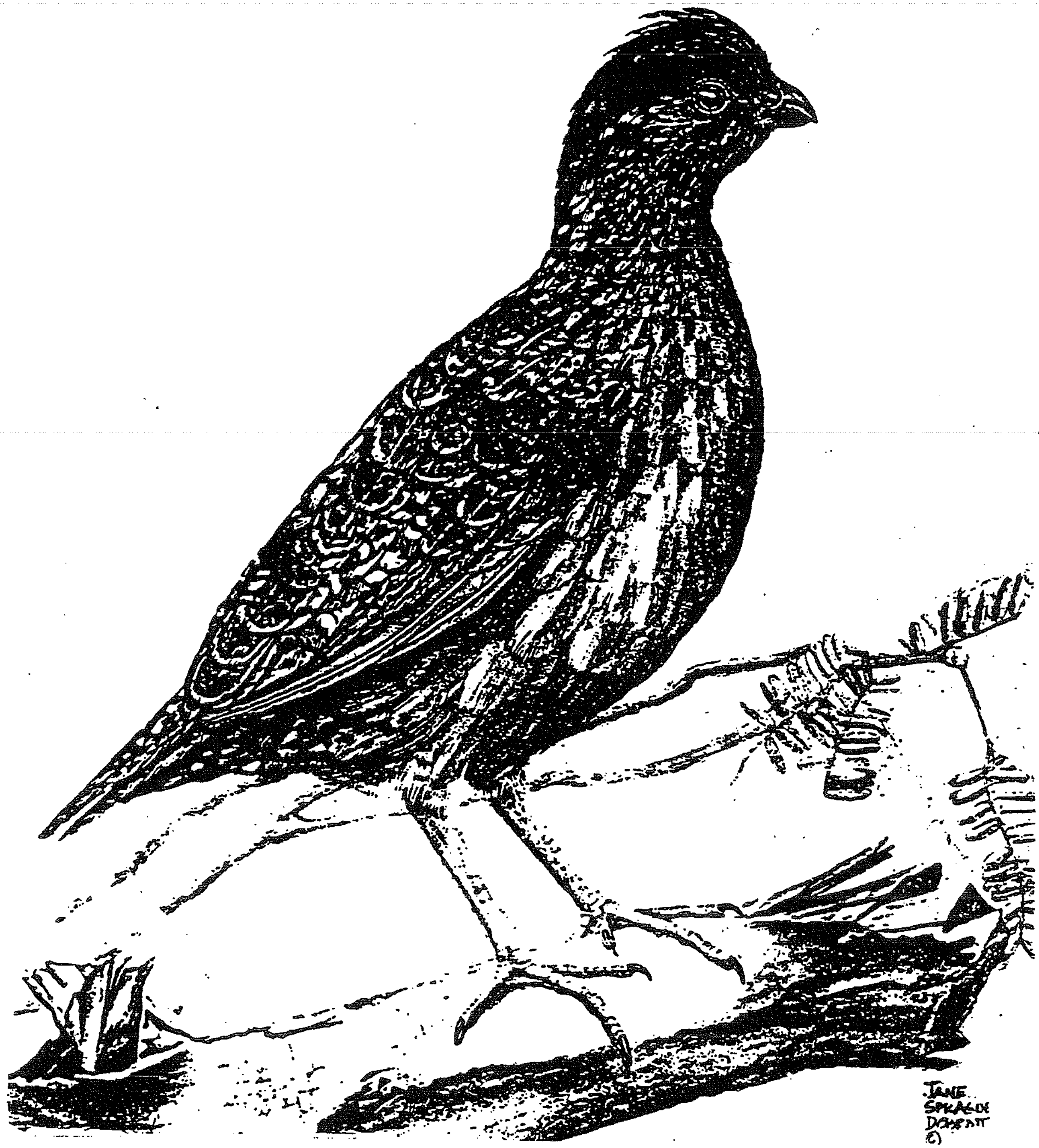
MASKED BOBWHITE
POPULATION AND HABITAT VIABILITY ASSESSMENT



U.S. FISH AND WILDLIFE SERVICE

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1996

MASKED BOBWHITE (Colinus virginianus ridgwayi)

POPULATION AND HABITAT VIABILITY

ASSESSMENT WORKSHOP

Buenos Aires National Wildlife Refuge, Arizona

April 25-28, 1995

Written by the Workshop Participants

Sponsored by U.S. Fish and Wildlife Service

Southwest Region

Edited by

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1996

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INTRODUCTION

Twenty-one specialists in quail biology, bird physiology, genetics, disease, small population modelling, range management, captive propagation, and small game management met April 25-27, 1995, at Buenos Aires National Wildlife Refuge (NWR) for a Population and Habitat Viability Assessment Workshop (PHVA) on masked bobwhite. Participants included representatives from Texas A & M University; Texas Tech University; University of Arizona; National Wildlife Health Research Center, and Patuxent Environmental Science Center (Patuxent) of the National Biological Service; Arizona Game and Fish Department; staff of Buenos Aires NWR, the Arizona Ecological Services Field Office, and personnel representing Refuges and the Endangered Species branches of the Southwest Region, U.S. Fish and Wildlife Service; staff of Centro Ecologico de Sonora (CES), Mexico; and the Conservation Breeding Specialist Group, Species Survival Commission of International Union For Conservation Of Nature, Minneapolis, Minnesota. A substantial portion of the first day was involved introducing participants to principles of small population biology, the Vortex modelling process, and presenting data on the masked bobwhite.

The group selected their goals for the workshop as follows:

1. Identify why the masked bobwhite is endangered.
2. Develop a plan for species recovery.
3. Identify research needs.
4. Identify some specific management guidelines.
5. Evaluate cost effectiveness of captive management versus other recovery approaches.
6. Identify habitat requirements.
7. Identify population status and stability in Mexico and United States.
8. Identify hindrances to management (i.e., policy, biology, archeology, political) and solutions.
9. Continue public education on the plight of masked bobwhite.
10. Evaluate aspects of historical distribution.
11. Evaluate habitat connectivity and disjunct populations.
12. Explore partnerships (private-state-federal) essential to recovery of masked bobwhite (sister refuges).
13. Evaluate population viability.
14. Identify how critical habitat components are met or not met?
15. Interpret whether environment (whether, vegetation) is the same (weather, vegetation) as historically.

The participants then identified five subgroups needed to accomplish the workshop goals. Subgroup topics were 1) Population Biology And Modelling; 2) Distribution And Status; 3) Threats And Solutions, 4) Habitat Management, and 5) Reintroduction And Captive Propagation. The subgroups developed draft reports on the afternoon and evening of the first day. The Population Biology And Modelling and the Habitat Management subgroups in particular evaluated field data not previously analyzed. Subgroup members are listed in the section they authored. The draft reports were presented in a plenary session on the second morning for discussion by the entire group. The subgroups then reconvened to refine their drafts. The modelling group was asked to model additional management scenarios. Revised reports were presented on the third morning in another plenary session for discussion and further revision. During the final sessions the group identified strategies for recovering the masked bobwhite. This report presents the accomplishments of the Workshop.

SECTION 1. EXECUTIVE SUMMARY

Specialists in aspects of quail biology, habitat management, and population modelling met April 25-28, 1995, for a Population and Habitat Viability Assessment Workshop on masked bobwhites (Colinus virginianus ridgway) to analyze the current situation. First discovered in 1884, this subspecies was essentially extirpated from Arizona by 1900 due to destruction of habitat by livestock overgrazing. The Sonoran population was considered severely threatened by 1937 and believed extinct by 1950. Quail trapped from a small population, rediscovered in north central Sonora in 1964, served as founders for the captive population located at Patuxent in Laurel, Maryland. During the past 40 years, unsuccessful attempts were made to re-establish masked bobwhites in historic habitats in Sonora, Arizona, and in nonhistoric habitat in New Mexico. Reintroduction efforts are now focused on Buenos Aires NWR in southern Arizona where habitat can be managed to favor survival of the birds. Some released birds have survived 2.5 years and natural reproduction has been documented, but a self-sustaining population has not been attained. The Refuge population was estimated at 500 masked bobwhites in spring 1995. Biologists believe the Sonoran population has been self-sustaining; it contained about 500 individuals in spring 1995 but may have declined dramatically since the winter of 1993-94.

Working groups were organized on the following topics: Population Biology and Modelling; Distribution and Status, Threats and Solutions, Habitat Management, and Reintroduction And Captive Propagation. The following were among the key points discussed in these groups:

1. Masked bobwhite historically inhabited the grassy savannas of south central Arizona and Sonora, Mexico. They were extirpated from Arizona about 1900 and only small populations persisted in Sonora by the 1930s. In spring 1995, an estimated 500 individuals occurred on Buenos Aires NWR and another 500 in two populations in Sonora. The Refuge population is not self-sustaining.

2. VORTEX modelling of the masked bobwhite population, including environmental variation, predicted population declines. Starting with a baseline population of 500 individuals, a population is under a 50 % risk of extinction within 20 years. The risk of extinction increases with increases in juvenile mortality, drought, and reduced numbers of females. Supplementing the refuge population with as few as 20 wild-captured quail per year eliminates the risk of extinction and theoretically would be an effective management strategy. However, the risk of extinction of source populations is increased. Management recommendations are made based on the modelling simulations.

3. Threats to survival include disease, parasites, predation, inbreeding, overgrazing, exotic plants, and environmental catastrophes. Avian predation is believed to account for a substantial portion of the losses in masked bobwhite chicks released on the refuge. The masked bobwhite gene pool appears to be healthy. The captive flock must be maintained

to protect the species during recovery. Grazing has been implicated as a major cause of decline in masked bobwhite populations, but in some situations moderate grazing may be beneficial.

4. If the Sonoran populations recover to secure levels it seems appropriate to attempt a translocation of a covey or two from Mexico to Sonora. If the survival is good a larger release number should be considered.

5. Use ongoing research and past information to evaluate masked bobwhite habitat on Buenos Aires NWR and in Sonora. Utilize appropriate management techniques to achieve favorable habitat characteristics (proportions of grasses, forbs, herbaceous biomass, shrub cover and height, and bare ground).

6. Plans to change the release program are in process. The quail will be fed insects and seeds to prepare them for the wild, they will be held in portable pens at the release site, as a "slow" release and they will be released in the early fall and early spring when they are older and in coveys. Quail will be monitored through radio telemetry and the success of the program will be evaluated. Other pre- and post-release techniques should be considered and the program modified when appropriate.

SECTION 2. DISTRIBUTION AND STATUS

Authors: Teresa Solis Herrera, Bill Kuvlesky, Jr., and Ann Witman

The masked bobwhite was first discovered in 1884 and became endangered soon thereafter. Masked bobwhites were essentially extirpated from Arizona by 1900 due to destruction of their habitat via livestock overgrazing. The population in Sonora was considered severely threatened by 1937 and believed extinct by 1950. However, in 1964 a small population was discovered on a privately owned ranch in north central Sonora. Quail live-trapped from this population in 1968 and 1970, served as founders for the captive population.

HISTORIC DISTRIBUTION

Historic accounts and collections indicate that this subtropical subspecies was always restricted to level plains and river valleys in Sonora, Mexico, and extreme south-central Arizona, between 150 and 1,200 m elevation (Brown 1885, 1904, Van Rossem 1945, Ligon 1952, Tomlinson 1972a). The primary habitat of the masked bobwhite was the grassy savanna habitats (Ilanos) within Shreve's (1942, 1951) Plains of Sonora, subdivision of the Sonoran Desert. These biotic communities have a mean rainfall ranging from 250 to over 500 mm, with more than 70 % received during July through September (Shreve 1951, Tomlinson 1972b).

The eastern and southern distribution is limited by the merging of Sonora savanna grassland and its summer-active grass-forb understory with the more structurally dense Sinaloan thornscrub where bobwhites are replaced by elegant quail (Lophortyx douglassi). Masked bobwhite occurrence south or east of the Rio Yaqui has yet to be documented. To the west and northwest, a decrease in summer precipitation excludes bobwhite from the desert scrub communities of the Central Gulf Coast, Lower Colorado River, and Arizona Upland subdivisions of the Sonora Desert. Northward and above 1,200 m in elevation, the subtropical scrub and grass understories of Sonora savanna grassland give way to sod forming perennial grasses, and shrubs, and leaf succulents characteristic of warm temperate desert grassland. At the northern limits of masked bobwhite range, in the Altar and Santa Cruz valleys of Arizona, semidesert grassland replaces Sonoran savanna grassland and the masked bobwhite is supplanted by scaled quail (Callipepla squamata). Reports of masked bobwhites outside this range are unsubstantiated by specimens or other corroborating evidence.

From 1967 through 1970, Tomlinson (1972b) conducted an extensive search to determine the bird's distribution and status in Sonora. He visited published localities and collection sites, and interviewed hundreds of Mexican citizens. Areas thought to harbor masked bobwhites were searched on foot with a dog during the fall and winter. Cactus wren (Campylorhynchus brunneicapillus) and verdin (Parus spp.) nests (which are frequently lined with feathers of other birds) were searched for masked bobwhite feathers. The distinctive roosts of masked bobwhites were also sought. During the summer breeding season, Tomlinson listened for bobwhite calls, and used taped female calls to elicit male responses. His investigations concentrated on eight general areas in Sonora: (1) Benjamin Hill-Carbo, (2) Mazatan-Cobachi, (3) Rancho Agua Fria-Valle de Agua Caliente, (4) Tecoripa-Rancho La Cuesta, (5) La Misa and San Marcial, (6) Cumpas and Bacoachi, (7) Sasabe-Molinos, and (8) Siete Cerros (Tomlinson 1972b).

Masked bobwhites were located at two sites in the Benjamin Hill-Carbo area, Rancho Grande/El Arpa and Rancho El Carrizo, and a very limited region east of Mazatan (Tomlinson 1972b). Population trends in these areas justified concern. More masked bobwhites were found east of Mazatan in 1974, when Roy Tomlinson, Steve Dobrott and Dave Ellis revisited the area. A few birds had been found there in 1968 in brushy habitat.

In the Benjamin Hill-Carbo area, Tomlinson established two call-count survey routes. In 1977, the trend in peak counts of calling males suggested the population was at or near extinction at Rancho El Carrizo (Ellis and Serafin 1977). Field studies in this area also suggested this population was close to being lost.

Data collected (Goodwin 1981, Mills and Reichenbacher 1982) for the Rancho Grande/El Arpa route initially suggested an upturn, possibly associated with the extensive program of brush removal, windrowing, and planting of buffelgrass (Cenchrus ciliaris). However, this advantage was short-lived, because the buffelgrass formed extensive monocultures that outcompeted native vegetation. Monoculture habitats are not suitable for masked bobwhite.

From 1988 to 1992, population trends between the two areas appeared to reverse. While the Rancho Grande/El Arpa population declined to near extinction, the Rancho El Carrizo population increased on two core areas (Dobrott 1992). However, the Rancho El Carrizo population has declined since the 1992 surveys due to the extremely dry summers of 1992 and 1993.

