REPORT OF THE SCIENTIFIC ADVISORY PANEL ON CONTROL OF TULE ELK ON POINT REYES NATIONAL SEASHORE

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FINAL REPORT

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INTRODUCTION

The need for control of overpopulation of deer and elk in parks is becoming commonplace in the United States (Porter 1992). The report of this scientific panel is in response to one such possible case, the tule elk population on Tomales Point in Point Reyes National Seashore (PRNS).

The tule elk occurred in considerable numbers on Point Reyes at the time of European arrival on the California coast, but they were extirpated following the gold rush period, along with most other populations in the original distribution (McCullough 1969). A small remnant, probably no more than 5 individuals, survived in the southern San Joaquin Valley, and all of the extant animals descended from that single source. The population on Point Reyes derived from translocations from the Tupman Reserve to the San Diego Zoo to San Luis Island Refuge in the San Joaquin Valley to Point Reyes (McCullough 1978). Three additional animals were introduced from Owens Valley, which in turn came from the Tupman Reserve. This population has built up to a population size at which the need for control must be addressed.

The charge to the panel was to evaluate the available evidence as to the need for control, and if control was indicated, what was the feasibility of various alternatives? Culling by rangers was proposed previously and public opposition to culling by some groups led to an alternative proposal for control by contraception.

We commend the Park Service for addressing this issue before the crisis stage was reached, and for involving both scientific expertise and public input. The schedule for this panel was to take public comment and visit the elk range the first day, deliberate for the following two days, and on the fourth morning, present our analysis first to PRNS personnel and then a public meeting.

We thank PRNS superintendent, John Sansing, for inviting us to serve on this panel, and PRNS staff Bill Shook, Sara Koenig, and Gary Fellers, for their technical support and hospitality. California Fish and Game biologists Jon Fischer and Fred Botti shared their information and explained the perspectives and policies of their agency. We thank the many members of the public who thoughtfully expressed their views and opinions on the tule elk program.

PASSIVE MANAGEMENT (NATURAL-REGULATION)

Background

A passive (i.e., non-intrusive) mechanism for population management is to allow the Tomales Point tule elk population to naturally-regulate. In essence, this is a hands-off approach in which NPS allows the population to grow until it reaches a dynamic equilibrium with the plant community. There is no question that this management strategy will control the population; however, both NPS and the public should clearly understand the consequences of implementing such a strategy. Natural-regulation occurs when available forage is inadequate to meet the animal's reproductive and maintenance requirements. As the population increases in density and less forage is available per animal, reproduction decreases and mortality increases. These changes in birth and death rates will gradually slow population growth and eventually produce a relatively stable population. We can reliably predict that if such a strategy is employed the tule elk will seasonally be malnourished and appear less "healthy" and that dead and dying animals will become more evident. We can also predict that elk would have an increased impact on plant communities and soils. These impacts will, in turn, affect other components of the animal community. Although we can make these statements with certainty, we cannot predict the magnitude of these impacts or evaluate if they will be acceptable to the public and/or compatible with overall ecological goals for Tomales Point.

Analysis of population data

A preliminary analysis of the population data available to date suggests that the population may be showing signs of natural-regulation. Early growth of the herd was slow due to over-utilization of the range by domestic cattle. This period lasted from introduction of the herd in 1978 until 1981 (Figure 1). Between 1982 and 1984 the herd began increasing more rapidly, approximately equal to the growth rate of the Grizzly Island population (Gogan 1986). Growth from 1985 to 1992 was even more rapid (Figure 1). However, in 1993 the growth of numbers tailed off. These results demonstrate that the carrying capacity derived by Gogan (140) was artificially low due to the prior impact of excessive cattle grazing.

When the growth in numbers is considered as a rate (expressed as $N_{t+1}-N_t / N_t$) it is clear that the rate increased from time of introduction until 1982, following which it declined. Presumably this change is due to an improvement or recovery of the range from previous livestock grazing followed by decline in rate due to increasing elk numbers; that is a density-dependent response. If the data from 1981 and earlier (the range recovery period) are deleted, the relationship in Figure 2 is obtained for the population rate of increase over time. This negative relationship is statistically significant (r^2=0.59, P=0.003). The year at which the population would reach zero growth is predicted to be 1998. If rate of increase is plotted on population size, the relationship is as shown in Figure 3. This relationship is statistically significant also (r^2=0.47, P=0.014). The population size at zero population growth is projected to be 346 elk.

There are many problems with these data. First, there is question of their accuracy. The results from Gogan (1986) are from intensive field work and a relatively small population, and are likely to be reasonably accurate. Counts since then have been somewhat more variable, particularly in recent years when elk numbers have been high. There is concern with missed animals, particularly calves. However, for the 1993 count no reasonable number of missed calves could significantly alter the conclusion that density-dependence is occurring. An increased count would result in a higher population size at predicted zero growth, however.

