Reintroduction of the Columbia Basin Pygmy Rabbit (*Brachylagus idahoensis*) in Washington

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EXECUTIVE SUMMARY

This plan addresses the reintroduction of the Columbia Basin pygmy rabbit (*Brachylagus idahoensis*) in shrub-steppe habitat of central Washington. The technical background for this plan, covering the history, biology, and ecology of pygmy rabbits, has been reviewed extensively in the preliminary *Draft Recovery Plan for the Columbia Basin Distinct Population Segment of the Pygmy Rabbit (Brachylagus idahoensis)* (USFWS 2006).

There are no known pygmy rabbits from the Columbia Basin distinct population segment remaining in the wild in Washington at this time. Consequently, this plan addresses the reintroduction of captive-bred pygmy rabbits originating from the joint captive population maintained since 2001 at Northwest Trek, Oregon Zoo, and Washington State University. The reintroduction plan relies heavily on the results of a pilot-scale reintroduction of pygmy rabbits conducted in southeastern Idaho in 2002-04, which yielded valuable information on the behavior and survival of pygmy rabbits reintroduced into shrub-steppe habitat known to support wild populations.

Based upon that pilot study, pygmy rabbits respond well to a simple set of reintroduction techniques and quickly adapt to eating available natural forage. Survival of young-of-the-year until their first breeding season appears to be low for animals released in mid-summer (0% - July) and highest for those released in mid-winter (71% - Feb.), which is at the onset of the breeding season. Thus, the optimal reintroduction strategy is primarily a calculated trade-off between the costs and expected mortality of holding captive-bred pygmy rabbits in pen facilities for varying amounts of time prior to release, versus mortality rates expected in the wild until first breeding. In general terms, the longer that young-of-the-year animals can be held in captivity, the higher the resulting payoff in released animals surviving to the next breeding season.

A genetic and population model of the captive population indicates that about 20-50 surplus animals may be produced for release annually while simultaneously maintaining the size and genetic diversity of the founding population. Stochastic population models simulating a reintroduced pygmy rabbit population indicate a growing population with a low probability of extinction for most feasible release scenarios of 20+ pygmy rabbits when supplemented annually for 3 or more years with additional release groups. However, there is considerable uncertainty in estimates of vital demographic parameters derived from wild populations and better information is needed to refine projected population growth rates and model the expected time line to achieve a sustainable, managed metapopulation in 3-5 distinct occupied habitat sites in Washington to achieve recovery goals.

Captive-bred pygmy rabbits will be released at Sagebrush Flat Wildlife Area, which is the last site known to be occupied by pygmy rabbits in Washington, between late fall and late winter (March). Individuals will be fitted with radio neck collars and tracked to

document habitat use, dispersal, mortality factors, reproductive success, seasonal and annual survival rates, and changes in population genetics.

If the reintroduced population at Sagebrush Flat achieves a desirable growth trajectory and population size, and assuming the captive breeding program continues to support multiple release efforts, subsequent reintroductions will proceed sequentially to previously identified and prioritized recovery areas, beginning with the next highest priority site at Beezeley Hills. Baseline stochastic population growth models using the best currently available data, indicate that a single reintroduced population (no augmentation) of 20 to 60 rabbits may grow to 159 to 454 animals within 10 years. However, if reintroduced populations of 20 to 60 rabbits are augmented for 2 years after the initial release, and if these populations are themselves harvested for additional release animals beginning at year 5, it may be possible to sequentially create up to 6 sub-populations in a managed metapopulation totaling about 1,036 to 1,697 pygmy rabbits in 10 years.

However, because of the paucity of critical information on key vital rates, empirical results from the first few years of the study will be used to adaptively modify population models to better predict the expected time line to meet recovery objectives. Based upon available data, productivity of the captive population is both driving and limiting population recovery scenarios.

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INTRODUCTION

Emergency Federal listing of the Columbia Basin distinct population segment of the Columbia Basin pygmy rabbit (*Brachylagus idahoensis*) in Washington, occurred in 2001. The population subsequently appears to have been extirpated from the wild by mid-2004. Fortunately, 16 individuals had been brought into captivity in 2001 to establish a founding captive population for future recovery efforts. However, these founders exhibited a high degree of apparent inbreeding depression, as evidenced by their low reproductive output, potential increased susceptibility to disease, and a declining population despite comprehensive management practices. Currently, there are only 2 females and 1 male alive in captivity in 2006, with limited likelihood of breeding because of age, making the purebred captive population functionally extinct as well.

However, an emergency genetic rescue restoration program was initiated in 2003 by intercrossing purebred Columbia Basin pygmy rabbits with Idaho pygmy rabbits. This intercross program has been successful, resulting in the restoration of lost genetic diversity and improved reproductive success among the captive intercross animals. Thus, by necessity, recovery of the Columbia Basin pygmy rabbit population segment now depends entirely upon continuing these genetic restoration efforts and reintroduction of appropriate intercross animals of suitable genetic constitution. In the unlikely event that some surviving purebred Columbia Basin pygmy rabbits are rediscovered in the wild, they will be incorporated into the captive breeding program and/or other associated recovery efforts (e.g., direct translocation to recovery areas), as feasible, according to the guidelines in the draft recovery plan (USFWS 2006).

This reintroduction plan addresses the strategies for creating free-ranging populations of pygmy rabbits in Washington to meet the recovery objectives identified in the *Draft Recovery Plan for the Columbia Basin Distinct Population Segment of the Pygmy Rabbit (Brachylagus idahoensis)* (U.S. Fish and Wildlife Service 2006). The history, biology, and ecology of pygmy rabbits, and the management goals and objectives for population recovery are identified and reviewed extensively in that document and are not repeated here. However, the results of a feasibility study of pygmy rabbit reintroductions conducted in Idaho (Westra 2004) are reviewed in this report along with the implications for designing and implementing the reintroduction program for the Columbia Basin pygmy.

Project Goals

The overarching goal of the recovery program for the Columbia Basin pygmy rabbit is to recreate free-ranging populations of sufficient size and number to assure the long-term existence of this distinct population segment (USFWS 2006). The quantitative measure of achieving this goal will come from the results of empirical field studies combined with population viability models that predict adequate population size, distribution, and persistence with an acceptably low probability of extinction in

Washington. This reintroduction plan outlines the steps necessary to accomplish that goal as well as to better define the future ecological risks of extinction for this population.

Conservation Objectives

This reintroduction plan includes a number of conservation objectives common to species recovery programs, including:

- Improving the chances of the long-term survival of this distinct population segment.

- Restoring pygmy rabbits as a characteristic biotic element of the shrub-steppe ecosystem of the Columbia Basin.

- Promoting increased awareness of landscape-scale conservation needs for the shrub-steppe ecosystem and other species of conservation concern in this ecosystem (e.g., greater sage grouse).

REVIEW OF PILOT REINTRODUCTION STUDY

In anticipation of the potential future need to reintroduce Columbia Basin pygmy rabbits, a pilot-scale reintroduction study was conducted in southeastern Idaho in 2002-04 (Westra 2004). During that study, 42 captive-bred pygmy rabbits originating from Idaho stock were radio-collared and released onto a prepared site in an extensive shrub-steppe habitat ecosystem at the Idaho National Engineering and Environmental Laboratory (now the Idaho National Laboratory – INL). Key elements of that reintroduction study, including selected unpublished observations, are reported here as background and justification for this reintroduction plan.

The INL pygmy rabbit reintroduction study was conducted to evaluate techniques potentially important to the reintroduction of Columbia Basin pygmy rabbits. Because the INL project was the first attempted reintroduction of pygmy rabbits, it was unknown how well or how quickly captive-bred pygmy rabbits might adapt to conditions in the wild in an arid environment. In the absence of precautionary measures to prevent habituation to humans and foods in captivity, captive-reared populations of species are typically poorly adapted to the wild and often exhibit low survival after release, necessitating consideration of soft-release techniques (Letty et al. 2000). Consequently, this project evaluated several soft-release techniques for pygmy rabbits that potentially could have beneficial effects on survival rates.