PRESENT DISTRIBUTION

Verifiable masked bobwhite populations are currently restricted to two sites. One population occurs on approximately 2,024 ha (5,000 acres) of habitat on and around Rancho El Carrizo, while the second population occurs on the Buenos Aires NWR in southcentral Arizona. A third population may still exist on Rancho Grande which is approximately 20 miles south of Rancho El Carrizo. Ranch cowboys have consistently reported seeing birds on this ranch for the past year. The Rancho El Arpa population is now believed to be extirpated.

The present distribution of this quail is fragmented. The Sonoran populations are separated by 20 miles of unsuitable habitat. Like the two Sonoran populations, the Arizona population will remain separated from birds in Mexico due to lack of suitable habitat between Buenos Aires NWR and the Rancho El Carrizo area. Translocation of birds will likely be the only method to maintain genetic diversity of the three wild populations.

There have been three reported sightings in Sonora. In March 1995, about 70 kilometers east of Hermosillo, one Masked Bobwhite was reported. In February of 1995, one was seen in Mazatan. There were 10 reported by a cowboy at Rancho los Sauces, about 20 kilometers southeast of Rancho El Carrizo in November 1994 and February 1995.

STATUS

Rancho El Carrizo

The Rancho El Carrizo masked bobwhite population was surveyed via line transects during January and December 1994. During January approximately 51 miles of transect were traversed and 10 coveys were observed. A density estimate of 0.7 birds /acre was generated though the coefficient of variation was over 40%, indicating that the estimate lacked precision. It is unlikely that 2800 masked bobwhites inhabited the 4000 acre ranch during January. A more reasonable estimate would be 1200-1500 birds. Nevertheless, this estimate exceeds what was anticipated based on the FY 93 whistling-count results. It is probably safe to assume that more masked bobwhites inhabited the ranch during January 1993 than Buenos Aires NWR biologist thought existed in 1992.

The December 1994 surveys were less encouraging. Three biologists with Centro Ecologico de Sonora joined the biologists from Buenos Aires NWR and Ken Nolte to conduct the census. Over 135 miles of transect were traversed in 5 days. Every pasture where masked bobwhites were observed in January, pastures where Ken had collected data this summer, as well as areas indicated to harbor masked bobwhites by the Camous and their cowboys, were surveyed. Four coveys were observed. These data indicate a density of 0.11 birds/ha (0.043 birds/acre). The coefficient of variation was 64% indicating that the density estimate lacks precision and also accuracy. One could assume that the population has drastically declined. Alternatively, one could also assume that the majority of the birds were simply not located. The Camous emphasized that masked bobwhites are very difficult to locate during winter. Additionally, the birds do not flush readily, they apparently prefer to remain immobile and thereby avoid detection. Each covey was directly on the transect line being traversed and was not observed until it was almost stepped upon. When detected, instead of flushing, the birds escaped on the ground. A significant number of coveys likely missed detection between detection.

In effort to obtain a better density estimate than that generated by the December 1994 line transect estimate, a bird dog census was conducted during March 1995. Two well trained bird dogs were utilized for approximately 6 hours/day over a 5 day period. Dogs were released on all of the areas surveyed in December and on additional areas thought to harbor masked bobwhites based on the observations of ranch personnel. Six coveys were located containing almost 60 birds. Kellogg et al. (1982) reported that bird dogs typically detect 40% of a bobwhite population. Therefore, the Rancho El Carrizo population may consist of only 150 birds. The dogs however, were not released on all of the potential habitat. The dogs surveyed 30-to-40 % of the masked bobwhite habitat on the ranch and biologists estimate 400-to-500 individuals currently comprise the Rancho El Carrizo population based on the bird dog survey

It is possible that the Rancho El Carrizo population has declined. The quail researchers suspect that a short spring breeding season is very important to masked bobwhite chick recruitment. Winter rainfall , and the associated climatic and habitat conditions necessary for breeding must exist for successful spring chick production to occur. Chick production may have been below average due to a lack of rainfall during the winter of 1993-94. Summer precipitation was better than 1993 and nesting activity was documented. Chicks were produced though numbers may have been insufficient to compensate for annual mortality.

The consensus of opinion is that the masked bobwhite population remains viable. Most coveys were simply not located. Masked bobwhite sign was observed in several pastures where coveys were not observed indicating that the quail were present in these areas. Detection was simply very difficult.

The masked bobwhite population was also surveyed during the first week of August 1994 by counting whistling males. Almost 60 males were heard calling on one morning on one survey route, but calling averaged 25 males for the five routes. Calling was most intense in habitats that received July precipitation. Calling was not evident along routes established in pastures that received no rainfall for over 2 years. Of course it is unlikely that masked bobwhites inhabited these pastures because herbaceous cover was almost totally absent. Calling was highly variable on pastures where habitat conditions were good. Evidently humidity levels were not sufficient to stimulate calling activity. It was apparent that masked bobwhites existed in these pastures, and Ken Nolte reported that the birds seemed abundant. Environmental conditions were not consistently suitable for calling activity during the week of the survey. Despite the variable results, the average number of calling males was higher during FY 1994 (25) than during the same period in 1993 (17).

Postscript: After this Workshop, bobwhite surveys in August 1995 confirmed that the ranch population had declined. An average of 4 males were heard daily on census routes compared to an average of 24 males whistling daily in 1994. The population decline is probably not as severe as the numbers imply because humidity and the intensity of calling by quail was lower during the 1995 survey period than in 1994.

Rancho Grande

Rancho Grande was also surveyed during December 1994. The owner of the ranch, Gustavo Camou and ranch cowboys saw masked bobwhites during the summer of 1994, and the cowboys observed birds in November, 1994. Unfortunately, masked bobwhites were not encountered during the December survey. Masked bobwhites probably remain on Rancho Grande because habitat conditions were still good on the pasture where sightings were reported. Masked bobwhites were probably not detected for the same reasons hypothesized at Rancho El Carrizo. Bird dogs will be used on Rancho Grande for further surveys later in 1995.

El Arpa

Masked bobwhites have not been observed on Rancho El Arpa since the summer of 1989. The pasture where masked bobwhites were observed in 1989 was censused during December 1994 but none were detected. Unlike Rancho Grande, the habitat on El Arpa has deteriorated significantly due to drought, over grazing, and brush encroachment. It is likely that the El Arpa population has been extirpated.

Buenos Aires NWR

The annual masked bobwhite census was conducted between December 1994 and February 1995 on all the 1994 chick release sites and on several other areas inhabited by masked bobwhites. Approximately 75 miles of line transect were traversed and only 2 observations were obtained (2.4 birds/observation). The line transect software utilized to calculate density generated a figure of 0.045 birds/acre with an accompanying coefficient of variation of almost 80%. Apparently the population had declined from the 0.25 birds/acre estimate of the winter of 1993-94. During the 1993-94 census approximately 55 miles of transect was traversed yielding 7 observations that averaged 5 birds/covey. More effort was expended during the 1994-95 census yet fewer observations were obtained which supports the assertion that the refuge population declined.

A professional bird dog trainer visited the refuge during January 1995 to assist Refuge Biologists with surveys. The trainer expended twice the amount of effort as in 1994 surveying the refuge but observed the same number coveys (6) as 1993. Half of the coveys were found in areas not surveyed the previous year. Fewer birds were located on the areas surveyed in 1994. The 1995 bird dog surveys thus support the biologist's conclusions that the masked bobwhite population declined between 1994 and 1995. The line transect and bird dog survey results did not yield precise data. It is therefore very difficult to estimate how many masked bobwhites currently exist on the refuge. Buenos Aires NWR biologists believe the refuge population is fewer than 500.

IS THE MASKED BOBWHITE A RECOVERABLE SPECIES?

There are several reasons for asking if the masked bobwhite is a recoverable subspecies in the United States, including biological, management, and/or political considerations. First of all, masked bobwhites on Buenos Aires NWR are believed to be at the northern extent of their range. Conditions, such as summer high or winter low temperatures, moisture levels, or habitat conditions, are generally extreme for a species near the edge of their geographic range. These extremes in conditions make management a greater challenge, and in some circumstances may preclude success of recovery. Another consideration is current and potential population size, and the proximity of the population to other groups of conspecifics. Small, disjoint populations are more vulnerable to localized extinction and recovery will likely be problematic under such conditions. It also is appropriate to ask if recovery of masked bobwhites is feasible and prudent, given limited resources and concerns for a myriad of other conservation problems.

We believe that recovery of the masked bobwhite on Buenos Aires NWR is a worthy goal. Historically, masked bobwhites were part of the faunal community in the open savanna grassland ecosystem of southeastern Arizona. Any attempt to restore natural native communities in this area should include considerations for masked bobwhites. The mix of different species of quail, including masked bobwhites, Gambel's, scaled, and Mearn's, makes this area unique in the United States. Quail, as prey for a large variety of predatory species, also play an important role in the ecology of this grassland ecosystem.

Buenos Aires NWR may represent the northern extent of the masked bobwhite range, but we believe that vegetative and climatic conditions are suitable to support a self-sustaining population. There is historical and current information to support this belief. Buenos Aires NWR contains enough acreage to permit large-scale habitat management and to maintain a self-sustaining population of bobwhites. Although reintroduction efforts have not been fully successful to date, small numbers of quail survive on the refuge each year, and new ideas and methods involving habitat management and reintroduction procedures give us hope that a self-sustaining population is a real possibility. Quail populations may build slowly, especially during re-establishment efforts, and the population on Buenos Aires NWR must be given an adequate amount of time to grow.

The presence of a unique subspecies of quail such as the masked bobwhite has the potential to attract fairly large numbers of people to Buenos Aires NWR. This influx of visitors to the area benefits the economies of local communities. This benefit occurs on a year-long, rather than seasonal, basis.

SECTION 3. POPULATION BIOLOGY AND MODELLING

Authors: Steve DeStefano, Fred Guthery, Phil Miller, Ron Olding, and Ron Engle-Wilson

INTRODUCTION

Federally listed as an endangered species, only one population of 300-500 masked bobwhite remains in the United States, with an estimated 500-1000 birds currently residing in perhaps three populations in Mexico. Habitat degradation is the primary cause of the recent decline in masked bobwhite populations.

The need for and effects of intensive management strategies can be modelled to suggest which practices may be the most effective in conserving this subspecies. VORTEX, a simulation modelling package written by Robert Lacy and Kim Hughes, was used as a tool to study the interaction of multiple stochastic variables. The VORTEX package is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. VORTEX models population dynamics as discrete, sequential events (e.g., births, deaths, sex ratios, catastrophes, etcetera) that occur according to defined probability distributions. The probabilities of events are modelled as constants or as random variables that follow specified distributions. The package simulates a population by stepping through the series of events that describe the typical life cycle of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters which enter into the model and because of the random processes involved in nature. Interpretation of the output depends upon our knowledge of the biology of the masked bobwhite, the conditions affecting the population, and possible changes in the future. Life history data specific to the masked bobwhite are limited, but abundant for the ecologically similar Texas bobwhite. So when information was lacking for the masked bobwhite, when appropriate, we utilized data from wild populations of Texas bobwhite.

INPUT PARAMETERS FOR SIMULATION

Mating System: Polyandry. In addition to males mating with more than one female, females may mate with multiple males. Pair fidelity may be weak; additional research is needed to determine the extent of this fidelity.

Average Age of First Reproduction: VORTEX defines breeding as the time when young are born, not the age of sexual maturity. Masked bobwhites begin nesting in July, with hatching reaching a peak in mid-September. The onset of sexual maturity in males and females occurs at one year, so we set the average age of first reproduction at one year.

Age of Senescence: VORTEX assumes that animals can breed (at the normal rate) throughout their adult life. Data from Texas bobwhites indicate that males and females are reproductively capable until three years of age.

Offspring Production: For the purposes of modelling masked bobwhite population dynamics, we defined reproduction as the production of fledglings. Masked bobwhites may, if unsuccessful in the first attempt, make up to two nesting attempts per breeding season. Data from Texas bobwhites indicate that the probability of nest failure for any nesting attempt is 0.7. Therefore, the proportion of females that fail to produce a group of fledglings is $(0.7)^2 = 0.49 \approx 0.50$, or 50%.

The presence of vasectomized Texas bobwhite males, used as foster parents in the chick reintroduction program on the Buenos Aires NWR, could have significant consequences for the reproductive success of masked bobwhite females. Despite being vasectomized, Texas bobwhite males have been seen paired with masked bobwhite females. Such pairing removes the masked female from the breeding population. To simulate this effect, a number of scenarios was modelled in which the proportion of females failing to produce fledglings was increased from 50% to 60%.

Environmental variation in reproduction is modelled in VORTEX by entering a standard deviation (SD) for the proportion of adult females producing no offspring. Because empirical data for this variable were lacking, we assumed that such variation (due to fluctuations in food abundance and variability in the age at which females reach sexual maturity) was 25-30% of the mean value. VORTEX then determines the percent of females breeding each year of the simulation by sampling from a binomial distribution with the specified mean (50% or 40%) and SD (12.5%). The relative proportions of fledglings produced per female, however, are held constant.

Each reproductive female lays 12-15 eggs. Hatchability is high, with newly-hatched broods numbering 6-15 chicks, an average of 11. Fledging occurs 10-14 days after hatching. A number distribution of offspring per female was then constructed with a minimum of 6, a maximum of 15, and a mean of 11.

Male Breeding Pool: The proportion of adult males breeding each year was set at 100%. The presence of Texas bobwhite males as discussed above could reduce the number of masked bobwhite males available for breeding.

Sex Ratio at Birth: Data indicate 50:50 sex ratio at hatching.

Mortality: Precise mortality data for masked bobwhites are not available, but relevant data from Texas bobwhites and other bobwhite species can be used for our analyses. Juvenile survival is defined as the survival from fledging to one year of age; similarly, adult survival is from one year throughout adulthood. Juvenile mortality was set at 70% based on observations of Texas bobwhites and other bobwhite species (Rosene 1969). Annual adult mortality was 65% for both sexes.

Rainfall patterns and other environmental processes can be highly variable in the southwestern United States and Sonora, Mexico. This variation can influence rates of individual survival as well as reproductive success. Environmental variability in mortality is treated by VORTEX similar to that for reproduction (defined as the standard deviation) set at 20% of mean mortality values. To assess the influence of this variation, scenarios were run in which variation in mortality was reduced by 50%.

Inbreeding Depression: Specific data do not exist on the prevalence and effects of inbreeding in masked bobwhite or on the frequency and severity of inbreeding in birds as a whole (Rowley et al. 1993). Based on the assumption that populations on Buenos Aires NWR and Rancho el Carrizo each number about 500 birds, it is unlikely that inbreeding depression is a serious concern. However, the rapid decline in suitable habitat and subsequent reduction in bobwhite population numbers will likely result in some degree of inbreeding in the future. Overall levels of genetic diversity will decline as a result of inbreeding and the reduction in general fitness that usually follows. Inbreeding depression, therefore, exacerbates the impact that other stochastic forces have on the viability of small populations. Although we are not modelling its effects here (primarily due to computational limitations), the potential deleterious consequences of this process on small populations must not be overlooked.