Second, the confidence limits are wide. This reflects the actual natural variation in growth of the population as well as counting errors. As for natural variation, the confidence limits are not unexpected, because they are comparable to many similar cases of population growth in ungulates. In fact, year-to-year variation is to be expected. A major source of variation is the annual variation in climate. However, the influence of climate on Point Reyes may be less than in inland areas given the dampening effect of frequent fogs on conditions during the summer, the most severe season in coastal California. Note, for example, that the high rates of population increase (well above the regression line) in 1991 and 1992 occurred following drought years whereas the low value in 1993 occurred after one of the highest rainfall years. One would assume that this pattern would have been reversed if conditions typical of inland areas applied to Point Reyes.

Current population status

Despite the limitations of these data, they are what we have available, and we must consider their indications on population performance of tule elk on Tomales Point. They should be neither trusted explicitly nor rejected out of hand. At minimum, they would suggest that density dependence is being expressed by current population levels. The apparent low number of calves in relation to the number of cows (by our estimation in the neighborhood of at least 100 at present) would suggest significant prenatal and neonatal mortality in the population.

The reliability of the projections of population size at zero increase (346), and the time that such a population will be reached (1998) are in serious doubt. The error in such projections is indicated by the width of the 0.95% confidence limits in the figures. However, these data suggest that natural regulation of this population in the absence of control is a realistic possibility. It is of interest that the mean estimate of "carrying capacity" indicated by the population data is similar to the 350 derived by Bartolome (1993) from range analysis. At best, this agreement might result from a convergence of independent methods on plants and animals due to accurate reflections of the true situation. However, the variation in each of the data sets would indicate caution in uncritically accepting these results. Furthermore, the use of residual dry matter, which is useful because it is readily measured, reflects only overall use. It does not take into account shifts in plant species composition, invasion of exotics, and other changes in vegetation that may be undesirable.

A conceptual model for monitoring

We view the elk-range relationship in the context of the model in Figure 4. In this figure, elk numbers are represented by the numbers counted, whereas range quality is represented by arbitrary units that we believe represent the history and current status of range quality. By range quality we mean both the area-wide impacts, as reflected by residual dry matter, and impacts on critical areas such as an increase in obvious trails, trampling of wetland areas, etc.

In our judgement, the critical areas may well set limitations on acceptable elk population size before the range-wide impacts. Impacts on biodiversity or individual threatened and endangered species could occur before the elk population reaches equilibrium with the overall plant community. The NPS must monitor these aspects of the range to follow its mandate of protecting the biodiversity of PRNS. Most of the threatened or endangered species do not occur on Tomales Point but special attention should be paid to those that do, such as the Blennosperma among the plants and the Myrtle's silverspot butterfly among the animals.

We believe that the current numbers of elk are not critical, and that an immediate crisis is not at hand. This conclusion is based on the generally favorable appearance of the vegetation (which agrees with the range analysis by Bartolome [1993]) and the good condition of the elk at this, the most critical time of year for both vegetation and elk. This suggests that there is still time to evaluate changes to see if indeed the elk are going to naturally regulate, or if intervention will be required. How long the time required to determine the outcome is not certain. If the projection shown in Figure 4 proves to be correct, then equilibrium should be approached by about 1998. The next few years should indicate what trend the elk and vegetation are taking. If the vegetation quality and elk numbers line in Figure 4 either converge or fail to intersect, natural-regulation will be indicated. If the elk line crosses the vegetation quality line, then intervention will be required.

As indicated in the next section of this report, contraception is not a useful option at high population size because of the need to treat a very high proportion of the females, and population reduction is not achieved until adult mortality subsequently occurs. In many respects, the current population is already at a size that makes the burden for contraception very high, and additional increases in population size will increase that burden. But if the natural regulation hypothesis is to be tested, the current course must be stayed for at least another year or two, despite the adverse impact on the feasibility of contraception as a control technique.

In the face of this uncertainty, an adaptive management approach is required. The vegetation and elk must be monitored, and criteria for assessing maximum acceptable impact on critical areas developed. Studies of the feasibility of contraception delivery must be carried out, either here or in another area of comparable difficulty. If the predictions of this analysis hold true, a natural-regulation system of management can be adopted. Given the variance between years, intervention may be required at periodic intervals if by chance, series of good years increase the population to a high level. Most of the time, intervention would not be required. However, if results from the next few years yield a shift of the predicted zero increase point to higher elk numbers (above the range quality line of Figure 4), a later year of stability, and damage to the range, active intervention would be required.