INL Study Objectives

1. Describe the behavior and dispersal of captive-bred pygmy rabbits released in the wild in southeastern Idaho.

2. Evaluate behavioral response to soft-release techniques (i.e., provision of artificial burrows, temporary containment pens, and provision of transitional supplemental foods).

3. Quantify and describe mortality agents and factors potentially related to survival rates (i.e., soft vs. hard release; season of release; habituation to humans via small vs. large pen rearing conditions).

Release Methods

Captive Rearing

The methods for captive rearing (Elias 2004) and reintroduction of pygmy rabbits have been described in detail elsewhere (Westra 2004). What follows is a brief summary of relevant procedures followed during the reintroduction project in Idaho.

Each rabbit had an internal transponder microchip inserted into the shoulder region for permanent identification. A tissue ear punch was taken for genetic analysis and sex identification. Kits were reared in either a naturalized 15 x 15 m outdoor enclosure planted with grasses and forbs, or were temporarily housed in commercial stainless steel rabbit cages (0.6 x 0.6 x 0.6 m) indoors prior to release.

Because of the timing and differential growth of multiple litters during the breeding season, kits were held in captivity for 15-260 days prior to release. A weight criterion of 300 g was used to establish a minimum body weight prior to release. Kits attained this weight after about 45 days post-emergence from the natal burrow.

Radio Collaring

Captive-bred pygmy rabbits were fitted with 6 g radio neck collars which were attached using plastic-coated metal fishing leader and a metal crimp. Polyvinyl chlorine (PVC) tubing covered the fishing leader. The collar was adjusted to prevent it from being too loose and slipping off. The radio package weighed about 2% of the minimum body weight of pygmy rabbits before release. Collars were placed on animals several days prior to release to be sure the fit was correct for each animal and to provide them an opportunity to adjust to the radio package.

Transport and Release

Releases were conducted in August and September, 2002, in July, 2003, and February, 2004, to evaluate seasonal differences in survival rates. The pygmy rabbits were transported about 1000 km (about 10 hr transit time) from Pullman, Washington, to the INL. For transport, the animals were placed in individual cardboard pet carrier boxes lined with grass and containing fresh cut forbs and a small quantity of pellet food to allow *ad libitum* feeding during transit. Most travel occurred either at night or with air conditioning or ventilation in covered vehicles to maintain cool temperatures. Upon arrival, the pygmy rabbits were inspected to insure general health before being released.

Artificial Burrows

Methods similar to those developed for releasing Utah prairie dogs (*Cynomys parvidens*) and black-footed ferrets (*Mustela nigripes*) (Biggins et al. 1999; Dean Biggins, USGS, pers. comm.), were used to create artificial burrows partially replicating natural pygmy rabbit burrows. The artificial burrows were provided for initial hiding cover from predators and to minimize translocation stress until natural burrows could be dug or located by the released animals. For each artificial burrow, a 3 - 5 m length of corrugated plastic drainage tubing (10 cm dia.) was buried in a shallow, v-shaped trench 0.75 – 1 m deep at the bottom. Depth at the deepest point was generally limited by a hard-pan of soil on the INL. Two side openings were cut in the plastic tubing at the bottom to allow pygmy rabbits to dig side chambers if they wished. After placement of the tubing, the trench was backfilled with soil and the two surface openings of the plastic tubing were concealed with dead sage brush.

Sites for artificial burrows were selected by experienced investigators familiar with the placement of wild pygmy rabbit burrows. Investigators visually selected locations containing mounds and ridges of deeper soil with taller, dense sagebrush cover, typical of natural burrow sites.

Soft-Release Pens

In 2002, small temporary containment pens were fitted around the two surface openings of each artificial burrow system to prevent immediate dispersal by released rabbits. Initially, open-topped pens, 92 cm tall and about 1 m. dia., were constructed of 2.5 cm mesh chicken wire with the bottom bent inwards and staked down to prevent escape by digging. In 2003-04, the temporary containment pens consisted of fully enclosed welded-wire boxes, 0.5x 1.2 x 0.6 m, placed over both burrow openings and staked to the ground. Released animals were fed and maintained in the temporary containment pens for up to 5 days prior to full release to evaluate the benefits of soft-release techniques. Rabbits were provided with fresh greens and pellets once a day while they remained in the soft-release pens and burrow systems. At full release, the temporary pens were removed from the burrow openings and the pygmy rabbits were allowed to disperse.

Radio Tracking

Released pygmy rabbits were monitored one to three times daily on a stratified time schedule during the daytime period by tracking animals on foot using a hand-held yagi antenna and receiver. Animals were generally approached until a visual sighting was made to confirm the status and behavior of the animal. A hand-held global positioning system (gps) was used to directly record the location of the animal without the need for radio signal triangulation.

Mortality Agents

Whenever possible, causes of mortality were determined by physical evidence at kill sites. Bird fecal material and feathers denoted a raptor kill. Weasels (*Mustela* spp.) tended to cache carcasses underground and inflict distinctive wounds, such as removing the head. Coyote (*Canis latrans*) kills were identified by tracks, scat, and regurgitated material.

Results of the Pilot Reintroduction Study

A total of 40 kits, 2 adults, and 2 wild adults believed to be offspring of a female released in August, 2002, were radio-collared and tracked during the reintroduction study in Idaho. Pygmy rabbits used the provided artificial burrows during both the soft release period for up to five days and after full release. About 27% of all radio locations of released pygmy rabbits occurred < 15 m from their primary artificial burrow, while 33% were found > 15 – 100 m away, and 40% were > 100 m from their primary artificial burrow. Each pygmy rabbit used an average of 3.4 (S.E. ± 0.64, range 1 – 13) burrows, both natural and artificial, across the release area. Released pygmy rabbits had an average 95% Kernel home range of 10 ha (n = 16, S.E. ± 3.5 ha, range 0.07 – 53.9 ha).

Initial movements of released pygmy rabbits did not differ by release cohort, age, or time spent in a naturalized pre-release pen at Washington State University, however, males moved further between sequential locations than females. The February release group remained closer to their burrows, probably because of the cold weather and snow cover.

Survival

Mortality rates were high during the five-day soft-release treatment because weasels successfully entered some of the temporary containment pens. Only 17 (40%) of 42 pygmy rabbits survived at least 18 days after release, at which point survival increased. The last cohort released in February had 4 of 10 individuals survive until the breeding season.

Calculated annual survival rates varied significantly among the four small release groups, ranging from 0 – 32%. Survival did not vary among animals with smaller vs. larger home ranges, however, pygmy rabbits that used artificial burrows less than the median percentage had a higher annual survival rate (62%) and mean survival time (362 days) than pygmy rabbits that used artificial burrows more (ASR 10%; MST 62 days). Survival quantiles for the released rabbits demonstrate a 76% survivorship for the first 6 days after soft-release declining to 28% by day 95. Survivorship did not drop below 25% until day 260 post release.

Mortality

Predators were the primary source of mortality and were attributed to at least 18 of 27 deaths of released pygmy rabbits. Four deaths were caused by raptors, of which two were caused by harriers (*Circus cyaneus*). Two deaths were confirmed kills by coyotes, while twelve were caused by long-tailed weasels.

Reproduction by Released Pygmy Rabbits

Despite the small number of animals surviving until the breeding season from the four cohorts, evidence indicated some successful reproduction by released pygmy rabbits. Three juvenile pygmy rabbits were observed within the release area during May, 2003. Because the kits were located at an artificial burrow where a female released in 2002 was residing, these kits were believed to be the offspring of that female. In April, 2004, three additional juvenile pygmy rabbits were observed adjacent to the artificial burrow of another released female. Consequently, it appears that two surviving females entering their first breeding season produced at least six kits.

Implications for Releasing Pygmy Rabbits in Washington

Specific results of the pilot study investigating reintroduction of pygmy rabbits in Idaho are available in Westra (2004), however, some of the key observations and conclusions from that study are as follows:

- Captive-bred pygmy rabbits transported well to the release site and continued to feed during transport and immediately after placement in the temporary confinement pens around the artificial burrow openings. Individuals also appeared to be consuming natural forage by the first visual observation (usually the first day) after full release.