Initial Population Size: Staff biologists at the Buenos Aires NWR recently surveyed approximately 50% of the available bobwhite habitat on the Refuge using bird-dogs. Six coveys were flushed. Bird-dog surveys usually locate about 40% of the total coveys, so we estimate that the area surveyed contained about 15 coveys. Extrapolating to the entire Refuge, it is estimated that 30 coveys occupy suitable habitat. Given an average covey size of 10 to 16, an estimate for the size of the masked bobwhite population in Arizona is 300-500. Similar estimates have been made, based on different criteria, for the Rancho el Carrizo population in Mexico. Continued habitat fragmentation will inevitably result in smaller population sizes. Recent sightings of masked bobwhites in areas surrounding Carrizo el Ranch suggest the existence of smaller isolated populations. To examine the impact of stochastic factors on survival of populations of various sizes, we constructed scenarios with initial population sizes of 50, 100, 250, 500, and 1000.

Carrying Capacity: Carrying capacity (K) defines an upper limit for population size, above which additional mortality is imposed equally across age and sex classes to return the population to this value.
Density estimates for a number of bobwhite subspecies occupying suitable habitat approach 2.47 per ha (1 per acre). This density estimate would indicate at least 20,000 birds on the Buenos Aires NWR under optimal conditions. For the purposes of our modelling, while focusing on the impacts of random factors on the viability of small populations, we set carrying capacity at 2,000 for all simulations.

Catastrophes: Catastrophes are singular events, outside the bounds of normal environmental variation, affecting reproduction and survival. Examples are tornadoes, floods, droughts, fire, disease, epizootics, or other similar circumstances. Catastrophes are modelled by assigning an annual probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect).

Climatic data show that severe reductions in precipitation occur in southern Arizona about every 5 years. Similar data exist for areas in Mexico near the Rancho el Carrizo. Therefore, drought was modelled with a 20% annual probability of occurrence. Reproductive activity of masked bobwhites is severely depressed during drought years, with survival affected to a much lesser extent. Consequently, drought was modelled as resulting in a 75% reduction in reproduction (proportion of females producing fledglings) and a 10% reduction in survival across all age and sex classes.

Supplementation: VORTEX allows for the supplementation of a population with individuals presumed to be unrelated to any individuals in the receiving population. As a result, supplementation is a means of increasing genetic diversity as well as population numbers. The chick reintroduction program currently underway at Buenos Aires NWR was modelled as a supplementation process. Instead of supplementing the modelled population with a large number of chicks (as is currently employed at the Refuge) in the fall, and then imposing high rates of post-release mortality over the winter, a smaller number of adult birds were added before the next breeding season. These birds are then subject to the same mortality rates as the resident wild birds. This alternative reintroduction strategy is currently being developed by biologists at the Refuge. Scenarios were constructed in which either 5, 10, or 20 adult females and males were added each year during the entire 20-year duration of the simulation.

Harvesting: It has been proposed that masked bobwhite adults from the Mexican population in and around the Rancho el Carrizo be used to supplement the Buenos Aires NWR population. It is important, however, to determine the level of harvest that is sustainable to the source population. To determine the impact of this harvest of adults on the population in Mexico, we harvested either 10 or 20 adult females each year from populations with an initial size of 500 or 1,000.

Iterations and Years of Projection: All scenarios were simulated 500 times, with population projections extending for 20 years. Output results were summarized at 2-year intervals for use in the Figures and Tables that follow.

SAMPLE VORTEX FILE INPUT

```
BOB517.OUT     ***Output Filename***
Y      ***Graphing Files?***
N      ***Each Iteration?***
Y       ***Screen display of graphs?***
500      ***Simulations***
20      ***Years***
2      ***Reporting Interval***
1      ***Populations***
N      ***Inbreeding Depression?***
Y      ***EV correlation?***
1      ***Types Of Catastrophes***
P      ***Monogamous, Polygynous, or Hermaphroditic***
1      ***Female Breeding Age***
1      ***Male Breeding Age***
3      ***Maximum Age***
0.500000     ***Sex Ratio***
15      ***Maximum Litter Size***
```

```
N     ***Density Dependent Breeding?***
50.000000     ***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***
1.000000     ***Population 1: Percent Litter Size 6***
2.000000     ***Population 1: Percent Litter Size 7***

2.000000     ***Population 1: Percent Litter Size 8***
2.500000     ***Population 1: Percent Litter Size 9***
7.500000     ***Population 1: Percent Litter Size 10***
25.000000     ***Population 1: Percent Litter Size 11***
7.500000     ***Population 1: Percent Litter Size 12***
1.000000     ***Population 1: Percent Litter Size 13***
1.000000     ***Population 1: Percent Litter Size 14***
0.500000     ***Population 1: Percent Litter Size 15***
5.000000     ***EV--Reproduction***
60.000000     ***Female Mortality At Age 0***
12.000000     ***EV--FemaleMortality***
65.000000     ***Adult Female Mortality***
13.000000     ***EV--AdultFemaleMortality***
60.000000     ***Male Mortality At Age 0***
12.000000     ***EV--MaleMortality***
65.000000     ***Adult Male Mortality***
13.000000     ***EV--AdultMaleMortality***
20.000000     ***Probability Of Catastrophe 1***
0.250000     ***Severity--Reproduction***
0.900000     ***Severity--Survival***
Y     ***All Males Breeders?***
Y     ***Start At Stable Age Distribution?***
500     ***Initial Population Size***
2000     ***K***
0.000000     ***EV--K***
N     ***Trend In K?***
N     ***Harvest?***
N     ***Supplement?***
Y     ***AnotherSimulation?***
```

RESULTS FROM SIMULATION MODELLING

Results of the simulation models appear in Tables 1-9. Each table represents a specified set of conditions, for example, for juvenile mortality, or female reproductive success. Within each Table, the results are organized in a nested structure: each initial population size was run with each level of juvenile mortality under specified conditions.

The column headings for the Tables are as follows:

r_d: deterministic growth rate, calculated by Leslie matrix methods from life table data;
r_s (SD): mean and standard deviation of stochastic growth rate across iterations, calculated from annual variation in population size;
P(E): probability of extinction over the 20-year time span of the simulation, calculated as the proportion of iterated population that became extinct within 20 years;
N_{20} (SD): final size of those populations remaining extant after 20 years;
H_{20}: proportion of the original heterozygosity expected to remain in extant populations after 20 years;

$T(E)$: mean time to extinction of those populations becoming extinct.

Note that VORTEX output file numbers are given for each scenario for future reference and retrieval, if necessary.

Figures 1 through 6 are a graphical compilation of the modelling results, attempting to show the relationships between specific factors and their impact on population persistence.

DETERMINISTIC SIMULATION RESULTS

The deterministic population growth rates for each scenario, calculated from life tables using Leslie matrix algorithms, are presented in the fourth column of Tables 1-9. These calculations assume that birth and death rates are constant (no annual variations nor stochastic fluctuations), there is no limitation of mates, and inbreeding has no impact on fecundity or viability. Note that mortality, inclusion or exclusion of catastrophes and proportional female reproductive success are the only variables that affect these deterministic rates. Therefore, the long-term rate of growth of these populations, in the absence of stochastic variation, is independent of initial population size and habitat carrying capacity.

Our baseline modelling scenario (File #501), with juvenile mortality set at 70%, results in a population in deterministic decline (r_d = -0.020; Table 1). However, a slight change in juvenile mortality to 65% results in a dramatic increase in r_d to 0.092 (File #503), while 60% juvenile mortality further improves r_d to 0.191 (File #504). Increasing juvenile mortality further to 75% erodes deterministic growth to r_d = -0.147; high juvenile mortality (80%) gives r_d = -0.297.

In the absence of catastrophic drought, our baseline scenario (File #526) shows a strong deterministic increase (r_d = 0.118; Table 3). Growth rates are still negative when juvenile mortality is increased above 70%, but the rate of decline is not as severe compared to when drought is added to the analysis (Files #529 and #530).

If vasectomized Texas bobwhite males remove masked bobwhite females from the breeding pool, resulting in fewer masked bobwhite females producing fledglings, deterministic growth becomes strongly negative under all but the most optimistic estimates of juvenile mortality (Table 4). If juvenile mortality is 60%, r_d = 0.041 (File #552), while the baseline mortality yields a deterministic rate of -0.161 (File #551). Deterministic growth falls to -0.427 under pessimistic conditions of high juvenile mortality.

It is imperative that more detailed information on survival be collected from wild populations due to the sensitivity of long-term population growth to changes in juvenile mortality. The consequences of Texas bobwhite males pairing with female masked bobwhites appear to be severe under the conditions modelled. Concerted attempts should be made to remove the Texas males whenever they are encountered.

Table 1. Masked bobwhite population analysis.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
501	50	70	-.020	-.212 (.749)	0.776	145 (363)	0.630	9
502		60	.191	.043 (.650)	0.294	763 (742)	0.776	11
503		65	.092	-.084 (.695)	0.558	376 (543)	0.738	10
504		75	-.147	-.386 (.838)	0.958	153 (435)	0.680	8
505		80	-.297	-.564 (.910)	0.996	15 (12)	0.698	6
506	100	70	-.020	-.214 (.746)	0.722	224 (419)	0.740	11
507		60	.191	.041 (.621)	0.190	755 (751)	0.821	11
508		65	.092	-.074 (.666)	0.414	410 (563)	0.782	12
509		75	-.147	-.382 (.854)	0.936	74 (126)	0.664	9
510		80	-.297	-.624 (.947)	0.994	38 (20)	0.632	6
511	250	70	-.020	-.216 (.740)	0.624	236 (455)	0.777	12
512		60	.191	.065 (.590)	0.106	1011 (753)	0.907	13
513		65	.092	-.052 (.647)	0.300	607 (690)	0.857	13
514		75	-.147	-.404 (.851)	0.894	75 (107)	0.696	10
515		80	-.297	-.573 (.916)	0.980	98 (134)	0.730	8
516	500	70	-.020	-.201 (.714)	0.504	274 (441)	0.824	13
517		60	.191	.075 (.578)	0.042	1025 (742)	0.934	—
518		65	.092	-.045 (.633)	0.226	628 (685)	0.894	13
519		75	-.147	-.415 (.854)	0.880	181 (390)	0.794	11
520		80	-.297	-.590 (.923)	0.976	159 (401)	0.693	9
521	1000	70	-.020	-.216 (.737)	0.454	263 (425)	0.843	13
522		60	.191	.071 (.581)	0.028	1013 (750)	0.949	—
523		65	.092	-.039 (.622)	0.172	727 (719)	0.913	14
524		75	-.147	-.390 (.846)	0.808	106 (188)	0.769	12
525		80	-.297	-.635 (.962)	0.966	22 (32)	0.709	9

Table 2. Masked bobwhite population analysis: reduced environmental variation.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
676	50	70	-.020	-.150 (.588)	0.642	109 (180)	0.645	11
677		60	.191	.084 (.529)	0.188	878 (759)	0.803	10
678		65	.092	-.027 (.562)	0.376	428 (601)	0.747	10
679		75	-.147	-.296 (.648)	0.894	36 (63)	0.565	9
680		80	-.297	-.431(.626)	0.990	10 (7)	0.259	8
681	100	70	-.020	-.130 (.556)	0.468	170 (352)	0.721	12
682		60	.191	.098 (.497)	0.068	945 (755)	0.871	—
683		65	.092	-.010 (.523)	0.230	548 (649)	0.810	12
684		75	-.147	-.259 (.594)	0.786	60 (151)	0.637	11
685		80	-.297	-.438 (.608)	0.978	11 (9)	0.541	9
686	250	70	-.020	-.116 (.526)	0.290	271 (440)	0.814	14
687		60	.191	.118 (.468)	0.018	1181 (707)	0.941	—
688		65	.092	.001 (.499)	0.110	697 (701)	0.882	14
689		75	-.147	-.268 (.582)	0.666	66 (113)	0.731	13
690		80	-.297	-.414 (.568)	0.950	13 (13)	0.637	11
691	500	70	-.020	-.116 (.507)	0.186	291 (453)	0.856	15
692		60	.191	.115 (.463)	0.010	1280 (705)	0.957	—
693		65	.092	.019 (.480)	0.036	825 (705)	0.930	—
694		75	-.147	-.268 (.570)	0.598	96 (209)	0.791	14
695		80	-.297	-.397 (.558)	0.886	24 (54)	0.661	13
696	1000	70	-.020	-.112 (.501)	0.144	413 (539)	0.905	16
697		60	.191	.116 (.464)	0.006	1321 (689)	0.973	—
698		65	.092	.009 (.474)	0.020	878 (713)	0.950	16
699		75	-.147	-.260 (.544)	0.468	112 (216)	0.817	15
700		80	-.297	-.425 (.562)	0.860	20 (27)	0.669	14

Table 3. Masked bobwhite population analysis: no drought.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
526	50	70	.118	-.043 (.675)	0.494	473 (582)	0.767	10
527		60	.336	.264 (.435)	0.024	1654 (508)	0.896	—
528		65	.233	.132 (.521)	0.162	978 (756)	0.824	10
529		75	-.014	-.251 (.845)	0.844	214 (392)	0.654	8
530		80	-.168	-.476 (.938)	0.988	133 (121)	0.570	7
531	100	70	.118	-.025 (.656)	0.356	568 (666)	0.827	11
532		60	.336	.273 (.420)	0.004	1721 (471)	0.942	—
533		65	.233	.141 (.510)	0.146	1173 (707)	0.901	11
534		75	-.014	-.237 (.831)	0.756	226 (414)	0.743	10
535		80	-.168	-.472 (.921)	0.982	101 (137)	0.743	8
536	250	70	.118	-.015 (.633)	0.224	668 (700)	0.882	12
537		60	.336	.275 (.418)	0.004	1762 (428)	0.974	—
538		65	.233	.135 (.521)	0.104	1249 (696)	0.944	11
539		75	-.014	-.230 (.813)	0.650	254 (447)	0.798	11
540		80	-.168	-.507 (.951)	0.956	110 (235)	0.728	9
541	500	70	.118	-.021 (.635)	0.196	710 (712)	0.897	13
542		60	.336	.273 (.408)	0.010	1810 (371)	0.984	—
543		65	.233	.146 (.503)	0.080	1370 (672)	0.971	—
544		75	-.014	-.230 (.806)	0.578	267 (445)	0.819	12
545		80	-.168	-.464 (.927)	0.918	144 (340)	0.812	10
546	1000	70	.118	-.015 (.622)	0.182	804 (737)	0.934	13
547		60	.336	.271 (.418)	0.004	1733 (455)	0.987	—
548		65	.233	.140 (.501)	0.062	1390 (643)	0.978	—
549		75	-.014	-.232 (.800)	0.498	287 (496)	0.837	13
550		80	-.168	-.459 (.928)	0.876	173 (377)	0.762	11