ACTIVE MANAGEMENT

Statement of the problem

Because the Pt. Reyes tule elk population is restricted within the Point Tomales area by a fence, there currently is no movement of animals into or out of the area and the dynamics of the population are driven exclusively by reproduction and survival. Manipulating one or both of these processes, therefore, can be used to control the population. Manipulating survival rates removes animals from the population and also decreases recruitment of new animals into the population if reproductive-age females are removed. Management actions potentially available include the capture and relocation of animals and/or the killing of animals by agency personnel or by restricted public hunting. From a demographic perspective, removing animals from the population is the most effective means of controlling numbers as such actions can affect both reproduction and survival and are capable of not only stabilizing the population but also reducing it if necessary (McCullough 1987). Manipulating reproduction through the use of contraceptive technologies can reduce recruitment of animals into the population, but does not remove animals from the population. Reproductive manipulations, therefore, are not as effective in population control as removing animals and, in all practicality, can only be used to slow population growth or stabilize the population at its current level (McCullough 1987, Garrott 1991).

Tradeoffs between culling and contraception

Although the manipulation of either reproduction or survival can be used to limit the tule elk population, the demographic attributes of the population conducive for successful management are somewhat different for the two approaches (Table 1). Manipulations of reproduction are best employed when the population is well below carrying capacity. The effective use of contraception technologies depends on the successful treatment of a large proportion of the females. Treatment tends to be relatively difficult, time consuming, and expensive; hence, the larger the number of animals that must be treated the less likely it becomes that effective population control can be achieved (Garrott 1991). In addition, when the population is well below carrying capacity most adult females are reproducing each year so that an effect will be realized for a high proportion of the animals treated with a contraceptive. In contrast, when the population is near carrying capacity, limited food resources depress both reproductive and survival rates. As a consequence only a small proportion of the animals treated with a contraceptive would have reproduced in the absence of treatment, reducing the efficiency and effectiveness of the manipulation. Another confounding factor is the potential for a compensatory change in survival rates. Reproduction is energetically costly and when animals are in poor nutrition, as they would be when the population is near carrying capacity, the additional energetic costs of reproduction can reduce survival rates. Using contraceptives to block reproduction, eliminates these energetic costs and can thus result in enhanced survival rates. Such a compensatory response has the potential of reducing the overall effectiveness of a contraceptive management program.

Removing animals can be effective at any population level, but is likely to be more practical than contraception when the population is near carrying capacity. Until additional research can be conducted on the status of Johne's disease in the tule elk population, translocation of excess animals is not a viable management option. Hence, excess animals would have to be removed by shooting. Although a well-designed shooting program could be both economical, effective, and humane, some elements of the public do not approve of the destruction of elk. If such a management plan were implemented, therefore, it would be wise to minimize the number of animals that must be culled from the population. If the population is maintained well below carrying capacity both reproductive and survival rates would be high, resulting in high annual population growth rates that may exceed 20%. Hence, if culling is used to stabilize the population this increment would have to be removed on an annual basis. If, however, the population were maintained near carrying capacity, reproduction and survival would be depressed resulting in low annual growth requiring the culling of a much smaller proportion of the population. If the annual growth rate is low then the absolute number of animals that must be removed could be considerably lower than if the population is managed well below carrying capacity. Since survival and reproductive rates will already be poor if the population is maintained near carrying capacity there is also little potential for a compensatory increase in reproduction and/or survival that would reduce the effectiveness of such a management program.

CONTRACEPTION

State of the art

Contraception is a viable means of preventing individuals from reproducing. Factors affecting successful contraception of a population of animals include (1) the efficacy of the contraceptive agent and (2) the proportion of animals in the population that can be successfully treated. In a free ranging population of animals, this is compounded by the number of treatments that have to be delivered to each animal to effect contraception. At the present time there is not sufficient information pertaining to this elk population to allow the development of a feasible plan for managing the population utilizing contraception.

Among several available contraceptive options, two different types, hormonal contraception and immunocontraception, have proven effective in preventing individual elk from reproducing. Side effects of these compounds in elk, however, are not known. Although the short term effects of using either method are probably negligible, based on currently available data, the long term effects of these contraceptive agents are completely unknown for elk. For example, hormonal contraceptives have been associated with uterine hyperplasias and neoplasias in some species (Buergelt and Kollias, 1987) and antibodies against porcine zona pellucida glycoprotein (PZP) have been reported to destroy structures within the ovary in several species (Dunbar et al. 1989; Mahi-Brown et al. 1985). Although the efficacy of these compounds appears to be quite high, no data are available as to how often failures occur with either type of treatment.