- About 86% (n = 36) of the released pygmy rabbits remained within < 1 km of the original release site and extensively utilized artificial burrows and natural burrows. Excluding 6 animals that were censured because of lost radio signals, pygmy rabbits dispersed 0 – 859 m during the first week after release.

- More than half of the release population died within the first 18 days, however, this mortality rate may have been reduced considerably if the initial soft-release containment pens had adequately protected pygmy rabbits from weasels. Also, the artificially high density of burrows and pygmy rabbits on the release site may have created a locally concentrated population that attracted predators more than if the pygmy rabbits had been released over a larger area.

- Despite the small number of released female pygmy rabbits surviving to the first breeding season (n = 4), there was evidence of successful reproduction and pygmy rabbits continued to be observed on the release site for a year after the study was terminated (Sayler unpublished).

THE WASHINGTON REINTRODUCTION PLAN

The pilot reintroduction study completed in Idaho (Westra 2004), coupled with results of ongoing studies of captive pygmy rabbits (Elias et al. 2006) and field investigations of wild pygmy rabbits in Idaho (J. Rachlow, pers. comm.), provide a good background for planning reintroductions of Columbia Basin pygmy rabbits in Washington.

Selection of Release Sites

Potential reintroduction sites for pygmy rabbits in the Columbia Basin were evaluated by developing maps of potential habitat using geographic information systems (GIS), field surveys for suitable soils and vegetation complexes, and expert opinion of biologists and managers working for state and federal agencies (USFWS 2006). Sagebrush Flat and Beezeley Hills were ranked as the number one and two priority reintroduction sites because of: 1) previous known occupation by pygmy rabbits, 2) access and management conditions for research and monitoring, 3) habitat condition and restoration activities, and 4) land area available to support a pygmy rabbit population. Sagebrush Flat was selected by the WDFW Science Team as the best initial reintroduction site (Fig. 1).

General Release Protocol

The release protocol developed during the test reintroduction of pygmy rabbits in southeastern Idaho was largely successful and elements of that methodology will be adapted to pygmy rabbit releases in the Columbia Basin. These basic protocol elements include:

1. Captive-bred, young-of-the year, Columbia Basin pygmy rabbits will be held in captivity in naturalized pens that contain growing grasses and forbs, supplemented with pellet food and water. Pygmy Rabbits held under these pen conditions have higher growth rates and body mass than individuals kept in smaller pens or cages without such vegetation and space (Sayler, unpublished),

and would be expected to enter the release phase in better physical condition.

2. All pygmy rabbits will have a microchip radio transponder inserted into the nape of the neck and shoulder region and will have an ear punch taken for genetic analysis prior to their release.

3. Radio neck collars equivalent to those previously used in Idaho (Westra 2004) and currently being used on pygmy rabbits in other field studies in Idaho (J. Rachlow, pers. comm.) will be used for the Columbia Basin releases.

4. Candidate pygmy rabbits identified for release will be inspected for general overall health and approved for release by attending project veterinarians at WDFW, Washington State University, or the Oregon Zoo.

5. Pygmy rabbits will be transported to release sites in individual pet carriers and provided with fresh food to allow *ad libitum* feeding in transport. The transport of pygmy rabbits will take from 4 – 8 hours from the captive rearing facilities, so transport time will be less than occurred in the pilot Idaho study.

Site Preparation and Artificial Burrows

Preparation of reintroduction sites at Sagebrush Flats and Beezely Hills have included management of old fields to increase shrub cover, boundary fencing, removal of unneeded fence posts to reduce predator perches, gating to prevent unrestricted vehicle access, weed control, construction of fire breaks, and other management activities designed to improve habitat conditions for pygmy rabbits (USFWS 2006). Both sites are being monitored for general abundance and species of predators present in the event that temporary predator control is deemed necessary and feasible. Winter snow tracking is used to gauge general abundance of mammalian predators and quarterly raptor surveys at fixed routes are in place to monitor abundance of aerial predators, including ravens. Such observations may guide the seasonal timing of releases if they indicate when, for example, raptor densities have decreased following fall migration, as experienced on the Idaho reintroduction site.

Adaptive Modifications to the Washington Release Plan

The Idaho study (Westra 2004) did not conclusively demonstrate the benefits or detriments to survival of providing artificial burrows for released pygmy rabbits. Consequently, it is a high priority to evaluate and improve techniques related to provision of artificial burrow systems to determine whether their use will be desirable or not in future releases of pygmy rabbits.

If artificial burrows improve rabbit survival, then maintaining a core of artificial burrows on release sites will be advantageous for the populations, but also may contribute to development of a method for population census and, possibly, may provide an efficient way to treat resident pygmy rabbits for parasites and diseases, if so desired (Sayler unpublished). In addition, if artificial burrows improve survival, they may allow populations to be established in smaller habitat blocks than would otherwise be feasible. However, if artificial burrows do not provide a survival advantage, then their use will be discontinued and logistical efforts to prepare release sites will be greatly simplified.

About 40 artificial burrows will be installed at the SBF release site (Fig. 3). Adjustments to be made during releases on Sagebrush Flat Wildlife Area will be to more widely space the artificial burrows to avoid an inappropriately high concentration of burrow sites and/or novice animals, which may attract predators. Maps of burrow locations generated just prior to the local extirpation of the pygmy rabbit population at Sagebrush Flat (Siegel 2002; Siegel Thines et al. 2004) will be consulted to help guide placement of artificial burrows on the reintroduction site. Selection of specific artificial burrow sites on Sagebrush Flat will be made by several experienced individuals with expertise in pygmy rabbit life history and reintroduction techniques.

Site preparation for the artificial burrows involves only minimal disturbance of soil from a trench dug about 0.4 m wide by 4 - 5 m long with the soil being replaced over a 3 – 5 m length of 10 cm dia. plastic drainage tubing used to form the burrow. Another modification of the artificial burrow system that was used in Idaho will be to use metal U-shaped stakes to better secure the two burrow openings to the ground in an effort to deter predators (e.g., coyotes, badgers) from easily digging up burrow systems. To reduce detection by predators, use of marker stakes or flagging will be avoided and the location of all artificial burrow systems will be documented using gps coordinates.

Selection of Animals for Release

Genetic Management Plan

The number of purebred Columbia Basin pygmy rabbits produced in the captive breeding program has been limited because of poor reproductive performance, which along with other factors such as historical evidence of declining genetic diversity, some skeletal deformities in a few offspring, and increased susceptibility to disease, indicates that inbreeding depression has affected the few survivors of this population segment (Elias 2004, WDFW 2005a, USFWS 2006). By 2003, after two breeding seasons in captivity, it became apparent that the purebred captive Columbia Basin pygmy rabbit population was experiencing continuing loss of genetic diversity and poor reproduction due to inbreeding (loss of genetic heterozygosity by mating among closely related individuals), and genetic drift (loss of alleles), despite intensive efforts to promote and manage appropriate mating opportunities. An experimental attempt to produce intercross animals generated by mating male or female Columbia Basin pygmy rabbits with individuals originating from Idaho populations demonstrated that the two populations were readily capable of interbreeding and producing viable offspring that exhibit higher fitness in captivity than purebred Columbia Basin pygmy rabbits (Sayler unpublished).

With the coordination of a state-appointed Science Team and a Federally-appointed Recovery Team for the Columbia Basin pygmy rabbit, the intercross strategy was increased in scope beginning in the 2004 season, which has resulted in expanding the captive breeding population, that currently includes 3 purebred animals and 67 intercross animals (USFWS 2006). Although the genetic management plan for the captive population included the objective of producing additional purebred Columbia Basin pygmy rabbits, this objective has been abandoned due to continuing poor reproductive success. No purebred animals produced during the 2005 or 2006 breeding seasons survived to maturity. Demographic models of the purebred Columbia Basin population also independently indicate a population declining to extinction (Warheit 2006), matching the empirical observation of extinction. Thus, the reintroduction program now hinges on the success of producing intercross animals with appropriately restored genetic diversity that has been lost from the purebred Columbia Basin captive population (USFWS 2006).