Table 4. Masked bobwhite population analysis: 40% hens fledging.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
551	50	70	-.161	-.372 (.761)	0.948	38 (42)	0.610	8
552		60	.041	-.117 (.678)	0.600	325 (484)	0.680	10
553		65	-.054	-.247 (.738)	0.834	72 (107)	0.606	9
554		75	-.283	-.483 (.838)	0.994	12 (4)	0.556	7
555		80	-.427	-.703 (.891)	1.0	—	—	5
556	100	70	-.161	-.346 (.759)	0.896	80 (279)	0.647	9
557		60	.041	-.113 (.655)	0.464	256 (421)	0.733	12
558		65	-.054	-.224 (.690)	0.736	156 (314)	0.671	11
559		75	-.283	-.511 (.844)	0.988	15 (22)	0.437	8
560		80	-.427	-.692 (.896)	0.998	15 (0)	—	6
561	250	70	-.161	-.346 (.733)	0.834	75 (185)	0.721	11
562		60	.041	-.100 (.612)	0.318	407 (579)	0.818	13
563		65	-.054	-.230 (.687)	0.642	187 (334)	0.759	12
564		75	-.283	-.505 (.826)	0.956	17 (17)	0.618	9
565		80	-.427	-.727 (.903)	1.0	—	—	7
566	500	70	-.161	-.339 (.728)	0.764	137 (329)	0.709	12
567		60	.041	-.082 (.594)	0.188	462 (599)	0.858	14
568		65	-.054	-.209 (.653)	0.508	226 (414)	0.807	13
569		75	-.283	-.505 (.803)	0.954	78 (173)	0.738	10
570		80	-.427	-.740 (.919)	0.998	4(—)	—	7
571	1000	70	-.161	-.341 (.719)	0.698	89 (221)	0.796	13
572		60	.041	-.086 (.595)	0.154	493 (584)	0.893	15
573		65	-.054	-.209 (.644)	0.450	285 (460)	0.835	14
574		75	-.283	-.525 (.838)	0.920	53 (198)	0.763	11
575		80	-.427	-.711 (.907)	0.992	12 (13)	0.739	9

STOCHASTIC SIMULATION RESULTS

Calculations of population growth rates from average birth and death rates in a life table will over-estimate long-term population growth if there are fluctuations in demographic parameters, even random sampling variation. Census estimates for masked bobwhite on the Buenos Aires NWR suggest considerable annual variation in population size, with likely variation in mortality rates as well due to random environmental fluctuations.

The inclusion of these random forces in the population modelling process results in stochastic growth rates that are, in every instance, lower than the deterministic growth rates calculated from the mean life table parameters. The baseline scenario (File #501) under the influence of stochastic forces yields a mean growth rate of r_s = -0.212, considerably lower than the deterministic rate. For example, under 65% juvenile mortality (File #503), the stochastic growth rate is -0.084 while the deterministic rate is 0.092. The inclusion of environmental variation in mortality and reproduction, under these modelling conditions, is sufficient to drive the population into short-term decline despite deterministic analyses predicting long-term population growth.

Under the baseline scenario, with 70% juvenile mortality and an initial population size of 500 individuals, a population is under a 50% risk of extinction within 20 years (File #516; Table 1). These conditions are thought to be generally representative of both the Refuge population and the population at El Rancho el Carrizo. Of those populations that survive for the 20-year duration of the simulation, the mean population size is reduced to about half of its original number (N_{20} = 274) with considerable variation around this mean value from environmental variance and the action of drought. As juvenile mortality is reduced with 500 initial individuals, the probability of extinction decreases to a minimum of 4%; this risk reaches a maximum of nearly 98% if juvenile mortality is as high as 80%. Mean population size also doubles under conditions of low juvenile mortality.

As initial population size is reduced for any given level of juvenile mortality, the risk of extinction increases and the final population size decreases. For example, under 70% juvenile mortality, extinction risk steadily climbs from 50% to nearly 78% as N_0 is reduced from 500 to 50 (Table 1). Under conditions of higher juvenile mortality, extinction risk is extremely high within 20 years, with the mean time to population extinction ranging from 6 to 12 years. Because of the significant variation around the mean rate of stochastic population growth seen in these simulation results, the risk of extinction for a given population can be considerable even if the stochastic growth rate is positive. To illustrate this point, consider that only when juvenile mortality is 60% is the mean stochastic growth rate positive. Despite this average rate of growth, a population that starts out at 100 individuals faces a nearly 20% risk of extinction within 20 years despite a mean rate of growth of 0.041 (File #507; Table 1).

To further illustrate the impact of environmental variation on masked bobwhite population dynamics, Table 2 presents results from a set of scenarios in which the environmental variation in annual mortality was reduced by half for both age and sex. The effects of this manipulation are more evident as initial population size is increased and juvenile mortality is low to moderate. Our baseline scenario with N_0 = 500 (File #516) results in a 50% risk of population extinction when there is high environmental variance in mortality, while the same scenario with low environmental variance (File #691) results in a 19% risk of extinction. The final mean extant population size is not significantly different in the alternative scenarios, but the reduction in extinction risk is considerable (although, perhaps, still unacceptably high). If juvenile mortality were slightly lower, at 65%, the risk of population extinction is nearly 4% (File #693)—dramatically reduced from the 23% probability under conditions of higher environmental variance (File #518). However, as juvenile mortality is increased to 75% or even 80%, the reduction in environmental variance does not affect the risk of extinction for populations smaller than 500 individuals. High juvenile mortality seems to dominate the dynamics of the population, regardless of any additional intrinsic conditions.

The sensitivity of masked bobwhite populations to changes in environmental conditions is clearly demonstrated when the effect of drought is removed from the modelling scenarios (Table 3). Removal of extreme catastrophic variation has considerable impact on the risk of population extinction, particularly under low to moderate levels of juvenile mortality. The baseline scenario without drought (File #541) results in a 20% probability of population extinction within 20 years (P(E) = 0.196)—a 60% reduction in this risk compared to the baseline scenario including drought (File #516: P(E) = 0.504). Under lower juvenile mortality, this reduction is more significant: extinction risk is reduced nearly 65% when juvenile mortality is 65% (compare File #543 with File #518). Moreover, final population size is more than doubled in these scenarios, although the variation around the means is quite high. As initial population size is reduced, the removal of drought has significant effects but they are not as marked as when initial size is larger. For example, P(E) = 0.494 without drought when juvenile mortality is 70% and N_0=50 (File #526), a 36% reduction in extinction risk compared to the corresponding drought scenario (File #501). Final population size in this scenario is nearly 500. Throughout the set of scenarios presented in Table 3, the effect of environmental variation in mortality is apparent. While stochastic growth rates are increased with the removal of drought, compared to simply reducing overall environmental variation on mortality, the standard deviation around these mean growth rates is still substantial owing to environmental variation. As a result, the risk of extinction remains relatively high to many of these populations.

Table 4 presents the results of simulations in which the proportion of hens producing fledglings is reduced from 50% to 40%. This removal of females from the pool of successful breeders has severe consequences for population persistence, even under more optimal conditions of mortality and initial population size. The baseline scenario (File #556) results in a 77% risk of extinction within 20 years owing to a stochastic growth rate of r_s = -0.339. Moreover, mean final population size under these conditions is only 27% of its original value. Under the most optimistic conditions considered—60% juvenile mortality with an initial population size of 100—the risk of extinction is still 15%, and the mean population size is reduced by over 50% in the 20-year duration of the simulation (File #572). These simulations suggest that masked bobwhite populations are unable to withstand much reduction in the size of the female breeding pool.

Based on these analyses of the current masked bobwhite population, supplementation was tested for its effectiveness as a management option for the Buenos Aires NWR population. A specified number of adult birds was added to the population each year for the 20 years of the simulation. If only females are added annually to the modelled population, stochastic rates of population growth are dramatically increased and final population sizes are increased over the non-supplementation scenarios, but extinction risk is still high (Table 5). If 10 males are also added annually, population growth is further increased and extinction risk is effectively eliminated (Table 6). Under higher levels of juvenile mortality, final population size is decreased despite the annual additions owing to negative stochastic growth. The addition of a larger number of individuals each year leads to positive population growth in all but the highest levels of juvenile mortality and initial population size (Table 7). Under the baseline scenario conditions with the annual addition of 10 females and 10 males, population size is increased under all initial population sizes (Files #661, 666, and 671). Twenty males and females added each year is sufficient to maintain masked bobwhite populations with even higher levels of juvenile mortality (Files #704, 709, and 714).

Table 5. Masked bobwhite population analysis: supplementation—10 females per year.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
611	50	70	-.020	.052 (.650)	0.132	324 (411)	0.956	9
612		60	.191	.177 (.562)	0.008	1070 (704)	0.957	—
613		65	.092	.111 (.606)	0.066	659 (601)	0.957	—
614		75	-.147	-.009 (.699)	0.380	167 (253)	0.955	9
615		80	-.297	-.079 (.725)	0.712	86 (98)	0.955	9
616	100	70	-.020	.022 (.660)	0.126	411 (542)	0.957	10
617		60	.191	.158 (.560)	0.006	1163 (727)	0.962	—
618		65	.092	.075 (.616)	0.078	689 (656)	0.961	—
619		75	-.147	-.044 (.715)	0.340	180 (296)	0.957	10
620		80	-.297	-.127 (.760)	0.694	82 (88)	0.953	10
621	250	70	-.020	-.022 (.664)	0.100	370 (482)	0.959	11
622		60	.191	.131 (.562)	0.002	1159 (716)	0.969	—
623		65	.092	.045 (.627)	0.074	754 (662)	0.967	—
624		75	-.147	-.085 (.738)	0.252	146 (211)	0.956	11
625		80	-.297	-.178 (.778)	0.654	111 (193)	0.955	10

It has been proposed that birds harvested from the Rancho el Carrizo bobwhite population be used to supplement the Buenos Aires NWR population. These birds would perhaps be preferred due to the absence of behavioral or other alterations that may accompany birds

Table 6. Masked bobwhite population analysis: supplementation—10 females, 10 males per year.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
661	50	70	-.020	.072 (.571)	0.0	363 (451)	0.981	—
662		60	.191	.180 (.528)	0.0	1087 (700)	0.978	—
663		65	.092	.115 (.566)	0.0	641 (605)	0.979	—
664		75	-.147	.033 (.586)	0.0	157 (235)	0.982	—
665		80	-.297	.012 (.594)	0.0	86 (96)	0.982	—
666	100	70	-.020	.040 (.577)	0.0	369 (453)	0.981	—
667		60	.191	.164 (.532)	0.0	1113 (688)	0.979	—
668		65	.092	.080 (.572)	0.0	623 (599)	0.980	—
669		75	-.147	.002 (.602)	0.0	168 (240)	0.981	—
670		80	-.297	-.022 (.601)	0.0	90 (109)	0.982	—
671	250	70	-.020	-.001 (.608)	0.0	407 (514)	0.981	—
672		60	.191	.128 (.551)	0.0	1159 (694)	0.982	—
673		65	.092	.055 (.596)	0.0	716 (656)	0.980	—
674		75	-.147	-.042 (.642)	0.0	169 (246)	0.981	—
675		80	-.297	-.068 (.642)	0.0	88 (92)	0.982	—

raised under captive conditions. A necessary prerequisite for this method, however, is confirmation that the Rancho el Carrizo population can sustain levels of harvest needed to supplement the Refuge population. Simulations were run in which 10 or 20 female bobwhites were harvested annually from populations starting with at least 500 birds. The results (Tables 8 and 9) suggest that such harvests are not sustainable even in populations of 1,000 birds.

Under baseline juvenile mortality conditions, the annual removal of 10 females leads to an extinction risk of over 88% within the 20 years of the simulation (File #626). Those populations that survive show an average increase in population size, but the risk of extinction under these conditions appears to be unacceptably high. Even optimistic juvenile mortality levels do not lead to a sustainable harvest of 10 females annually (i.e., File #627).

CONCLUSIONS

The risk of population extinction increases dramatically as juvenile mortality increases from 60% to 80% (Fig. 1). The influence of initial population size in determining extinction risk is more pronounced at lower mortality levels; high mortality leads to very high extinction risk, regardless of population size. Final population sizes average about 900 under low juvenile mortality and about 200 for the baseline 70% mortality (Fig. 2).

Table 7. Masked bobwhite population analysis: supplementation—20 females, 20 males per year.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
701	50	70	-.020	.106 (.559)	0.0	549 (550)	0.990	—
702		60	.191	.221 (.520)	0.0	1298 (647)	0.988	—
703		65	.092	.148 (.564)	0.0	836 (624)	0.989	—
704		75	-.147	.074 (.572)	0.0	333 (396)	0.991	—
705		80	-.297	.046 (.573)	0.0	168 (182)	0.991	—
706	100	70	-.020	.076 (.564)	0.0	561 (542)	0.990	—
707		60	.191	.185 (.529)	0.0	1249 (680)	0.989	—
708		65	.092	.122 (.562)	0.0	883 (677)	0.989	—
709		75	-.147	.036 (.583)	0.0	292 (315)	0.991	—
710		80	-.297	.014 (.575)	0.0	181 (193)	0.991	—
711	250	70	-.020	.030 (.582)	0.0	561 (562)	0.990	—
712		60	.191	.154 (.534)	0.0	1295 (667)	0.989	—
713		65	.092	.079 (.574)	0.0	893 (659)	0.990	—
714		75	-.147	-.011 (.605)	0.0	303 (375)	0.991	—
715		80	-.297	-.034 (.601)	0.0	170 (198)	0.991	—

Table 8. Masked bobwhite population analysis: harvest—10 females per year.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
626	500	70	-.020	-.354 (.781)	0.884	621 (664)	0.957	9
627		60	.191	-.017 (.638)	0.398	1063 (732)	0.963	11
628		65	.092	-.179 (.677)	0.696	710 (650)	0.954	10
629		75	-.147	-.642 (.967)	0.984	449 (664)	0.957	7
630		80	-.297	-.87 (1.032)	1.0	—	—	5
631	1000	70	-.020	-.333 (.778)	0.868	596 (574)	0.967	11
632		60	.191	.014 (.605)	0.264	1137 (749)	0.971	14
633		65	.092	-.148 (.683)	0.588	806 (712)	0.966	12
634		75	-.147	-.596 (.956)	0.982	328 (363)	0.966	8
635		80	-.297	-.83 (1.011)	1.0	—	—	6

Table 9. Masked bobwhite population analysis: harvest—20 females per year.

File #	N_0	0-1 Mort. (%)	r_d	r_s (SD)	P(E)	N_{20}(SD)	H_{20}	T(E)
636	500	70	-.020	-.432 (.834)	0.952	586 (507)	0.969	7
637		60	.191	-.072 (.648)	0.574	1061 (697)	0.972	10
638		65	.092	-.229 (.716)	0.806	895 (701)	0.968	9
639		75	-.147	-.672 (.932)	0.994	164 (172)	0.970	5
640		80	-.297	-.926 (1.02)	1.0	—	—	4
641	1000	70	-.020	-.365 (.786)	0.922	710 (694)	0.970	9
642		60	.191	-.046 (.645)	0.468	1055 (720)	0.975	12
643		65	.092	-.180 (.680)	0.728	852 (700)	0.975	11
644		75	-.147	-.621 (.931)	0.986	388 (220)	0.973	7
645		80	-.297	-.851 (1.02)	1.0	—	—	5

Figure 1.

