should be contacted and furnished with sufficient information about the species and its habitat needs.

Agricultural contacts should not be overlooked as a resource. County extension agents can distribute and communicate needed information to a substantial segment of the public. Quasi-governmental entities established in relation to a specific resource, such as water use (i.e., Lower Colorado River Authority), should also not be forgotten.

Important channels for reaching the general public include local libraries and directors and members of local Chambers of Commerce. Civic and community groups and service organizations can also be an effective resource, for educational as well as volunteer service efforts. City or county resource guides should be consulted for the names and range of such groups.

Media contacts are of extreme significance to the success of an educational campaign. All facets of the media should be utilized, including radio spots, television programs (including public access), and newspaper submissions. The potential for specific campaigns that require involvement of the general public, such as adopt-a-toad programs and "toad tours", which introduce participants to the habitat and behavior of the species, should be explored.

However, it is important to ensure that consistent information is provided to all of the involved entities and that consensus has been reached regarding the instruction made available to the general public and community planners. It should be remembered that most receivers of the information will not be receptive unless a direct impact on them has

been identified. An example is the development of guidelines for water conservation in areas in which water use is becoming restrictive. It is most likely that the guidelines will be followed by those who recognize that the cost of water use will increase significantly in the near future.

An important aspect of the adoption of toad protection measures is the need to identify financial incentive programs that encourage the incorporation of habitat stewardship measures into land-use plans by landowners and urban planners. A number of such programs have been established and can be used by interested landowners. The development and distribution of a summary guide which details the contacts and requirements of each program would be of substantial help in this endeavor.

Recommendations

1. **One of the most important initial needs of such a campaign is the development of instructional documents detailing a description of the species, its habitat, and its range in user-friendly language, accompanied by attractive clear color photos of the toad. Also useful would be photos of *B. woodhousei, B. valliceps,* and *Scaphiopus couchi* as part of a simple key.**

2. **The public school system has long been recognized as an important component of the public base that is receptive to educational campaigns. Targeting elementary grades can be particularly effective. Such an effort should be launched by contact with the president and members of the local school board.**

3. **Education of and coalition-building with city and county officials is of extreme importance to a successful effort.**

4. **Media contacts are of extreme significance to the success of an educational campaign. Development and distribution of a summary guide which details the contacts and requirements of each program would be of substantial help in this endeavor.**

5. **Compile and distribute information about economic incentives and assistance programs for landowners and planners to increase their use in assisting to conserve toad habitat.**

6. **Provide guidance to the public regarding the Houston toad, its ecological requirements, and compliance with the Endangered Species Act.**

7. **Link recovery efforts to other benefits, such as protection of water quality, pine forest community (in Bastrop County), the deep sand ecosystem, ecotourism, and community planning.**
8. **Develop an organized public outreach effort to promote public awareness,**

understanding, appreciation, and support for the Houston toad recovery efforts.

POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 9

CAPTIVE PROPAGATION AND RELEASE

Evaluation of Captive Management, Translocation, and Releases

Captive Management

This avenue may be implemented into the Houston Toad program depending on specific needs. Captive propagation has been done at the Houston Zoo but reintroductions were unsuccessful possibly because of fire ant predation on toadlets. The term "Captive management" can be divided into several branches, depending upon specific wild population needs. Some programs could be used in a very limited aspect, while other events may find cause for a more aggressive program.

There are several different types of captive program that can be maintained in conjunction with support from a wild population. With the resources and organizations that exist today, this can be done at very low or minimal costs, depending upon the extent of involvement.

The most obvious need for a captive program as a result of a catastrophic event, (natural disasters, disease, etc.) that decimates the wild population. This would be a "last resort" aggressive program with all aspects of captive breeding techniques being applied. This could be part of a contingency plan.

Other needs for a short term program might be one of supplementation of animals at different stages of development. Examples of this might include a need for introduction of new genetic material into isolated subpopulations in order to stop extinction of that group. (This can also be done by translocating animals from other populations that exist in the wild.) Other events such as predation or drought might call for introduction of captive bred tadpoles, or toadlets to supplement a population. However, due care must be taken to avoid introduction of diseases into the population.

