Horses of Assateague Island Population and Habitat Viability Assessment Workshop

29 – 31 March 2006
Berlin, MD, US

FINAL REPORT

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Conservation Breeding Specialist Group / SSC / IUCN

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Thank You!
September 2006

Horses of Assateague Island
Population and Habitat Viability Assessment

Berlin, MD, US
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SECTION 1

Executive Summary

Executive Summary

Background

Since the 1600s a population of feral horses (*Equus caballus*) has been present on Assateague Island, a 37-mile barrier island off the Atlantic coast of Virginia and Maryland. Although their exact origins are unknown, the first horses on Assateague may have been brought there by early colonists to avoid taxation. Today this population is managed as two herds, which are separated by a trans-island fence at the state line. The Virginia herd inhabits the Chincoteague National Wildlife Refuge and is owned by the Chincoteague Volunteer Fire Department, which manages the population size by holding an annual summer roundup to auction off most of the foals. The Maryland herd inhabits the Assateague Island National Seashore (ASIS) and Assateague State Park (ASP) and is managed by the National Park Service (NPS).

From 1968 to 1994 the Maryland herd grew from 28 to 166 horses; with this expansion came evidence of negative impacts of horses upon other species and ecological processes of the island. To address these concerns, in 1994 a concerted effort began to reduce population size through contraception using porcine zona pellucida (PZP) vaccine. Contracepted mares, however, live significantly longer, and herd reduction has been slower than initially expected.

In early 2006 the Conservation Breeding Specialist Group (CBSG) of the IUCN-World Conservation Union was requested by the National Park Service to conduct a Population and Habitat Viability Assessment (PHVA) workshop to evaluate management strategies for this feral horse population in Maryland. NPS is faced with the competing interests of managing these horses in balance with the island ecosystem, which includes several threatened species and rare plant communities, while also meeting their mandate of providing visitor opportunities to view free-roaming horses. While contraception has stalled population growth and is now leading to a decline in horse numbers, reliance upon contraception as the sole management strategy may potentially jeopardize the ecological health of the island if population decline is too gradual. Public sentiment for these high profile animals and concern for their continued well-being complicates any management strategies that involve removal of horses from the island. These issues and others can be addressed through population modeling and structured analysis by the various stakeholders within the framework of a PHVA workshop.

Pre-PHVA Planning Workshop

In preparation for the PHVA, CBSG facilitated a one-day planning workshop on 24 February 2006 at the ASIS headquarters in Berlin, MD. This meeting provided a forum for informational presentations, issue generation and discussion of management goals, and data assembly for the *Vortex* population model. The 17 participants represented a wide diversity of stakeholder interests, including Assateague Island National Seashore and State Park staff, Maryland Department of Natural Resources staff, researchers, and representatives from Cape Lookout National Seashore, the Bureau of Land Management Wild Horse and Burro Program, the American Horse Protection Association, and the Humane Society of the United States. NPS has a history of innovative, stakeholder inclusive, adaptive management of this population, and acknowledges the conflict between those who would prefer to remove horses from the ecosystem and those who desire a large population of horses in the park.

The group reviewed the past management plans for horses in ASIS and delineated six management objectives based on reoccurring themes throughout the history of park management. Participants also discussed available information on demographic rates, population trends, and management actions needed to develop the *Vortex* population model. This allowed a complex baseline model to be constructed prior to the PHVA that was then used to test various management strategies to reduce and maintain this population at target levels.

PHVA Management Goal Working Groups
Workshop participants reconvened on 29-31 March 2006 at the same venue to explore these issues in more depth in concert with a population viability assessment of this horse population. Participants discussed the NPS mandate to manage horses on Assateague as a "desirable feral species" while maintaining horse impacts on the park's natural resources at acceptable levels. The stated management goals for this population were revisited, defined and prioritized. Issues of concern related to accomplishing these goals were addressed in smaller working groups.

The resulting six management goals (in order of priority) are:

1. Reduce the negative impacts of horses on key species, communities and natural processes to levels compatible with legal mandates and the continued evolution of Assateague Island toward a natural condition.
2. Maintain a free-roaming herd of feral horses that exhibit natural characteristics and are subject to natural processes.
3. Maintain a healthy population of horses capable of successful reproduction.
4. Educate the general public on the Assateague horses, including their history, behavior, ecological impacts and scientifically-based management.
5. Recognize and utilize this population as a valuable research resource; however, management strategies shall not be modified in the interests of research.
6. Provide a reasonable opportunity for visitors to view horses safely.

These objectives are interrelated, and the management actions needed to meet them often conflict. It was therefore important to evaluate proposed management strategies with respect to impacts upon other management goals. Working groups explored these issues and developed recommendations designed to meet these objectives, incorporating NPS data and *Vortex* model results in their analyses when appropriate.

The *Ecological Impacts Working Group* identified gaps in knowledge needed to address this issue, including better knowledge of impacts due to deer vs. horse herbivory, population dynamics between these species, and the effect of horses on the dispersal of invasive exotic plant species. Recommendations included the potential exclusion of horses from the north end of Assateague Island (prime habitat for many species of concern) and one-time reduction of the horse population. Monitoring is considered essential to evaluate the effectiveness of any management actions, and should document short- and long-term changes in both impacted and non-impacted areas. Suggested indicators that should be monitored for improvement with a reduction in horse numbers include: relative size of seabeach amaranth (*Amaranthus pumilus*), a Federally listed threatened plant species; productivity of American beachgrass (*Ammophila breviligulata*) and smooth cordgrass (*Spartina alterniflora*); rate of dune formation; change in

low salt marsh elevation; and abundance or reproduction rates of salt marsh obligate fauna species.

The *Population Health Working Group* defined population health in terms of behavior, nutrition, reproduction, genetics and life history characteristics. Potential consequences of population reduction on population health were discussed, which may suggest attributes that might be monitored during population reduction as indicators of population health. These included genetic status, nutritional status, behavioral changes, sex ratio, and compensatory increases in deer numbers.

Members of this group believed that target population size should be considered in an adaptive management framework, and that goals should be ranges rather than a single number. If horses are removed, care should be taken not to reduce the number of potential breeding animals too drastically to avoid severe reductions in the reproductive potential of the population. Adjustments will be needed to the contraception program as population size decreases and the population passes through pulses in age classes before stabilizing at the desired target size. Immunocontraception rate may need to be decreased if horses are removed from the population. The group also discussed factors to be considered in the selection of individual horses to remove (e.g., age, sex, genetic background, status within its band) if this management strategy is pursued, as well as issues related to the placement of these horses. Importation of additional horses for genetic and/or demographic supplementation was recognized as a potential option if population health becomes jeopardized in the future.

The *Horse Behavior and Visitor Viewing Working Group* explored two related management goals – the maintenance of a free-roaming herd that can be observed by park visitors. Important aspects of these goals are that the horses have access to all critical resources needed to meet their biological/social requirements, including long-distance movement; that the public have access to areas of the island that provide opportunities to view horses; that horses have the ability to travel more or less freely on the island except for specific areas for which exclusion is necessary (e.g., sensitive habitat); and that permanent exclusion of horses from certain areas be avoided. Exclusion barriers should be as unobtrusive as possible. A reduction in the horse population may reduce the need to limit horse access to sensitive areas. Population management strategies should be designed and monitored so as to ensure that the behavior of the horses remains within the normal range for equids.

NPS has the responsibility to provide a reasonable opportunity for visitors to experience and learn from this resource in a positive and productive way. The working group felt that the current opportunities provided are reasonable to accommodate the public's need to experience horses. Complete exclusion of horses from developed areas of the island would severely restrict the visitors' ability to encounter horses and is not recommended. The current "problem horse" protocol used by the NPS to assess and respond to dangerous horse behavior was concluded by the group to be an appropriate and effective tool for creating safe opportunities for visitors to view horses. NPS and state park personnel should continue to collaborate on educational initiatives for visitors and staff that promote safe and appropriate visitor and horse behavior. Because the goal is to maintain horses with natural characteristics, the public should be informed

that they may see horses with injuries or poor appearances and that this is critical to maintaining the "wild" status of the horses.

Two small working groups briefly addressed the management goals related to education and research, which were not deemed to be the primary focus of this PHVA. These groups provided a description of these goals – to educate the general public on all aspects of the Assateague horses; and to recognize and utilize this population as a value research resource. The existing ASIS educational program is broad in scope, ranging from actions to improve compliance with resource protection regulations, to developing political support for potentially controversial actions. The target of these efforts is equally broad and includes local, national and international audiences.

The horses of Assateague Island represent one of a small number of free-ranging animal populations that can provide long-term longitudinal study in a natural setting and have served as a valuable research resource for decades. The development of new technologies, such as remote pregnancy testing, fetal health evaluation, ovarian endocrine function in large free-ranging wildlife, immunocontraception, and fecal DNA analysis in the field all began with the Assateague horses. The scientific legacy of Assateague wild horse research now extends worldwide and across hundreds of species. The *Research Working Group* strongly encouraged the NPS to continue their studies of these horses, recognizing that it will require a long-term continuous commitment of personnel and resources.

Vortex Modelling Results
Modelling was used primarily to project immediate short-term trends in the population size under current management contraception schemes, and to evaluate short-term accumulation of inbreeding if the population were managed at various target sizes. The horse model was validated against historical census data (1975 to present), during periods both prior to and during contraceptive management, and appears to be a reasonable representation of population dynamics for horses on Assateague.

Under current management practices, the model predicts that the population will decline to about 100 animals in about 5 to 6 years, 80 horses in 7 to 8 years, and 50 animals within 9 to 10 years. If managed at these levels, inbreeding is likely to accumulate slowly over the next 50 years to levels that are unlikely to result is any significant inbreeding depression effects. Given what is known about the demography of the population, contraceptive management schemes can likely be designed to manage the population at any of these levels. More likely, adaptive management contraceptive programs can be designed to scale the level of contraception to exactly what is needed on a year-by-year basis to manage the population very precisely at a desired level.

Population Management Options
The pinnacle discussion of the workshop addressed the complex issue of balancing the primary goals of horse management at Assateague – to maintain a healthy, reproductive, free-roaming and naturally-behaving population with little to no ecological impact on key species, communities, and ecological processes of this barrier island. At the heart of the conflict is the number of horses that should be maintained on ASIS – more horses mean greater negative ecological consequences and may require exclusion of horses from some areas, while fewer horses threaten population viability and reduce visitor viewing opportunities.

In order to address the issue of horse population size, workshop participants first discussed available information on how population size is related to population health in order to determine the minimum acceptable population size for population health. This was followed by a similar discussion of how horse numbers and densities affect the ecosystem to arrive at an estimated maximum acceptable number of horses to maintain sufficient ecosystem health. These plenary discussions helped to define a tentative range of target population sizes that balance these conflicting management goals. Through consensus the group ended up with a short-term target of 80-100 horses, with the understanding that this target will be adjusted through adaptive management as the impacts of changing population size on horse and ecosystem health are monitored.

Interventive management will be necessary in order to reduce the current population of approximately 144 horses (at the time of the workshop) down to the suggested target size of 80-100 horses. Two primary methods of population reduction were considered by the workshop participants: 1) immunocontraception to control reproduction (current strategy); and 2) one-time removal of horses to achieve target population size.

A plenary discussion of these management options included the identification of advantages and disadvantages of each. Each management option offers advantages as well as risks or costs. The primary benefit in the consideration of the removal of horses is the more immediate and greater reduction in the ecological impacts of horses on the island. It was estimated, however, that it would take about two years to secure approval and to organize logistics for a large-scale horse removal. In comparison, *Vortex* model projections suggest that the target size of 80-100 horses may be reached in 5-8 years using the current immunocontraception strategy. In order for horse removal to offer greater ecological benefit, this strategy would need to be pursued and executed in a timely manner.

A third management strategy was considered – the use of a combination of immunocontraception and removals rather than complete dependence upon one type of management. In a broad sense, this is what the NPS is doing now, as they have removed problem horses in the past (primarily before full-scale immunocontraception efforts). A combined management strategy could expand upon this by also removing select horses for population management purposes. Advantages of this combined approach include its flexibility and the opportunity to take advantage of the benefits of both strategies. This would allow the ability to deal with problem horses and potentially other more straightforward removals while avoiding some of the disadvantages of both methods. A majority of the participants were comfortable with this intermediate approach. Regardless of the strategy chosen, recommendations were made to continue contraception and monitoring of the horse population, to continue protecting a portion of the seabeach amaranth population from horse grazing until the targeted horse population size is achieved, and to prepare the public for possible removals through an intense education program.

Management Decisions and Implementation
The purpose of this PHVA report is to serve as a pre-planning document and is advisory to the National Park Service for consideration in their development of a management strategy for feral horses on the Maryland portion of Assateague Island. This document deals only with the Maryland horse population and is not related to the management of horses in Virginia.

The National Park Service outlined a series of steps that it envisions will follow this workshop in the continuing development of management plans for ASIS horses:

- Conduct scoping to understand public concerns associated with the Assateague horses.
- Use that information and PHVA results to develop potential management alternatives.
- Evaluate the environmental impacts of those alternatives.
- Present the resulting analysis in a draft Environmental Assessment of Alternatives (EAoA).
- Distribute the draft EAoA for public and agency review.
- Consider the public's comments on the draft EAoA and identify a selected alternative.
- Prepare a decision document if no significant impacts.
- Implement the selected management alternative.

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SECTION 2

Summary of Pre-PHVA Planning Workshop

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Pre-PHVA Planning Workshop
In preparation for the PHVA workshop scheduled for 29-31 March, CBSG facilitated a one-day planning workshop on 24 February 2006 at the ASIS headquarters in Berlin, MD. The 17 participants represented a wide diversity of stakeholder interests, including Assateague Island National Seashore and State Park staff, Maryland Department of Natural Resources staff, researchers, and representatives from Cape Lookout National Seashore, the Bureau of Land Management Wild Horse and Burro Program, the American Horse Protection Association, and the Humane Society of the United States.

The group reviewed the past management plans for horses in ASIS and delineated six management objectives based on reoccurring themes throughout the history of park management. Participants also discussed available information on demographic rates, population trends, and management actions needed to develop the *Vortex* population model. This allowed a complex baseline model to be constructed prior to the PHVA that was then used to test various management strategies to reduce and maintain this population at target levels.

Management Objectives
The meeting began with a series of plenary presentations by NPS staff and researchers related to the history, ecology, management, and genetic analyses of the Assateague horses. The group then reviewed the past management plans for horses in ASIS and delineated four management objectives based on reoccurring themes throughout the history of park management. Two additional objectives were added in recognition of the research and education value of this population.

1. Reduce the negative ecological impacts of the horses to acceptable levels to maintain the native species and natural processes of the island ecosystem.
2. Maintain a free-roaming herd of feral horses that exhibit natural characteristics and behavior.
3. Maintain a healthy herd of horses capable of reproduction.
4. Provide a reasonable opportunity for visitors to view horses safely with minimal negative human-horse interactions.
5. Educate the general public on the Assateague horses, including their history, behavior, ecological impacts and management.
6. Recognize and utilize this population as a valuable research resource in the context of a natural laboratory.

These objectives are interrelated, and the management actions needed to meet them sometimes conflict with each other. This emphasizes the need to clearly define and prioritize these objectives, and to evaluate proposed management strategies with respect to impacts upon all six objectives.

The participants next discussed each of these objectives to identify key issues and questions to be considered during the PHVA workshop. In some instances, the need for additional data

collection and/or analysis was determined, and individuals agreed to take on these tasks prior to the PHVA. These discussion points are summarized below for each objective.

1. Reduce Ecological Impacts

The horses of Assateague represent a desirable feral population of historic and cultural significance to the island. It is not surprising, however, that a large population of this non-native species can adversely affect island flora and fauna and natural ecological processes. Preferential grazing by horses has been shown to alter plant species abundance and reproductive potential as well as community structure, with cascading effects on animal species dependent upon these communities. Horse grazing has also been shown to interfere with dune formation and stabilization processes, ultimately reducing the protective characteristics of the island dune system. Horses can also affect other animal species directly (e.g., disturbance of threatened piping plover breeding grounds). These impacts are related both to the number of horses present (e.g., overgrazing effects) as well as their habitat use and migration patterns. Behaviorally, it is believed that horses prefer the more fragile dune habitat in the summer to escape flies; this space use pattern has escalated in recent years as horses congregate in the northern, more sensitive area of the island during the summer, where their ecological impacts are greatest.

Immunocontraception has been used systematically since 1994 to limit reproduction in this herd. Because extended contraception has led to increased longevity of mares, the population remained relatively stable until 2005 and is just now demonstrating a decline in numbers. There is some concern that it might take too long for the population to decline substantially using contraception as a sole control method. In addition to concerns of possible demographic implications (see *Healthy Herd*), this management strategy would not immediately reduce or reverse the ecological changes caused by horses on the island. The removal of a number of horses from the population is an alternative management option that could be used in concert with contraception to provide a more immediate reduction of negative ecological impacts by horses. Management will also need to address the long-term control of horse numbers to avoid population expansion and increasing negative impacts in the future.