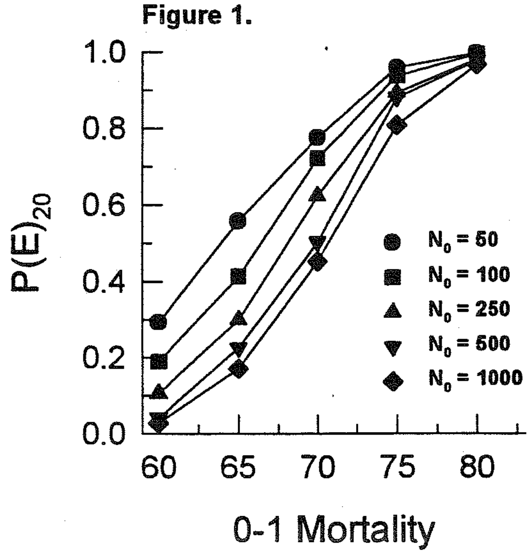


Figure 2.

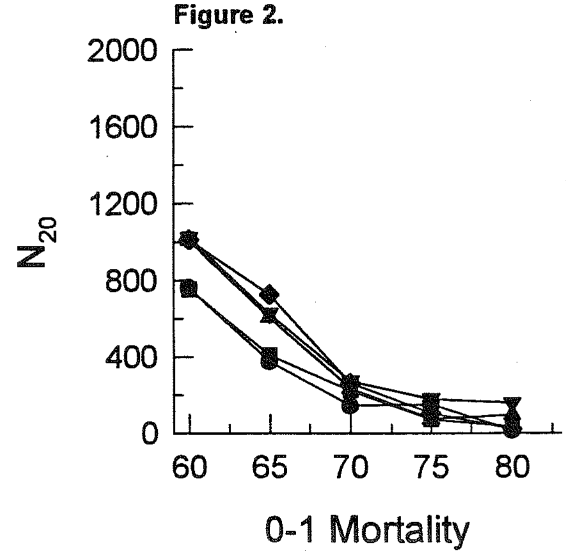


Figure 1. Probability of population extinction within 20 years as a function of juvenile mortality for the set of initial population sizes used in all model scenarios.

Figure 2. Final population size after 20 years as a function of juvenile mortality for the set of initial population sizes used in all model scenarios. Symbols as in Figure 1.

When drought is removed from the population modelling scenarios, extinction risk is very low under lower levels of juvenile mortality, but high mortality once again leads to high risk regardless of the environmental conditions (Fig. 3). The influence of initial population size on extinction risk is not as pronounced compared to drought conditions, particularly when juvenile mortality is low. Final population sizes are dramatically increased when drought is not considered; mean size is about 1,700 when juvenile mortality is low, but population size remains low under conditions of higher mortality (Fig. 4).

Overall, masked bobwhite populations appear to be sensitive to changes in environmental variation, whether it is modelled as reduced annual variation in survival rates or as elimination of a significant environmental impact. Given the severity of the drought as defined in the simulations, with a 75% reduction in reproductive success in years that drought occurs, it is not surprising that this factor appears to be a major influence in determining persistence of masked bobwhite populations.

Figure 3.

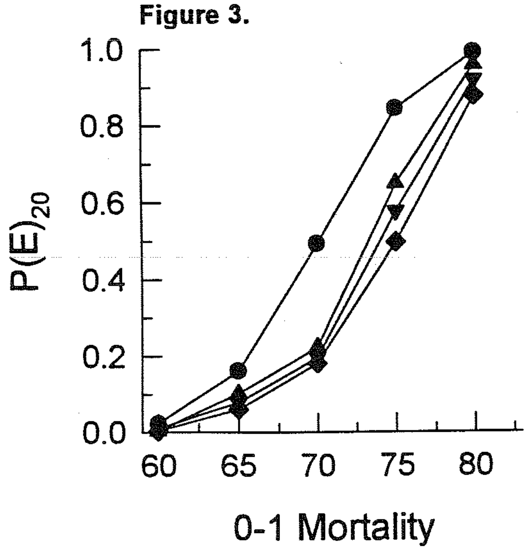


Figure 4.

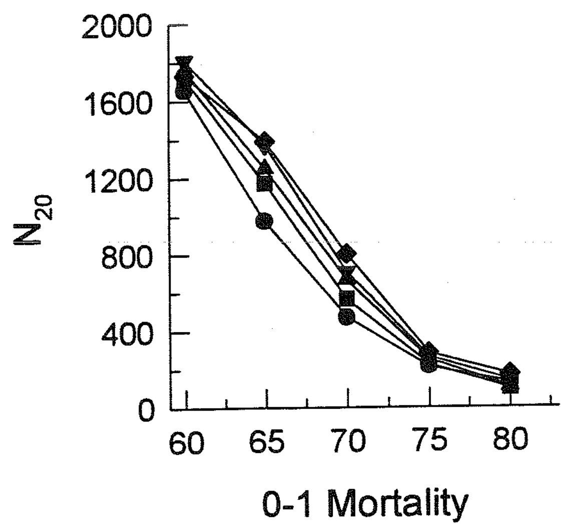
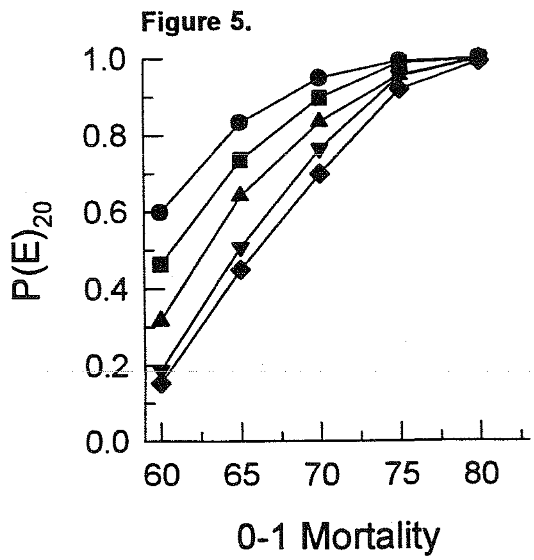


Figure 3. Probability of population extinction within 20 years as a function of juvenile mortality after the elimination of drought for the set of initial population sizes used in all model scenarios. Symbols as in Figure 1.

Figure 4. Final population size after 20 years as a function of juvenile mortality after the elimination of drought for the set of initial population sizes used in all model scenarios. Symbols as in Figure 1.

Reducing the number of females successfully reproducing has dramatic impacts on the viability of masked bobwhite populations (Fig. 5). When the average proportion of females fledging chicks is 50%, the mean extinction risk across initial population sizes at 70% juvenile mortality is approximately 60%; this mean risk jumps to over 80% when 40% of females on average fledge offspring. Under conditions of lower juvenile mortality, this disparity is more pronounced. Of those simulated populations that survive, final population size is significantly reduced (Fig. 6). If the operating assumption is that masked bobwhite females are being removed from the breeding pool as a consequence of pairing with vasectomized Texas bobwhite males released as part of the foster parent program, a priority strategy should be the removal of any Texas bobwhite males.

Supplementation of the Buenos Aires NWR population with unrelated birds appears to be an effective management strategy. As few as 10 adult females and 10 adult males added annually to the population eliminate the risk of extinction and lead to population growth in all but the highest juvenile mortality scenarios. Sink populations as small as 50 individuals can be successfully managed through supplementation. Given the relatively small investment in the number of birds required for successful supplementation, a larger number of birds could perhaps be used for this purpose.



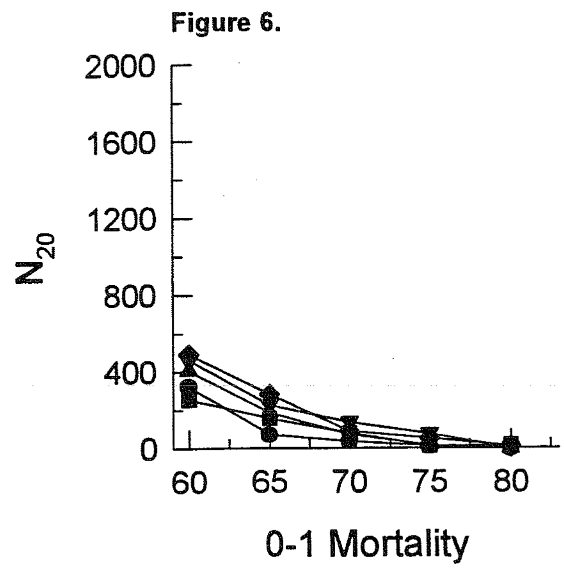


Figure 5. Probability of population extinction within 20 years as a function of juvenile mortality for the set of initial population sizes used in all model scenarios. In this set of scenarios, the average proportion of females successfully fledging chicks has been reduced from the baseline value of 50% to
40%. Symbols as in Figure 1.

Figure 6. Final population size after 20 years as a function of juvenile mortality for the set of initial population sizes used in all model scenarios. In this set of scenarios, the average proportion of females successfully fledging chicks has been reduced from the baseline value of 50% to 40%. Symbols as in Figure 1.

However, models in which birds are harvested from larger populations for use in the above supplementation suggest that even relatively low levels of harvest result in substantial risk of source population extinction. The rates of "harvest" modelled here do not appear to be sustainable. If the Rancho el Carrizo population is considered as a source for these birds, the size and characteristics of this population must be determined to assess its utility as a source of birds for supplementation programs. If the population is not capable of sustaining such a harvest, it may become necessary to refocus efforts towards the current strategy of using captive-reared quail for reintroduction efforts.

RECOMMENDATIONS

The following recommendations are made based on the simulation results discussed above:

1. Additional research is needed to determine mortality and reproductive rates in wild masked bobwhite populations.

2. Census and monitoring programs must be continued and improved to more accurately assess current and projected population characteristics.

3. Habitat management practices should be adopted that attempt to mitigate the deleterious effects of wide variations in environmental characteristics. More specifically, actions which should be considered include intensive habitat management.

4. Texas bobwhite males probably should be removed from areas with masked bobwhites after their use as foster parents for reintroduction efforts. An alternative strategy would be the elimination of Texas bobwhites as foster parents in any type of reintroduction program.

5. The current reintroduction program should be compared to one that focuses on the release of a smaller number of adult birds instead of a larger number of chicks. Radiotelemetry tracking of released birds should be conducted systematically to assess viability immediately after release.

5. The Rancho el Carrizo masked bobwhite population should be assessed for its use as a source for birds to be reintroduced into the Buenos Aires NWR. If population size is deemed too low for successful harvesting of adults, the current scheme of using captive-reared birds should be evaluated for its success and appropriate actions taken to improve the survival of these birds upon release.

SECTION 4. THREATS

Authors: Chris Brand, Mario Galen, George Gee, and Lorena Wada

GRAZING

Historically, overgrazing has been implicated as a major cause of extinction of masked bobwhite in the United States, and was responsible for a serious decline in populations in Mexico. The decline and current plight of the masked bobwhite is "wholly related to livestock overgrazing and the consequent destruction of a fragile subtropical grassland ecosystem" (Brown and Ellis 1977, Phillips et al. 1964). Excessive livestock use of Arizona's rangelands, beginning in the 1800's contributed to the destruction of southern Arizona's grasslands (Brown 1900, Hastings and Turner 1965, Hollon 1966, and Wilson 1976 in Brown 1989). In large part due to the impacts of livestock grazing management, the masked bobwhite disappeared from Arizona around the turn of the century (Phillips et al., 1964 Tomlinson 1972a).

Habitat destruction was not as severe in Sonora, where Ligon (1952) found several healthy populations of masked bobwhites as late as 1937. However, by 1950, masked bobwhite habitat in Sonora had been degraded by livestock and related management activities. No observations of masked bobwhite were reported again until 1964, when a team of biologists discovered a single population north of Hermosillo near Benjamin Hill (Gallizioli et al. 1967).
The lower parts of valleys are highly susceptible to livestock concentrations and are easily overgrazed. Removal of soil and vegetation seriously impact cover, food, and nesting sites for masked bobwhite. Recent overgrazing and drought on Rancho el Carrizo, has reduced potential habitat. In some instances, properly applied livestock grazing provides the diversity of range condition classes favored by this quail. In other situations, exclusion of livestock may be necessary. Research on grazing and management of quail is recommended on Rancho el Carrizo in Mexico.

INTRODUCTION OF EXOTIC PLANTS

Areas of the Altar Valley which are now part of the Buenos Aires NWR were once representative of the Sonoran Savanna Grassland, a biotic community which now only exists as small, relict stands in Mexico. The Sonora Savanna Grassland was a subtropical fire-climax grassland which occurred in valleys with level plains and gentle rolling hills on deep, fine textured soils. The principal grass species were summer-active root perennials such as Rothrock gramma (Bouteloua rothtockii) and species of three-awns (Aristida spp.).

The ecosystem in which the masked bobwhite historically occurred is greatly modified. The prevalence of livestock grazing and associated impacts of humans on the landscape have transformed areas of the Altar Valley from a biotic community which may have at least approached the Sonoran Savanna Grassland into an inter-mix of desert scrub, semidesert grassland and mesquite-Lehmanns lovegrass (Eragrostis lehmanii) grassland communities (Brown 1982). The removal of grasses and forbs by livestock eliminated the masked bobwhite's escape cover, food, and nesting habitat. The lack of fine fuels prevented natural fires, and in combination with fire suppression activities, allowed woody plants to invade. As a result of the reduction of native grass species, the invasion of exotic plants, and increases in the densities of shrubs and subshrubs (Tomlinson 1984), grassland habitats were gradually altered and rendered unsuitable for masked bobwhite.

Velvet mesquite (Prosopis juliflora) is the most abundant woody species throughout the bobwhite's range, though other species such as paloverde (Cercidium sp.) and hackberry (Celtis pallida) are also present. Mesquite and the exotic Lehmanns lovegrass dominates much of the refuge. Large areas are nearly monotypic stands of Lehmanns lovegrass, while native perennial grasses dominate smaller patches. Past fires, including prescribed, wild, and human-caused, have locally reduced mesquite densities, or altered the growth form of mesquite.

The intentional introduction of exotic Lehmanns lovegrass into southern Arizona in 1930 significantly altered the structure and composition of native grasslands. Lehmanns lovegrass continues to expand locally and regionally because it is relatively successful in disturbed areas. Species richness and structural diversity of grasslands have declined in these areas.

Lehmanns lovegrass can be killed by a hot fire but it uses two strategies to out-compete native species after a fire. Roots develop from the nodes of decumbent tillers (Ruyle et al. 1988), maintaining and spreading the stand and seeds germinate after a fire. Cable (1965, 1971) reported that Lehmanns lovegrass seedlings germinating after a fire converted a native black grama (Bouteloua eriopoda) stand to a Lehmanns lovegrass stand.