Both the Science Team of the WDFW and the Pygmy Rabbit Recovery Team for the U.S. Fish and Wildlife Service have considered the necessity of producing intercross animals to affect the genetic restoration of the Columbia Basin pygmy rabbit. After careful consideration of all the genetic evidence, the conclusion was reached that it is necessary to produce intercross animals with higher genetic diversity for release, which we predict will result in increased fitness because of the genetic rescue effect and increase in genetic diversity of the reintroduced population.

Genetic rescue, or genetic restoration (Hedrick 2005), has been achieved for a number of wildlife species (e.g., Florida panther) by introducing a small number of more genetically diverse individuals from another population (Tallmon et al. 2004). The primary difference in the current situation with the Columbia Basin pygmy rabbit is that genetic restoration has to be effected on the captive population, because the wild population has apparently been extirpated.

Models of the Reintroduced Population

Model 1: Qualitative/Empirical Model

Westra (2004) used survival curves derived from the Idaho reintroductions to estimate the number of pygmy rabbits that would have to be released in either fall or winter to carry a target number of surviving animals through to the spring breeding season. For example, if a spring population of 25 females was the reintroduction target, then it would be necessary to release about 56 females in September, but only about 33 females in February to achieve the same end result. This simple empirical calculation illustrates the potential benefits of delaying releases until just before the breeding season.

Westra (2004) concluded, given the low annual survival rates of reintroduced pygmy rabbits, that it likely will be necessary to augment an initial reintroduction with additional releases for one or more years to achieve an increasing local population. However, the apparent observation of kits being produced and surviving for at least a year from a small number of females (n = 4) indicates that even a small number of released animals might be able to establish an initial wild population which could be augmented in subsequent years.

Model 2: Vortex

We evaluated stochastic population growth models for reintroduced pygmy rabbits using Vortex (Lacy et al. 2005). Vortex is an individual-based simulation model that follows the fates of each animal in the population by simulating the events of its life history, such as birth, reproduction, and death as discrete events that happen according to defined probabilities (specified frequency distributions).

A conservative baseline Vortex population model using current cumulative data from the WSU captive intercross population predicts an initial population of 30 reintroduced animals (15 females, 15 males) increasing to about 227 animals within 10 years (Fig. 2). This baseline model was used to evaluate a number of basic questions regarding the potential population response after reintroduction, with the following tentative initial conclusions:

1. Population growth rates are not sensitive to carrying capacity (K) within the first 5 years of reintroduction for any realistic number of annually released animals ranging from 20 - 60. A carrying capacity of about 591 pygmy rabbits was estimated for the area of Sagebrush Flat (1556 ha), using a low density estimate of 0.38 rabbits/ha from a field study in Idaho (J. Rachlow pers. comm.). The demographic models produced stochastic growth rates (r) between 0.160 and 0.165 for carrying capacities between 100 and 2000.

2. The size of the initial reintroduced population has a major influence on the rate of population recovery. The mean estimated size of extant populations after 10 years was 159, 227, 302, 382, and 454 pygmy rabbits for reintroduced populations started with a single initial release group of 20, 30, 40, 50, or 60 pygmy rabbits, respectively (Fig. 4).

3. Annual augmentation for 2 - 3 additional years beyond the initial release is highly beneficial to growth of the reintroduced population. For example, when the single introduction baseline model was expanded by annual augmentation of 30 animals each for three years following the initial reintroduction of 30 rabbits, a 10-year population estimate of 676 pygmy rabbits is predicted for the extant population (Fig. 5).

4. Barring catastrophic habitat loss (e.g., from fire) or other severe population impact (e.g., from disease), starting a single reintroduced population with a

larger number of individuals (e.g., 40 rabbits) is equivalent to starting with two separate populations of half the number each (e.g., 20 animals in each).

A single population started with 40 animals results in an estimated 10-year mean population size of 303 pygmy rabbits, while two populations of 20 animals each results in an estimated 10-year population size of 315 pygmy rabbits. However, in the absence of a catastrophe, or large differences in carrying capacity, the single larger population results in a probability of extinction of 0.001, while the two-population scenario results in a probability of extinction of 0.0275. The choice of optimal reintroduction scenarios therefore depends primarily on availability of animals for release and management estimates of potential catastrophes that could eliminate a single population, primarily by risk of fire and severe disease outbreaks.

5. The single introduction baseline population models (Fig. 4) are not sensitive to male mortality in any age class because of the polygynous mating system and the assumption that all males are available for breeding. The models are sensitive to female mortality rates and juvenile mortality is more sensitive than adult female mortality. In sensitivity analyses on the single baseline model for 20 released rabbits, a zero growth rate occurs when the adult female mortality rate increases by about 0.225. By contrast, a zero growth rate occurs when the juvenile mortality rate increases by about 0.075.

6. Using realistic numbers of animals potentially available from the captive-rearing program, and a three-year augmentation strategy, population growth scenarios for a single reintroduced population without density dependence range approximately from a 10-year estimated mean population of 676 pygmy rabbits (one pop. of 30 animals; 3 annual supplements of 30 animals) to a projected 10-year mean extant population of 908 pygmy rabbits (one introduced pop. of 40 animals; 3 annual supplements of 40 animals) (Fig. 4). The range of variability ($\pm$ 1 SD) of the latter population estimate ranges from about 449 – 1,221 rabbits, illustrating the wide range of possible outcomes.

   When density dependence is entered in this model using a presumably conservative estimated carrying capacity for Sagebrush Flat, then the 10-year mean population estimates decline to 491 and 538 animals for the above reintroduction scenarios of 30 and 40 rabbits, respectively.

7. We used these population models to develop a relatively optimal reintroduction strategy that maximizes population growth and the number of separate populations in a metapopulation over a 10-year period. That scenario is as follows: a) introduce 30 animals, b) supplement for 2 additional years, c) start second population with 30 animals, d) supplement for 2 years, e) in year 5, harvest 30 rabbits from population 1 to start another population, and f) continue this sequential process for 10 years.

The projected result of this reintroduction process is a managed metapopulation of 6 separate populations, ranging in size from 30 to about 400 animals, with a total metapopulation of about 1,065 pygmy rabbits (Fig. 6).

8. If the number of rabbits available for reintroduction were doubled from the current baseline of 30 animals to 60 animals annually, then the preceding reintroduction scenario would result in approximately 1,800 pygmy rabbits in a metapopulation of 7 populations ranging from about 76 – 504 animals within 10 years.

9. Unless productivity and survival of pygmy rabbits in the wild is substantially higher than that modeled using current data from the captive population, the primary limiting factor to achieving population recovery goals appears to be the productivity of the captive population via its influence on the numbers of animals available for reintroduction.

While these baseline population models provide some insights into potential growth of a reintroduced pygmy rabbit population, the paucity of information on vital rates of wild pygmy rabbits precludes making more precise estimates of population growth rates until the means and variability in key parameters are better estimated during the first several years of the release program. Therefore, these initial modeling results should be viewed with caution until input parameters are validated from results of additional field studies, and especially, from demographic rates determined directly from studies of Columbia Basin pygmy rabbits released in the wild.

Reintroduction Research Objectives

The factors that originally contributed to the extirpation of local populations of the Columbia Basin pygmy rabbit are largely unknown, because the last known population was extirpated before ecological studies could be conducted. Consequently, the reintroduction program offers the opportunity to simultaneously restore local populations while gaining better understanding of population dynamics and ecological factors critical to the long-term survival of the Columbia Basin population as a whole (Table 1).

Many basic aspects of the population biology of pygmy rabbits are either poorly known or have not been duplicated among independent field studies. Improving the estimates of survival and key reproductive parameters, including their variability, is important to improve the results of population modeling. The following primary research objectives are central to the reintroduction and monitoring program:

1. Describe the behavior, dispersal, and movement patterns of reintroduced Columbia Basin pygmy rabbits and their wild progeny.