Available contraceptive agents

There are numerous contraceptive agents that may be effective but only three have been tried and proven in this species. Those agents that may be useful but have not yet been fully developed and/or tested in elk include (1) gonadotropin releasing hormone (GnRH) super analogue, a hypothalamic hormone that if administered in supra-physiological dosages will chemically castrate the male or female animal (Vickery et al. 1984); (2) Norgestimet, a synthetic progestin currently utilized in the food industry (D. Jessup, unpublished); (4) sperm acrosomal membrane protein (SAMP) immunization which stimulates antibodies against the sperm cell surface proteins which results in infertility in the male and female (Herr et al. 1990); (5) a conjugated GnRH molecule which elicits antibodies against GnRH and achieves the same end as the GnRH super analogue, (see No. 1 above; Hasson et al. 1985); (6) a GnRH analogue conjugated to a cellular toxin which destroys certain cells in the pituitary and chemically castrates the male or female animal (T. Nett, unpublished).

The three agents which have been proven successful in elk are (1) diethylstilbestrol (DES, a nonsteroidal synthetic estrogen); (2) melengestrol acetate (MGA, a synthetic progestin); and (3) porcine zonae pellucidae (PZP, a vaccine which prevents fertilization in the female). In 1968, attempts were made to regulate reproduction in Yellowstone National Park elk by administering i.m. doses of 75-200 mg of DES to 36 pregnant animals between December and March (Greer et al. 1968). Pregnancy was terminated in 30% of the treated animals.

Melengestrol acetate (MGA) is a synthetic progestin which can be delivered orally, by implant, incorporated into a homogenous silastic implant, or by injection if coupled with microencapsulation technology. It causes suppression of estrus and ovulation in the female. Implants containing MGA have been effective in preventing estrus and pregnancy in 19 captive elk (E. Plotka and U. Seal, unpublished).

PZP vaccine is the only immunocontraceptive agent which has been tested in elk. The zona pellucida is a non-cellular membrane made up of glycoproteins that covers the mammalian oocyte (egg). One of these proteins, ZP3, is postulated to be the sperm receptor (Florman and Wassarman, 1985). PZP is a zona pellucida glycoprotein isolated from porcine oocytes. Intramuscular injections of PZP cause the female to raise antibodies against this glycoprotein which in turn can attach to the target animal's own sperm receptors and thereby inhibit fertilization (Liu et al. 1989). The PZP vaccine was tested in eight female elk at the Bronx Zoo and resulted in the inhibition of fertility in seven (J. F. Kirkpatrick, unpublished). A remote delivery trial to elk is underway at Battelle Northwest Laboratories but results are not yet available (R. A. Garrott, personal communication). This vaccine must be delivered by hand or remotely by dart or biobullet. Some very preliminary research is underway by the Denver Wildlife Research Center to produce a form of this vaccine which can be delivered orally in a feed source, but it is unlikely that it will be available in the near future.

Nature of the problem

Contraception is a tool for regulating the growth of a herd of animals and its use requires several conditions. First, an agent has to be available that can be administered to the animal that will prevent the animal from delivering a viable offspring. As mentioned above, several agents that prevent animals from becoming pregnant are available and have demonstrated efficacy in elk.

Second, a sufficient number of animals has to be treated to reduce the number of births in the herd. Thus, the type and ease of delivery of the contraceptive agent must be considered. Data are not available to determine if sufficient numbers of animals can be gathered or darted on Tomales Point to allow delivery of the contraceptive to enough animals to arrest population growth. Some agents have to be delivered by hand (e.g. implants), requiring the handling of the animals. Other agents can be delivered remotely (e.g. with a dart or biodegradable biobullet) from a distance of up to 50 yards. In order to administer a contraceptive agent to the numbers of animals necessary to significantly reduce population growth, techniques or procedures for delivery have to be worked out for the conditions of the specific population and habitat where contraception is required. As discussed elsewhere in this report, in order to significantly slow the growth of the population, a large proportion of the females would have to be treated (Garrott 1991). The precise number of animals that need to be treated is a function of the effectiveness of the contraceptive (i.e. an effectiveness of 90% means that 90 of every 100 animals treated would not become pregnant when bred by a fertile male) and the percentage of animals in the population that can be treated (Garrott 1991). For example, if the population contains 100 females, and 80 of these females can be treated reliably with the contraceptive agent, only 72% (90 x 80) of the population of females would be effectively treated with contraception.

Because the success of this technique as a management tool depends on the percent of the population that receives the active agent, studies to determine the most efficient and acceptable method for dispensing the contraceptive to the Point Reyes elk would have to be conducted. These studies should consider the effects on elk behavior, health, accessibility to the public and public viewing as well as frequency with which the treatment has to be given and the cost and feasibility of administering the active agent. If the contraceptive is to be delivered remotely by dart, then recovery of the dart should also be considered.

Third, the long term effects of having a large number of non-reproducing animals in a herd are unknown. These effects may differ with different contraceptive approaches. For example, hormonal contraception of females will suppress ovarian function and prevent the exhibition of estrous cycles. Females will not be attractive to males and mating will not occur. With immunocontraception using a zona pellucida vaccine, ovarian cycling does occur and the males will be attracted to the females repeatedly through to the end of the breeding season. The breeding season likely will be extended because of the polyestrous nature of non-pregnant animals. The effects of the extended breeding season and repeated mating on herd behavior or body condition of the males and females is unknown at present.