- There is a need to identify ecologically sensitive areas (see ASSIGNMENT under Free-Roaming Herd).
- What is an acceptable level of impact? This needs to be defined.
- What are the indicator species (or other ecological indicators) that should be used to monitor and assess horse impact? Horses can impact species of concern, plant communities, and land topography.
- What mitigating effect will a horse herd reduction have on these sensitive ecological parameters? There is a need to gather baseline data and put monitoring in place in order to assess the effects of herd reduction.
- What are the ecological impacts of the sika and white-tailed deer in ASIS? Sika deer are controlled/harvested via a hunting season. There is currently on ongoing study comparing habitat use and impacts of horses and deer.
- How do deer densities affect resources/habitat for horses?
- Is there a need to reduce deer numbers? Current winter population estimates for ASIS deer are about 400 sika and 100 white-tailed deer.
- The energetic requirements of Assateague horse and deer populations should be understood in order to fully comprehend the proportional impact of each population.

- If horse numbers decrease, what will happen to deer numbers?
- There is a need to prioritize impacts (which are most critical to reduce) and assess resources available to implement management strategies.
- What is the target population size for horses to meet the main objectives? This is difficult to determine with the currently available data. Although estimates can be made, it is likely that the NPS will adopt an adaptive management approach and will adjust the target population size based on indicators (this will likely be a recommendation of the PHVA).
- Given the impacts that have already occurred to the ecosystem, do we need to reduce the horse herd even more at first than indicators or analyses suggest to enable ecosystem recovery?
- If a horse removal management strategy were adopted, what might be the best removal strategy to reduce ecological impacts (number of horses, removal schedule, which horses to remove, etc.)? (see Healthy Herd discussion). Greater understanding may result from removing horses in stages, while a one-time reduction would lead to a quicker reduction of impacts and require less handling of horses (thereby reducing negative consequences of handling).
- Is it better to remove individuals from across the park, or entire bands?

2. Maintain a Free-Roaming Herd

Since the establishment of ASIS, the general philosophy regarding horse management has been that the herd should not be contained but rather free roaming as part of the island ecosystem. Due to the negative impacts of horses on other species, particularly threatened species and plant communities, and the resulting cascading effects on ecological processes such as dune formation and erosion, it has become desirable to restrict access by horses to certain areas (e.g., sensitive habitats, threatened species nesting areas). Restriction of other areas, such as around visitor campgrounds, might also be used in an effort to reduce negative human-horse interactions. Understanding how and why horse bands utilize and migrate through the habitat will aid in managing their movements and habitat utilization.

- How much restriction is acceptable for a "free roaming" herd?
- It was recognized that some restrictions are needed only seasonally; however, it might not be practical to restrict areas only on a seasonal basis.
- Visitor perception is important; the population needs to be perceived as a free roaming herd.
- How should we define "free roaming"? Perhaps as having access to all biological requirements for a healthy herd (e.g., food, water, refugia from flies, ability to avoid people, ability to migrate between bands).
- How might population reduction affect band size, home range, area use, migration?
- GIS data may be used to identify essential habitat components to aid in determining possible area restrictions.
- GIS data may also be useful in analyzing habitat differences for horse bands that migrate and those that do not (perhaps in response to flies).
- Are there behavioral aspects between bands (dominance/territoriality) that affect area use and migration (e.g., competition over a restricted resource)?
- What are the expectations of the visiting public? No information currently exists from visitor surveys, etc.
- There is little visitor use of the northern portion of ASIS, where negative impacts of horses are greatest; there may be fewer objections to restricted areas there.

- There is a need to identify potential areas where horse access should be restricted, such as:
  - North end of island (north of ASP)
  - Developed areas
  - Selected areas where horses tend to congregate
  - Sparsely vegetated habitat
  - Critical areas for threatened species
- There is an inherent conflict: sensitive areas often coincide with areas preferred by horses. It may or may not be that if horse density is reduced, this will translate into lower impact.
- ASSIGNMENT: Complete spatial analysis of these conflict areas (NPS staff).
- ASSIGNMENT: Provide data and maps at the PHVA that indicate areas that meet biological requirements (fresh water, etc.) (NPS staff).
- ASSIGNMENT: Compile from historical data where bands spent time during large fly hatches and evaluate the attributes of those areas (this may be difficult to do before the PHVA) (NPS staff).

3. Maintain a Healthy Herd

Horse populations generally are capable of fairly rapid growth. The ASIS herd exhibited about 7% annual growth for the 20 years prior to contraception despite the transfer of 44 horses to the Virginia herd during that time. To remain viable and reproductive, the Assateague horse herd must be both demographically and genetically healthy. This includes maintaining an age-sex structure that provides for some minimum level of reproduction and retaining enough genetic variability to avoid significant inbreeding effects and other consequences of low genetic variation. The smaller the population, the more significant these problems become due to stochastic processes; yet, population size needs to be controlled to reduce negative ecological impacts on the island.

There is concern over the continued implementation of the present contraception strategy, as it may lead to permanent sterilization of older mares and leave the population with too few potential breeders. Immediate removal of horses from the population needs careful evaluation from both biological and political perspectives, including an evaluation of factors determining the selection of individuals to remove. It was recognized that this has probably not been a closed population in the past. Other East Coast feral horse herds may be able to serve as donor populations if needed.

- How do you define "healthy" herd (in terms of growth rate, genetic diversity, etc.)?
- Given the current age structure, is there a need to back off on contraception and allow more future breeding to produce more breeders? This would lead to the need to remove horses to contain the population.
- If a horse removal management strategy were adopted, what is the best removal strateg(ies) to promote demographic and genetic health?
- What factors should be use to select horses to remove (e.g., age, genetic characteristics, behavioral characteristics)?
- What management strateg(ies) are best for long-term maintenance of horses at the target population range?
- The consequences of various contraception and/or removal strategies can be explored using the Vortex population model that simulates the stochastic processes to which small

populations are vulnerable. A matrix of management strategies will be evaluated using various combinations of:
- Target population size (20, 40, 60, 80, 100, 120)
- Timeline (1, 2, 5 yrs)
- Number of removals (all at once vs split between multiple events)
- Methods (contraception, removal, both)
- For the long-term health of the herd at reduced population size, it may not be possible to maintain this herd as a closed population. Vortex can be used to test the effects of supplementing the ASIS herd with horses from other barrier island populations.
- ASSIGNMENT: CBSG needs the following information for each living horse before the PHVA workshop to begin development of the Vortex model; NPS and Lori will provide the information to Jon and Kathy.
    - Band
    - Contracepted status, including nonresponsiveness to contraception
    - Horses with nuisance (undesirable) behaviors
    - Horse with rare alleles
- ASSIGNMENT: NPS will provide CBSG with needed estimates for catastrophes (diseases, storms, etc.), including the expected frequency and the effect on horse survival, reproduction and habitat (carrying capacity for horses); NPS will contact the Chincoteague National Wildlife Refuge for information on the effects of the 1962 storm.

4. Provide Safe Viewing Opportunities
Assateague horses are valued primarily for their cultural rather than ecological significance. Opportunities for visitors to view and experience horses therefore are important aspects of management. Visitor behavior, such as feeding of horses, can negatively influence both horse health and behavior. The development of nuisance behaviors is not only counterproductive to maintaining a healthy and naturally behaving herd, but also jeopardizes the safety of visitors interacting with horses. In the past some individual horses have been transferred out of the population due to undesirable behavior toward humans.

- What kinds of horse viewing experiences do visitors want? What are their expectations?
- Should problematic horses displaying nuisance behaviors be removed from the population?
- There are some educational efforts and regulations in place to discourage undesirable visitor-horse interactions.

5. Educate Public
Public awareness and education can be a tool to accomplish many of the previously described objectives. Education itself, however, is also considered by the workshop participants to be a specific objective of the management strategy for horses on Assateague. This includes information on the history of the horse herd, behavior, ecological impacts, and management strategies. Current educational efforts should be adjusted to reflect these issues.

6. Utilize Research Resource
The nature of this island ecosystem allows it to serve as a "natural laboratory", and it has been the focus of many past research efforts both on horses and on other aspects of the ecosystem. The

participants recognized this valuable research resource, and encourage its appropriate use in future research, within limits, as a management objective.

Developing a Population Model

Computer modeling is a valuable and versatile tool for assessing population viability. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to evaluate the effects of alternative management strategies to identify the most effective management actions to achieve population goals.

A *Vortex* population model for the ASIS horse population was developed prior to the PHVA to examine the effectiveness of various management strategies and the resulting viability of the horse population. *Vortex* is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. To build the baseline horse model, detailed information was needed on demographic rates, population trends, and management actions. Participants at the planning workshop identified the following potential sources of information for model development:

- Life history information: All Pony Access dataset (NPS); Underwood's study on precontracepted life history data (unpublished PVA); also check with Gus Cothran
- Age of first reproduction: Keiper study
- Maximum age of reproduction: 18-20 years, based on estimates from pre-contracepted data
- Mating system: long-term polygyny (stallions keep harem for several years); there are also bachelor herds; NPS can provide estimates of the percent of males that sired young (or percent of males in harem vs. bachelor herd/lone)
- Percent females breeding (per year): NPS
- Inbreeding depression studies: None identified; maybe check for domestic horse breeds
- Contraception success: Information available from NPS; Pryor study; Rubenstein (population growth and contraception; unpublished); Kirkpatrick monograph
- Catastrophes: Horses are affected by Category 3 storms and higher; NPS will get the return rates for these storms for Assateague. There have been 2 storms in past 20 years, lost 0 and 12 horses (horses were in a low lying area and drowned; most horses on the island have a protected area in which to take refuge during storms). The Virginia Chincoteague Fire Department may have information on the effect of the 1962 storm on their horse population (NPS will inquire). Based on past observations it was decided for the purpose of modelling that storms have the greatest effect on survival and no effect on reproduction or carrying capacity; however, there is the potential for severe storms to affect large areas of habitat.

This population provided an interesting situation to model in *Vortex*, incorporating an existing pedigree, demographic characteristics based on the changing contraceptive status of each female, and testing various contraception and removal strategies. The plethora of data available for this population allowed the development of a detailed and complex model that could be validated against historical population trends.

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SECTION 3

Horse Behavior and Visitor Viewing Working Group Report

Horse Behavior and Visitor Viewing Working Group Report

Members: Cineva Kline, Jack Kumer, David Powell, Andrew Roach, Allen Rutberg, Allison Turner, Raj Williams.

This working group was tasked with further development of two management goals for the horse population on the Maryland portion of Assateague island that were identified in the first PHVA meeting on February 24, 2006. The group reviewed the wording of these goals, identified areas of ambiguity that needed clarification, discussed issues that would arise in the implementation of management programs to achieve these goals, and made recommendations about how the revised goals could be achieved while addressing the issues. The revised goals are presented below. Words or phrases in the goals that the group felt were in need of clarification or further discussion are underlined.

Management Goal: Maintain a <u>free-roaming</u> herd of feral horses that exhibit <u>natural characteristics</u> and are subject to natural processes.

"Free Roaming"
The main thrust for keeping horses free roaming is that they are being managed as a desirable population on the island because of their ability to exhibit characteristics of free-roaming equids. To that end, the population should have access to all natural resources that horses need to meet their biological/social necessities. In addition, we recognize the natural history value of this population and its appeal to the public. To support that, the public should have access to portions of the island that provide opportunities to view areas commonly used by horses. The "free roaming" characteristic is important to the horses, the NPS, and the public.

1. The working group felt that free roaming in this context means that horses have the ability to travel more or less freely on the island, except for specific areas that are determined to be incompatible with horse use. Examples of incompatible areas include sensitive resources (including areas that are severely degraded now) and areas where humans and horses are likely to have harmful contact.

2. It is recognized that the structure of the island, human use of the island, and the horse population will change over time, so the need to protect specific areas will also change over time. For that reason, and because permanent barriers are perceived as diminishing the free roaming characteristic of the horses, the group felt that permanent barriers to horses should be discouraged.

3. It is acknowledged that a horse population reduction may reduce the need to limit horse access to sensitive areas.

The group recommended that access to important biological resources be maintained if restrictions are proposed. These include forage, fresh water sources, fly relief sites, and seasonal thermal cover. In addition, natural behavioral processes such as migration and dispersal should

not be obstructed. A second concern was that visitor perception of free range status be maintained. Therefore, any barriers should be designed to be as unobtrusive as possible.

"Natural Characteristics"
NPS and the public also wish to have horses that exhibit natural characteristics. These include physical appearance, behavior and social organization. As such, horses are expected to occasionally display wounds, injuries and poor condition, and be exposed to storms, biting insects, parasites and diseases.

It is likely that any population management will have some impacts on behavior, but the working group recommended that management efforts be designed to maintain horse behavior within the normal range for equids.

Summary Recommendations
Based upon these discussions, the working group made the following recommendations:

1. Horse access to critical biological and social resources must be maintained at all times. This includes opportunities to undertake long distance movements. Any plans for excluding horses from portions of the island should take this into account.

2. Permanent exclusion of horses from portions of the island should be avoided.

3. Exclusion plans should also be designed to eliminate or minimize the risk of diminishing the public's perception that the horses are free roaming.

4. Population management strategies should be designed and monitored so as to ensure that the behavior of the horses remains within the normal range for equids.

Management Goal: Provide a <u>reasonable opportunity</u> for visitors to view horses <u>safely</u>.

"Reasonable Opportunity"
The public has a range of expectations when they visit Assateague Island. NPS has the responsibility to provide a reasonable opportunity for visitors to experience and learn from this resource in a positive and productive way. The group's working assumption was that visitors want to see horses in person and would not be satisfied with seeing horses only via videotape or live remote cameras at the National Park's visitor's center.

The park currently offers a variety of opportunities to experience horses. These include roadside pull-offs, trails, the pedestrian bridge, and other developed areas of the park, with additional facilities planned. Assateague also supports a range of eco-tour activities that provide access to horse habitat. The working group felt that these opportunities are reasonable to accommodate the public's need to experience the horses.

The majority of the current viewing opportunities are located in the developed areas of the island. Complete exclusion of horses from that area would severely restrict the visitors' ability to encounter horses, and therefore is not recommended by the working group. The group felt that

partial exclusion of horses from the developed area may be appropriate as long as it does not eliminate the opportunity to view horses in the developed area. Reducing horse density in developed areas by selective removal is considered appropriate with the understanding that removed horses are likely to be replaced naturally through dispersal. Two suggestions were offered for trying to maximize the likelihood of visitors seeing horses in developed area, if a reduction in herd density in that area occurred. One suggestion was that horses could somehow be enticed to spend time in areas where they would be visible to the public. The group was concerned about the likelihood that this practice would diminish the free-roaming and natural characteristics of the herd and therefore did not recommend this approach. It was also suggested that information could be provided to visitors that would inform them of viewing locations where horses are most likely to be visible. The group did not discuss this idea in detail but felt this would be a workable possibility if horses became more difficult to view in the developed area following a localized reduction in horse density.

"Safely"
The park relies on a combination of education and varying degrees of regulation enforcement to ensure safety for visitors and horses alike. Education initiatives include: signage, graphics, interpretive material, radio announcements and visitor contacts. There was a suggestion that additional educational efforts related to horse biology and safe behavior around horses be directed at seasonal and lifeguard staff in the state and national park areas. In group discussion it was recognized that greater collaboration on public and staff education between the national park and state park would advance progress toward the goal of providing safe opportunities for horse viewing and ensuring positive interactions between horses and visitors. Enforcement initiatives include verbal warnings by roving volunteers and park employees, and citations issued by law enforcement personnel.

NPS also has a "problem horse" protocol to guide NPS in the assessment of and response to dangerous horse behavior. This protocol was described by NPS staff for the working group, and the group felt this was an appropriate and effective tool for creating safe opportunities for visitors to view horses.

Summary Recommendations
The working group made the following recommendations related to visitor viewing of horses:

1. Total exclusion of horses from the developed area of the park is incompatible with achieving this management goal and is therefore not recommended.

2. If population management strategies lead to a decrease in horse density in developed areas of the park, the NPS should investigate ways to maintain the likelihood that visitors would still be able to view horses there.

3. NPS and state park personnel should continue to collaborate on educational initiatives for visitors and staff that promote safe and appropriate visitor and horse behavior.

Additional Recommendations Related to Education and Research
During the working group sessions, a number of recommendations were made regarding education programs for the public. The group also recommended one research directive. These are outlined below:

1. Inform the public about what "free roaming" and "wild" means to the NPS.

2. Related to this, the public should be made aware that since the horses are free roaming, the visitors may not see them during their visit.

3. Because the goal is to maintain horses with natural characteristics, the public should be informed that they may see horses with injuries, unkempt appearances, etc. and that this is critical to maintaining the "wild" status of the horses.

4. The rules and guidelines for safe visitor conduct around horses should be reviewed by NPS to ensure that they are appropriate for various types of visitors, specifically pedestrians, cyclists, and motorists.

5. Research that seeks to determine exactly what expectations visitors have regarding their interaction with horses should be initiated, and after their visit, visitors should be surveyed as to how their experience met their expectations.