2. Evaluate the importance of soft-release techniques (e.g., provision of artificial burrows) to determine their influence on dispersal and survival rates of released pygmy rabbits.

3. Assess ecological relationships between pygmy rabbits and the shrub-steppe vegetative community to develop better quantitative models of habitat use and selection.

4. Quantify and describe reproductive success, mortality agents, and ecological factors potentially related to survival rates of pygmy rabbits following their release.

5. Collect tissue samples to monitor spatial and temporal trends in the population genetics of progeny of reintroduced intercross pygmy rabbits and evaluate the potential need for future genetic management (e.g., genetic consequences of augmentation, supportive breeding, enhancing gene flow). If possible, fitness and survival consequences related to the genetic make-up of the reintroduced population will be measured over time.

6. From the above data, develop better empirically-driven population viability models and comprehensive systems dynamics models (Ford 1999) to project the timeline and management conditions necessary for determining delisting criteria and achieving the recovery goals addressed in the draft federal recovery plan (USFWS 2006).

Research Hypotheses

Completion of these basic research objectives will allow the reintroduction program to be adjusted to achieve higher survival rates for reintroduced Columbia Basin pygmy rabbits. If the same survival pattern observed in southeastern Idaho holds true for central Washington, then survival will be higher for pygmy rabbits released later in the year (i.e., fall or early winter rather than summer). However, the initial study results will allow further evaluation of this and other working hypotheses (e.g., soft-release is beneficial) for factors influencing pygmy rabbit survival.

The reintroduction program also provides a general post-hoc method of evaluating the local adaptation hypothesis and the genetic rescue hypothesis (Tallmon et al. 2004). The local adaptation hypothesis suggests that genetic differences in local and regional populations reflect important adaptations that increase individual and population fitness within their local environmental setting. By contrast, the genetic rescue hypothesis predicts that the reduced genetic diversity within the small, isolated Columbia Basin pygmy rabbit population led to inbreeding depression and genetic drift, and that increasing genetic diversity in the population will improve its overall fitness rather than reduce it.

While there are no comparative experimental groups to cleanly test these hypotheses through controlled releases of animals with different levels of genetic diversity, or by comparisons with any wild animals, the responses of reintroduced populations will be indicative. If the more genetically diverse reintroduced populations grow, then there will be evidence supporting the genetic rescue hypothesis. However, if the reintroduced populations fail to stabilize and become established, then it will indicate that factors other than inbreeding depression and low genetic diversity (e.g., ecological influences) are largely driving populations. Evaluating the relative balance between these two hypothesized influences will improve management efforts to achieve the more comprehensive objectives of genetic restoration (Hedrick 2005) and recovery of the Columbia Basin pygmy rabbit (USFWS 2006). Once two or more populations are established, genetic sampling will provide good information on genetic trajectories in reestablished pygmy rabbit populations and the interplay between genetic management of a captive founding population and its reintroduced counterpart.

Monitoring / Study Methodology

Once reintroduced pygmy rabbits enter their first breeding season and produce their first progeny, it will then be necessary to once again estimate distribution and size of the wild pygmy rabbit population using indirect sampling methods. During the first 2 – 3 years of the reintroduction program, a relatively large sample of radio-collared animals of both released and wild progeny will provide a good tool to help evaluate size, distribution, and survival of the reintroduced population. However, as the population grows, other indirect methods for estimating population dispersion and size will become more important.

Radio-Collaring Rabbits

One of the primary methods of obtaining data on survival and habitat use will come through the collection of location data from pygmy rabbits that have been fitted with radio neck collars previously field tested in Idaho (Westra 2004). Neck collars are constructed by using a 6 g radio (battery life 6 mo.) and whip antenna attached via a neck collar consisting of a wire loop run through plastic tubing to shield the skin from abrasion. The wire loop is adjusted to fit the neck of each rabbit and clamped with a metal crimp to hold the appropriate diameter. Rabbits will be fitted with radio neck collars about 4 - 10 days prior to release to allow the animal time to adjust to the collar and provide investigators with time to verify the fit for individual animals.

Released rabbits will be tracked about 3-4 times weekly during the first 3 months after release, a period of expected high mortality, and a minimum of about 2 times weekly thereafter. Such tracking rates provide adequate information to accurately estimate seasonal and annual survival rates and will allow many mortalities to be investigated shortly after they occur.

Based upon previous field studies (Westra 2004), tracking will be conducted by investigators on foot, using hand-held directional antennas. Previous experience has demonstrated that pygmy rabbits may be approached carefully on foot by circling around the suspected location, which oftentimes may be subsequently confirmed by direct visual sightings or by locating a rabbit in a burrow. Rather than through triangulation, which is difficult in the road-less shrub-steppe habitat of SBF, radio locations will be marked directly by taking gps readings of the spot in which the rabbit was originally located, even if it subsequently moves away from the investigator.

Radio locations will be collected on a stratified time sampling scheme by dividing the day into 3 diurnal periods (morning, mid-day, evening). Most locations will be collected in the diurnal period, but a smaller sample (< 10%) of night-time locations will be collected seasonally to investigate nocturnal movement and activity patterns. Clusters of burrows and the sequence of individuals tracked will be alternated to avoid a systematic time bias and assure an equitable distribution of radio locations grouped by geographic clusters and time of day.

Modeling Habitat Use

Radio locations will be plotted on a GIS system for analysis of dispersal distances, home range size, and habitat utilization patterns. Current habitat suitability models for pygmy rabbits use a relatively coarse filter and predictive model to identify areas containing relatively deep soils for digging burrows and stands of tall, dense sagebrush for cover and foraging. However, small-scale habitat requirements and rabbit interaction with shrub-steppe vegetation ecology are much less clear and work is needed to identify more specific habitat features that influence habitat quality and selection and ultimately influence fitness and survival.

We will classify available habitat and plant species composition and distribution of grasses, forbs, and shrubs on the reintroduction site using several different methods. One habitat characterization will follow a range and shrubland monitoring protocol developed at the Jornada Research Station in New Mexico. It is a bottom up approach that starts with soil types, classifies them into ecological types, and then measures vegetation within permanent sampling plots on those sites.

We will also use high-resolution (1m) aerial photography and statistical image classification algorithms to characterize habitat on the reintroduction site using spectral reflectance values. Once the high-resolution image is clustered into a suitable number of groupings that appear to have ecological validity, we will ground truth the clusters to define soil, slope, aspect, and fine-scale vegetative characteristics of ecological patches on the release site.

Vegetation will also be described and monitored by using occupied and unoccupied burrow mounds (e.g., sites with mounded deeper soils typically characterizing burrow sites) as a natural experiment to evaluate the direct influence of pygmy rabbits on surrounding vegetation. Line transects (30m) will be established on each occupied burrow mound allowing spatial and temporal sampling of vegetation species composition, frequency of occurrence, and aerial coverage of plants at varying distances on the burrow mound and in the inter-mound zone. Over time, we expect to see a pattern of more intensive browsing and grazing on and near the mounds than at greater distances from them.

Habitat use will be statistically evaluated by overlaying locations of radio-collared pygmy rabbits with detailed GIS maps of ecological zones and patches identified through the two described habitat classification methods. Classification and regression trees (CART), and other statistical classification methods, will be used to compare habitat features of used and unused areas, used and random point locations, and occupied and unoccupied burrow sites. CART models are somewhat unique in that the technique provides both a concise quantitative as well as a visual model description of pygmy rabbit habitat use and selection (Breiman et al. 1984).

The expectation is that results of these different habitat assessment methods will be complementary and help produce a better and more detailed habitat selection model for pygmy rabbits than is currently available. The analytical methods for vegetation, combined with radio-location data, will produce a quantitative habitat use model that will be transferable to future recovery sites in Washington and also help develop habitat variables useful in metapopulation models.