The techniques learned from the Houston Zoo program for captive propagation of this species can be implemented into other facilities that have the resources to devote to various levels of programs whether it be long term or short term. The Houston Toad program is well ahead in the aspects of captive propagation if the need should ever arise.

Information that can prove useful for design of a captive programs might include:

Hibernation

1. Burrows: How far down do toads burrow in the substrate?

2. Substrate: What types of sand or soil are used and what is the moisture content?)
3. Temperature: Over what ambient temperature range is the toad active?

4. Environmental triggers: What are the environmental events that induce the toad to hibernate such as temperature, humidity levels, precipitation, light cycle, and food supply.

5. Duration: What are the minimum and maximum periods of hibernation necessary to allow for egg/sperm development?

Diet

1. Diet studies are needed at all stages of the toad's development. Any information on nutrition requirements could prove valuable, especially during the tadpole stage.

Behavior

1. What distances do toadlets and toads travel during different times of the year.

2. What different types of habitat are utilized during the year? (Basking sites, cover, and foraging sites).

3. Do cover types vary during different life stages? (aquatic plants, leaves, logs, rodent holes, etc.).

Water Quality

1. Water testing for various pollutants and pH levels may prove useful in habitat assessment and may help determine tolerance levels for egg mass and tadpole development as well.

Disease

1. This is one of the most needed areas of research. Many species of amphibians are experiencing die-offs from a bacterial infection, *Aeromonas hydrophila* known as Red Leg. It can be highly contagious and is often times hard to treat. This infection normally occurs in captivity, but has now become a problem in wild populations. This disease and a fungal infection, *Basiobolus ranarum*, has impacted the Wyoming Toad, *Bufo hemiophrys baxteri* almost to extinction. It is not known why the Wyoming Toad has become so susceptible, but there is speculation that something has suppressed their immune system, and that some kind of stress factor exists.

Translocations and Releases

Translocation can be integrated into all stages of development (egg mass, tadpole, toadlet, and adult stages). As mentioned in the captive program section, translocation can be used to supplement other subpopulations, as well as repopulating areas that have lost toads due to catastrophic events.

Translocation could also be used to move toads to areas that have not yet been populated (man made ponds, private lands, etc.). It is important to note that the area should be favorable to toad development/livelihood, and that the area will need to be carefully studied. If private land is considered, a positive approach to working with the land owners and getting them involved in the program should prove helpful. It is also noted that the new locations should be within the known range of the toad.

Careful consideration and study should be given prior to moving toads into historical habitat that is no longer occupied without careful consideration and study. Studies should be conducted to find out why the previous population of toads was lost in the first place (habitat destruction, unfavorable climate changes, other species encroachment, etc.). Restoration may be necessary in some localities if that in fact was the cause of decline.

Prospective release stock must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for selected pathogens must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.

Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk. Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary. Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.

Draft Guidelines for Re-introductions

Reintroduction Specialist Group SSC/IUCN
May 1994

Introduction

These policy guidelines have been drafted by the Re-introduction Specialist Group of the lUCN's Species Survival Commissionl, in response to the increasing occurrence of re-introduction projects world-wide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although the IUCN developed a Position Statement on the Translocation of Living Organisms in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re- introduction exercises.

These guidelines are intended to act as a guide for procedures useful to re-introduction programmes and do not represent an inflexible code of conduct. Many of the points are more relevant to re-introductions using captive-bred individuals than to translocations of wild species. Others are especially relevant to globally endangered species with limited numbers of founders. Each re-introduction proposal should be rigorously reviewed on its individual merits. On the whole, it should be noted that re-introduction is a very lengthy and complex process.

This document is very general, and worded so that it covers the full range of plant and animal taxa. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

Definition of Terms

a. "Re-introduction": an attempt to establish a species in an area which was once part of its historical range, but from which it has become extinct.

> **(The taxonomic unit referred to throughout the document is species. it may be a lower taxonomic unit [e.g. sub-species or race] as long as it can be unambiguously defined). CITES criterion of "extinct": species not definitely located in the wild during the past 50 years. "Re-establishment" is a synonym, but implies that the re-introduction has been successful.)**

b. "Translocation": deliberate and mediated movement of wild individuals or populations from one part of their range to another.

c."Re-inforcement/Supplementation": addition of individuals to an existing population of conspecifics.

(Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN for CITES.)

d. "Conservation/Benign Introductions": an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area.

Aims and Objectives of the Re-introduction

Aims:

A re-introduction should aim to establish a viable, free-ranging population in the wild, of a species or subspecies which was formerly globally or locally extinct (extirpated). In some circumstances, a re-introduction may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range, and require minimal long-term management.

Objectives:

The objectives of a re-introduction will include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of these.

Re-introductions or translocations of species for short-term, sporting or commercial purposes - where there is no intention to establish a viable population - are a different issue, beyond the scope of these guidelines. These include fishing and hunting activities.

Multidisciplinary Approach

A re-introduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. They may include persons from: governmental natural resource management agencies; non-governmental organisations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

Pre-project Activities

Biological

Feasibility study and back ground research

An assessment should be made of the taxonomic status of individuals to be re-introduced. They must be of the same subspecies as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re- introduction area, as well as molecular genetic studies, should be undertaken in case of doubt. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.

Detailed studies should be made of the status and biology of wild populations (if they exist) to determine the species' critical needs; for animals, this would include descriptions of habitat preferences, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases. For plants it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators, insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re- introduction scheme.

The build-up of the released population should be modelled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.

A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

Previous Re-introductions

Thorough research into previous re-introductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing re-introduction protocol.

Choice of release site

Site should be within the historic range of species and for an initial re-inforcement or re-introduction have very few, or no, remnant wild individuals (to prevent disease spread, social disruption and introduction of alien genes). A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist.

The re-introduction area should have assured, long-term protection (whether formal or other wise) .

Evaluation of re-introduction site

Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.

Identification and elimination of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programs; competition with domestic livestock, which may be seasonal.

Where the release site has undergone substantial degradation caused by human activity, a habitat restoration program should be initiated before the reintroduction is carried out.

Availability of suitable release stock

Release stock should be ideally closely-related genetically to the original native stock.

If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.

Re-introductions should not be carried out merely because captive stocks exist, nor should they be a means of disposing of surplus stock.

Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.

Prospective release stock must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for selected pathogens must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.

Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.

Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.

Socio-economic and Legal Activities

Re-introductions are generally long-term projects that require the commitment of long-term financial and political support. Socio-economic studies should be made to assess costs and benefits of the re-introduction program to local human populations.

A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss of habitat). The program should be fully understood, accepted and supported by local communities.

Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimise these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.

The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing national and international legislation and regulations, and provision of new measures as necessary. Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state.

If the species poses potential risk to life or property, these risks should be minimised and adequate provision made for compensation-where necessary; where all other solutions fail, removal or destruction of the released individual should be considered. In the case of

migratory/mobile species, provisions should be made for crossing of international/state boundaries.

Planning. Preparation and Release Stages

Construction of a multidisciplinary team with access to expert technical advice for all phases of the program.

Approval of all relevant government agencies and land owners, and coordination with national and international conservation organizations.

Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.

Identification of short-and long-term success indicators and prediction of program duration, in context of agreed aims and objectives.

Securing adequate funding for all program phases.

Design of pre- and post- release monitoring program so that each re-introduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data.

Appropriate health and genetic screening of release stock. Health screening of closely related species in re-introduction area.

If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.

If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.

Appropriate veterinary or horticultural measures to ensure health of released stock throughout program. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to release site.

Determination of release strategy (acclimatization of release stock to release area; behavioural training - including hunting and feeding; group composition, number, release patterns and techniques; timing).

Establishment of policies on interventions (see below).

Development of conservation education for long-term support; professional training of individuals involved in long-term program; public relations through the mass media and in local community; involvement where possible of local people in the program.

The welfare of animals for release is of paramount concern through all these stages.

Post-release Activities

Post release monitoring of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.

Demographic, ecological and behavioural studies of released stock. Study of processes of long-term adaptation by individuals and the population.

Collection and investigation of mortalities.

Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary .

Decisions for revision, rescheduling, or discontinuation of program where necessary .

Habitat protection or restoration to continue where necessary.