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SECTION 4

Ecological Impacts
Working Group Report

Ecological Impacts Working Group Report

Members: Dave Brinker, Jay Charland, Bill Haglan, Mark Sturm, Wayne Tyndall, Carl Zimmerman.

This working group addressed the management goal related to reducing the ecological impacts of horses on Assateague. Two issues received particular emphasis during discussion of the goal. The first centered on the park's legal mandate under the Threatened and Endangered (T&E) Species Act to ensure the conservation of listed species. This requirement places a special burden on the park to manage horses in ways that fully support the protection of T&E species. Seabeach amaranth (*Amaranthus pumilus*) is Federally listed as threatened and is particularly well understood to be significantly impacted by horse grazing. The second issue related to the ecological condition of Assateague Island. The working group felt it was important to recognize that historic activities (e.g. intensive livestock grazing, residential development) have significantly influenced the current state of Assateague Island, and that there is an imperfect understanding of what constitutes natural conditions. After discussion, the group refined the wording of the management goal to read as follows:

Management Goal: Reduce the negative impacts of horses on key species, communities and natural processes to levels compatible with legal mandates and the continued evolution of Assateague Island toward a natural condition.

Issues Related to Goal

The working group identified and discussed several issues related to the ecological impacts of horses. The first of these discussions focused on the state of knowledge regarding horse impacts on the barrier island environment, and generated a list of the types and mechanisms of impacts, and the affected organisms and processes. This was followed by a discussion of existing horse impact monitoring programs and potential opportunities for refined and/or enhanced monitoring. From this, the working group identified priority issues where the significance of the impact and/or the feasibility of monitoring and assessment protocols suggested a high potential for use as long-term indicators of ecological condition. Lastly, the working group identified several areas where a lack of knowledge is impeding the understanding of how the horses influence the island ecosystem.

Types of Horse Impacts

Over the years many studies have documented horse herbivory effects on Assateague Island, and still other monitoring projects are ongoing today. These research projects have typically focused on understanding the influence of horse herbivory within specific island plant communities. Collectively this body of research has allowed us to understand many of the detrimental ecological impacts horses currently have on Assateague Island.

Herbivory Impacts
- Reduced vegetative diversity
- Reduction in vegetation cover

- Alteration of plant community composition
- Reduced reproductive capacity
- Loss of functional value (e.g. nutrient cycling, primary productivity, habitat)
- Disruption of plant succession processes
- Decreased dune stability and inhibition of dune formation processes
- Reduced abundance of rare species (e.g., seabeach amaranth, a Federally listed threatened species)

Physical Impacts
- Damage to vegetation from trampling and rubbing (direct mortality or loss of vigor)
- Disruption of soils (breakup and/or compaction)

Fish and Wildlife Impacts
- Disturbance of ground nesting birds (e.g. piping plover, colonial waterbirds)
- Loss of habitat for marsh-dependent birds and estuarine aquatic species

Indirect Impacts
- Loss of biodiversity from habitat modification and herbivory
- Reduced capacity to respond to sea level rise (disruption of salt marsh sedimentation processes and dune functionality)

Potential Opportunities for Monitoring Horse Impacts on Assateague
- Smooth cordgrass (*Spartina alterniflora*) as proxy for salt marsh community
- American beachgrass (*Ammophila breviligulata*) as proxy for dune community
- Sea rocket (*Cakile edentula*) as proxy for beach community
- Rare plants, including Seabeach amaranth and state listed species
- Birds (distribution and abundance of piping plovers, rails, sharp-tailed sparrows, seaside sparrows)
- Crustaceans (distribution and abundance of fiddler crabs and periwinkles)
- Community succession (beach-dune-shrubland-maritime forest)
- Wildlife habitat value
- Dune formation
- Marsh elevation and sedimentation processes
- Island geomorphology (changes in sand mobility and patterns of deposition)
- Accelerated island migration
- Increased sand mobility

Priority Issues
The following issues were identified for priority consideration in long-term efforts to achieve a sustainable balance between protecting the island ecosystem and the horse population. All of the issues involve measurable indicators of ecological impacts based on established datasets. Other issues listed above were considered but not recommended for future monitoring. Selection was based on ease of measurement, understanding of the cause-effect relationship between horses and the impacted resource, and the existence of a quality dataset. While importance of the resource issue was a consideration, this does not mean that non-selected issues are unimportant.

- Horse herbivory reduces amaranth size, abundance, distribution, and reproductive capacity (lower seed production). Ongoing research has demonstrated that horse herbivory is a primary factor limiting amaranth recovery on Assateague Island.
- Horse herbivory reduces the abundance and distribution of salt marsh obligate breeding birds (e.g. rails, sharp-tailed sparrow).
- Horse herbivory reduces the primary productivity and vigor of *S. alterniflora* (saltwater cordgrass), altering species composition of salt marsh plant communities.
- Horse herbivory reduces the abundance of *Ammophila breviligulata* (American beach grass), increasing dune instability and preventing new dune formation; essential processes for maintaining the integrity of barrier island ecosystems.

Knowledge Gaps
The following topics were identified as areas where there is a need for more information in order to address the issue of horse impacts.

Horse vs. Deer Impacts
White-tailed deer (*Odocoileus virginianus*) and the non-native sika deer (*Cervus nippon*) also inhabit Assateague Island. The working group recognized the need to be able to distinguish between the impacts of horse and deer herbivory. In addition, the group felt a system should be put in place that assures that any reduction in the horse population will not result in an expansion in the Assateague deer populations, resulting in a "no net gain" effect. These concerns have been and will continue to be incorporated into the park's management strategies.

The proportional impact of deer versus horses is being documented in several island communities. Horse population censuses and deer population estimates can be used to estimate the relative energetic requirements of these populations and correspondingly the relative impact of each population on island's resources.

Invasive Plant Species
Invasive exotic plant species and the potential role that the Assateague horses play in their dispersal is an issue that is poorly understood at this time. It should be noted, however, that a graduate student thesis project is currently investigating the role of horses in seed dispersal on Assateague Island.

Recommendations
Several strategies may be available to address the ecological impacts of horses on Assateague. These strategies are interrelated and could be used in combination to achieve the management goal of reducing ecological impacts. These strategies are:

- Changing the distribution of horses
- Changing the density of horses
- Mitigating the impacts of horses

1. Changing the distribution of horses on Assateague Island.
Managers can influence the distribution of horses on Assateague via containment, exclusion, and/or habitat manipulation. However, the maintenance of a free-roaming herd may be compromised should management begin to consider these options on a landscape level. Care should be taken to not cause additional detrimental effects in areas where horses are contained or concentrated.

Excluding horses from the north end of Assateague Island would potentially make it possible to achieve the management objective for many species of management concern. Given the relative importance of this part of the island to species of concern, this management strategy might give the park a "big bang" toward accomplishing the stated objective.

2. Reducing the number of horses on Assateague Island.
It may be desirable to consider a large, one-time reduction of the horse population, and then allow the remaining horse population to reproduce freely for a time while monitoring the response of the island as the population increases. This strategy would provide an opportunity to monitor ecological conditions and processes as the horse population shifts from a low density to a higher density, rather than evaluating changes starting with a large population that is periodically reduced to achieve some vegetation criterion.

Monitoring the ecological response to a reduction in the horse population should include consideration of both short- and long-term changes. There already exists a suite of vegetation community parameters that would be able to capture these different time-scale responses.

3. Mitigating the impacts of horses on specific resources.
In certain circumstances, it may be feasible to mitigate horse impacts through discrete actions in localized areas or for some portion of an affected population. For example, an ongoing program to reduce horse grazing on seabeach amaranth through the use of exclosure cages has successfully increased the average size of plants and seed production. Other potential mitigation opportunities include supplementing impacted populations with greenhouse grown plants, or using chemical deterrents to reduce grazing pressure. Actions such as these, however, are costly and labor intensive, and may not be sustainable over time. In general, the working group believed that it will be more efficient to broadly reduce resource impacts by achieving an appropriate horse population size.

4. Monitoring the vegetation communities' response to a reduction in horse density..
Monitoring is essential to evaluate the effectiveness of any management actions, and should always attempt to compare impacted versus non-impacted areas.

American Beachgrass/Dune Development
A program could be designed to monitor changes in American beachgrass (*A. breviligata*) abundance and dune formation. Horse density should be monitored as part of any impact monitoring program in order to correlate acceptable levels of grazing impacts with horse density. This would help determine the horse density at which appropriate rates of dune formation are re-established, a process that is currently being interrupted by horse herbivory.

Seabeach Amaranth
Data from previous monitoring of seabeach amaranth (*A. pumilus*) suggest that a moderate-sized horse population of 100 horses would continue to have unacceptable negative impacts on amaranth. Under conditions that exist today a density of 3 horses per square kilometer has led to a 40% reduction in average amaranth size and significantly reduced its survival and reproductive rates. Therefore, horse density may have to be lowered to a level below 3 horses per square kilometer in order to permit amaranth to successfully grow and reproduce.

Changes in horse behavior and habitat utilization patterns resulting from a smaller horse population may, however, influence the degree to which horses affect amaranth size and reproduction. Horse density should continue to be monitored along the length of the island and compared with average amaranth size. Additionally, Maryland amaranth should be compared to amaranth from Virginia, which is not exposed to horse grazing. A target amaranth management objective might be to have the average size of Maryland plants achieve a set percentage (80% or 90%) of that of Virginia plants. This would promote an increased probability that a viable population of seabeach amaranth could be maintained over the long-term on the Maryland portion of Assateague Island.

In addition to amaranth, there exists a suite of state threatened and endangered plant species that also occur in the sparsely vegetated habitats of the upper beach and overwash flats and fans. These species are also being affected by horse herbivory and would similarly benefit by reducing the number of horses on Assateague. Success in increasing the average size of amaranth on the Maryland end of Assateague would likely also result in improved conditions for these species.

Smooth Cordgrass/Marsh Elevation
The impacts of horse density on salt marsh elevation and the marshes' ability to increase in elevation in response to rising sea levels should be more completely understood. A program to monitor and assess salt marsh elevation and sedimentation processes on Assateague Island is scheduled to begin in 2006-07.

A program to monitor low salt marsh productivity is already taking place in several marshes at ASIS. This program has been designed in part to document grazing impacts and should be able to detect responses (increased productivity, altered species composition, changes in surface elevation) by ASIS low salt marsh communities to a reduction in the number of horses.

5. Monitoring impacts on salt marsh obligate bird species.
Along with the vegetation parameters listed above, the value of the low salt marsh as wildlife habitat for salt marsh obligate fauna is a parameter that should be monitored and used to help determine appropriate horse densities given the apparent high sensitivity of these species to low horse densities.

Horse densities per unit area of low salt marsh currently range from approximately 1 horse per hectare to 1 horse per 12 hectares. The abundance of salt marsh obligate fauna should be monitored along this density gradient as well as on the mainland in order to determine acceptable horse densities that will allow populations of these obligate species to exist.

A monitoring program could be designed to detect a response by salt marsh obligate birds, focusing on sharp-tailed and seaside sparrows, to a reduction in horse density (via removal of horses or fencing them out of specific areas). Changes in both sparrow populations would likely be mirrored by similar responses in the more secretive rail populations.

6. Developing objectives for species and processes of concern.
The working group believed that specific objectives should be developed for each monitored species or process that are designed to achieve a targeted level of improvement. Examples include: relative size of amaranth, productivity of American beachgrass or smooth cordgrass, detectable increased rate of dune formation, and an increase in the abundance or reproduction rates of salt marsh obligate species. These measures should be monitored as part of any implemented horse impact reduction activities.

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SECTION 5

Population Health
Working Group Report

Population Health Working Group Report

Members: Jon Ballou, Dean Bolstad, Lori Eggert, Jay Kirkpatrick, Jack Kumer, Robin Lohnes, Aurelio Malo, Jesus Maldonado, Stephanie Manka, Sue Stuska.

Defining the Management Goal
This working group addressed the management goal related to the health of the Assateague horse population. After preliminary discussion of this issue, the group agreed on the following definition of this management goal:

Management Goal: Maintain a <u>healthy</u> population of horses <u>capable of successful reproduction</u>.

The group recognized the need to further discuss and define the underlined terms in the management goal, as follows:

"Healthy"
This management goal focuses on the health of the herd (population), not on the health of individual horses. A healthy herd would exhibit the following characteristics that define various aspects of health:
- <u>Behavior</u>: Demonstrates social organization and behaviors consistent with the species [wild horses]; free-roaming implied.
- <u>Nutrition</u>: Exhibits average body condition that is indicative of adequate nutrition.
- <u>Reproduction</u>: Capable of sustaining target population size through adequate reproduction.
- <u>Genetic</u>: Maintains sufficient genetic diversity to avoid deleterious effects of inbreeding.
- <u>Life History</u>: Demonstrates life history characteristics consistent with other healthy wild horse populations (e.g., longevity, sex ratio, age structure).

Other potential aspects of health also were discussed by the working group. Specifically, phenotype was discussed, but it was decided not to include coat color phenotype diversity in the definition of a healthy population. With respect to injuries and disease (e.g., rabies, EEE), under current NPS management policies horses are managed as wildlife and thus are not treated or euthanized when unrecoverable except when injuries are the direct result of a human action (e.g. auto collision).

"Capable of Reproduction"
Maintaining a herd capable of reproduction includes management designed to:
- Preserve animals in peak reproductive status (e.g., 7-12 years of age).
- Maintain enough genetic diversity to avoid inbreeding effects (i.e., control inbreeding at a level that is not detrimental to reproduction).
- Maintain appropriate age/sex distribution (that will provide a predictable number of foals and mortality).

Reproduction should not exceed that which maintains the population at +/- target population size (to be defined). Adaptive management will modify target population size depending on conditions.

Issues Related to Population Reduction
The working group recognized that there will always be a problem with conflicting management goals for this population. Some participants were uncomfortable with managing for a specific target population size, and it was suggested that a target range of numbers might be more acceptable. Much of the concern was related to the uncertainty of how a reduction to a specific population size might affect the health of the population. Some of these issues were subsequently addressed through exploration of the *Vortex* model population. However, the group also recognized that on some level, this issue deals with value systems rather than science. Areas of concern were discussed to outline potential consequences of population reduction. This also suggests attributes that might be monitored during population reduction as indicators of population health.

Concerns Related to Deer Population
Although not directly related to horse population health, group members were concerned over the complication of the presence of deer on Assateague. The island is inhabited by about 500 deer (Sika and white-tailed) and 143 horses. The impetus for reducing the number of horses is to reduce the negative impact on the habitat. Care should be taken that a reduction in horses does not enable the deer population to grow and increase deer impacts on the ecosystem.

Behavioral Concerns
To a large extent, behavior is not dependent on population numbers or whether individuals or whole bands are removed. For instance, the J band was removed and sent to Chincoteague many years ago; this did not appear to affect the behavior of the population as a whole, as the horses sorted themselves out.

The issue of "free roaming" was discussed. It was decided that the ability to remain free roaming is not dependent upon numbers but rather is a space-use issue.

One factor that can affect behavior is sex ratio – this affects not only reproduction but habitat use and therefore band number and structure. Historically, Shackelford tried to keep a sex ratio of 55:45. Today the population has stabilized at about 29-30 bands containing 90 mares and about 50 stallions. The age and sex structure has changed in favor of mares because of their increased lifespan due to contraception; this bias is not anticipated to continue to widen, because we have finally reached the point where older mares are beginning to die off. At what point will sex ratio become a concern? As sex ratios change, the nature of the social organization will naturally change as the horses adjust to numbers and changes in sex ratio. The group felt that sex ratio is not a concern as long as it does not become extremely skewed (i.e., do not allow the number of males to get so low that it becomes a problem).

Nutrition and Genetic Concerns
It was suggested that population health be viewed more holistically – if the goal is to maintain a sufficient number of horses on the island that is consistent with nutritionally healthy and genetically healthy criteria, other aspects of health (i.e., reproduction and behavior) will follow.

Population reduction should not present nutrition concerns – even at the largest population size reached in the past, the horses were nutritionally healthy. Nutrition would be expected to improve rather than decrease at lower horse numbers.

Preliminary *Vortex* model results during the workshop suggested that a population of 50-60 horses or larger will accomplish what the group is envisioning – a self-sustaining population that does not accumulate appreciable levels of inbreeding, at least over the next 50 years (see Section 6 for further discussion of final modeling results).

Managing Through Immunocontraception
Now that the population is aging and that contracepted mares are reaching their new age limit, mortality will result in a much more predictable decline in population size. Adjustments will be needed to the contraception program as population size decreases and the population passes through pulses in age classes before the population stabilizes at the desired target size. Immunocontraception rate may need to be decreased if horses are removed from the population. Attention should be paid to the age structure to ensure that there are enough animals in each age class. One idea is to adopt a moving target as the population ages (for instance, 110-130 horses in the early years, then reduce to 90-110 horses).