Study of contraception feasibility at PRNS

Although current information on the status of the PRNS elk herd is not sufficient to make clear recommendations on contraception as a tool for managing the population, the NPS is in the position of being able to set up experiments to determine the feasibility of utilizing contraceptives to retard population growth should the need arise.

Controlled studies with sufficient numbers of contraceptive treated and placebo treated animals for statistical reliability would be quite reasonable and achievable in this setting. However, in making this consideration, one would have to accept the need for utilizing identifiable (marked) animals. This would necessitate the acceptance of some disturbance of the elk social structure. The effect of this disturbance on public viewing to the animals could easily be monitored and used to determine how much herd manipulation can occur before public access is reduced. This approach would also necessitate accepting that some animals will need to be sacrificed for necropsy to determine contraceptive side effects. Because a study on contraception would not interfere with studies on the incidence of disease, these same animals would also be available for the study of Johne's and other wildlife diseases.

Advances in wildlife contraceptive technology are occurring at a rapid rate and at least 7 research groups are involved. Thus, it is incumbent on the NPS to seek frequent updates on the progress of research in this field and to incorporate the advances within the framework of these recommendations.

JOHNE'S DISEASE AND TRANSLOCATION OUTSIDE PRNS

Constraint on relocation

If the Tomales Point herd were disease free, limited opportunities to reduce population size through translocation might arise from time to time as DFG identifies new areas of suitable tule elk habitat. However, it is becoming increasingly hard to find such suitable areas, so translocation cannot be relied upon as a primary tool for population control.

Johne's disease (paratuberculosis) is a contagious disease caused by an environmentally resistant bacterium, Mycobacterium paratuberculosis. PRNS tule elk were shown to be infected with this disease at one time (Gogan 1986) but the current status of disease in the population is unknown. Good wildlife management practices and appreciation of cattle producers' concerns dictate that tule elk known to be exposed or infected with Johne's disease should not be moved to other locations off PRNS. Little is known regarding the occurrence of other livestock and wildlife diseases in the herd.

Current status of Johne's disease

A survey for Johne's disease by culture of fecal samples is currently underway. Even a single culture-positive fecal sample would prove that Johne's disease is still present and that elk cannot be translocated. However, fecal culture is not highly sensitive and false negatives are fairly common. Thus, negative results would not be sufficient to prove that the disease is absent from the herd and elk could not be translocated based on evidence from fecal samples alone.

More extensive studies would be required to demonstrate that Johne's disease is no longer present if translocation were to be an alternative means of population control. Such a program should involve culture of 100 fecal samples per year for five years and necropsy of a minimum of 50 adult elk over a period of five years or less. If results are negative in all cases, it would be reasonable to assume Johne's disease is absent and that animals could be removed for translocation. However, each animal selected for translocation should be tested for Johne's disease by an ELISA, or comparable test.

If Johne's disease is found to be present at any time, fecal sampling and necropsies could be terminated and the PRNS should appoint a panel of wildlife veterinarians and elk biologists to develop a program to eradicate the disease.

Necropsy program

Current knowledge of the tule elk on Tomales Point is rather sparse and much could be learned by initiating a limited necropsy program. Such a program would provide information on diseases in the herd, including Johne's disease, reproductive status, body condition, etc. In addition, much could be learned about elk response to agency culling.

A necropsy program should involve:

1. Shooting of adult elk by agency personnel.
2. Field necropsies conducted by a certified veterinary pathologist.
3. Collection of samples for serologic and cultural evaluation for diseases commonly found in California wildlife and livestock.
4. Collection of appropriate tissues for histologic and other laboratory evaluations.
5. Collection of reproductive tracts for evaluation of pregnancy, physical abnormalities, and to serve as a baseline for future contraception studies.
6. Salvage of carcasses whenever possible. An outfitter could be hired if necessary.
7. The estimated cost of 10 field necropsies per year is \$5,000-\$10,000.

GENETIC MANAGEMENT

Genetic diversity in tule elk

All living tule elk are descended from the few individuals that gave rise to the Tupman population (McCullough 1969). Other populations throughout the state were started with a relatively small number of individuals from that population or one descended from it (McCullough 1978). Because tule elk populations have been periodically reduced to a small number of individuals, theory predicts that they should possess reduced genetic variation and this prediction has been confirmed by laboratory analyses. Electrophoretic studies found variation at none of 23 allozymes from blood samples in 76 individuals from Tupman Reserve and Owens Valley and 2 of 30 allozymes from liver and kidney samples from 24 animals from Owens Valley (Kucera 1991). The overall proportion of polymorphic loci was 0.053. DNA fingerprinting of samples from four geographically isolated populations indicated that the average bandsharing frequency among individuals was 0.96 (B. Lundrigan and K. Ralls, unpublished data). This is an extremely high frequency of bandsharing. For example, the expected bandsharing frequency among first degree human relatives -- parents and children or full siblings -- is about 0.65. Thus, individual tule elk are genetically quite similar and the entire population is inbred. Fortunately, however, tule elk show little sign of inbreeding depression. In good habitat, they exhibit high fecundity and juvenile survival. Both measures are sensitive indicators of inbreeding depression (e.g., Ralls et al. 1988).