Continuing public relations activities, including education and mass media coverage.

Evaluation of cost-effectiveness and success of re-introduction techniques.

Regular publications in scientific and popular literature.

POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 10

LITERATURE

Literature

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2. Minutes of: Houston Toad Recovery Team meetings.

3. Oral presentations from typed manuscripts of: Preliminary reports from field personnel to Recovery Team Meetings.

4. Research Proposals: from various scientists who have or with to study the Houston Toad.

5. Letters: from and between various members of the Houston Toad Recovery Team and from private parties and/or Endangered Species Office personnel.

6. Tape recordings of Houston toad vocalizations.

7. Photographs and slides of a number of individuals.

POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 11

APPENDIX
Sample Vortex Input File

HTOAD505 ***Output Filename***
Y ***Graphing Files?***
N ***Each Iteration?***
100 ***Simulations***
100 ***Years***
10 ***Reporting Interval***
10 ***Populations***
1 ***Lower Age For Migration***
4 ***Upper Age For Migration***
B ***MigratingSex: F, M, or Both***
0.000000 ***Migration From 1 To 2***
0.000000 ***Migration From 1 To 3***
0.000000 ***Migration From 1 To 4***
0.000000 ***Migration From 1 To 5***
0.000000 ***Migration From 1 To 6***
0.000000 ***Migration From 1 To 7***
0.000000 ***Migration From 1 To 8***
0.000000 ***Migration From 1 To 9***
0.000000 ***Migration From 1 To 10***
0.000000 ***Migration From 2 To 1***
0.000000 ***Migration From 2 To 3***
0.000000 ***Migration From 2 To 4***
0.000000 ***Migration From 2 To 5***
0.000000 ***Migration From 2 To 6***
0.000000 ***Migration From 2 To 7***
0.000000 ***Migration From 2 To 8***
0.000000 ***Migration From 2 To 9***
0.000000 ***Migration From 2 To 10***
0.000000 ***Migration From 3 To 1***
0.000000 ***Migration From 3 To 2***
0.000000 ***Migration From 3 To 4***
0.000000 ***Migration From 3 To 5***
0.000000 ***Migration From 3 To 6***
0.000000 ***Migration From 3 To 7***
0.000000 ***Migration From 3 To 8***
0.000000 ***Migration From 3 To 9***
0.000000 ***Migration From 3 To 10***
0.000000 ***Migration From 4 To 1***
0.000000 ***Migration From 4 To 2***
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0.000000 ***Migration From 4 To 9***
0.000000 ***Migration From 4 To 10***
0.000000 ***Migration From 5 To 1***
0.000000 ***Migration From 5 To 2***
0.000000 ***Migration From 5 To 3***
0.000000 ***Migration From 5 To 4***
0.050000 ***Migration From 5 To 6***
0.000000 ***Migration From 5 To 7***
0.000000 ***Migration From 5 To 8***
0.050000 ***Migration From 5 To 9***
0.000000 ***Migration From 5 To 10***
0.000000 ***Migration From 6 To 1***
0.005000 ***Migration From 6 To 2***
0.000000 ***Migration From 6 To 3***
0.000000 ***Migration From 6 To 4***
0.050000 ***Migration From 6 To 5***
0.020000 ***Migration From 6 To 7***
0.000000 ***Migration From 6 To 8***
0.050000 ***Migration From 6 To 9***
0.000000 ***Migration From 6 To 10***
0.000000 ***Migration From 7 To 1***
0.000000 ***Migration From 7 To 2***
0.005000 ***Migration From 7 To 3***
0.000000 ***Migration From 7 To 4***
0.000000 ***Migration From 7 To 5***
0.020000 ***Migration From 7 To 6***
0.050000 ***Migration From 7 To 8***
0.000000 ***Migration From 7 To 9***
0.050000 ***Migration From 7 To 10***
0.000000 ***Migration From 8 To 1***
0.000000 ***Migration From 8 To 2***
0.000000 ***Migration From 8 To 3***
0.000000 ***Migration From 8 To 4***
0.000000 ***Migration From 8 To 5***
0.000000 ***Migration From 8 To 6***
0.050000 ***Migration From 8 To 7***
0.000000 ***Migration From 8 To 9***
0.050000 ***Migration From 8 To 10***
0.000000 ***Migration From 9 To 1***
0.000000 ***Migration From 9 To 2***
0.000000 ***Migration From 9 To 3***
0.000000 ***Migration From 9 To 4***
0.050000 ***Migration From 9 To 5***
0.050000 ***Migration From 9 To 6***