Ecological Health Considerations
Another topic discussed by the group was the suggestion that habitat carrying capacity should drive target horse numbers. For instance, Brian Underwood's study pointed out that it took 25 years to destroy the habitat at a high population size of horses, but a much smaller number of horses kept the habitat from recovering. Therefore, the target number of horses should be driven by ecological health as well as population health.

Preliminary Target Population Size
It was the consensus of the group that target population size for horses should be considered in an adaptive management framework, and that goals should be ranges rather than set numbers. The group also recognized that spring census numbers are different than population numbers in the fall. About 110-130 horses were suggested as a reasonable range, but participants were more comfortable with a range of 80-150 managed under an adaptive management regimen. Can this be achieved in an acceptable timeline without removal of horses? This question was addressed using the *Vortex* model, which suggests that under current contraception management the population will reach 80 horses in about 7-8 years (see Section 6 for detailed model results). If horses are removed to achieve the target population size more quickly, care should be taken not to reduce the number of potential breeding animals (those of peak reproductive years) too drastically to avoid severe reductions in the reproductive potential of the population.

Catastrophic Events
Catastrophes are somewhat unpredictable and have the potential to impact the population. Catastrophes have affected this horse population in the past. From 1989-1993, 27 animals were lost – 12 to tidal storm surge (random across age and sex classes) and 14 to equine encephalitis (EEE), which selectively took lactating females and old stallions.

If a catastrophe were to occur, there may be no need for further removal, and there could potentially be a need for reintroduction to reconstruct demographics or genetic diversity. Contraception could be adjusted according to compensate for changes in the population. The most likely catastrophe is disease, as hurricanes are not likely to be severe enough to cause catastrophic losses to horses. Tidal surge on the north end of the island was a problem during the 1992 storm as there is no cover in that area, but this is a rare event. These two catastrophes were incorporated into the *Vortex* population model, which takes their effects into consideration.

The effects of fire and drought were discussed but were not thought to be a significant concern for horses. Potential impacts on the deer population are currently unknown, but a study is underway to better understand deer dynamics over time.

Issues Related to Removal of Horses

Sanctuaries
NPS is considering the removal and relocation of horses to *sanctuaries* rather than through individual adoptions. This does not include Chincoteague. The working group suggests that NPS consult with an appropriate animal welfare NGO to help find suitable sanctuaries. We believe the current thought is for NPS to retain title of the horses, and that annual follow-up regarding the care of the horses would be done. It has not been discussed whether or not these will be breeding herds. The working group felt that any removed horses should not be allowed to reproduce, but was uncertain as to how that should be accomplished (e.g., geld stallions, separate sex herds, or contraception). Other considerations include capture/transport logistics, non-invasive research opportunities, care, and the availability of funds for this effort. Horses that have been removed potentially could serve as a "reserve" herd (for replacements in the event of problems on Assateague Island). Conditions in the sanctuary ideally should be as close as possible to conditions on Assateague Island.

Selection of Individuals
The primary conclusion of this discussion was that what is left behind on Assateague Island is more important than what is removed. Many factors should be considered when selecting individual horses for removal, including:
- Sex
- Age
- Genetics

Suggestions to be considered if selecting horses for removal include the following:
- The best removal strategy might be one that minimizes stress to the remaining animals.
- If the entire band is not removed, the lead mare/dominant stallion should remain on the island.
- It is not necessary to leave the same number of bands on the island.
- Horses in the T5 and T6 bands carry a rare mtDNA haplotype; therefore reproductively capable individuals from those matrilines should not be removed if possible.

Age considerations may be challenging. Many group members felt that it is inappropriate to move old horses. This presents a conflict – how should horses be selected for removal if we

want to preserve young animals in the population as potential future breeders, yet do not want to remove older horses? For example, consider the current age structure for females:

N	Age (yrs)
10	1-6
19	7-12
53	13+

(plus 9 other females)

To reduce this population of 143 horses down to ~100, we need to remove 40 horses (24 females, 16 males using a sex ratio of 60:40). Which 24 females should be removed to preserve the young animals for the future without removing the older horses? These numbers underscore the difficulties that will be encountered as we attempt to choose animals for removal.

Additional Issues for Future Consideration

Several other topics arose during the discussion of population health and the selection of individuals for removal/preservation on Assateague, but were not addressed by the working group.

- Genetic management: Immunocontraception could be used to preferentially breed certain females. This is often done in captive populations to counteract drift or selection in captivity to preserve all genetic lines from the wild stock. Should the horse population be managed to counteract drift and natural selection on Assateague?

- Genetic supplementation: If inbreeding depression or other factors suggest the need for new genetic lines, there is the potential to introduce additional horses to Assateague, potentially from other coastal barrier island horse populations as well as other sources.

- Phenotype selection: A diversity of phenotypes may reflect a diversity of underlying genotypes and hence evolutionary potential relevant to the health of the population. The working group chose not to include phenotype diversity as a measure of population health.

- Euthanasia policy

- Vaccination for West Nile virus/protocol for infectious diseases

Horses of Assateague Island Population and Habitat Viability Assessment Workshop

29 – 31 March 2006
Berlin, MD, US

Final Report
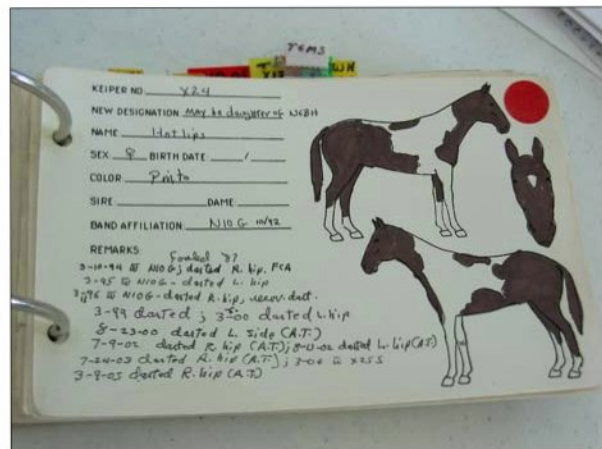
SECTION 6

Education and Research Working Group Reports

Education and Research Working Group Reports

Members: Carl Zimmerman (Education); Jay Charland, Lori Eggert, Jay Kirkpatrick, David Powell (Research).

Management goals related to education and research were addressed by small working groups outside of the main workshop activities so that all participants could devote their efforts to the high priority goals related to ecological impacts, population health and maintaining a free roaming herd. These small working groups limited their discussions to definition and description of each respective management goal.

Role of Education in Horse Management

Management Goal: Educate the general public on the Assateague horses, including their history, behavior, ecological impacts and scientifically-based management.

Education plays a central role in managing the feral horses of Assateague Island National Seashore. Without a vigorous and committed effort to educate the public, it is unlikely that the NPS will achieve its goal of protecting the barrier island ecosystem while ensuring the welfare of the horses. The existing educational program is broad in scope, ranging from actions to improve compliance with resource protection regulations, to developing political support for potentially controversial actions. The target of these efforts is equally broad and includes local, national and international audiences.

The following are the primary objectives and/or themes of the National Seashore's educational programs related to horses. While most are intended to facilitate and enhance management of the ASIS horse population, others are directed outwards to provide information in support of conservation and management efforts elsewhere.

- Develop the public's understanding of, and support for, management of the horse population by explaining the effects an unmanaged population can have on the barrier island ecosystem.

- Increase the public's appreciation for the nature and value of the horses, as both a unique natural resource and an expression of this nation's cultural heritage.

- Describe how the NPS is managing the horse population, and the philosophies and objectives that guide the effort.

- Improve the public's understanding of the value of Assateague Island as a natural laboratory for the study of horses, conservation biology and wildlife management.

- Utilize the Assateague horse management program as a forum for discussion of broader wildlife management and conservation issues, both local and beyond.

- Promote the importance of "wild-ness", using horses as a means of communicating the need to treat all wildlife in ways that engender natural behavior and characteristics.

- Provide data and information about the Assateague horses and associated research and management programs to the scientific and resource management communities.

Assateague Horses as a Research Resource

Management Goal: Recognize and utilize this population as a valuable research resource; however, management strategies shall not be modified in the interests of research.

The horses of Assateague Island National Seashore represent one of a very small number of free-ranging animal populations that provide a unique long-term longitudinal examination of animals in a natural setting. There are perhaps only a dozen populations of mammals around the world that have been studied in as much detail and over a comparable period of time (e.g., chimpanzees in Gombe, red deer in Rhum), and perhaps another half-dozen populations provide the opportunity for the same kind of information to be gathered. Such populations provide unparalleled windows into behavioral ecology, reproduction, population dynamics, genetic underpinnings, and the processes of evolution, none of which can be viewed in the short term.

The Assateague horses have provided all this, and more. This population has also availed itself as a laboratory for the development of new technologies with which to understand the natural history of large mammals. For example, the entire field of remote pregnancy testing, fetal health evaluation, and ovarian endocrine function in large free-ranging wildlife, through the measurement of urinary and fecal steroid metabolites, had its birth with the Assateague horses in the 1980s. The world's first application of immunocontraception at both the research and management levels began with these animals, and the first application of fecal DNA analysis in free-ranging horses occurred here. The scientific legacy of Assateague wild horse research now extends worldwide and across hundreds of species.

While any megavertebrate population has intrinsic value, those with a 35-year longitudinal database covering several generations have scientific value on an immense scale, and there is an obligation among its stewards to preserve these opportunities for future non-intrusive scientific investigation. We strongly encourage the NPS to continue their studies of these horses. The detailed records are not only valuable to longitudinal studies, but they allow for sound science-based management. This work cannot be done efficiently by short-term researchers, such as interns, graduate students, or postdoctoral fellows. It requires a long-term continuous commitment of personnel and resources. We recognize that it may be difficult to keep this work funded, but we encourage the NPS to continue to consider this to be a high priority.

It should not be the purpose of management strategies to provide such a laboratory per se, but rather, management philosophy should recognize the uniqueness of the resource and, as a matter of policy, avail it appropriate and accessible to legitimate research purposes.

Horses of Assateague Island
Population and Habitat Viability
Assessment Workshop

29 – 31 March 2006
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Final Report

SECTION 7

Horse Population Dynamics
and Modelling Report

Horse Population Dynamics and Modeling Report

Members: Jon Ballou, Aurelio Malo, Kathy Traylor-Holzer.

The purpose of this chapter is to present the results of the simulation modelling that was conducted during the workshop to assist in evaluating the different strategies for reducing and contracepting the Maryland Assateague horse (ASISH) population.

An initial workshop was held February 24, 2006 to develop initial goals and identify data sources for use in developing a baseline model for the full PHVA workshop on March 29-31. As a result of the initial workshop, the NPS provided an extract of their ACCESS "All Ponies" database, as well as historical information on census size, and frequency and severity of catastrophic events. The data from the "All Ponies" database were then converted into a SPARKS database (ISIS 2005) to be able to quickly calculate annual age- and sex-specific mortality and fecundity rates. The SPARKS database is now current (as of March 31, 2006) with all living and historical horses.

Modelling was used primarily to project immediate short-term trends in the population size under current management contraception schemes, and to evaluate short-term accumulation of inbreeding if the population were managed at various target sizes. Concerns over the deleterious effects of inbreeding, however, are not a priority in this non-endangered species, as any accumulation of inbreeding can be offset through the import of additional horses, possibly from other unrelated barrier island populations.

Vortex Simulation Model

Computer modelling is a valuable and versatile tool for quantitatively assessing risk of decline and extinction of wildlife populations. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to evaluate the effects of alternative management strategies to identify the most effective conservation actions for a population or species and to identify research needs. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA).

The simulation software program *Vortex* v9.60 (Lacy *et al*. 2005) was used to examine the future projections of the ASISH population using different contraception strategies. *Vortex* 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 that occur according to defined probabilities. The program begins by creating individuals to form the starting population and stepping through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, litter size, sex at birth, and survival are determined based upon designated probabilities. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities. For a more detailed explanation of *Vortex* and its use in population viability analysis, see Lacy (1993, 2000) and Miller and Lacy (2003).

Vortex Model Parameters
Two baseline models were developed using the data from the NPS "All Ponies" database
converted into SPARKS. The first ("*Pre-Contraception*") was developed to model the growth of
the population from 1975 until the late 1980s before the widespread use of contraceptives. This
model was used to simulate the potential rapid growth of the population without the use of
contraceptives.

The second model ("*Contracepted*") was used to simulate the population when managed using
the current contraception strategy. This strategy contracepts females when they become sexually
mature and maintains contraception for three years, after which PZP inoculations are withheld
until the mare produces one foal. Once a female has produced an offspring, she is contracepted
indefinitely thereafter. This strategy ensures a gradual decline in the population over time.

The parameter values used for these models are presented below.

Number of iterations: *500*
500 independent iterations were run for each scenario.

Number of years: *50*
As generation length for horses is about 10 years (see deterministic results below), 50 years
represents 5 generations. This timeframe is short relative to many PHVA models (100 years is
typical) because this modelling exercise places less emphasis on long-term viability and is more
focused on exploring contraceptive use strategies.

Extinction definition: *Only one sex remains*
Extinction is defined in the model as no animals of one or both sexes.

Number of Populations: *1*
A single population was modelled.

Initial Population Size (N):
Pre-Contraception Model: Set at 44 horses (the number in the population in 1975); distributed
among age classes as a stable age structure.

Contracepted Model: *Vortex* imported a studbook file created from the software SPARKS and
PM2000. The imported file contained the exact age and sex distribution of the ASISH population
on March 29, 2006. Initial size was 145 horses (56 males, 89 females); their age structure is
shown in Figure 1.

Carrying capacity (K): *1000*
Both models used a carrying capacity set artificially high at 1000 to allow the population to grow
without restriction since contraceptives would be used to control population growth, not the
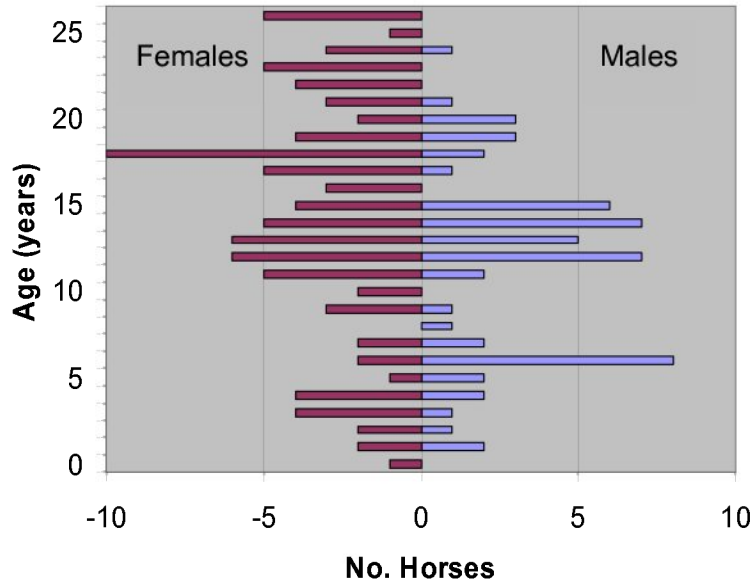ecological carrying capacity.

Figure 1. Age structure of current ASISH population (as of 29 March 2006).

Inbreeding depression: Yes
Lethal equivalents for ASISH is not known. We used the default of 3.14 lethal equivalents calculated as the average across 45 mammalian populations (Ralls *et al.* 1988), with 50% due to recessive lethal alleles.

Concordance between environmental variation in reproduction and survival: Yes
Assumed a positive correlation exists, meaning for example that good years for reproduction are also good years for survival.

Mating system: Long-term polygyny
During breeding season ASIS horses live in harem mating systems with a single stallion male and multiple females, with the male remaining as the resident male across multiple years. *Vortex* provides the option of modelling long-term polygyny (in which harems are stable from one year to the next); this option was used.

Age of first offspring: 3 years for females; 4 years for males
Figure 2 shows the fecundity curve for males and females using data from 1975 to 1992. This period reflects the life history of the horses prior to extensive use of contraceptives. Although males do not show high levels of reproduction until over age 10, enough males contribute to reproduction by age 4-5 to include in the model.
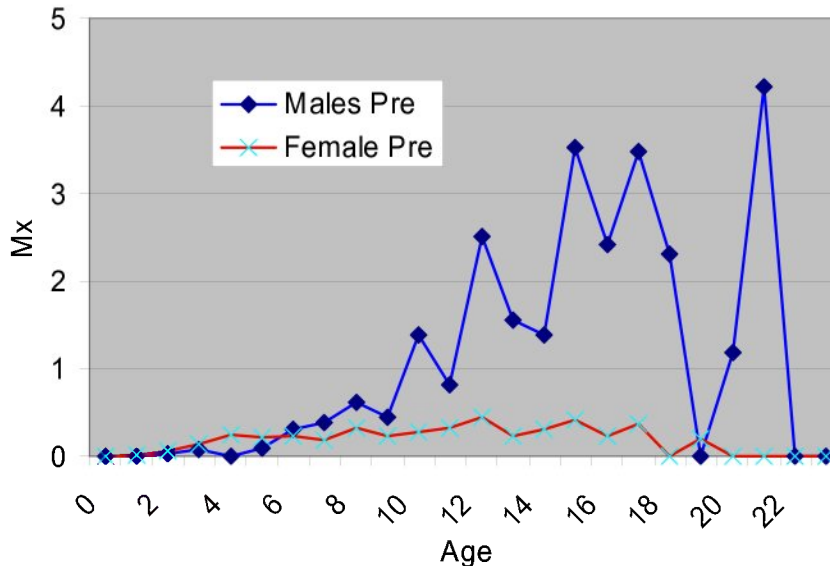
Figure 2. Fecundity rate (number of male and female offspring produced per male and female) against age in Assateague horses in the time period prior to full-scale contraception (1975 - 1992).