Survival Analysis

Survival rates will be determined by staggered entry Kaplan-Meier survival analysis as well as by other parametric survival modeling techniques (e.g., Cox proportional hazards) (JMP 2006). Survival rates will be compared for various data partitions and variables, including: a) dispersers and non-dispersers, b) use of artificial vs. natural burrows, c) males vs. females, d) young of the year vs. adults, e) season, and f) edge effects and spatial location on the study area. Mortalities will be characterized by month or season of death and mortality agent.

Population Monitoring

Population census and analysis of population trend are critical elements in the recovery program. In addition to radio monitoring, we will census pygmy rabbit populations using several different techniques, including:

1. Monitoring artificial burrows for occupancy.
2. Monitoring occupancy of natural burrows along historically established transects at Sagebrush Flat.
3. Tracking during fresh snow events in winter to identify the number of active burrows on the release site.
4. Mark-recapture estimates as animals are trapped and captured for radio replacement and ongoing studies.
5. Tissue sampling and genetic analysis to estimate effective population size.

6. Intensive line transect searches at the end of the summer breeding season or early fall to directly observe and census pygmy rabbits using known radio-collared rabbits as marked references (Rachlow and Witham 2004).

The later technique employs a large number of people (20 - 30) slowly walking in a tight line on established routes through occupied habitat to carefully scan for pygmy rabbits sitting under sagebrush plants. Using a combination of these techniques in the first several years of the reintroduction program will allow the variability and reliability of different population estimates to be evaluated empirically.

Reintroduction Timeline

- Sept. – Dec., 2006 – Survey and placement of artificial burrows at Sagebrush Flat.
- Feb. - March, 2007 – Pygmy rabbits fitted with radio transmitters and released. Intensive radio tracking begins.
- March – May, 2007 – Released animals enter first breeding season.
- April – July, 2007 – Monitoring continues for dispersal, survival, and reproductive success.
- August - September, 2007 – Intensive field surveys for population monitoring. Mark-recapture operations conducted. Periodic monitoring for survival.
- October – December, 2007 – Periodic monitoring for survival. Population modeling and systems models updated with field data.
- Jan. - March, 2008 – Release population augmented with second release of captive-bred pygmy rabbits. Annual monitoring cycle continues, as above.

Conclusions

The poor reproductive performance of the founding captive population of Columbia Basin pygmy rabbits removed from the wild strongly suggests that inbreeding depression contributed to the last stages of population decline and extirpation from the wild. Faced with the continuing decline and likely extinction of even the managed captive population of purebred Columbia Basin pygmy rabbits, the genetic restoration program involving intercross breeding with pygmy rabbits originating from Idaho has succeeded in conserving the Columbia Basin population’s remaining unique genetic characteristics and restoring some of the genetic diversity lost during early bottleneck events (Warheit pers. comm.).

The pilot project to experimentally reintroduce captive-bred Idaho rabbits into southeastern Idaho (Westra 2004) demonstrated the potential to restore populations of pygmy rabbits in Washington. Captive-bred pygmy rabbits transported well, handled radio collars well, and adapted quickly to eating natural forage after release. The majority of released rabbits remained within 1 km of the release site and utilized both artificial and natural burrows.

Predators were the most common documented source of mortality of released pygmy rabbits. Short-term survival of pygmy rabbits released in Washington should be improved by modifying the soft-release techniques used in the pilot study in Idaho. During the Washington reintroduction, rabbits will be released into an artificial burrow, provided with a small quantity of pellet food and fresh vegetation, but they will not be restrained in a temporary holding cage or pen. This approach hopefully will reduce the susceptibility of confined rabbits to weasel predation. The response of pygmy rabbits to the provision of supplemental food for up to 10 days after release, combined with the limited dispersal of most released rabbits in Idaho, suggests that the immediate release of Washington rabbits into an artificial burrow, without restraint, is likely a better soft-release technique.

The discovery that pygmy rabbits released shortly before the breeding season have higher survival, and that they may reproduce their first breeding season, indicates that it is better to hold young-of-the-year in captivity until at least mid to late fall, and possibly as late as mid- to late winter (March) before release. This approach, rather than releasing large numbers of young animals in summer, will increase the number of reintroduced pygmy rabbits successfully entering the breeding season and improve population growth trajectories.

A key initial objective of the reintroduction program will be to determine whether artificial burrows are beneficial or detrimental to released pygmy rabbits. In light of the proposed fall to late-winter releases of pygmy rabbits in Washington, artificial burrows may provide important initial hiding cover and perhaps thermal advantages in the absence of deep snow. However, if provisioning of artificial burrows confers no survival advantage, then such efforts will be discontinued early in the reintroduction program.

Empirical observations from the pilot reintroduction study of pygmy rabbits conducted in southeastern Idaho suggest that even small numbers of surviving females may produce offspring in their first breeding season that also may survive for a year or more. Using the best available data, stochastic population models suggest that a single reintroduced Columbia Basin pygmy rabbit population consisting of 20 or more intercross animals will grow, especially if supplemented annually for 2 to 3 years.

Baseline population models indicate that a single reintroduction of 20 to 60 pygmy rabbits will result in estimated 10-year populations of 159 to 454 rabbits. When initial reintroduced pygmy rabbit populations of 20 to 60 rabbits are augmented annually for 2 subsequent years, projected population sizes range from about 339 to 989 rabbits.

Density dependence may begin to occur after about year 5 of the reintroduction, if estimates of carrying capacity derived from Idaho studies are relevant to Sagebrush Flat in Washington. If harvests of 30 to 60 founding individuals are removed from reintroduced populations beginning at year 5 for each population, and sequentially used to start new populations, it may be possible to create up to 7 separate populations in a managed metapopulation of about 1,065 – 1,786 total animals in 10 years.

However, these baseline population models currently lack adequate information from studies of wild pygmy rabbits to accurately parameterize the models, which creates significant uncertainty in the projected growth rates of reintroduced pygmy rabbit populations. Consequently, the ecological research conducted during the initial stages of the reintroduction program in Washington will provide important data to be used in an adaptive fashion to adjust reintroduction procedures and develop better population models. Such refined population models will provide quantitative delisting criteria and help achieve recovery objectives as rapidly as possible.

Based upon available data, productivity of the captive population is driving population recovery scenarios by limiting the number of animals that can be reintroduced. Efforts to maximize production of the captive population will reduce the time line needed to meet recovery goals.

Recommendations

We have two primary recommendations for the reintroduction program for the Columbia Basin pygmy rabbit. First, we recommend that only a single population be started and augmented for 2 -3 additional years if the number of captive-bred rabbits available for release ranges from 20 – 40 animals per year. Unless the demographic rates observed in the field are dramatically higher than that predicted by current population models, it is better to establish higher growth rates in one larger population than trying to start a second population prematurely. This approach also will reduce the logistical difficulty and expense of the initial reintroduction program. If the number of animals for release can be increased to about 50 – 60 rabbits per year, then a second population could be started earlier.

Secondly, given the limiting nature of the numbers of rabbits available for release, we recommend that considerable effort be put into increasing productivity of the captive population. Failure to do so may result in an extended time line to recovery of greater than 10 years, using existing state recovery criteria. Based upon available data, productivity of the captive population currently limits and drives the reintroduction program for the Columbia Basin pygmy rabbit.