0.000000 ***Migration From 9 To 7***
0.000000 ***Migration From 9 To 8***
0.020000 ***Migration From 9 To 10***
0.000000 ***Migration From 10 To 1***
0.000000 ***Migration From 10 To 2***
0.000000 ***Migration From 10 To 3***
0.000000 ***Migration From 10 To 4***
0.000000 ***Migration From 10 To 5***
0.000000 ***Migration From 10 To 6***
0.050000 ***Migration From 10 To 7***
0.050000 ***Migration From 10 To 8***
0.020000 ***Migration From 10 To 9***
N ***Inbreeding Depression?***
N ***EV correlation?***
2 ***Types Of Catastrophes***
P ***Monogamous Or Polygynous***
2 ***Female Breeding Age***
1 ***Male Breeding Age***
4 ***Maximum Age***
0.500000 ***Sex Ratio***
10 ***Maximum Litter Size***
N ***Density Dependent Breeding?***
0.000000 ***Population 1: Percent Litter Size 0***
0.000000 ***Population 1: Percent Litter Size 1***
0.000000 ***Population 1: Percent Litter Size 2***
0.000000 ***Population 1: Percent Litter Size 3***
0.000000 ***Population 1: Percent Litter Size 4***
0.000000 ***Population 1: Percent Litter Size 5***
0.000000 ***Population 1: Percent Litter Size 6***
0.000000 ***Population 1: Percent Litter Size 7***
0.000000 ***Population 1: Percent Litter Size 8***
0.000000 ***Population 1: Percent Litter Size 9***
100.000000 ***Population 1: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***

10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 2: Percent Litter Size 0***
0.000000 ***Population 2: Percent Litter Size 1***
0.000000 ***Population 2: Percent Litter Size 2***
0.000000 ***Population 2: Percent Litter Size 3***
0.000000 ***Population 2: Percent Litter Size 4***
0.000000 ***Population 2: Percent Litter Size 5***
0.000000 ***Population 2: Percent Litter Size 6***
0.000000 ***Population 2: Percent Litter Size 7***
0.000000 ***Population 2: Percent Litter Size 8***
0.000000 ***Population 2: Percent Litter Size 9***
100.000000 ***Population 2: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***

100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 3: Percent Litter Size 0***
0.000000 ***Population 3: Percent Litter Size 1***
0.000000 ***Population 3: Percent Litter Size 2***
0.000000 ***Population 3: Percent Litter Size 3***
0.000000 ***Population 3: Percent Litter Size 4***
0.000000 ***Population 3: Percent Litter Size 5***
0.000000 ***Population 3: Percent Litter Size 6***
0.000000 ***Population 3: Percent Litter Size 7***
0.000000 ***Population 3: Percent Litter Size 8***
0.000000 ***Population 3: Percent Litter Size 9***
100.000000 ***Population 3: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 4: Percent Litter Size 0***
0.000000 ***Population 4: Percent Litter Size 1***

0.000000 ***Population 4: Percent Litter Size 2***
0.000000 ***Population 4: Percent Litter Size 3***
0.000000 ***Population 4: Percent Litter Size 4***
0.000000 ***Population 4: Percent Litter Size 5***
0.000000 ***Population 4: Percent Litter Size 6***
0.000000 ***Population 4: Percent Litter Size 7***
0.000000 ***Population 4: Percent Litter Size 8***
0.000000 ***Population 4: Percent Litter Size 9***
100.000000 ***Population 4: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 5: Percent Litter Size 0***
0.000000 ***Population 5: Percent Litter Size 1***
0.000000 ***Population 5: Percent Litter Size 2***
0.000000 ***Population 5: Percent Litter Size 3***
0.000000 ***Population 5: Percent Litter Size 4***
0.000000 ***Population 5: Percent Litter Size 5***
0.000000 ***Population 5: Percent Litter Size 6***
0.000000 ***Population 5: Percent Litter Size 7***
0.000000 ***Population 5: Percent Litter Size 8***
0.000000 ***Population 5: Percent Litter Size 9***