Maximum age of reproduction:
Vortex assumes that animals can reproduce throughout their adult life and does not model reproductive senescence. Individuals are removed from the model after they pass the maximum age of reproduction.

Pre-Contraception Model: 23 years
Contracepted Model: 32 years for females, 23 years for males
Females on long-term contraception have significantly reduced mortality and significantly extended longevity (Fig. 4).

Maximum number of progeny per year: 1
Only one foal is produced per birth event.

Percent males at birth: 50%
No indication of unequal sex ratio at birth.

Density-dependent reproduction: No
Reproduction was assumed to be density-independent in the model. Reproductive rates were modified through contraception as needed to achieve a desired population size.

Percent adult females breeding:
Pre-Contraception Model: 50.8% (SD_{EV} = 9.5%)
This is the average annual percent females breeding from 1975 through 1992. Environmental variation was calculated by subtracting the expected average demographic variation (average of annual expected demographic variation calculated as $[(p)(1-p)/SQRT(N-1)]$ where p is percent females breeding and N is the number of adult females in the population that year): $V_{Env} = V_{Total} - V_{Demo}$. The standard deviation of the calculated environmental variation was 9.5%.

Contracepted Model:
Each year, for each female, *Vortex* determines whether or not a female will reproduce based on the value entered. With contraception, this depends on whether or not a female is contracepted, or how long it has been since she was last contracepted.

Data from Turner and Kirkpatrick (pers. comm.) indicate that the probability of a female producing her first foal after contraception changes as a function of how long it has been since contraception was stopped (Table 1).

To convert these probabilities to a function that can be used in *Vortex*, the value:

$$100 - (\text{probability of female reproducing} * 100)$$

was plotted against year since last contracepted and fitted with a negative exponential curve (value of 0% for year 7 replaced with 1% to allow function to work). The fitted curve provided the cumulative probability function (Fig. 3):

$$B_t = 100 - 147.2e(-.6t)$$

with B_t = probability of female producing foal by year *t*.

To calculate the probability of a female reproducing during year *t* we used:

$$B'_t = B_t - B_{t-1} \text{ for } t > 1; \text{ and}$$
$$B'_t = B_t \text{ for } t = 1.$$

Table 1. Percent of females returning to reproduction depending on the number of years since she was last contracepted.

Years since last contracepted	1	2	3	4	5	6	7	8
Percent of females producing first foal after contraception	21%	34%	21%	10%	7%	3%	0%	3%

Figure 3. Cumulative probability of producing a foal over time since last contracepted fitted with an exponential function.

The current contraceptive management scheme is to contracept females from sexual maturity (age 3) until age 6, let them produce a foal, then contracept them indefinitely thereafter. To simulate this contraceptive practice, the model needs to track the female's age, whether or not she produced a foal when the contraception was withheld, and, because the probability of producing a foal depends on the number of years since contraceptives have been withheld (see above), the time since she was last contracepted. To track these events, three individual state variables were created with the following transition rules (Table 2). Individual state variables are variables assigned to each individual in the population and can take on values set by user defined functions. These individual state variables can then be used to modify other parameters in the model. The values at the initiation of each model iteration were read in through the imported studbook file and defined in that file.

Table 2. Individual state variables used in the model.

Individual State Variable	Definition	Value at model initiation	Value assigned to individuals at birth	Function used to change value each year
IS1 Number of offspring	Number offspring produced. The variable Q is the male mate of a female when she has produced a successful offspring in the polygyny mating system. When Q > 0 the female has a mate and produced an offspring that year; when Q = 0, the female has not reproduced.	= # offspring each female had produced by March 2006	0	=PARITY (PARITY is a new *Vortex* variable that tracks the number of offspring previously produced by a female)
IS2 Reproductive status	Set to 1 if the female is reproductively capable; set to 0 when she is contracepted. Since females are automatically contracepted for ages 3, 4 and 5, females are reproductive when older than 5 and have not yet produced an offspring. Once they have produced offspring, they are contracepted and IS2 is set to 0.	Set to 0 for currently contracepted females, 1 otherwise	1	=[(A>5)*(IS1=0)]
IS3 Yrs since contraception	The number of years since last contracepted. Counted as every year older than 5 that a female has not produced a foal.	Based on historical contraceptive records	0	=[IS3+[(A>5)*(IS1=0)]]

Therefore, the percent of females breeding was a function of whether or not the female was contracepted (IS2) and how long it had been since she was last contracepted:

% females breeding = {(IS2=1)*{[(IS3=1*21]+[(IS3>1*[{[(100-(147.2*EXP(-.6*[IS3+1])))-(100-(147.2*EXP(-.6*(IS3))))]}]]}}

Standard deviation for environmental variation was kept at 9.5%.

Percent adult males in the breeding pool: *60.8%*
Based on average of annual % of males listed as sires in the "All Ponies" and SPARKS datasets using number of bands that had foals born into them each year.

Mortality rates:
Survivorship and longevity were significantly higher for contracepted females than for non-contracepted females (Fig. 4).
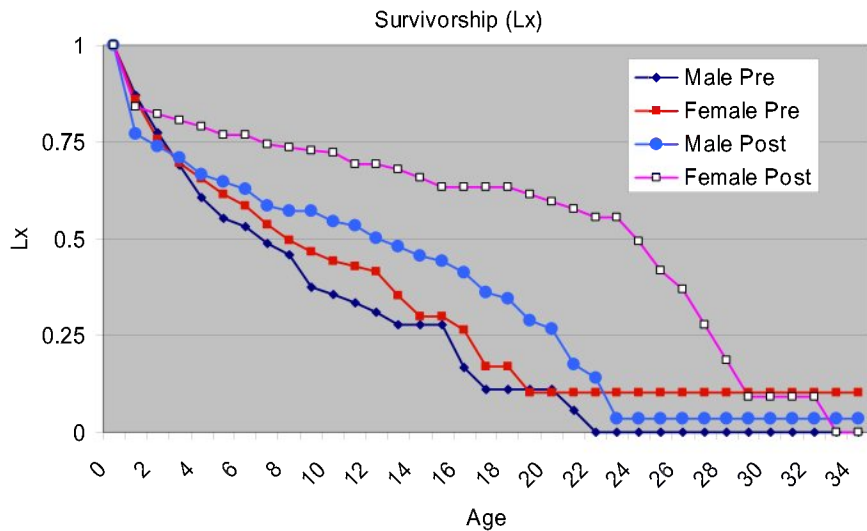
Figure 4. Survivorship (% of individuals surviving from birth to older ages) for male and female horses during the pre-contraception period (1975 - 1992) vs. the contraceptive period (1992 - current).

The sex- and age-specific mortality rates were calculated as the average annual mortality from the "All Ponies" and SPARKS data (Table 3). Demographic variation was removed from total variation to estimate environmental variation as define above for percent of females breeding. Since adult mortality rates were a function of contraception for females, the rates were entered as functions.

Table 3. Age- and sex-specific mortality rates for ASISH.

Sex	Age (yrs)	Mortality (%)	SD due to Environmental Variation (%)
Females	0	10.2	5.4
	1	9.1	6.8
	2	5.8	3.7
	Adult	a	4.1
Males	0	10.2	9.9
	1	7.2	5.3
	2	7.7	10.2
	3	8.7	9.3
	Adult	b	4.0

In the above table, for the adult female mortality rate:

$$a = 4.9 - [(IS2=0)*(A<24)*(2.9)] + [(IS2=0)*(A>=24)*(17.1)] + [(IS2=1)*(A>=24)*(95.1)]$$

This translates into:
− 4.9% annual mortality for non-contracepted female adults, with 100% mortality after age 25
− 2% annual mortality for contracepted female adults to age 23, then 22% annual mortality from 24 and older

For the adult male mortality rate:

$$b = 5.9 + ((A>23)*(94.1))$$

This truncates male longevity at age 24.

In the functions above, IS2 is the individual state variable defined as 0 = contracepted and 1 = non-contracepted, and A = age in years. These functions increase senescent mortality above the age of 23 to match the survival rates shown in Figure 4.

Number of catastrophes: 2
Two catastrophes were included based on historical information:
 Storms: 4% chance per year with an 8% reduction in survival rates for that year
 Disease: 10% chance per year with a 3% reduction in survival rates for that year

Harvest: None

Supplementation: None

Model Results and Validation

Deterministic Output

The demographic rates (reproduction, mortality and catastrophes) included in the baseline models can be used to calculate deterministic characteristics of the model population. These values reflect the biology of the population in the absence of stochastic fluctuations (both demographic and environmental variation), inbreeding depression, limitation of mates, and immigration/emigration. It is valuable to examine deterministic growth rates (lambda, generation lengths, and age structure) to assess whether they appear realistic for the species and population being modelled. *Vortex* can only calculate deterministic values for models without functions using individual state variables, because individual state variables can affect demographic rates, yet *Vortex* has no a-priori knowledge of what values the ISVs can take on and how they change.

Table 4. Deterministic results.

Parameter	Pre-Contraception Model
Lambda	1.097
Generation length (yrs)	9.8

Table 4 presents some of the deterministic outputs of the *Pre-Contraception* model. These values indicate populations with the potential to grow about 10% per year, and with generation lengths and age structures that are representative of what is known about horse biology. The parameters in the model are producing reasonable results.

Validation Based on Historical Data

The *Pre-Contraception* model was validated against the actual observed growth of the horse population from 1975 until 1988 (Fig. 5). The actual population sizes fall well within the range of outcomes from the model simulations (mean +/- one standard deviation), indicating that the model does a good job at replicating the life history of the horses during this initial growth period (Fig. 6).
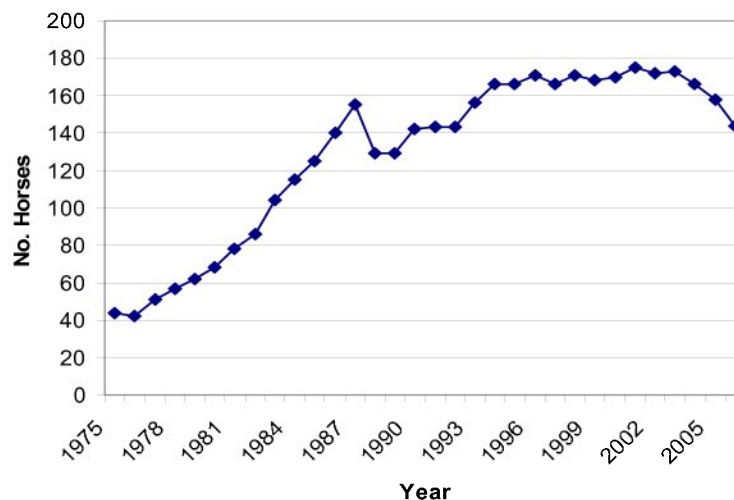

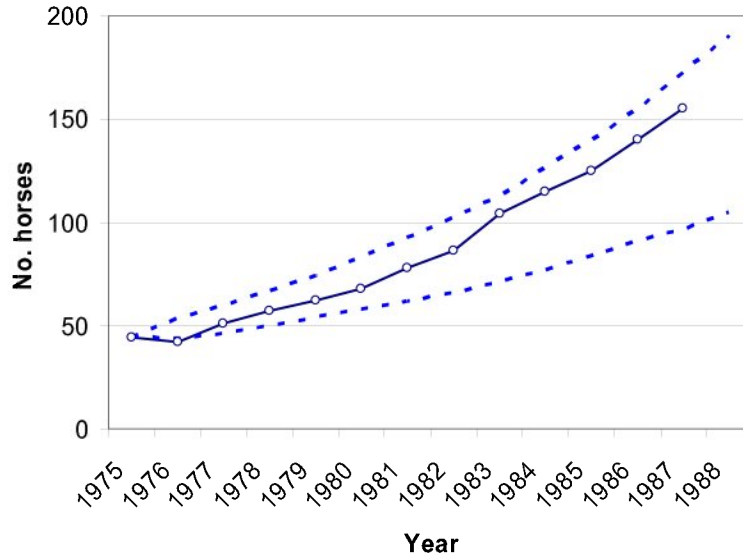Figure 5. Changes in Maryland Assateague horse population size over time.

Figure 6. Actual population size (solid line) compared to plus and minus one standard deviation of estimated population size (dashed lines) from model simulations.

The *Contracepted* model was also validated against the historical population size (Fig. 7) by modelling the growth of the population from 1975 until about 1992, then turning on the contraception program in 1990 to stabilize the population at about 140-150 horses. Appendix A shows the historical data for the population. The validation was run with catastrophes occurring in 1989 and 1990 (EEE – equine encephalitis) and the storm in 1992. An 18% decline in survival was added in 1988 to incorporate the large number of animals that died that year. Harvests of 12 adults that took place were added to the years 1988 and 1994. While the contraception program began in 1988, it was not fully implemented until 1994. Therefore, the validation model applied contraception randomly to 30% of the females from 1988 until 1994, then 71.5% thereafter. These rates were based on the average percent of mares implanted from Appendix A.

The average of the 500 simulated projections (solid lines) with +/- one standard deviation overlaid on the actual population size (line with diamonds is shown in Figure 7). The model did a fairly good job in mimicking the actual population size, with the actual size falling well within the range of possibilities projected by the model. The modelled population does not show the decline in the last few years because this model did not incorporate the reduced probability of reproducing seen in previously contracepted females.

The validated model appears to be a fair representation of this horse population and was used to explore various management scenarios.
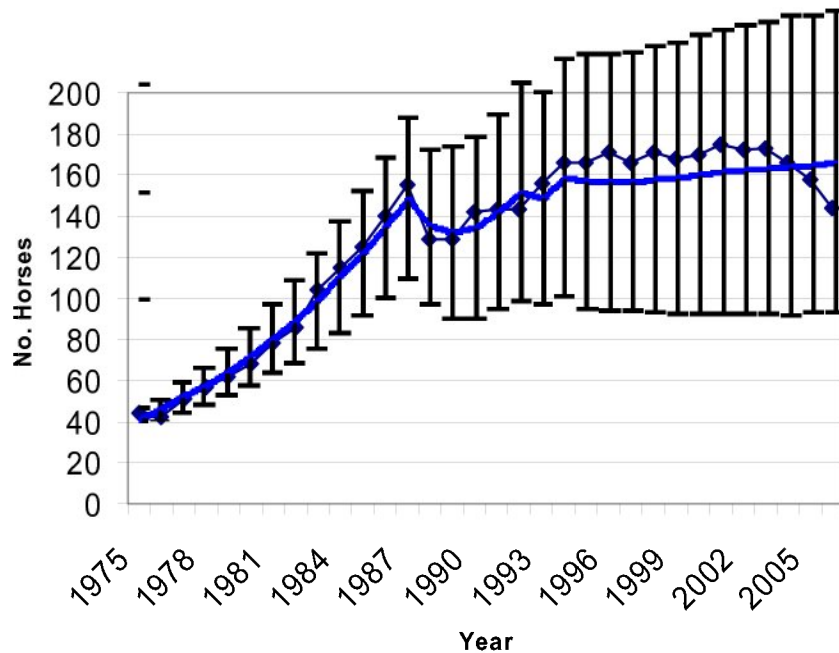
Figure 7. Historical population trends (line with diamonds) and the modelled trends (solid line), with bars indicating +/- one SD.

Management Scenarios

Scenario 1: Projected Decline Under Current Management
(*Vortex* scenario "Current, No Removals Large K Male Limit 10")

Question: *Using the current contraceptive management scheme, how rapidly is the population expected to decline?*

This scenario modelled the future projected decline in population size over the next 50 years using the current management practices of contracepting at maturity, continuing contraception for 3 years, then letting the females breed until one foal is produced, at which point the female is then again contracepted for the rest of her reproductive life.

Results: The projected decline in population size is shown in Figure 8. Vertical bars show +/- one standard deviation (68% of results) around the mean for 500 simulations. Average rate of decline was 13% per year. With this rate of decline, the population is expected to reach 100 animals within 5 to 6 years, 80 animals within 7 to 8 years, and 50 animals within 9 to 10 years.