The tule elk population at PRNS has passed through at least four population "bottlenecks". First the entire subspecies was reduced to the few remaining individuals that gave rise to the Tupman population. Second, elk from Tupman were used to found a population at the San Diego Zoo. Third, elk from San Diego Zoo were taken to the San Luis Island Refuge, which, fourth, was the source of elk brought to PRNS.

Maintaining genetic diversity

Although the subspecies as a whole contains limited genetic variation, the PRNS population may not contain all the variation present in the subspecies. Thus, it would be prudent to manage the PRNS population as a subpopulation within the entire "metapopulation" of tule elk in California, rather than as an isolated, genetically closed population. Metapopulation management would require the occasional addition of elk from other populations into the PRNS population.

California Dept. of Fish and Game has indicated that they would provide animals for introduction to PRNS. Providing they survived and reproduced, very limited numbers of elk would be required, on the order of two to three individuals every elk generation (approximately five to six years). We recommend the addition of female, rather than male, elk because females would be more easily integrated into the population and more likely to reproduce successfully. The first introduction of new elk should be made in the near future. Introduced individuals should be permanently marked and their survival and reproductive success monitored to be sure that they have indeed contributed to the population. In view of the fact that the PRNS population should not be managed as a closed population, it is not necessary to be concerned about possible genetic consequences of population manipulations, such as maintaining the population at a particular size, or curtailing reproduction of some individuals through culling or contraception.

Current management confines the PRNS population to Tomales Point. It is unrealistic to think that this limited area could ever support a population large enough to qualify as a long-term "minimum viable population" on either demographic or genetic grounds. Although Gogan (1986) estimated that 50 to 63 elk would constitute a minimum viable population, the early models he used are obsolete. As models have become more realistic and planning more long-term, estimates of long-term viable population sizes for vertebrates have tended to increase (Soule 1987) and are currently in the range of thousands of individuals (Boyce 1992, Nunny and Campbell 1993).

EXPANDED MONITORING PROGRAM

Elk population monitoring

This panel found that the available data on the elk population and its impact on its habitat were insufficient to make detailed management recommendations. Current elk monitoring techniques are providing useful but insufficient information. Better information on total size and the age/sex composition of the herd are vital both to determine if and when natural regulation will occur and to design a contraception program. Changing the survey date to a more optimal time, such as late September or early October, when weather conditions would be more favorable and animals more visible, would help achieve this goal. If age/sex composition cannot be obtained from aerial surveys, these surveys should be supplemented with ground observations. If funding and personnel are available, more detailed information such as pregnancy rates and calf survival would be useful.

Habitat monitoring

Habitat monitoring techniques are providing acceptable information on overall habitat changes, including residual dry matter and species composition. Existing photo points have the potential to assess long-range changes. Because it is likely that unacceptable levels of damage to high-use and critical areas will occur before over-all range deterioration. These impacts need to be measured. At minimum, additional photo points should be established around water sources, in areas of potential trailing, and locations of threatened and endangered plants.

EXOTIC CERVIDS

Axis and fallow deer were introduced into what is now PRNS in the 1940's. They are of little or no cultural or historical significance and their continued presence is clearly inappropriate. These deer were demonstrated to harbor Johne's disease and some limited surveys for other diseases have been conducted.

Exotic deer should be eliminated by NPS. Appropriate samples should be collected from carcasses for evaluation by a veterinary diagnostic laboratory. An appropriate sample collection protocol should be developed in collaboration with the cooperating laboratory. The estimated cost of pathologic evaluation of samples from 100 animals per year is $6,000.

PUBLIC EDUCATION

A strong educational program must accompany every step of the research initiated or action taken by the NPS with regard to the management of the tule elk. Controversy attends each management action taken with highly visible mammals in national parks. Regardless of the success or failure of each action, the public at large must be informed of the rationale behind such actions and the possible outcomes.

These lessons have been brought to focus by the Assateague Island National Seashore wild horse contraception program. This project was highly visible to the public and the subjects of the research - the horses - are considered a highly valued resource by the public. From the first day of the project, the NPS embarked upon a carefully designed and well-implemented educational program designed to keep the public informed.