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Table 1. Summary of Research Objectives for Studying Population Dynamics, Habitat Use, and Burrow and Vegetation Ecology of Reintroduced Columbia Basin Pygmy Rabbits

Research Area	Objectives	Questions / Hypotheses	Methods
Habitat Use	1. Examine home range, behavior, movement and dispersal in relation to edge effects and patch characteristics. 2. Describe vegetative community at Sagebrush Flat (SBF) and pygmy rabbit use and selection of fine-scale vegetative attributes. Relate to fitness and survival if possible. 3. Conduct a natural experiment of spatial and temporal vegetative composition and change (grasses, forbs, shrubs; native vs. exotics) at occupied vs. unoccupied burrow sites. 4. Construct a habitat suitability model for pygmy rabbits in WA.	1. How do pygmy rabbits disperse within and use SBF in relation to vegetation, patch edge, and surrounding matrix? 2. <u>Hypothesis</u>: Pygmy rabbits change composition and structure of vegetation at and near burrow sites. 3. Are burrow sites over-utilized or self-renewing in terms of food supply? 4. Can we determine specific micro-habitat values to more precisely and quantitatively predict good habitat?	1. Location and movement studies of radio-collared rabbits using GPS locations and GIS analytical tools. 2. High-resolution image classification and cluster analysis. GIS analysis for ecological site classification. All ground truthed in permanent plots. 3. Line transects running through mound-intermound topography and associated vegetation gradients. 4. Classification tree models defining habitat variable predictions for: a) use and non-use areas and b) occupied and unoccupied burrow sites.
Survival and Population Demography	1. Estimate survival rates for adults and older juveniles. 2. Estimate productivity and recruitment rate. 3. Monitor and census population for trend and growth.	1. How do wild pygmy rabbit demographic rates differ from the captive population? 2. <u>Hypothesis</u>: Juvenile recruitment is more important to population growth rates than adult survival. 3. <u>Hypothesis</u>: Reintroduced population will show a positive growth trend.	1. Tracking radio-collared individuals for mortality estimates and factors. 2.Population estimates derived from several census techniques, *i.e.*, mark-recapture, an annual intensive line-drive census, active burrow use/snow tracking, DNA samples. 3. Staggered entry Kaplan-Meier and other parametric survival analysis.
Population Modeling	1. Construct stochastic population models for reintroduced pygmy rabbits in WA. 2. Estimate potential growth rate, probability of persistence and time to recovery.	1. What is the risk of decline and what metapopulation structure is needed to achieve recovery goals? 2. What habitat quality factors have the most influence on population size and carrying capacity at SBF?	1. Individual-based population modeling (Vortex) for demographic and sensitivity analysis. 2. System dynamics modeling (Vensim) of population in relation to habitat factors and suitability.

Fig. 1. Pygmy rabbits reintroduced in Idaho began foraging on natural vegetation almost immediately after release. Note antenna from the radio collar extending over the back.

Fig. 2. Typical sagebrush habitat in the reintroduction area for the Columbia Basin pygmy rabbit.

Fig. 3. Surface opening of artificial burrow system on Washington reintroduction site.

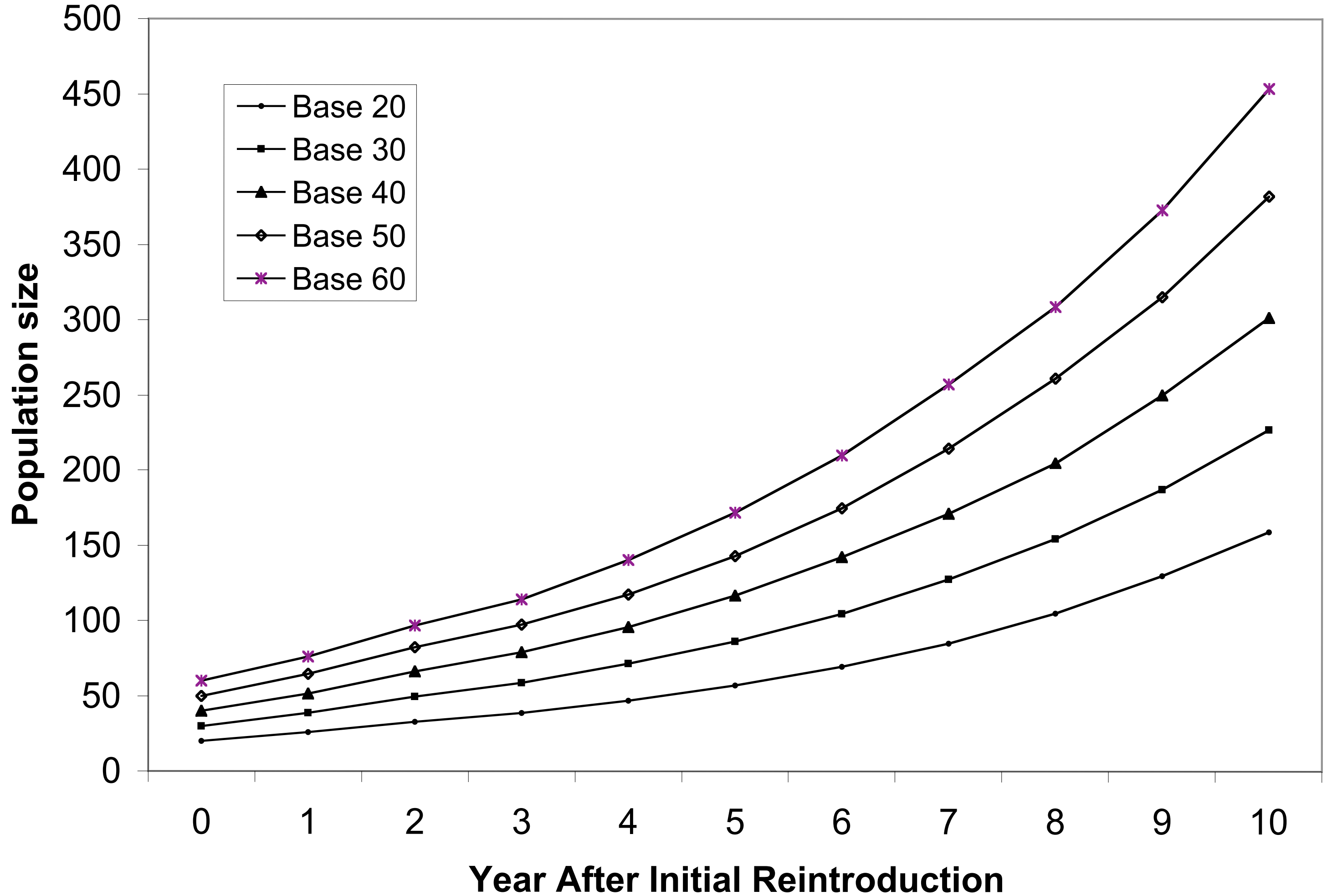

Fig. 4. Mean of all extant populations of reintroduced pygmy rabbits after 10 years, when starting with 20 to 60 reintroduced animals and no additional augmentation (single introduction baseline population models). Predicted ten-year populations (Vortex population model) range from about 159 to 454 pygmy rabbits.