Discussion: The combination of: 1) the large number of older animals in the current population reaching maximum longevity in the upcoming years; 2) the low percent of adult females provided with reproductive opportunities each year using this management scheme; and 3) the decreased probability of females successfully breeding after contraceptives have been removed (Table 1) drives the population down rapidly. We are already starting to see the effects of a sharp drop in population size over the last few years (Fig. 7) – an indication of what is likely to be a continued decline in the population size.
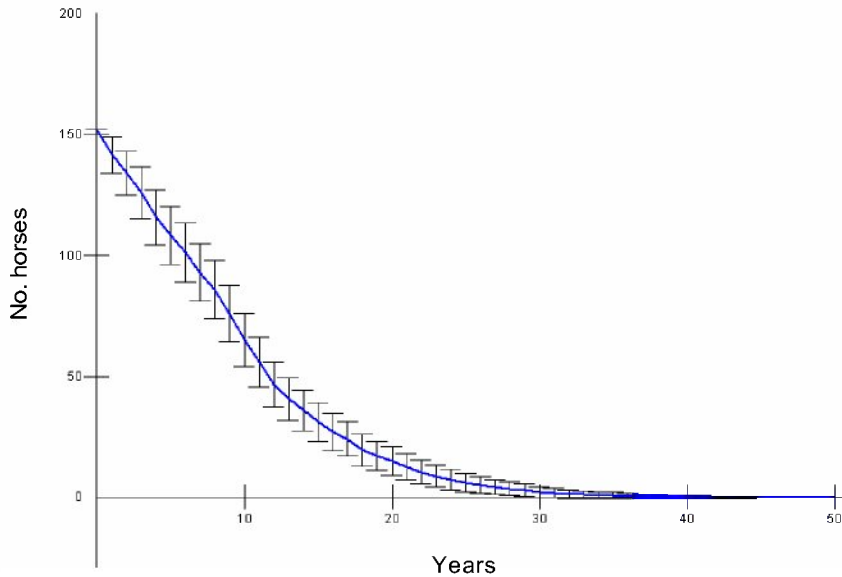
Figure 8. Projected decline in the ASISH population with continuation of current contraception management program.

Scenario 2: Decline and Stabilize at Different Population Sizes
(*Vortex* scenarios "Limit 100" to "Limit 20")

Question: *How long will it take the population to decline to various sizes, and what are the implications of size on accumulation of inbreeding over the longer term?*

In these scenarios, the population was allowed to decline using the current contraceptive management scheme until it reached a predetermined population size, at which point the contraceptive management scheme was modified to allow enough animals to breed to maintain the population at that size (management to allow projected births each year to equal expected deaths each year calculated from demographic analysis). The population was allowed to decline to target sizes of 100, 80, 60, 40 and 20 horses, respectively.

Technical note: In *Vortex* this was done by adding a Population State Variable (PS1) titled Target Size and setting this to equal the target sizes of 100 to 20. The reproductive rate function was modified so that current contraception techniques were used when the population was above the target size, but reproduction was returned to normal rates (50.8% females breeding) when the population size was below the target:

% females breeding = [(N<=PS1)*50.8]+[(N>PS1)*{(IS2=1)*{[(IS3=1)*21]+[(IS3>1)*[{[(100-(147.2*EXP(-.6*[IS3+1])))-(100-(147.2*EXP(-.6*(IS3))))]}]]}}]

Results: Changes in population size under these 5 different management scenarios is shown in Figure 9. The declining population reaches its target population size by 6 years for 100 horses to about 18 years for size of 20 horses.
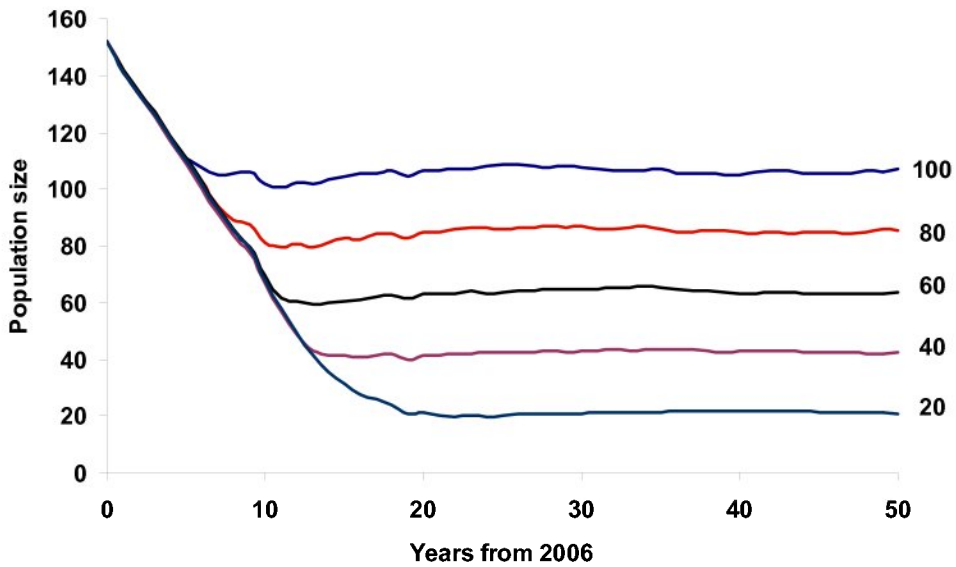
Figure 9. Timeframes for levelling the population off at different levels.

The accumulation of inbreeding under these different scenarios over the 50-year time period is shown in Figure 10. The dotted line at 0.0625 represents the level of inbreeding equivalent to offspring produced by the mating of two first cousins. If the population were reduced to between 40 and 60 individuals, and maintained at that size for 50 years, the level of inbreeding in an average offspring would be about this level. If the population were reduced to 20 individuals or fewer, the level of inbreeding would approach being equivalent to matings among half-siblings.
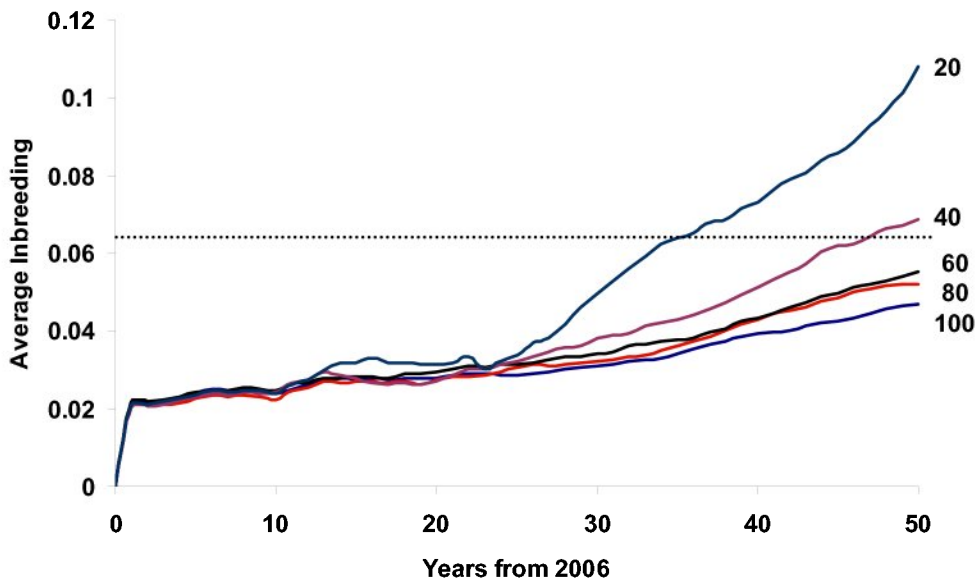
Figure 10. Accumulation of inbreeding over time for different target population sizes.

Discussion: Populations reduced in size will accumulate inbreeding at a faster rate than larger populations. The deleterious effects of inbreeding are expected to be directly proportional to the increase in inbreeding. While we do not have data on the effects of inbreeding in this population, data from other species show that inbreeding problems have been documented when average inbreeding coefficients reach as high as 0.10 or 0.12, although this level of inbreeding is unlikely to cause serious viability threats to the population. Furthermore, unlike the sole surviving population of an endangered species, accumulation of inbreeding in this population can be easily alleviated simply introducing unrelated horses into the population, potentially from other barrier island horse populations.

Summary

The model projections predict that the population will decline to about 100 animals in about 5 to 6 years and 80 horses in 7 to 8 years. If managed at these levels, this number of horses will accumulate only a low amount of inbreeding over the next 50 years – levels that are unlikely to result is any significant inbreeding depression effects. Given what is known about the demography of the population, contraceptive management schemes can likely be designed to manage the population at any of these levels. More likely, adaptive management contraceptive programs can be designed to scale the level of contraception to exactly what is needed on a year-by-year basis to manage the population very precisely at a desired level.

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Appendix A: Historical trends and events from 1961 to 2005.

Year	Spring Herd	Harem Bands	Foals	Known Deaths	EEE/Storms	Transfer	Treated with Contraceptives	% of mares
1961	9							
1966	10+							
1967	21							
1968	28							
1969	35							
1970								
1971	50				EEE			
1972								
1973								
1974					EEE			
1975	44		10	1				
1976	42		9	0				
1977	51		12	0				
1978	57	6	15	2				
1979	62		9	1				
1980	68		19	1		1		
1981	78	8	18	2				
1982	86		18	10				
1983	104		26	5				
1984	115		24	2		3		
1985	125	12	25	5				
1986	140		25	10		7		
1987	155		27	5				
1988	129		35	14		12	28	
1989	129		17	34	7+ EEE	7	18	
1990	142	22	26	33	7+ EEE		10	
1991	143	25	25	11		1	10	
1992	143	25	30	24	12 storm		30	
1993	156	26	22	13	1 EEE		16	
1994	166	29	22	6		13	76	95%
1995	166	28	10	6			68	83%
1996	171	29	5	9			72	84%
1997	166	28	7	4			54	59%
1998	171	29	3	7		2	49	52%
1999	168	30	7	4			48	52%
2000	170	30	11	7			64	68%
2001	175	33	5	6			75	79%
2002	172	32	7	5			66	69%
2003	173	29	5	8		1	66	70%
2004	166	29	5	15		1	74	76%
2005	158	29	9	14			69	71%

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SECTION 8

Plenary Discussions of Population Management

Population Management Plenary Discussion Report

Plenary Discussion: All PHVA workshop participants (facilitator: Kathy Traylor-Holzer, CBSG)

Maintenance of Feral Horses on Assateague Island

There was a brief discussion at the PHVA workshop regarding the maintenance of an exotic species (feral horses) in the Assateague Island ecosystem. Although uncommon, the maintenance of a "desirable feral species" on public lands is allowed under National Park Service Management Policies (2001):

> **Section 4.4.1.3. Definition of Native and Exotic Species**. "Native species" are defined as all species that have occurred or now occur as a result of natural processes on lands designated as units of the national park system. Native species in a place are evolving in concert with each other. "Exotic species" are those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities. Exotic species are also commonly referred to as non-native, alien, or invasive species. Because an exotic species did not evolve in concert with the species native to the place, the exotic species is not a natural component of the natural ecosystem at that place.

> **Section 4.4.4. Management of Exotic Species**. Exotic species will not be allowed to displace native species if displacement can be prevented.

> **Section 4.4.4.1. Introduction or Maintenance of Exotic Species**. In general, new exotic species will not be introduced into parks. In rare situations, an exotic species may be introduced or maintained to meet specific, identified management needs when all feasible and prudent measures to minimize the risk of harm have been taken, and it is:
> - Directed by law or expressed legislative intent.

Based upon the legislative history of the park and General Management Plan, it is the objective of the NPS to maintain a free-roaming population of feral horses on the Maryland portion of Assateague in a manner that is in compliance with the above policy.

Management Goals for Horses on Assateague

The first two days of the PHVA workshop involved the refinement of the six identified management goals for horses on the Maryland portion of Assateague Island by small working groups. These groups also delineated many of the issues and difficulties in achieving these goals, offering recommendations as appropriate (see working group reports in Sections 3-6 as well as issues outlined in Section 2).

These finalized goals were presented to all workshop participants in plenary. Participants were then asked to prioritize these goals in terms of importance to managing horses in ASIS. This was accomplished by giving five dots to each participant and requesting them to distribute these dots next to those goal(s) that they feel should be the highest priorit(ies) for management of horses in Assateague. The resulting six management goals in order of priority (indicated by the number of dots, given in parentheses) are:

1. Reduce the negative impacts of horses on key species, communities and natural processes to levels compatible with legal mandates and the continued evolution of Assateague Island toward a natural condition (*35*).

2. Maintain a free-roaming herd of feral horses that exhibit natural characteristics and are subject to natural processes (*25*).

3. Maintain a healthy population of horses capable of successful reproduction (*22*).

4. Educate the general public on the Assateague horses, including their history, behavior, ecological impacts and scientifically-based management (*12*).

5. Recognize and utilize this population as a valuable research resource; however, management strategies shall not be modified in the interests of research (*4*).

6. Provide a reasonable opportunity for visitors to view horses safely (*2*).

Participants placed the greatest importance on reduction of ecological impacts on the island. The maintenance of a free-roaming, naturally-behaving, healthy herd of horses also was viewed highly. While management should strive to achieve all management goals, providing research opportunities and viewing opportunities were not considered to be overriding goals of management.

All participants recognized the interrelated and often opposing nature of these goals that cannot be easily resolved. This led to a plenary discussion involving all participants on the third and final day of the workshop to attempt to reach some consensus in how the NPS might approach this task through horse population management.

Balancing Ecosystem and Population Health

Management of a population of feral horses on Assateague Island presents a challenge to the National Park Service – to balance the primary goals of horse management in Assateague, that is, to maintain a healthy, reproductive, free-roaming and naturally-behaving population with little to no ecological impact on key threatened species, communities, and ecological processes of this barrier island. At the heart of the conflict is the number of horses that should be maintained on ASIS – more horses mean greater negative ecological consequences and may require exclusion of horses from some areas, while fewer horses threaten population viability and reduce visitor viewing opportunities.

In order to address the issue of horse population size, workshop participants first discussed available information on how population size is related to population health in order to determine the minimum acceptable population size for population health. This was followed by a similar discussion of how horse numbers and densities affect the ecosystem to arrive at an estimated maximum acceptable number of horses to maintain sufficient ecosystem health. These discussions helped to define a tentative range of target population sizes that balance these conflicting management goals.

Minimum Acceptable Population Size (N) for Population Health
Small population size is associated with increased risk of decline or extinction due to stochastic events, such as demographic stochasticity, inbreeding depression, and catastrophes. The following information was considered by workshop participants to help evaluate a minimum acceptable target population size for horses on ASIS with little risk to population viability.

The *Vortex* model was used during the discussion session to evaluate the viability of the horse population at different target population sizes (N = 40, 50, 60 80). The risk of population extinction (within 50 years) and the remaining gene diversity after 50 years were used to assess population viability. Model results are presented in Table 1.

Table 1. Probability of extinction (PE) and gene diversity (GD) after 50 years vs. population size (N).

Target N	N = 40	N = 50	N = 60	N = 80
PE_{50}	2%	0%	0%	0%
GD_{50}	84%	86%	88%	90%

Populations of 50 horses or more showed essentially no risk of extinction over a period of 50 years. As expected, smaller populations were associated with greater loss of gene diversity and more rapid accumulation of inbreeding. The retention of at least 90% gene diversity is a common goal among managed captive populations – below this level, reproduction may be increasingly compromised by lower birth weights, smaller litter sizes, and greater juvenile mortality.

Model results suggest that under current immunocontraception conditions and with no additional horses imported to the island, populations below 80 horses may not be able to retain 90% gene diversity over 50 years. However, the Assateague horse population is not necessarily a closed population, and has a history of migrants in and out of the population. There exists the option for future occasional supplementation for demographic or genetic reasons if population viability is threatened. This would require careful consideration of the source of animals to be added. Increased population management, whether through the addition of new horses or through genetic management, may allow smaller populations to retain more gene diversity. For instance, *Vortex* modelling suggests that a population of 60 horses can retain 90% gene diversity if two mares are added to the population every 10 years. Strong genetic management, in which rarer genetic lines are selectively allowed to breed, would allow a population of 60 horses to retain 94% gene diversity. Importations, genetic management, manipulation of sex ratio and other management interventions can be used to increase the viability of smaller populations. On the other hand, extensive management needed to maintain a small population requires more resources and may be in conflict with maintaining a free-roaming, naturally behaving population. There are also concerns whether or not genetic management is appropriate in this free-ranging situation. The NPS prefers to minimize extensive management of the horse population. *Vortex* results suggest that a population of 50 horses may be viable if NSP is willing to accept increased management, and that a population of 80 horses appears viable with no additional management.

Some concern was expressed with basing the minimum number of horses solely on genetic criteria, and that the effects on behavior and visitor viewing opportunities should also be considered. Horses were still visible to visitors in the past when there were only 30-40 horses, but it may have required more than one day to see horses. It was recognized, however, that the

situation and management is different now and so this may no longer be the case. Participants suggested that viewing opportunities might not be jeopardized with a population of 70-80 horses. This would not require intensive management, which may have negative behavioral consequences.