Reading material, in the form of pamphlets for visitors, which described the reasons for the research and the methods employed were printed and distributed at visitor centers. A video of the most potentially controversial part of the project - darting horses - was made and shown at the visitor centers. Naturalists were briefed each spring and visitor programs described the project. To the extent possible, research was conducted out of sight of visitors, but when that was not possible, the research team and NPS personnel were instructed to inform any visitors present of what was taking place. The regional scientist and regional director were kept apprised of progress on an annual basis, and the National Seashore's PR apparatus was kept informed with accurate up-to-date information. The end result was that a potentially charged project received the full support of the public through an eight-year period. A similar carefully planned and open educational program should be implemented as the panel's recommendations are implemented.

LONG-RANGE PLANNING

We believe that the long-range goal of elk management at PRNS should be to re-establish of free-ranging tule elk throughout the park and associated public lands. While it is not possible to achieve this goal today, changing agricultural practices and values and increasing public appreciation of free-ranging elk will make it possible in the not-too-distant future. Current management can work towards this goal through control/eradication of certain contagious diseases, improved monitoring of elk demography and habitat changes, elimination of exotic cervids, a public education program, and a cooperative long-range elk management plan developed jointly by PRNS and CDFG. The goal of such a plan should be a large, healthy population of free-ranging elk subjected to minimum management intervention. Once these goals are achieved, culling would likely be necessary.

CONCLUDING REMARKS

We recognize that this report leaves many issues unresolved. This is because the current status of the elk population is uncertain, and the future trends not entirely predictable. Only better information and time will address the fundamental issue: will the tule elk herd on Tomales Point naturally regulate or is active management required? We cannot give a prescription at the present time. The best we can do is to lay out the alternatives and recommend a course of action that will address alternate outcomes of this experiment in population growth. The crisis stage has not yet been reached, but the time to act is now. There are no perfect solutions and good information and hard work are necessary to establish the best program, taking into account NPS policies and public acceptance.

The NPS faces some difficult problems. How can elk impacts on critical areas be measured, and what threshold (that if exceeded, active intervention is indicated) should be adopted?

Only careful study of specific impacts can address these issues. And, should active intervention prove to be required, is it preferable to maintain a large population near carrying capacity, or a smaller population well below carrying capacity? Clearly the method of control will strongly influence the choice.

RECOMMENDATIONS:

1. We recommend that the elk herd be permitted to self-regulate with regard to population size unless some predefined threshold of impact upon habitat has been exceeded. We strongly recommend that the NPS establish the habitat impact threshold as soon as possible. Threshold criteria could be based upon a)a reduction in residual dry matter in critical areas below the levels that would protect the soil, b) excessive localized impacts such as trailing in localized critical areas, and c)excessive impact on threatened and endangered flora and fauna. Without this standard, there is no basis for determining whether active management (e.g. culling or contraception) or passive management (e.g. natural population regulation) is appropriate.

   The consequences of not establishing a threshold are possible excessive damage to the habitat and natural systems that are incompatible with the NPS goals for management of Tomales Point.

2. We view the integrity of the ecosystem as the predominant goal of elk management. Therefore, we recommend that if necessary, agency culling be employed as the ultimate control method to hold elk numbers to the predefined habitat impact threshold. If alternative controls can be achieved, either by natural regulation, translocation or contraception, culling may not be necessary.

3. The only current management technique available for controlling the elk population is agency culling of animals assuming that public hunting is not an option. Translocation and reproductive control are both potential management techniques but cannot be implemented at present due to a lack of baseline information. Therefore, we recommend implementation of the following research initiatives to increase management options.

   a. Establish a pilot study to assess the feasibility of utilizing contraceptives as a means of population control.

   b. Initiate a program of fecal culture and necropsy to establish the current status of Johne's and other important livestock diseases in the population. This is required in order to evaluate the feasibility of translocation of animals outside of the National Sea Shore.

4. We recommend that the habitat and animal monitoring programs be expanded. This is essential to establish the validity of the current estimate of range carrying capacity of 350 animals and the feasibility of population control with contraceptives. The plant monitoring program needs to include critical areas, e.g. areas of high physical impacts, water sources and threatened and endangered plants. Better information on total size of the herd and the sex/age composition need to be obtained. For example, changing the survey date and implementing ground surveys to obtain sex/age composition would help achieve this goal.

5. We recommend the addition of 2-3 female elk every elk generation to maintain genetic variation within the population. The first addition of new elk should be made as soon as possible.

6. The long-range goal of elk management at PRNS should be the re-establishment of free-ranging elk throughout the seashore and associated public lands. This would involve elimination of exotic cervids and removal of the fence across Tomales Point. NPS and CDFG should develop a long-range management plan with the goal of achieving a large, healthy, free-ranging elk population subjected to a minimum of management intervention.