100.000000 ***Population 5: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 6: Percent Litter Size 0***
0.000000 ***Population 6: Percent Litter Size 1***
0.000000 ***Population 6: Percent Litter Size 2***
0.000000 ***Population 6: Percent Litter Size 3***
0.000000 ***Population 6: Percent Litter Size 4***
0.000000 ***Population 6: Percent Litter Size 5***
0.000000 ***Population 6: Percent Litter Size 6***
0.000000 ***Population 6: Percent Litter Size 7***
0.000000 ***Population 6: Percent Litter Size 8***
0.000000 ***Population 6: Percent Litter Size 9***
100.000000 ***Population 6: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***

0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 7: Percent Litter Size 0***
0.000000 ***Population 7: Percent Litter Size 1***
0.000000 ***Population 7: Percent Litter Size 2***
0.000000 ***Population 7: Percent Litter Size 3***
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0.000000 ***Population 7: Percent Litter Size 8***
0.000000 ***Population 7: Percent Litter Size 9***
100.000000 ***Population 7: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***

1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 8: Percent Litter Size 0***
0.000000 ***Population 8: Percent Litter Size 1***
0.000000 ***Population 8: Percent Litter Size 2***
0.000000 ***Population 8: Percent Litter Size 3***
0.000000 ***Population 8: Percent Litter Size 4***
0.000000 ***Population 8: Percent Litter Size 5***
0.000000 ***Population 8: Percent Litter Size 6***
0.000000 ***Population 8: Percent Litter Size 7***
0.000000 ***Population 8: Percent Litter Size 8***
0.000000 ***Population 8: Percent Litter Size 9***
100.000000 ***Population 8: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***

N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 9: Percent Litter Size 0***
0.000000 ***Population 9: Percent Litter Size 1***
0.000000 ***Population 9: Percent Litter Size 2***
0.000000 ***Population 9: Percent Litter Size 3***
0.000000 ***Population 9: Percent Litter Size 4***
0.000000 ***Population 9: Percent Litter Size 5***
0.000000 ***Population 9: Percent Litter Size 6***
0.000000 ***Population 9: Percent Litter Size 7***
0.000000 ***Population 9: Percent Litter Size 8***
0.000000 ***Population 9: Percent Litter Size 9***
100.000000 ***Population 9: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
0.000000 ***Population 10: Percent Litter Size 0***
0.000000 ***Population 10: Percent Litter Size 1***
0.000000 ***Population 10: Percent Litter Size 2***
0.000000 ***Population 10: Percent Litter Size 3***
0.000000 ***Population 10: Percent Litter Size 4***
0.000000 ***Population 10: Percent Litter Size 5***

0.000000 ***Population 10: Percent Litter Size 6***
0.000000 ***Population 10: Percent Litter Size 7***
0.000000 ***Population 10: Percent Litter Size 8***
0.000000 ***Population 10: Percent Litter Size 9***
100.000000 ***Population 10: Percent Litter Size 10***
1.000000 ***EV--Reproduction***
0.000000 ***Female Mortality At Age 0***
0.000000 ***EV--FemaleMortality***
80.000000 ***Female Mortality At Age 1***
1.000000 ***EV--FemaleMortality***
80.000000 ***Adult Female Mortality***
1.000000 ***EV--AdultFemaleMortality***
0.000000 ***Male Mortality At Age 0***
0.000000 ***EV--MaleMortality***
80.000000 ***Adult Male Mortality***
1.000000 ***EV--AdultMaleMortality***
10.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
10.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity--Reproduction***
1.000000 ***Severity--Survival***
Y ***All Males Breeders?***
Y ***Start At Stable Age Distribution?***
100 ***Initial Population Size***
100 ***K***
3.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
Y ***AnotherSimulation?***

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

HOUSTON TOAD

Bufo houstonensis

SECTION 11

APPENDIX B

Distribution Map

Houston Toad
Bufo houstonensis