Maximum Acceptable Population Size (N) for Ecosystem Health
The next step was to assemble available information to help guide participants in estimating the relationship between horse numbers and ecological impacts on the island. The following points were made during this discussion:

Horse Numbers and Impacts
- In the 1970s and early 80s, when there were about 60 horses present (50-100), studies showed relatively little horse impact; however, the validity of this research is questionable.
- In the mid-1980s, horse impacts on salt marshes started being observed (about 100 horses at this time).
- When there were fewer than 100 horses present, the horses used all available areas with little overlap of home ranges. At about 100-110 horses, overlapping home ranges started to appear. This has both ecological and behavioral implications.
- Horse distribution is not random across the area; horses may congregate at localized resources (e.g., fresh water, fly relief areas).
- Horses trample and permanently reduce salt marshes (compact substrate) and also negatively affect secretive marsh birds.
- Even at moderate horse densities (about 1.2 horses/km^2), primary productivity of *S. alterniflora*, the dominant low salt marsh species, is reduced. Additionally, *S. alterniflora* does not exhibit compensatory growth after exposure to horse grazing. From 1994 to 2000, across varying horse densities, *Distichlis spicata* (saltgrass) increased in abundance in some low salt marshes – horses do not eat this species, giving it a selective advantage over other *S. alterniflora* in the presence of horses. This presents a problem for ASIS regarding the management of its low salt marshes, since unlike *S. alterniflora*, *D. spicata* is intolerant of extended periods of submersion in brackish water and therefore does not exhibit the sediment trapping and filtration properties that are essential to the health of a tidal marsh ecosystem.
- Current levels of horse herbivory decrease the abundance of *Ammophila breviligulata*, a grass species essential to dune formation. Dune formation is a key process for maintaining the integrity of barrier island ecosystems.
- Data from M. Sturm indicate a 40% reduction in the size of amaranth under a density of 3.2 horses/linear km (3.2 x 35 km = population of 112 horses); therefore, approximately 100 horses may result in an unacceptable level of impact on amaranth.
- Habitat on the barrier island is likely to change over time.

North Portion of Assateague Island
- The north end of the island has higher horse density; this is a seasonal increase in the summer, as the habitat is more open there and provides relief from flies.
- This area supports an important piping plover population (threatened species). As shrubby vegetation increases in this area, horses are moving into plover nesting areas to escape flies, disturbing prime plover habitat.

- Developing salt marshes attract horses. Storms that overwash the island initially inhibit salt marsh development and therefore are beneficial to plovers.
- By the early 1990s, secretive salt marsh birds had disappeared from the north end of the island.
- One hypothesis offered at the workshop is that the recent restriction of horses from the dunes in Assateague Island State Park (located just south of the more open "north" end of the island) is causing horses that seek fly relief in the park to move north to find forage.

Available information on the ecological impacts observed at various horse densities suggests that the current ASIS horse population (144 at the time of the workshop) far exceeds the ecological tolerance threshold of the most sensitive island resources described in Section 4. Furthermore, available data show that, at a minimum, the horse population will need to be reduced and managed at levels at or below 100 animals. Further population reductions may also be required if the monitored ecological parameters do not show sufficient improvements. It was recognized that some of the existing data are outdated and that better and more current data are needed to assess both present and future conditions on the island. A program should be in place that will monitor the response of the ecological indicators described in Section 4 prior to any significant horse reduction.

Developing a Target Population Size
Horse population size is positively correlated with population health (at numbers below carrying capacity) and negatively correlated with ecological health of the island. The task facing the workshop participants was to use the above available information to suggest a target population size that would balance these two relationships in a way that was acceptable to both management goals. This was accomplished with the aid of a graphical representation of these relationships (see Figure 1). Health curves were drawn via consensus to indicate the relative health of horse population – this was depicted as a range using two curves (in dark blue), based on projections with and without intensive management. Similar curves were indicated for ecological health (in light green), with a broader range indicative of the greater uncertainty in this relationship.

Using the blue population health curve that depicts less intensive management of horses, a minimum of 80 horses is needed; ecological health curves suggest that the population be limited to no more than 50-100 horses. Historically, management of horses in ASIS has been characterized by gradual changes, followed by monitoring of the resulting effects and subsequent adjustments in management as needed. **The PHVA participants recommended a short-term target population size of 80-100 horses**, perhaps managing toward the lower end of this range. The effect of this population reduction should be monitored, both in terms of the effects on the horses as well as on changes in habitat, key species and communities, and ecological processes.

Barrier islands represent a dynamic system and changing environment. Unforeseen changes may occur over the next few years. Monitoring will allow the NPS to evaluate how the horses and environment respond not only to changes in the number of horses but with any other changing conditions, and will allow the use of adaptive management to respond to these changes.
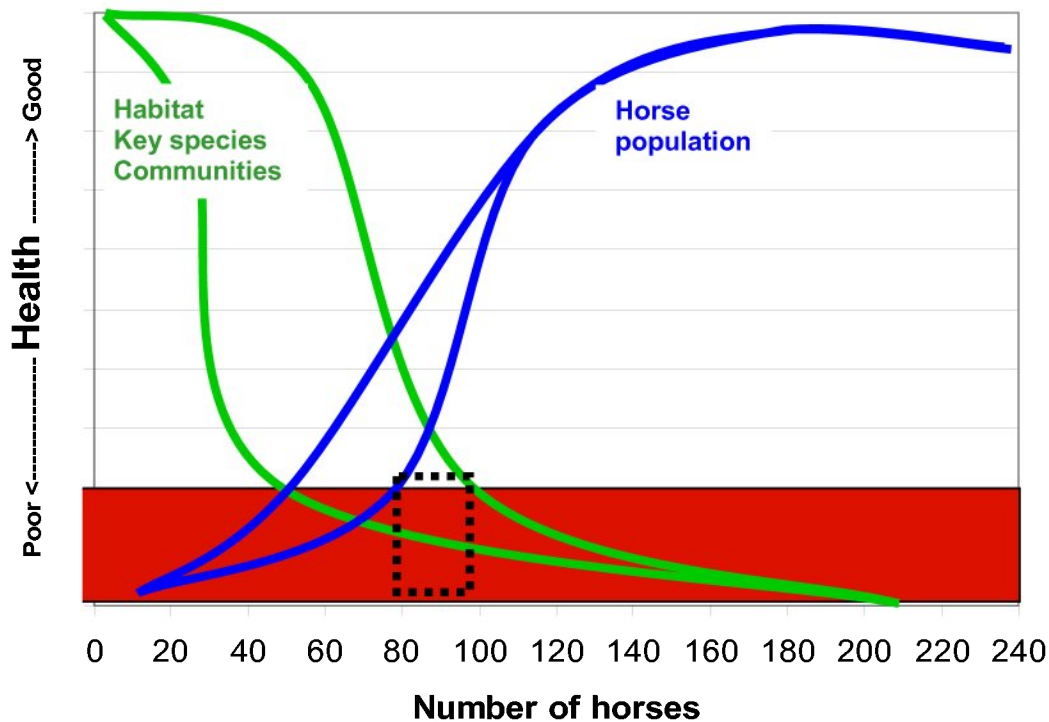
Figure 1. Estimated relationship between number of horses on Maryland portion of Assateague Island and the relative health of the horse population (in blue) and ecosystem (in green).

Analysis of Population Management Strategies

Interventive management will be necessary in order to reduce the current population of approximately 144 horses down to the suggested target size of 80-100 horses. Two primary methods of population reduction were considered by the workshop participants:
1) immunocontraception to control reproduction (current strategy); and 2) one-time removal of horses to achieve target population size.

A plenary discussion of these management options included the identification of advantages and disadvantages of each, which are outlined in Table 2. In considering these management strategies, the group assumed that immunocontraception would be conducted in a similar manner as is currently done. The specifics of a one-time large-scale removal of horses were not discussed; however, it was assumed that all horses may not be removed in one event, but that the designated removals may occur over several years to achieve the target population size.

Each management option offers advantages as well as risks or costs. The primary benefit in the consideration of the removal of horses is the more immediate and greater reduction in the ecological impacts of horses on the island species, communities and processes. It was recognized, however, that if a removal strategy were adopted, it would take some time to secure approval and to organize logistics. Realistically, it may likely take two years before horses could be removed from the island. In comparison, *Vortex* model projections suggest that the target size of 80-100 horses may be reached in 5-8 years using the current immunocontraception strategy. In order for horse removal to offer greater ecological benefit, this strategy would need to be pursued and executed in a timely manner.

Table 2. Comparison of advantages (in blue boldface) and disadvantages for two management options for population reduction.

Immunocontraception *Est. time to reach target: 5-8 years*	One-Time Removal *Est. time to reach target: 2+ years*
Continued ecological pressure on island for longer time period	****Faster reduction of ecological pressures****
More difficult to detect gradual response of habitat	**Easier to identify immediate response of habitat**
Less controversial / objectionable to public	More controversial / objectionable to public
Less risky (have been doing this to horse population safely for years)	More risky in terms of risk to horses (during capture and transport)
More gradual; allows for assessment and adaptive management	More immediate; less time for assessment and adaptive management
Less flexibility to manage age structure, genetics, problem animals, horses that do not respond to contraceptives	**Ability to remove problem animals, manipulate age/sex structure, and use genetic management**
Outcome less predictable; will require more adaptive management	**Less uncertainty about outcome; can achieve desired N with desired age/sex structure**
Does not affect older horses	Potential impact on older horses if selected to be removed (to retain breeding structure on island)
Potential behavior changes related to high contraception levels (some disagreement over the extent of impact on behavior)	**Impact on behavior is under more control through careful selection of horses to remove**
Not faced with determining which horses to remove	Difficult decision to identify which horses to remove
Less intrusive	More intrusive
Less effort required	More effort required
Higher level of interventive management (more unnatural manipulation)	**Less interventive management needed once horses are removed**
Less expensive (but still have expense of higher level of contraception)	More expensive
Do not have to monitor removed horses	Need to monitor removed horses
High cost for other endangered species (e.g., horse exclusion areas)	**Reduced need for management for other endangered species (e.g., horse exclusion areas)**
No need to locate sanctuaries	Need to find sanctuaries for horses
No impacts due to horse removal efforts	Potential environmental impact from horse removal efforts (trucks, fences, etc.)
Approval is already in place	Approval needed (may take 2 years until horses are actually removed)

A third management strategy was considered – the use of a combination of immunocontraception and removals rather than complete dependence upon one type of management. In a broad sense, this is what the NPS is doing now, as they have removed problem horses in the past (primarily before the full-scale use of immunocontraception). A combined management strategy could expand upon this by also removing select horses for population management purposes. Advantages of this combined approach include its flexibility and the opportunity to take advantage of the benefits of both strategies. This would allow the ability to deal with problem horses and potentially other more straightforward removals while avoiding some of the disadvantages of both methods. A majority of the participants were comfortable with this intermediate approach. While opinions differed among participants regarding whether or not they favored the removal of horses, very few individuals could not "live with" either the immediate removal of some horses or with absolutely no removal of horses from the island.

No matter which management option is adopted, it is likely that a significant reduction in ecological impacts will not be possible for at least two years. The question was posed: What can NPS do in the next two years to reduce ecological impacts? Participant recommendations were:
- To continue to monitor the horse population;
- To continue to contracept the horse population;
- To consider exclusion enclosure in amaranth areas; and
- To prepare the public for possible removals through an intense education program.

It was noted that all strategies are projected to converge upon a similar situation in about 15 years.

Management Strategy Decision and Implementation
The final decision regarding target population size/range, which population reduction management strategy will be used to achieve this objective, and how it is implemented cannot be made by the participants of this workshop. Therefore, the participants and the NPS were comfortable with providing this analysis of the potential options without making a firm recommendation over which strategy to use.

The purpose of this PHVA report is to serve as a pre-planning document and is advisory to the National Park Service for consideration in their development of a management strategy for feral horses on the Maryland portion of Assateague Island. This document deals only with the Maryland horse population and is not related to the management of horses in Virginia.

The National Park Service outlined a series of steps that it envisions will follow this workshop in the continuing development of management plans for ASIS horses:

- Conduct scoping to understand public concerns associated with the Assateague horses.
- Use that information and PHVA results to develop potential management alternatives.
- Evaluate the environmental impacts of those alternatives.
- Present the resulting analysis in a draft Environmental Assessment of Alternatives (EAoA).
- Distribute the draft EAoA for public and agency review.
- Consider the public's comments on the draft EAOA and identify a selected alternative.
- Prepare a decision document if no significant impacts.
- Implement the selected management alternative.

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APPENDIX I

Assateague Horse/
Equid Immunocontraception Bibliography

Assateague Horse / Equid Immunocontraception Bibliography

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APPENDIX II

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APPENDIX III

Introduction to CBSG Processes

CBSG Workshop and Training Processes

Information on capabilities of the Conservation Breeding Specialist Group (CBSG/SSC/IUCN)

Introduction

There is a lack of generally accepted tools to evaluate and integrate the interaction of biological, physical, and social factors on the population dynamics of threatened species and populations. There is an urgent need for tools and processes to characterize the risk of species and habitat extinction, on the possible impacts of future events, on the effects of management interventions, and on how to develop and sustain learning-based cross-institutional management programs.

The Conservation Breeding Specialist Group (CBSG) of IUCN's Species Survival Commission (SSC) has more than 15 years of experience in developing, testing and applying a series of scientifically-based tools and processes to assist risk characterization and species management decision making. These tools, based on small population and conservation biology (biological and physical factors), human demography, and the dynamics of social learning are used in intensive, problem-solving workshops to produce realistic and achievable recommendations for both *in situ* and *ex situ* population management.

Our workshop processes provide an objective environment, expert knowledge, and a neutral facilitation process that supports sharing of available information across institutions and stakeholder groups, reaching agreement on the issues and available information, and then making useful and practical management recommendations for the taxon and habitat system under consideration. The process has been remarkably successful in unearthing and integrating previously unpublished information for the decision making process. Their proven heuristic value and constant refinement and expansion have made CBSG workshop processes one of the most imaginative and productive organizing forces for species conservation today (Conway 1995; Byers and Seal 2003; Westley and Miller 2003).

Integration of Science, Management, and Stakeholders

The CBSG PHVA Workshop process is based upon biological and sociological science. Effective conservation action is best built upon a synthesis of available biological information, but is dependent on actions of humans living within the range of the threatened species as well as established national and international interests. There are characteristic patterns of human behavior that are cross-disciplinary and cross-cultural which affect the processes of communication, problem-solving, and collaboration: 1) in the acquisition, sharing, and analysis of information; 2) in the perception and characterization of risk; 3) in the development of trust among individuals; and 4) in 'territoriality' (personal, institutional, local, national). Each of these has strong emotional components that shape our interactions. Recognition of these patterns has been essential in the development of processes to assist people in working groups to reach agreement on needed conservation actions, collaboration needed, and to establish new working relationships.

Frequently, local management agencies, external consultants, and local experts have identified management actions. However, an isolated narrow professional approach which focuses primarily on the perceived biological problems seems to have little effect on the needed political and social changes (social learning) for collaboration, effective management and conservation of habitat fragments or protected areas and their species components. CBSG workshops are organized to bring together the full range of groups with a strong interest in conserving and managing the species in its habitat or the consequences of such management. One goal in all workshops is to reach a common understanding of the state of scientific knowledge available and its possible application to the decision-making process and to needed management actions. We have found that the decision-making driven workshop process with risk

characterization tools, stochastic simulation modeling, scenario testing, and deliberation among stakeholders is a powerful tool for extracting, assembling, and exploring information. This process encourages developing a shared understanding across wide boundaries of training and expertise. These tools also support building of working agreements and instilling local ownership of the problems, the decisions required, and their management during the workshop process. As participants appreciate the complexity of the problems as a group, they take more ownership of the process as well as the ultimate recommendations made to achieve workable solutions. This is essential if the management recommendations generated by the workshops are to succeed.

Participants have learned a host of lessons in more than 120 CBSG workshop experiences in nearly 50 countries. Traditional approaches to endangered species problems have tended to emphasize our lack of information and the need for additional research. This has been coupled with a hesitancy to make explicit risk assessments of species status and a reluctance to make immediate or non-traditional management recommendations. The result has been long delays in preparing action plans, loss of momentum, and dependency on crisis-driven actions or broad recommendations that do not provide useful guidance to the managers.

CBSG's interactive and participatory workshop approach produces positive effects on management decision-making and in generating political and social support for conservation actions by local people. Modeling is an important tool as part of the process and provides a continuing test of assumptions, data consistency, and of scenarios. CBSG participants recognize that the present science is imperfect and that management policies and actions need to be designed as part of a biological and social learning process. The workshop process essentially provides a means for designing management decisions and programs on the basis of sound science while allowing new information and unexpected events to be used for learning and to adjust management practices.

Workshop Processes and Multiple Stakeholders

Experience: The Chairman and Program Staff of CBSG have conducted and facilitated more than 260 species and ecosystem workshops in 50 countries. Reports from these workshops are available from the CBSG Office or at *www.cbsg.org*. We have worked on a continuing basis with agencies on specific taxa (e.g., Florida panther, Atlantic Forest primates in Brazil, black-footed ferret) and have assisted in the development of national conservation strategies for other taxa (e.g., Sumatran elephant, Sumatran tiger, Mexican wolf).