On Rancho el Carrizo, in Sonora, Mexico, the replacement of native Sonora Savanna Grasslands with buffelgrass monocultures also threatens the masked bobwhites. Because buffelgrass provides ample forage for cattle, little incentive exists among ranchers to restore native grasslands. Though buffelgrass mixed with perennial grasses can improve habitat structural diversity, monotypic stands reduce the habitat diversity required by masked bobwhites. Consequently, herbaceous habitat diversity is declining throughout the bobwhite's historic range.

Refuge personnel have developed a grassland restoration plan using prescribed burning as the primary management tool. Management plots will be subjected to various burn prescriptions.
Research recommendations include studying how masked bobwhite use Lehmanns love grass, soil analyses for nitrogen, and studying the potential effects of adding nitrogen.

PREDATION

In any attempt to restore populations of gallinaceous birds, the impact of predation is a concern. Preliminary data on newly released masked bobwhites on Buenos Aires NWR indicate that losses to predators are high. Several raptors kill chicks and adults, especially

Cooper's hawks (*Accipiter cooperii*), red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*B. swansoni*), and harriers (*Circus cyaneus*). Ravens (Corvus corax and C. cryptoleucus), coyotes (Canis latrans), grey fox (Urocyon cinereoargenteus), ringtails (Bassariseus astutus), raccoon (Procyon lotor), coatimundi (Nasua narica), opossums (Didelphis virginia), and skunks (Mephitis mephitis, Spilogale putoris, Mephitis macroura, Conepatus leuconotus) may be important predators of eggs, chicks, and adult bobwhite.

Quail are preyed upon by a number of avian, mammalian, and perhaps reptilian predators, and it would not be possible to control such a large and varied assortment of predators. Large influxes of migratory raptors occur in and around Buenos Aires NWR during spring and fall migration. Efforts to reduce populations of these predators would be impractical and unsound from the standpoint of sound ecology, conservation, and management.

We believe that habitat management is the most effective, long-term method for dealing with predation. Predation is a natural component of quail ecology; however, habitat that includes adequate cover is probably the best way for quail populations to avoid excessive predation losses. Removal of mesquite that provides raptor perches may be a beneficial management measure. However, this would likely have to be done on a large scale, and measuring a response on a population level would be difficult. If mesquite tree removal could be included in efforts to restore historical, natural vegetative communities on Buenos Aires NWR, then this management practice would have additional justification.

Masked bobwhite survival has been monitored via radio telemetry. Transmitters were placed on 26 chicks released at approximately 2 week intervals between August and November 1994. Radios were also placed on the Texas and masked bobwhite foster parents that were released with the radioed chicks. Post-release survival for chicks released with Texas males (n=10) ranged from 1-to-4 days and averaged 1.6 days. Similar survival was recorded for chicks released with masked bobwhites (range 1-4 days, average survival 1.2 days). Adult masked bobwhite (n=16) survived an average of 2.5 days (1-18 days) and Texas male bobwhite (n=10) averaged 7 days (1-30 days). Higher Texas male survival can be attributed to the fact that they are wild birds. The masked bobwhite adults were individuals not needed in the captive breeding program. Survival probabilities for captive-reared birds are usually lower than those for translocated wild birds. These data are thought to be representative of survival among the chicks released during 1994. It is possible that survival is reduced when radios are attached to chicks. However, survival data in radio-tagged birds is similar to survival rates indicated by life-trapping.

Although the majority of the chick mortalities (>60%) could not be verified because transmitters were retrieved in the absence of carcasses or even feathers, most chicks were probably killed by raptors. Numerous studies throughout the United States have documented that raptors are the principal threat to bobwhites. Cooper's hawk and red-tailed hawk predation are responsible for more bobwhite mortality than mortality attributable to mammalian predators (Stoddard 1936). Survival, however, can be improved by modifying the habitat and several aspects of the propagation and release protocol. These modifications will be implemented during FY 1995.

DISEASES

The impact of disease on masked bobwhite and the role of disease in inhibiting recovery is poorly understood. Numerous parasitic and infectious agents capable of causing large-scale mortality, chronic low-level losses, reproductive impairment, and unthriftiness have been documented in captive and wild masked bobwhite. The masked bobwhite is undoubtedly susceptible to other pathogens that affect other captive and wild gallinaceous birds. Some local poultry flocks could be a source of diseases to quail in the area. Captive propagation of masked bobwhites for release, the use of wild Texas bobwhites in adoptions of released masked bobwhite chicks and the proposed transplantation of wild masked bobwhite from Mexico to Buenos Aires NWR present scenarios for the introduction of pathogens from other geographic areas and species into potentially naive wild populations, and have been demonstrated in other reintroduction programs (Heuschele 1991, Viggers et al. 1993). The probabilities of locating intact masked bobwhite carcasses in the field to identify and quantify introduced or enzootic diseases are extremely low, and hinder assessing of the impact of disease on this subspecies, unless specific monitoring of mortality factors, such as with mortality-sensitive radiotelemetry, is employed.

The following discussion briefly summarizes major diseases that have been documented in masked bobwhites or are of specific concern because of their potential to affect the populations if introduced through captive propagation and release, translocation, or transmission from other host species.

Avian Adenoviruses: Group I (avian) adenoviruses comprise an array of serotypes, several of which have caused major mortality in captive quail. Quail bronchitis virus (serotype 1) has been a major source of mortality in captive (game farm) quail since the 1930s. Mortality ranges from 10-100%, with chicks under 4 weeks of age frequently suffering >50% mortality (Du Bose 1971). The disease, first reported in game farms along the Atlantic coast, occurs across the U.S. and world. A virus believed to be closely related to quail bronchitis virus was isolated from 2-3 week old masked bobwhite chicks at Patuxent during an episode of excessive mortality in 1992 (Patuxent, unpubl. data). Follow-up serology showed a 28% (5/18) prevalence of quail bronchitis virus antibody, with titers ranging from 1:8 to 1:64 (National Wildlife Health Center, unpubl. data). Experimental inoculation of this virus into northern bobwhites did not result in mortality (Patuxent, unpubl. data). The status of this virus in wild quail populations is unknown. A seroprevalence of 23% was reported in wild bobwhites in Florida (82% positive in adults) during a survey following an apparent epizootic of a different adenovirus (TR59) (King et al. 1981).

Serotype 6 avian adenovirus was isolated from wild bobwhites with an inclusion body hepatitis in Florida and Georgia in the 1970s during an apparent widespread increase in mortality (King et al. 1981). A survey of 181 wild bobwhites showed 32 (18%) with inclusion bodies, although virus was isolated from cecae of only two, and serology of a subsample of these (not including the two virus-positive birds) was negative. King et al. (1981) concluded that either the virus was not circulating in the population when sampled, or that the prevalence was low. It may be that susceptible birds were eliminated rapidly from the population. The current status of this virus in wild quail is not known.

Necrotizing hepatitis, with inclusion bodies associated with a group I adenovirus, was reported in captive-raised bobwhites in Indiana, causing mortality in 250 of 400 birds <3 weeks of age (Jack et al. 1987). A similar syndrome, again associated with a group I adenovirus, was reported in wild Gambel's quail chicks in Arizona during 1991 and 1992 (Bradley et al. 1994). In 1991, 60 of 200 "orphaned" quail found by locals in the Tucson vicinity died in captivity. In 1992, 50 of 100 chicks found under similar circumstances in the Phoenix and Tucson area died in the care of a rehabilitator. These infections were most likely acquired in the wild. In both the Indiana and Arizona incidents, the virus isolate was not fully characterized to compare with other group 1 viruses.

Reovirus: A commercial bobwhite operation in Mississippi suffered extensive mortality in two groups of birds received at a new facility in 1990. Mortality began one week after a shipment of 5,800 2-day-old quail was received. Within 24 days, 5,500 (95%) had died. A second shipment of 2,000 eggs from a different source was received and hatched. By age 9 days, 900 (45%) had died. A reovirus was isolated during latter stages of this epizootic, but an adenovirus was the agent most frequently isolated during the investigation. Inoculation of the reovirus separately into quail caused mortality, so this agent may be considered a primary pathogen in addition to the adenovirus (Magee et al. 1993).

Avian Poxvirus: Avian pox has long been known to occur in captive and wild quail (Davidson et al. 1980) including Texas bobwhites and masked bobwhites at Buenos Aires NWR (National Wildlife Health Center, unpubl. data; Arizona Veterinary Diagnostic Lab, unpubl. data). Lesions caused by this virus are often not extensive enough to cause direct mortality, but secondary infections are common, and behavioral alterations resulting from lesions may affect survival by making birds more susceptible to predation or unable to feed or see normally. An epizootic of avian pox in bobwhite was reported in Georgia and north-central Florida during 1978-79 (Davidson et al. 1980). A survey of a four-state area showed a 12% (312/2586) prevalence of pox lesions in live bobwhites, with 23% of the lesions classified as extensive. The percentage with extensive lesions varied locally as high as 39%.

Highlands J Virus: In 1992, mortality was reported among captive chukars (<u>Alectoris chukar</u>) in South Carolina from this Togavirus (Eleazer and Hill 1994). This virus was previously thought to be a strain of Western Equine Encephalitis Virus, but it is now considered distinct, and previous eastern cases of Western Equine Encephalitis-related viruses in the eastern U.S. are now considered as Highlands J virus. The significance of the virus in the east is not known, but of potential concern is the susceptibility and potential transmission of this agent to captive masked bobwhite at Patuxent and transfer to Buenos Aires NWR.

Quail Disease (Ulcerative Enteritis): There is no consensus among wildlife disease specialists about the causative bacterium for this syndrome, although <u>Corynebacterium perdicum</u> is frequently associated. Other spore-forming anaerobic bacteria also have been implicated. This disease syndrome appears to affect all species of galliforms (Peckham 1971), and has been primarily documented in captive situations, including masked bobwhite at Patuxent (Patuxent, unpubl. data). Ulcerative enterocolitis was identified among Texas bobwhites (Texas Veterinary Medical Diagnostic Laboratories, unpubl. data), although further details were not provided (C.N. Carter, pers. comm.)

Coccidiosis: This protozoan infection has been diagnosed in the past in masked bobwhite at Patuxent (Patuxent, unpubl. data). As a result of this recurrent problem, coccidostat medication has been provided to all masked bobwhite hatched at Patuxent and has been continued at Buenos Aires NWR until the time of release. In December 1993, a 1993-release masked bobwhite was found dead from coccidiosis in Bailey Wash on Buenos Aires NWR. Since this organism was not identified to species, it could not be compared to the coccidia present at Patuxent.

Concern has been raised over the coccidiostat medication provided for masked bobwhite destined for release. This coccidiostat has effectively prevented coccidiosis from occurring in chicks produced at Patuxent. Maintaining this preventative treatment may prevent natural exposure of chicks to coccidia in numbers low enough to establish immunity without disease. When birds are removed from coccidiostats upon release, they are generally at an age highly susceptible to infection but are unlikely to encounter parasites at levels able to induce disease.
Current efforts are underway to develop a killed (irradiated) vaccine to the coccidia that has occurred at Patuxent. This tool could alleviate concern about prolonged coccidiostat medication and provide protection from the coccidian species affecting wild masked bobwhite at Patuxent. Additional information is required on the species of coccidia infecting wild masked bobwhite and the degree of protection vaccination may offer.

Other Diseases of Potential Concern: Review of diagnostic cases submitted to the National Wildlife Health Research Center, Patuxent, Arizona Veterinary Diagnostic Laboratory, and Texas Veterinary Medical Diagnostic Laboratories indicate several additional diseases of concern that may be present in captive-raised masked bobwhite, wild Texas bobwhite, and masked bobwhite at Buenos Aires NWR:
capillariasis, mycoplasmosis, chlamydiosis, candidiasis, gapeworm (Syngamus tracheae), and amyloidosis (etiology unknown).

These diseases, and poultry diseases to which quail are susceptible, such as salmonellosis, tuberculosis, cryptosporidiosis, avian influenza, Newcastle disease, and several parasitic diseases can serve as an initial list to be considered when developing disease surveillance protocols and preventative management schemes. The list also can help in guiding diagnostic and research efforts on the presence and impact of diseases on the masked bobwhite.

MANAGEMENT RECOMMENDATIONS:

1. Protocols for health screening of captive-reared masked bobwhite, wild Texas bobwhites captured for the adoption program, and other translocated birds should be

reviewed and revised as necessary, including application of any new diagnostic technologies.

2. Quarantine periods for birds to be released should be reviewed and revised as necessary to allow for latent stress-induced diseases to be manifested before release. The age of release of chicks should be extended to allow expression, while still in captivity, of certain viral diseases to which chicks are most susceptible.

3. Consider discontinuing coccidiostat medication in chicks to allow for buildup of natural immunity. The current status of coccidia in masked bobwhites at Patuxent should be determined, as well as the species identified. If coccidia are present, vaccine development and application should be continued.

4. Monitoring and surveillance for selected pathogens should be initiated in wild populations of masked bobwhite and in Texas bobwhites at the La Copita Research Area. To the extent possible, regular monitoring should be conducted for mortality in wild populations with prompt submission of carcasses to a diagnostic facility. All birds dying during transport or quarantine should also be submitted. A standard necropsy sampling protocol should be developed to obtain a comprehensive assessment of health and disease status and to determine cause of death.

5. Consideration should be given to holding an ad hoc meeting of individuals with expertise and experience in masked bobwhite ecology, epizootiology, and disease. The purpose of the meeting would be to compile and analyze all available masked bobwhite disease information, review and develop recommendations for disease management protocols and diagnostic protocols and operational guidelines, and further identify and develop priorities and strategies for research relating to disease in this species. Participants should include representatives of Buenos Aires NWR; Arizona Game and Fish Department; and masked bobwhite workers in Mexico, Patuxent, National Wildlife Health Research Center, Arizona Veterinary Diagnostic Lab, and Texas Veterinary Medical Diagnostic Laboratories.

PESTICIDES AND OTHER CONTAMINANTS

The potential for agricultural and other pesticides to be a major threat to masked bobwhite is apparently minimal under current land use practices. Pesticides are not currently used on the Buenos Aires NWR, and use on adjacent ranch land is insignificant and probably does not affect habitat or contaminate food sources of the masked bobwhite. In Mexico, masked bobwhite habitat does not have any commercial crops. However, croplands north of Rancho el Carrizo near the town of Benjamin, including oats, soybean, potatoes, corn, and grapes, likely are managed with a variety of herbicides and pesticides. Runoff from these croplands may contaminate masked bobwhite habitat, particularly during periods of flooding in bottomlands used by these quail.

Several inactive gold and silver mines are present on Buenos Aires NWR. These sites pose no known contaminant risks to the quail. About 1,012/ha (2,500/acres) of third-party mining claims occur on the refuge. The Service is evaluating the merits of acquiring the mining rights from these interests.