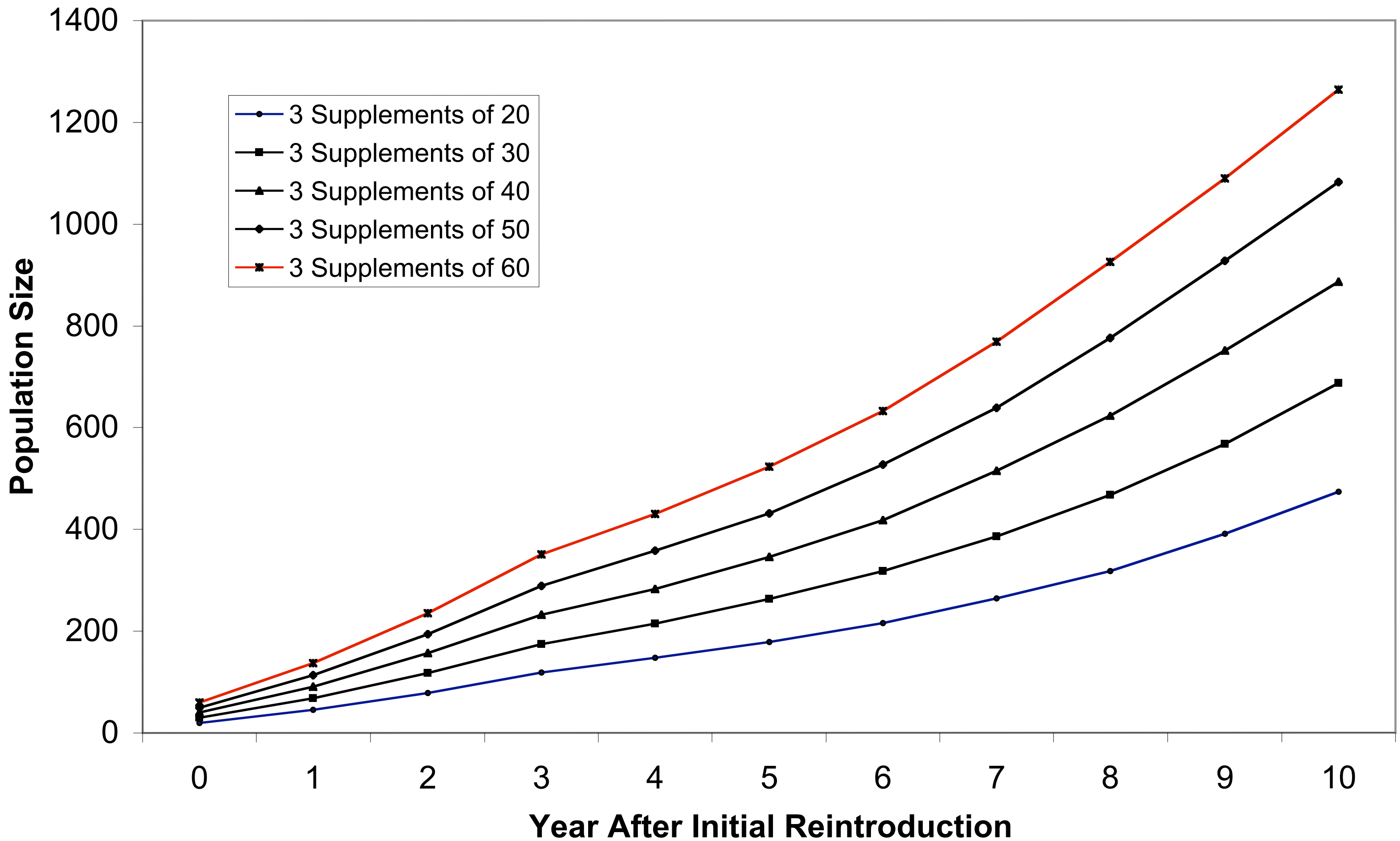

Fig. 5. Mean size of all extant populations of reintroduced pygmy rabbits after 10 years, when starting with 20 to 60 reintroduced animals and supplemented annually with 3 additional augmentations (augmentation baseline models). Predicted 10-year populations (Vortex population model) range from about 466 to 1279 pygmy rabbits.

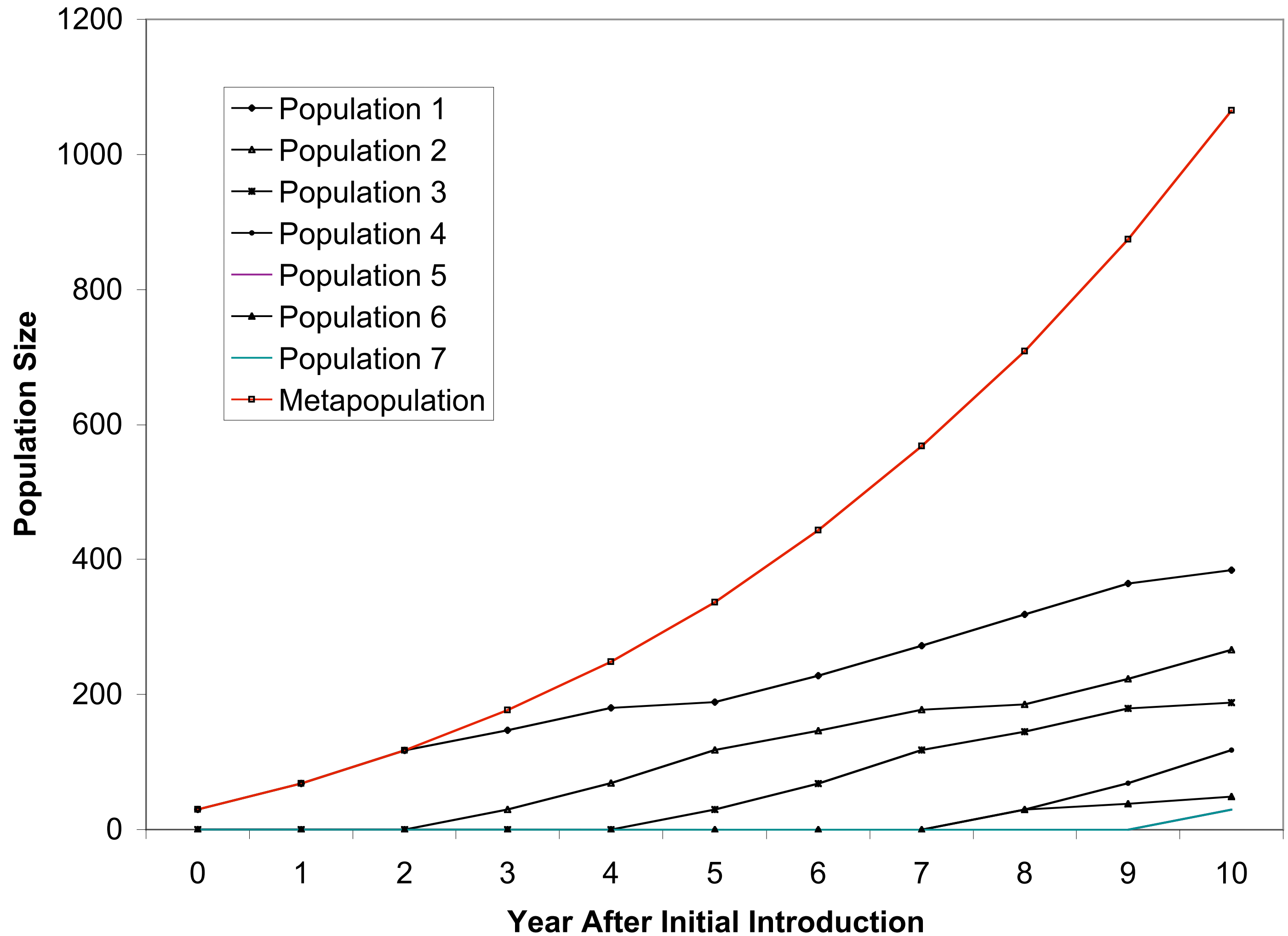

Fig. 6. Mean size of all extant populations of reintroduced pygmy rabbits after 10 years, when starting with 30 reintroduced animals, supplemented annually with 2 additional augmentations, and harvesting 30 individuals from population 1 at year 5 and population 2 at year 10 to start additional populations. Predicted ten-year populations (Vortex population model) range from about 30 to 398 pygmy rabbits with a metapopulation of 7 populations totaling about 1,065 animals.

Appendix 1. Input variables used in Vortex population modeling for Columbia Basin pygmy rabbits.

The demographic rates for mortality and reproductive potential are derived from the captive breeding program (2003-2005) because there are no estimates from the extirpated wild Washington population. The data is only from the intercross population and does not include the original Columbia Basin founders. Because reintroduced rabbits will be derived from the intercross population, these data provide the best available estimate of the expected reproduction and mortality rates and their associated variability.

Parameter	
Number of populations	1
Simulation time	10 years
Number of iterations	1000
Extinction	no animals of one or both sexes
Inbreeding depression	no (genetic diversity is tracked)
Reproduction correlated with survival	no
Catastrophes	none
Breeding system	Polygynous
Age at first breeding, male and female	1
Maximum breeding age	3
Sex ratio at birth	50:50
Maximum number of progeny/year	23
% males in the breeding pool	100
% adult females breeding	62.9
SD % adult females breeding	12.5
Mean number of young produced per female	7.1
SD mean number of young produced per female	1.48
% Juvenile mortality male and female	66.7
SD juvenile mortality male and female	5.5
% adult female mortality	45.9
SD % adult female mortality	1.3
% adult male mortality	45.9
SD % adult male mortality	1.3
Initial population size (baseline)	20 to 60 (half males and half females)
Carrying capacity	591 - 2000
SD in carrying capacity	5%