Scientific Studies of Workshop Process: The effectiveness of these workshops as tools for eliciting information, assisting the development of sustained networking among stakeholders, impact on attitudes of participants, and in achieving consensus on needed management actions and research has been extensively debated. We initiated a scientific study of the process and its long-term aftermath four years ago in collaboration with an independent team of researchers (Westley and Vredenburg, 2003). A survey questionnaire is administered at the beginning and end of each workshop. They have also conducted extensive interviews with participants in workshops held in five countries. A book detailing our experiences with this expanded approach to Population and Habitat Viability Assessment workshops (Westley and Miller, 2003) will provide practical guidance to scientists and managers on quantitative approaches to threatened species conservation. The study also is undertaking follow up at one and two years after each workshop to assess longer-term effects. To the best of our knowledge there is no comparable systematic scientific study of conservation and management processes. *We would apply the same scientific study tools to the workshops in this program and provide an analysis of the results after the workshop.*

CBSG Workshop Toolkit
Our basic set of tools for workshops include: small group dynamic skills; explicit use in small groups of problem restatement; divergent thinking sessions; identification of the history and chronology of the problem; causal flow diagramming (elementary systems analysis); matrix methods for qualitative data and expert judgments; paired and weighted ranking for making comparisons between sites, criteria, and options; utility analysis; stochastic simulation modeling for single populations and metapopulations; and deterministic and stochastic modeling of local human populations. Several computer packages are used to assist collection and analysis of information with these tools. We provide training in several of these tools in each workshop as well as intensive special training workshops for people wishing to organize their own workshops.

Stochastic Simulation Modeling
Integration of Biological, Physical and Social Factors: The workshop process, as developed by CBSG, generates population and habitat viability assessments based upon in-depth analysis of information on the life history, population dynamics, ecology, and history of the populations. Information on demography, genetics, and environmental factors pertinent to assessing population status and risk of extinction under current management scenarios and perceived threats are assembled in preparation for and during the workshops. Modeling and simulations provide a neutral externalization focus for assembly of information, identifying assumptions, projecting possible outcomes (risks), and examining for internal consistency. Timely reports from the workshop are necessary to have impact on stakeholders and decision makers. Draft reports are distributed within 3-4 weeks of the workshop and final reports within about three months.

Human Dimension: We have collaborated with human demographers in several CBSG workshops on endangered species and habitats. They have utilized computer models incorporating human population characteristics and events at the local level in order to provide projections of the likely course of population growth and the utilization of local resources. This information was then incorporated into projections of the likely viability of the habitat of the threatened species and used as part of the population projections and risk assessments. We are preparing a series of papers on the human dimension of population and habitat viability assessment. It is our intention to further develop these tools and to utilize them as part of the scenario assessment process.

Risk Assessment and Scenario Evaluation: A stochastic population simulation model is a kind of model that attempts to incorporate the uncertainty, randomness or unpredictability of life history and environmental events into the modeling process. Events whose occurrence is uncertain, unpredictable, and random are called stochastic. Most events in an animal's life have some level of uncertainty. Similarly, environmental factors, and their effect on the population process, are stochastic - they are not completely random, but their effects are predictable within certain limits. Simulation solutions are usually needed for complex models including several stochastic parameters.

There are a host of reasons why simulation modeling is valuable for the workshop process and development of management tools. The primary advantage, of course, is to simulate scenarios and the impact of numerous variables on the population dynamics and potential for population extinction. Interestingly, not all advantages are related to generating useful management recommendations. The side-benefits are substantial.

- Population modeling supports consensus and instills ownership and pride during the workshop process. As groups begin to appreciate the complexity of the problems, they have a tendency to take more ownership of the process and the ultimate recommendations to achieve workable solutions.
- Population modeling forces discussion on biological and physical aspects and specification of assumptions, data, and goals. The lack of sufficient data of useable quality rapidly becomes apparent

and identifies critical factors for further study (driving research and decision making), management, and monitoring. This not only influences assumptions, but also the group's goals.

- Population modeling generates credibility by using technology that non-biologically oriented groups can use to relate to population biology and the "real" problems. The acceptance of the computer as a tool for performing repetitive tasks has led to a common ground for persons of diverse backgrounds.

- Population modeling explicitly incorporates what we know about dynamics by allowing the simultaneous examination of multiple factors and interactions - more than can be considered in analytical models. The ability to alter these parameters in a systematic fashion allows testing a multitude of scenarios that can guide adaptive management strategies.

- Population modeling can be a neutral computer "game" that focuses attention while providing persons of diverse agendas the opportunity to reach consensus on difficult issues.

- Population modeling results can be of political value for people in governmental agencies by providing support for perceived population trends and the need for action. It helps managers to justify resource allocation for a program to their superiors and budgetary agencies as well as identify areas for intensifying program efforts.

Modeling Tools: At the present time, our preferred model for use in the population simulation modeling process is called *VORTEX*. This model, developed by Bob Lacy (Chicago Zoological Society), is designed specifically for use in the stochastic simulation of the extinction process in small wildlife populations. It has been developed in collaboration and cooperation with the CBSG PHVA process. The model simulates deterministic forces as well as demographic, environmental, and genetic events in relation to their probabilities. It includes modules for catastrophes, density dependence, metapopulation dynamics, and inbreeding effects. The *VORTEX* model analyzes a population in a stochastic and probabilistic fashion. It also makes predictions that are testable in a scientific manner, lending more credibility to the process of using population-modeling tools.

There are other commercial models, but presently they have some limitations such as failing to measure genetic effects, being difficult to use, or failing to model individuals. *VORTEX* has been successfully used in more than 100 PHVA workshops in guiding management decisions. *VORTEX* is general enough for use when dealing with a broad range of species, but specific enough to incorporate most of the important processes. It is continually evolving in conjunction with the PHVA process. *VORTEX* has, as do all models, its limitations, which may restrict its utility. The model analyzes a population in a stochastic and probabilistic fashion. It is now at Version 9.5 through the cooperative contributions of dozens of biologists. It has been the subject of a series of both published and in-press validation studies and comparisons with other modeling tools. More than 2000 copies of *VORTEX* are in circulation and it is being used as a teaching tool in university courses.

We use this model and the experience we have with it as a central tool for the population dynamic aspects of the Workshop process. Additional modules, building on other simulation modeling tools for human population dynamics (which we have used in three countries) with potential impacts on water usage, harvesting effects, and physical factors such as hydrology and water diversion will be developed to provide input into the population and habitat models which can then be used to evaluate possible effects of different management scenarios. No such composite models are available.

CBSG Resources as a Unique Asset
Expertise and Costs: The problems and threats to endangered species everywhere are complex and interactive with a need for information from diverse specialists. No agency or country encompasses all of the useful expert knowledge. Thus, there is a need to include a wide range of people as resources and analysts. It is important that the invited experts have reputations for expertise, objectivity, initial lack of local stake, and for active transfer of wanted skills. CBSG has a volunteer network of more than 800

experts with about 250 in the USA. More than 3,000 people from 400 organizations have assisted CBSG on projects and participated in workshops on a volunteer basis contributing tens of thousands of hours of time. We will call upon individual experts to assist in all phases of this project.

Indirect cost contributions to support: Use of CBSG resources and the contribution of participating experts provide a matching contribution more than equaling the proposed budget request for projects.

Reports: Draft reports are prepared during the workshop so that there is agreement by participants on its content and recommendations. Reports are also prepared on the mini-workshops (working groups) that will be conducted in information gathering exercises with small groups of experts and stakeholders. We can print reports within 24-48 hours of preparation of final copy. We also have CD-ROM preparation facilities, software and experience.

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APPENDIX IV

Simulation Modelling and PVA

Simulation Modeling and Population Viability Analysis

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Bob Lacy – Chicago Zoological Society / IUCN CBSG
Phil Miller – Conservation Breeding Specialist Group (IUCN / SSC)

A model is any simplified representation of a real system. We use models in all aspects of our lives, in order to: (1) extract the important trends from complex processes, (2) permit comparison among systems, (3) facilitate analysis of causes of processes acting on the system, and (4) make predictions about the future. A complete description of a natural system, if it were possible, would often decrease our understanding relative to that provided by a good model, because there is "noise" in the system that is extraneous to the processes we wish to understand. For example, the typical representation of the growth of a wildlife population by an annual percent growth rate is a simplified mathematical model of the much more complex changes in population size. Representing population growth as an annual percent change assumes constant exponential growth, ignoring the irregular fluctuations as individuals are born or immigrate, and die or emigrate. For many purposes, such a simplified model of population growth is very useful, because it captures the essential information we might need regarding the average change in population size, and it allows us to make predictions about the future size of the population. A detailed description of the exact changes in numbers of individuals, while a true description of the population, would often be of much less value because the essential pattern would be obscured, and it would be difficult or impossible to make predictions about the future population size.

In considerations of the vulnerability of a population to extinction, as is so often required for conservation planning and management, the simple model of population growth as a constant annual rate of change is inadequate for our needs. The fluctuations in population size that are omitted from the standard ecological models of population change can cause population extinction, and therefore are often the primary focus of concern. In order to understand and predict the vulnerability of a wildlife population to extinction, we need to use a model which incorporates the processes which cause fluctuations in the population, as well as those which control the long-term trends in population size (Shaffer 1981). Many processes can cause fluctuations in population size: variation in the environment (such as weather, food supplies, and predation), genetic changes in the population (such as genetic drift, inbreeding, and response to natural selection), catastrophic effects (such as disease epidemics, floods, and droughts), decimation of the population or its habitats by humans, the chance results of the probabilistic events in the lives of individuals (sex determination, location of mates, breeding success, survival), and interactions among these factors (Gilpin and Soulé 1986).

Models of population dynamics which incorporate causes of fluctuations in population size in order to predict probabilities of extinction, and to help identify the processes which contribute to a population's vulnerability, are used in "Population Viability Analysis" (PVA) (Lacy 1993/4). For the purpose of predicting vulnerability to extinction, any and all population processes that impact population dynamics can be important. Much analysis of conservation issues is conducted by largely intuitive assessments by biologists with experience with the system. Assessments by experts can be quite valuable, and are often contrasted with "models" used to evaluate population vulnerability to extinction. Such a contrast is not valid, however, as *any* synthesis of facts and understanding of processes constitutes a model, even if it is a mental model within the mind of the expert and perhaps only vaguely specified to others (or even to the expert himself or herself).

A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and

many of the factors interact in complex ways. For example, increased fragmentation of habitat can make it more difficult to locate mates, can lead to greater mortality as individuals disperse greater distances across unsuitable habitat, and can lead to increased inbreeding which in turn can further reduce ability to attract mates and to survive. In addition, many of the processes impacting population dynamics are intrinsically probabilistic, with a random component. Sex determination, disease, predation, mate acquisition -- indeed, almost all events in the life of an individual -- are stochastic events, occurring with certain probabilities rather than with absolute certainty at any given time. The consequences of factors influencing population dynamics are often delayed for years or even generations. With a long-lived species, a population might persist for 20 to 40 years beyond the emergence of factors that ultimately cause extinction. Humans can synthesize mentally only a few factors at a time, most people have difficulty assessing probabilities intuitively, and it is difficult to consider delayed effects. Moreover, the data needed for models of population dynamics are often very uncertain. Optimal decision-making when data are uncertain is difficult, as it involves correct assessment of probabilities that the true values fall within certain ranges, adding yet another probabilistic or chance component to the evaluation of the situation.

The difficulty of incorporating multiple, interacting, probabilistic processes into a model that can utilize uncertain data has prevented (to date) development of analytical models (mathematical equations developed from theory) which encompass more than a small subset of the processes known to affect wildlife population dynamics. It is possible that the mental models of some biologists are sufficiently complex to predict accurately population vulnerabilities to extinction under a range of conditions, but it is not possible to assess objectively the precision of such intuitive assessments, and it is difficult to transfer that knowledge to others who need also to evaluate the situation. Computer simulation models have increasingly been used to assist in PVA. Although rarely as elegant as models framed in analytical equations, computer simulation models can be well suited for the complex task of evaluating risks of extinction. Simulation models can include as many factors that influence population dynamics as the modeler and the user of the model want to assess. Interactions between processes can be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes. In theory, simulation programs can be used to build models of population dynamics that include all the knowledge of the system which is available to experts. In practice, the models will be simpler, because some factors are judged unlikely to be important, and because the persons who developed the model did not have access to the full array of expert knowledge.

Although computer simulation models can be complex and confusing, they are precisely defined and all the assumptions and algorithms can be examined. Therefore, the models are objective, testable, and open to challenge and improvement. PVA models allow use of all available data on the biology of the taxon, facilitate testing of the effects of unknown or uncertain data, and expedite the comparison of the likely results of various possible management options.

PVA models also have weaknesses and limitations. A model of the population dynamics does not define the goals for conservation planning. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used. Because the models incorporate many factors, the number of possibilities to test can seem endless, and it can be difficult to determine which of the factors that were analyzed are most important to the population dynamics. PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models probably underestimate the threats facing the population. Finally, the models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data

and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (2003) for more details).

The VORTEX Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

VORTEX Simulation Model Timeline

Events listed above the timeline increase N, while events listed below the timeline decrease N.
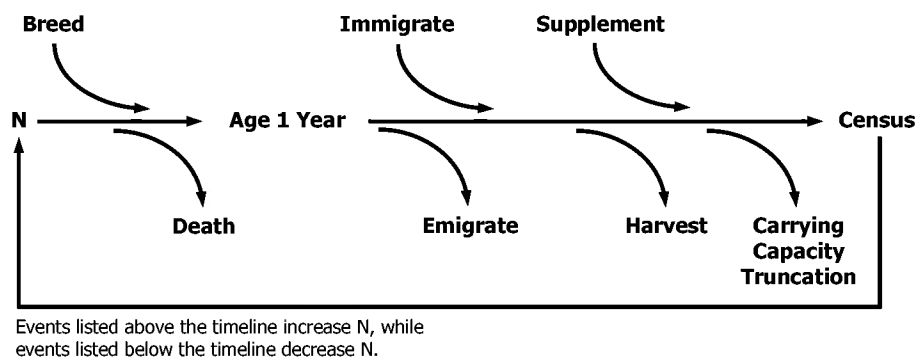
Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. (See figure below.) Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the

frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on *VORTEX* is available in Miller and Lacy (1999) and Lacy (2000).

Dealing with Uncertainty

It is important to recognize that uncertainty regarding the biological parameters of a population and its consequent fate occurs at several levels and for independent reasons. Uncertainty can occur because the parameters have never been measured on the population. Uncertainty can occur because limited field data have yielded estimates with potentially large sampling error. Uncertainty can occur because independent studies have generated discordant estimates. Uncertainty can occur because environmental conditions or population status have been changing over time, and field surveys were conducted during periods which may not be representative of long-term averages. Uncertainty can occur because the environment will change in the future, so that measurements made in the past may not accurately predict future conditions.

Sensitivity testing is necessary to determine the extent to which uncertainty in input parameters results in uncertainty regarding the future fate of the pronghorn population. If alternative plausible parameter values result in divergent predictions for the population, then it is important to try to resolve the uncertainty with better data. Sensitivity of population dynamics to certain parameters also indicates that those parameters describe factors that could be critical determinants of population viability. Such factors are therefore good candidates for efficient management actions designed to ensure the persistence of the population.

The above kinds of uncertainty should be distinguished from several more sources of uncertainty about the future of the population. Even if long-term average demographic rates are known with precision, variation over time caused by fluctuating environmental conditions will cause uncertainty in the fate of the population at any given time in the future. Such environmental variation should be incorporated into the model used to assess population dynamics, and will generate a range of possible outcomes (perhaps represented as a mean and standard deviation) from the model. In addition, most biological processes are inherently stochastic, having a random component. The stochastic or probabilistic nature of survival, sex determination, transmission of genes, acquisition of mates, reproduction, and other processes preclude exact determination of the future state of a population. Such demographic stochasticity should also be incorporated into a population model, because such variability both increases our uncertainty about the future and can also change the expected or mean outcome relative to that which would result if there were no such variation. Finally, there is "uncertainty" which represents the alternative actions or interventions which might be pursued as a management strategy. The likely effectiveness of such management options can be explored by testing alternative scenarios in the model of population dynamics, in much the same way that sensitivity testing is used to explore the effects of uncertain biological parameters.

Results

Results reported for each scenario include:

Deterministic r -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When r = 0, a population with no growth is expected; r < 0 indicates population decline; r > 0 indicates long-term population growth. The value of r is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat "carrying capacity" limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

Stochastic r -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic r will be less than the deterministic r predicted from birth and death rates. The stochastic r from the simulations will be close to the deterministic r if the population growth is steady and robust. The stochastic r will be notably less than the deterministic r if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the genetic and demographic instabilities inherent in small populations.

P(E) -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the VORTEX model as the lack of either sex.

N -- mean population size, averaged across those simulated populations which are not extinct.

SD(N) -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.

H -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993b), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls et al. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez et al. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé et al. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

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