GENETICS

The masked bobwhite gene pool appears to be healthy. Egg fertility and hatchability, and chick vitality in the captive flock and wild populations compare favorably to the northern bobwhite. Protein electrophoresis allozyme studies from 1983-1986, including captive and wild birds, indicate genetic diversity was robust and comparable to large northern bobwhite populations. Although the captive flock contains a good gene pool, new birds are needed from the wild to reduce the inbreeding coefficient. Some pairs have an inbreeding coefficient of 0.051 in 1995 and in this closed system the coefficient will continue to increase.

Inbreeding is a threat to the masked bobwhite. Inbreeding in the captive 1965-1968 masked bobwhite population reduced egg fertility and hatchability and reduced chick survival and growth below that expected from a captive northern bobwhite flock. Inbreeding can occur in small wild demes as well as in the captive flock. In some situations, releases or translocations to augment small wild demes can improve chances for survival (Frankel and Soule 1981:42-59)

We have maintained gene frequency from the founder animals by selecting an equal number of birds from each line each generation (Frankel and Soule 1981:40-41). In 1986, we acquired 18 new birds from Sonora (Gable and Gee 1987) and were able to establish 16 new lines to help us reduce inbreeding coefficients in the captive flock. The captive population taken from the wild in 1968 exhibited normal fecundity and vitality. We need to start again with 64 new lines composed of one half captive and one half wild-caught birds (about 75 birds from the wild) and maintain an outcrossing program with the new lines. The 64-line approach (Fig. 7) allows us to outcross over the next six generations (12-18 years) and then repeat the 64-line process again. Inbreeding coefficients of birds six generations removed are too small to consider in calculating the inbreeding coefficient (Table 10).

Loss of the captive gene pool would threaten survival of the masked bobwhite. The captive population, the only secure population, is located at one site and at some seasons kept in one building. A catastrophe could eliminate or critically reduce the flock. The Service should endeavor to maintain two or more captive flocks as insurance against a catastrophic loss of the entire captive gene pool.

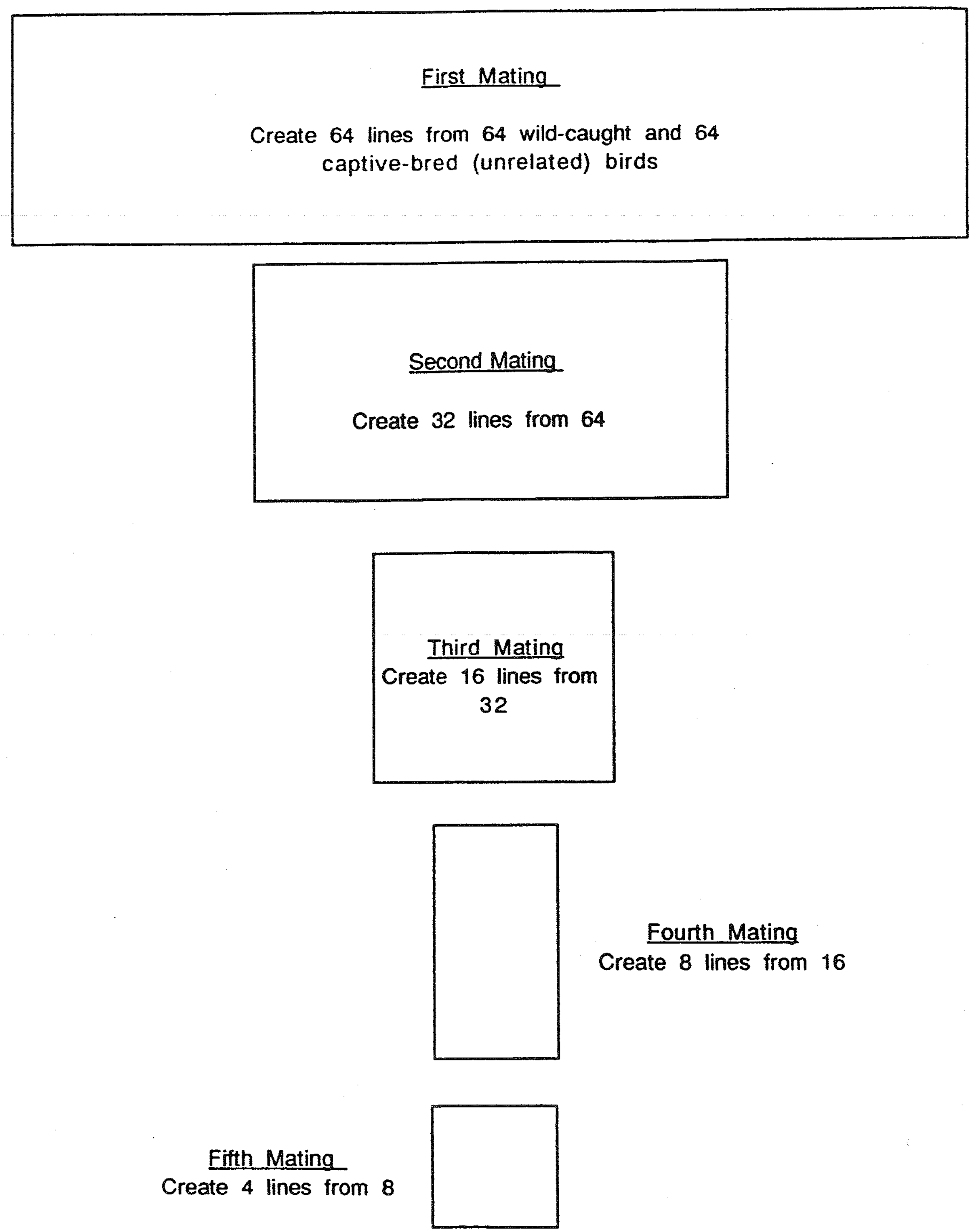


Figure 7. Mating scheme to prevent inbreeding in captive masked bobwhite.

ENVIRONMENTAL CATASTROPHES

Major droughts and floods may have catastrophic effects on survival and reproduction, depending on seasonality. Summer drought or floods can reduce nesting success, clutch size, and survival of chicks, and under some circumstances may result in lack of recruitment. Uncontrolled fires, both lightning and human-caused, may be catastrophic for chick survival or may destroy herbaceous cover. This risk is probably very low, and is probably well managed through routine fire suppression procedures and prescribed burns.

Table 10. Contributions of some common relationships to the coefficient of inbreeding (Hutt 1949).

Number of generations to the common ancestor		Contributions to the coefficient of inbreeding
Behind one parent	Behind the other parent	
0	1	$(1/2)^2$ = 0.25
1	1	$(1/2)^3$ = 0.125
1	2	$(1/2)^4$ = 0.0625
2	2	$(1/2)^5$ = 0.0312
2	3	$(1/2)^6$ = 0.0156
3	3	$(1/2)^7$ = 0.0078
3	4	$(1/2)^8$ = 0.0039
4	4	$(1/2)^9$ = 0.0019

CULTURAL AND ARCHAEOLOGICAL RESOURCES

Cultural resources exist on Buenos Aires NWR and it is important to protect these resources. The potential exists, however, for conflicts with habitat management for masked bobwhites and preservation of cultural resources. Mechanical habitat management practices, such as disking and chaining, disturb soils and could destroy artifacts or disturb archeological sites. Prescribed burning is also an important habitat management tool used to improve quail habitat and to restore native vegetation communities. Prescribed burning is also often used to maintain suitable bobwhite habitat conditions after mechanical treatments have been applied. Burning does not destroy or disturb soils; however, fire could destroy artifacts located on the soil surface.

These habitat management practices have proven effective in improving habitat for bobwhites on south Texas rangelands. We must use management techniques to improve and to recover masked bobwhite on Buenos Aires NWR. Coordination and cooperation between Refuge personnel and state and federal archaeologists are essential for preserving and maintaining both natural and cultural resources on Buenos Aires NWR. Current legislation and policy mandates that surveys for cultural resources be conducted before soil disturbance or prescribed burning takes place on federal or state lands. These surveys are expensive and time-consuming. Because of these constraints, habitat management for masked bobwhite is problematic. Efficient and timely methods for cultural surveys are needed so that cultural resources can be protected and habitat management for masked bobwhites and other wildlife species can occur.

SECTION 5. HABITAT MANAGEMENT

Authors: Nina King, R. Scott Lutz, Dave McKown, Ken Nolte, and Bruce Palmer

HABITAT GOALS

Refuge biologists and other researchers should use current research and integrate past information on masked bobwhite habitat characteristics to quantify potential habitat on the Buenos Aires NWR and in Mexico. This information should be used to implement management techniques to meet the desired habitat characteristics (grass species richness, forb species richness, herbaceous biomass, percent shrub cover, shrub height, and percent bare ground).

EXPERIMENTAL HABITAT MANAGEMENT

Proper habitat management is critical to re-establish self-sustaining masked bobwhite populations. Habitat management should be applied experimentally and therefore adhere to rigorous experimental designs which enable investigators to scientifically evaluate effects of specific management practices Practices creating habitat conditions favorable for masked bobwhite can then be applied on a larger scale. Habitat management should be implemented as soon as possible to support birds that may need nutritional and habitat essentials during stress periods. An experimental (core area) of approximately 405/ha (1,000/acres) needs to be established on the refuge. This area should be close to occupied habitat and suitable for experimental management. Habitat management techniques developed for other subspecies of northern bobwhite should be tested on the refuge.

Disking or soil aeration for the purpose of soil disturbance are effective tools for bobwhite habitat management in the southeastern United States but needs to be tested in the Southwest. In the Southeast, timely management will stimulate production of a variety of food- and insect-bearing plants important to bobwhites. Soil disturbance sets back plant succession and provides plant diversity and forb production. These techniques should be tested in sandy loam and deep loam soils where maximum response would be expected from summer rains.

Vegetation should be managed to provide suitable vertical and horizontal structure preferred by bobwhites. Mesquite half-cutting (pruning) should be conducted when canopy heights need to be reduced and where cover is limiting. Habitat composed of large expanses of dense woody cover that has matured beyond what is useful to masked bobwhites, can also be treated mechanically to lower vertical cover as well as to set back plant succession. Unlike half-cutting, mechanical treatments can be applied on a large area over a short period of time.

Overgrazing has been implicated as a major reason for extirpation of masked bobwhite in the United States and was responsible for serious population declines in Sonora, Mexico. However, carefully regulated grazing may prove useful in managing quail habitat where range conditions have recovered to appropriate levels. Proper grazing management has been shown to improve herbaceous habitat conditions for bobwhites in South Texas (Spears et al 1993). Properly applied livestock grazing provides the plant diversity and range condition classes favored by Texas bobwhites. Cattle production is the primary livelihood for landowners that control rangelands supporting masked bobwhite in Sonora. Therefore, proper grazing management is essential to the recovery of the species in Mexico. Grazing studies conducted on Buenos Aires NWR would potentially benefit recovery efforts on the refuge and in Mexico. Prescribed grazing should remain an option for managing masked bobwhite habitat if conditions and management objectives warrant.

Prescribed burning is a management tool that provides an economical means of controlling woody plant species encroaching on grassland ecosystems. Fire has been absent from the refuge grassland for about 80 years. Fire is believed to be an important factor in controlling mesquite invasion and stimulating growth of important desert legumes. Prescribed burns should be conducted on a rotational basis to produce a mix of habitats in various stages of plant succession. The objective should be to produce a mosaic pattern of habitat types that are easily accessible within bobwhite home ranges.

Attempts should be made to reestablish native vegetation using range fertilization or irrigation. Soil nutrients analysis could identify nitrogen deficiencies resulting from past land-use practices. Sprinkler systems have been installed in south Texas to mitigate the effects of drought on bobwhite populations, and the results have been encouraging (Howard pers. comm. 1992). The captive masked bobwhite population appears to function at optimal levels when exposed to high humidity and unlimited free water (Gee pers. comm. 1993). Since the masked bobwhite population has yet to become self-sustaining in Arizona, any technique that maintains or elevates reproduction and suppresses mortality should be evaluated. Therefore, a sprinkler system should be installed on an experimental basis to determine if irrigation stimulates food production and elevates masked bobwhite reproduction and survival above that which occurs on control areas lacking supplemental water.

EVALUATE HABITAT MANAGEMENT

Habitat should be monitored to determine effectiveness of various management techniques. A variety of monitoring techniques are available for measuring vegetation response to management. Permanent and temporary vegetation transects should be established and monitored perhaps by photographic documentation on an annual basis. Appropriate experimental designs should be employed to ensure sound data collection and analysis.

With the exception of prescribed burns and mesquite half-cutting in a very small area, little has been done to enhance habitat conditions for masked bobwhite on the Refuge. After Buenos Aires NWR was purchased, it was assumed that allowing the vegetation to recover from the effects of livestock grazing would recreate conditions suitable for masked bobwhites. However, establishment of nonnative grasses throughout the refuge and the effect of past livestock management practices has greatly affected the native grassland community. Potential management areas should be identified and selected for treatment. All areas should be evaluated for their management potential and suitability for masked bobwhites.

Refuge personnel should develop criteria for evaluating masked bobwhite habitat site-suitability. Factors to consider are elevation, temperature extremes, soil types, rainfall, appropriate food and cover, and proximity to other masked bobwhites. The appropriate criteria should be: 1) grass richness at 5-10 species (0.25-m^2 Daubenmire frame), 2) forb richness at 10-15 species (0.25-m^2 Daubenmire frame), 3) herbaceous biomass between 500-1500 kg/ha, 4) percent shrub cover from 15-30% (100 m line-intercept), 5) decrease and maintain woody structure < 1.5 m tall, and 6) bare ground between 10-25% (0.25-m^2 Daubenmire frame). Refuge personnel should also investigate potential habitats on the Buenos Aires NWR. All potential masked bobwhite ranges on the Refuge should be located and evaluated by the above criteria. Releases should not be conducted in areas that lack appropriate habitat conditions. Some presently unsuitable areas may become suitable for masked bobwhites as a consequence of management.

MANAGEMENT OBJECTIVES

Determine the habitat requirements necessary to sustain the Buenos Aires NWR population and the factors that limit production and survival of masked bobwhites.

Implement a drought management strategy evaluating precipitation, temperature, humidity, and wind speed on 90-day intervals (Brown 1985).

Perform habitat suitability analyses. Habitat suitability should be determined before quail are reintroduced to specific habitats. Construct a habitat model for masked bobwhites. Continue studies of habitat use in Arizona and Mexico to identify masked bobwhite seasonal habitat requirements.

The flora of the Buenos Aires NWR needs to be available in a herbarium accessible to scientists, biologists, and students for identification purposes. Native vegetation determined to be important sources of masked bobwhite food should be restored or, if present in low densities, encouraged to increase in Arizona. The introduced species (Lehmanns lovegrass and buffelgrass) should be evaluated to assess their role in bobwhite habitat selection.

SECTION 6: REINTRODUCTION AND CAPTIVE PROPAGATION

Authors: Sally Gall, George Gee, and Dick Steinbach

HISTORY

Efforts to restore the masked bobwhite into its former southern Arizona range have been on going since 1937. Attempts were made to translocate wild caught masked bobwhite from Sonora, Mexico to areas in Arizona and New Mexico on several occasions (1937-1950) (Campbell 1968, Lawson 1951). Twenty-three wild-trapped individuals were released in December 1937, on the Heady-Ashburn Ranch, San Rafael Valley. Ten wild-trapped birds were released late December 1937 on the Nogales Ranger Station. Seven wild-trapped birds that had been held in captivity for 1 year were released in January 1939. Twenty quail wild-trapped in December 1937 were released "before" March 1940. The 1940 release was made in Animas, New Mexico, outside the historic range of the quail because the historic range was not considered suitable for a release due to overgrazing and invasion of desert scrub. In 1950, 15 wild-trapped quail were held 3 days before being released at Garden Canyon in the Huachuca Mountains, Arizona. Birds were seen for 10 days post-release. The releases appeared to involve too few birds to provide a high probability of successfully reestablishing a population.

More recently masked bobwhites were wild-trapped on Rancho el Carrizo, Sonora, Mexico, in 1968 and 1970 and used for captive propagation at Patuxent. In 1970, the U.S. Fish and Wildlife Service began to release masked bobwhite within its historic range using these propagated birds. Originally, these birds were released with little or no conditioning, but in 1976, two primary techniques were implemented in attempts to condition the birds for the wild. These included, first, the use of sterilized male Texas bobwhites as foster parents to adopt captive-bred chicks and secondly, a modification of a call-box conditioning program. The foster parent/adoption program was intended to increase chick survival by having the Texas bobwhite "bond" to chicks and "teach" them how to survive. The Texas bobwhite and a group of chicks would be placed in brooders and then pens for approximately 3 weeks before being released in the wild.

The call-box techniques involved holding a small group of birds in a box after releasing the majority of a brood from that box. The intent was that the released birds would be called back to the site by the birds in the box in order to provide the free-roaming birds secure roosting cover. The foster parent-adoption program proved more promising than the call-box technique. The call-boxes were discontinued and foster-adoption remains the primary release technique used today.

CURRENT PROBLEMS AND A NEED FOR CHANGE

Although there is evidence of short-term success using the foster-adoption program, the technique had not been fully evaluated until 1994. Research efforts showed that significant numbers of Texas bobwhites abandoned the chicks soon after being released. These recent findings have raised doubts about whether this technique is effective in increasing chick survival.

The use of Texas bobwhites should be eliminated from the propagation and release program. Aside from the fact that the birds are not remaining with the chicks, several other factors support eliminating Texas bobwhite from the program. First, the vasectomies performed on these birds may not be 100% effective and once released in the wild there is always the risk of breeding between the subspecies. Second, conducting call counts to estimate population numbers is impossible because the calls of the Texas bobwhite and the masked bobwhite are indistinguishable. Finally, there is concern that there may be competition for females between males of the two subspecies during the breeding season. A pair bond established between a sterile male Texas bobwhite and a female masked bobwhite would effectively eliminate productivity of the female for that year.

NEW TECHNIQUES

With the Texas bobwhite eliminated from the program, other pre-release techniques must be considered to ensure better survival of the released birds. Some combination of the following techniques should be implemented:

PRE-RELEASE

One adult bobwhite will be placed in a brooder with each group of chicks. The adults brood the chicks, which produces a stronger and healthier chick. Chicks will be fed game bird chow and a variety of insects (i.e., fruit flies, mealworms, and crickets) served on small, metal feed trays. Being exposed to natural foods should increase the chicks ability to feed after release in the wild.

Three-week-old chicks will be placed in ground level runs within flight pens for 1-2 weeks before being released in flight pens. Masked bobwhite adults will remain with the chicks, but any Texas bobwhite will be returned to the holding pens. Game bird chow and natural foods will be provided. Once on the ground in the flight pens, the quail will remain there until their release to the wild. The flight pens have naturally occurring insects and seeds most of the year, but the bobwhite's diet will also be supplemented with additional natural foods. When possible, a portion of the masked bobwhites trapped on the refuge will be placed with and released with the captive birds. Hopefully, the wild bird will aid in the survival of the released group.

RELEASE PROTOCOL

There will be two release periods in which approximately 400 birds in groups of 20 will be released at each period. The first release period will be during Sept.-Oct. when quail naturally form coveys and the second period will be in early spring (Mar.-Apr.) at the end of the covey season.

Five release sites will be established throughout the Refuge where temporary, portable flight pens will constructed. Each pen will contain natural cover and an automatic seed disperser that will provide a mix of native wild seeds as food. Each pen will also have a temporary electric fence constructed on the perimeter to keep predators from disturbing the area.

Approximately 20 quail at a time (3 females:1 male) will be placed in the portable pen and during each release will remain in the pen, undisturbed about 1 week. The pen will then be opened to allow the birds to leave voluntarily. The automatic feeder will be provided for 3-4 days post-release. Each pen will be moved a short distance before another release group is placed in the pen and the identical post-release process repeated. Prior to each release, four quail from each group will be fitted with radio transmitters to monitor post-release movements patterns, survival and habitat use. Each technique associated with the new release protocol will be evaluated and modified if necessary. Additional techniques may be considered as well.

FUTURE CONSIDERATIONS - TRANSLOCATIONS

If Buenos Aires NWR contains suitable masked bobwhite habitat, it would be desirable to attempt translocation of wild-trapped birds from Sonora, Mexico. However, the current low level of the Sonoran population precludes trapping and removal of even a small number of individuals. If the population recovers to secure levels, it may then be possible to attempt an experimental translocation of wild-trapped birds. Initially the plan might involve translocating several coveys to the Buenos Aires NWR and then using radio telemetry to monitor movements and survival. If this initial release proves favorable, a larger release should be considered.

FUTURE OF PROPAGATION PROGRAM

Since the late 1960's the Patuxent has held breeding birds and has participated in the various reintroduction projects that have been conducted in Arizona, New Mexico and Sonora, Mexico. The Center has previously played a major role in developing release strategies and protocols, and utilizing staff expertise in maintaining a healthy, diverse source stock. It's contribution to saving the species has been significant. During the late 1980's, when one release strategy was agreed upon, the Center stopped participating in reintroduction release research. For the next several years the apparent success or promise of the release of chicks being foster-reared by wild, vasectomized Texas bobwhite males, coupled with livestock removal and subsequent habitat improvements, did not indicate a need for further alternative research on release strategies. There were problems identified with the program but they were considered manageable through monitoring and program adjustments at the refuge. During this period Patuxent expressed a desire to discontinue maintaining the captive flock solely for management purposes because Center-conducted research was no longer a part of the program. Administrators with National Biological Service therefore proposed transferring the flock to the Southwest Region of the Fish and Wildlife Service where the Service would continue to propagate quail for reintroduction. During the past several years, personnel from the Southwest Region and Buenos Aires

NWR have evaluated and explored various locations to which the breeding stock might be transferred. Subsequent to the PHVA Workshop, a site was selected on Buenos Aires NWR and a captive facility has been constructed to house the birds in 1996.

Coincidentally, during the past several years when the refuge and regional staff have struggled with the possibility of receiving the propagation program, the magnitude of problems with the Texas foster-parent release technique also became apparent. It is evident that the solution to successfully reintroduce these bobwhite has not yet been found. Additional research is needed to evaluate the alternative release strategies that have been developed on the basis of information collected from past efforts.

Captive rearing for the purpose of reintroducing a wild population or supplementing an existing, low density wild population was discussed by the group during the plenary sessions. The question was posed, "Why not eliminate the captive rearing program and spend the money on habitat management and protection in Sonora, Mexico, where a viable population exists but its future is tenuous." The subsequent discussion brought out several points. The population in Sonora is believed to be in particular jeopardy of extinction due to the small disjunct populations, drought, and associated overgrazing. The wild population at Buenos Aires NWR does not appear to be self-sustaining. The captive population must be maintained as a gene pool for insurance in the event that the subspecies becomes extinct in the wild. Subsequent discussion led to an estimate of the funds that might be saved if quail were no longer produced for reintroduction. Most of the current expenditures for propagation involve salaries, feed, and medication. To maintain a gene pool in captivity would still require some annual production. Thus, the estimated annual savings that would result if reintroductions were discontinued was only $20,000. In these times of budget cuts and staff downsizing there is no assurance that the savings would result in funds which could be diverted to protecting habitat in Sonora from overgrazing.

If reintroduction efforts are not continued in the United States there would be a potential for eliminating at least one staff position at Buenos Aires NWR and further budget savings. However, it appears the Fish and Wildlife Service would no longer be fulfilling the Endangered Species Act mandate to recover the subspecies in the wild within our national boundaries. Constraints on spending U.S. funds in other nations further complicate the issue.

SECTION 7. RESEARCH AND INFORMATION NEEDS

Authors: All Workshop Participants

The following lists research needs for masked bobwhites on Buenos Aires NWR and in Sonora, Mexico.

Estimates of survival rates for adults and juveniles, although difficult to obtain for almost any wildlife species, are nonetheless critical to understand demographic processes and conduct population viability analyses. Subcategories under the topic of survival estimation might include: estimates of annual survival (all quail; female and male; adult and juvenile), estimates of seasonal survival rates, estimates of survival rates under different conditions (e.g., drought versus wet years, grazed versus ungrazed sites).

Estimates of reproductive output and how environmental conditions, such as drought or habitat conditions, may influence fecundity. Survival and reproductive data are vital to meaningful population simulation and an understanding of quail population dynamics.

Influence of microclimate and habitat structure on quail habitat use and survival.

Information on habitat use, including use of native versus exotic vegetation, dispersal capabilities of adults and juveniles, movement patterns, and structure of nesting, roosting, brood, and covey habitat.

Comparison of Texas bobwhite and masked bobwhite biology, habitat, and life history. Many aspects of masked bobwhite ecology are probably similar to Texas bobwhite ecology. If this assumption is correct, then the wealth of data on Texas bobwhite can be applied with confidence to recovery and management of masked bobwhites.

Habitat conditions and population structure of the masked bobwhite population on Buenos Aires NWR should be compared to those in Mexico.

Identify the differences between masked bobwhite genetics and other quail. Subspecies differences can be greater than differences between some species when molecular and morphological characteristics are used to measure the separation. Measure the genetic diversity in the captive and wild populations to determine how likely the masked bobwhite is to persist as a subspecies over the next 100 years.

Comprehensive, long-term studies are needed to examine critical aspects of masked bobwhite ecology, life history, management and propagation in Arizona and Sonora. These research projects should be based on rigorous experimental designs that yield statistically valid results. Though a few research projects were undertaken on the Buenos Aires NWR in the past, these projects were of short duration (1-2 yr) and limited focus (Goodwin 1982, Simms 1989, Vleck and Dobrott 1993). Information for the Sonoran population is even more limited, confined largely to data obtained from periodic demographic and habitat surveys (Tomlinson 1972b, Mills and Reichenbacher 1982, U.S. Fish and Wildlife Service 1984).

Competition between quail species should be evaluated. Brown (1989) reported that masked bobwhites and Gambel's quail have distinct habitat preferences, and thus habitat partitioning occurs. However, cursory observations indicate that masked bobwhites and Gambel's quail are currently utilizing similar habitats on selected areas of the Buenos Aires NWR and in Mexico. Since Gambel's quail are typically larger than masked bobwhites, occur in larger coveys and are more abundant on the Refuge than masked bobwhites, potential exists for competition between the two species which likely is unfavorable to masked bobwhites. Most of the habitat management practices that will be implemented to increase masked bobwhite populations will probably also benefit Gambel's quail. Therefore, competition for habitat between masked bobwhites and Gambel's quail should be examined and verified before habitat management is implemented on a large scale.

A bobwhite-habitat model should be developed for Buenos Aires NWR, using data from habitat interaction studies, to facilitate future habitat management planning.

Conduct bobwhite food habit studies to determine effectiveness of habitat management. Identify seasonal dietary preferences. Droppings collected at roost sites should be analyzed for seed and insect content. Sampling should occur in Arizona and Sonora and the results should be compared. The crop contents of Texas foster males should be analyzed to supplement food habits data obtained from fecal analysis. Foster male diets likely mirror those of their masked bobwhite broods, so the contents of the Texas bobwhite crops would be indicative of the food habits of masked bobwhites. Consequently, foster males should be collected during late spring-early summer, while quail are still in coveys, and their crop contents analyzed.

Evaluate various census techniques. Several census techniques have been used in the past to estimate masked bobwhite densities; however, none have been critically evaluated to determine method-specific accuracy and precision. Research should be initiated to address these shortcomings. Techniques to be evaluated should include line transects, mark-recapture, and bird dog-induced flushing counts. Incorporate appropriate post-release studies to gather information on population movements. Identify the population density necessary for a self-sustaining population.

Evaluate specific release techniques. Releases involving broods adopted by vasectomized Texas bobwhite males should continue, however brood survival should be monitored periodically to determine the success of this technique. Suspected causes of mortality could thus be identified and appropriate measures implemented to mitigate mortality events. Broods should also be held for variable time intervals with their foster males to determine if longer periods of conditioning in flight pens enhances brood survival. Pairing of masked bobwhite hens and vasectomized Texas males should be attempted in an effort to induce infertile egg-laying and then subsequent replacement of infertile eggs with fertile eggs produced by the captive population. It is possible that chicks incubated and raised by pairs in flight pens over variable time intervals may experience higher rates of survival upon release. Therefore, the efficacy of paired adoption and release should be evaluated as well as the traditional foster male technique.

Maintain genetic diversity and increase heterozygosity in captive populations. One of the primary reasons for maintaining the genetic diversity of a captive breeding population is to preserve as much of the wild founders genetic variation as possible (Ralls and Ballou 1992). This is generally accomplished by selecting for heterozygosity. With regard to masked bobwhite, genetic diversity refers to the number of alleles for each gene loci in the population, while heterozygosity refers to the number of individual birds in the population that have two different alleles on a gene loci (Gee, pers. comm. 1993). The genetic variation of the captive masked bobwhite population is currently acceptable. However, infusion of new genetic material from the wild Sonoran populations will be necessary during the next few years. Before wild birds are captured and added to the captive population, a genetic reconnaissance should be conducted on all of the Sonoran populations to determine the heterozygosity of each population and the degree of genetic similarity between the wild populations and the captive population. Wild birds selected for addition to the captive population could then be removed from the most genetically distant wild population or from the population displaying the highest degree of heterozygosity.

Incorporate intensive disease and health assessments into population dynamics studies to elucidate the role of disease in population dynamics. Conduct periodic surveillance and epizootiological studies of wild masked bobwhite populations for selected pathogens, particularly adenoviruses, poxvirus, Chlamydia, and coccidia. Continue development of vaccine for coccidia in masked bobwhite. Characterize adenovirus isolates from bobwhites and other quail for comparative studies, and conduct pathogenicity studies in masked bobwhite. Conduct studies on the etiology and epizootiology of amyloidosis in captive masked bobwhite at Patuxent with regard to potential impact on masked bobwhite recovery efforts.

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