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Table 1. Management tradeoffs for control programs of ungulate populations maintained near carrying capacity or well below carrying capacity.

MANAGEMENT NEAR CARRYING CAPACITY	
Advantages	Disadvantages
Possibility of no active mgmt More "natural" Least costly	Increased vegetation impacts Increased mortality Less "healthy" animals More animals to manipulate Contraception less viable
MANAGEMENT WELL BELOW CARRYING CAPACITY	
Advantages	Disadvantages
Lower vegetation impacts Lower mortality "Healthier" animals Less animals to manipulate Contraception more viable	Active management required Continued expense Less "natural" Initial large reduction may be required

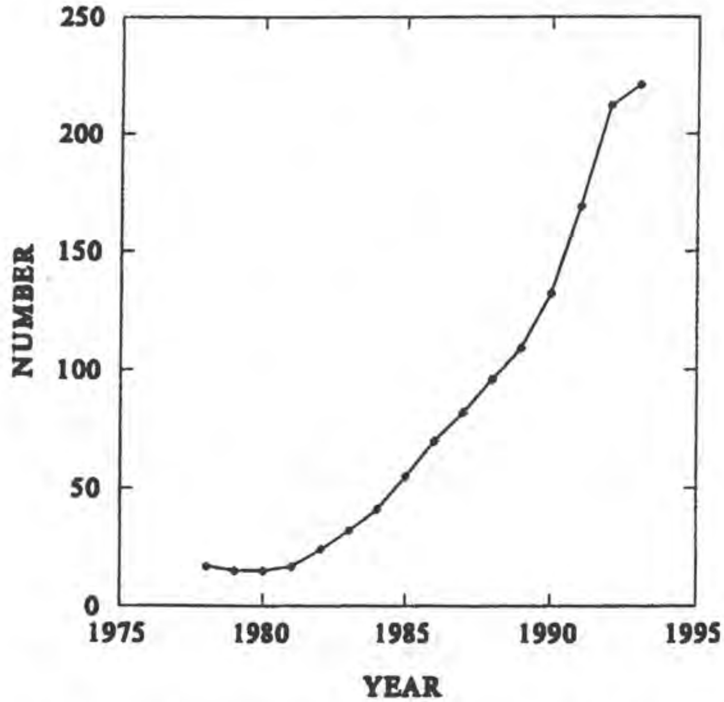
FIGURE LEGENDS

Figure 1. Counts of tule elk population size over time on Tomales Point, PRNS.

Figure 2. Regression of the population's rate of increase on time with 0.95% confidence intervals. The slope is significantly different from zero ($r^2 = 0.59$, $p = 0.003$). The predicted year at which zero population increase is reached is 1998.

Figure 3. Regression of the population's rate of increase on population size with 0.95% confidence intervals. The slope is significantly different from zero ($r^2 = 0.47$, $p = 0.014$). The predicted population size at attainment of zero population increase is 346.

Figure 4. Observed elk population size in relationship to hypothesized range quality to illustrate the adaptive management scenario. If elk numbers and range quality remain separated or converge, natural regulation will occur. If they cross, then either intervention or range degradation will occur.



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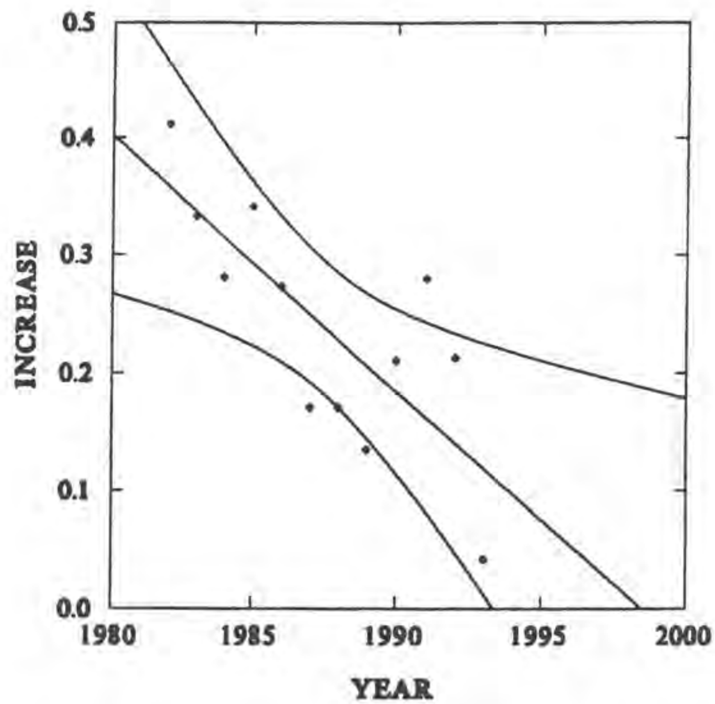

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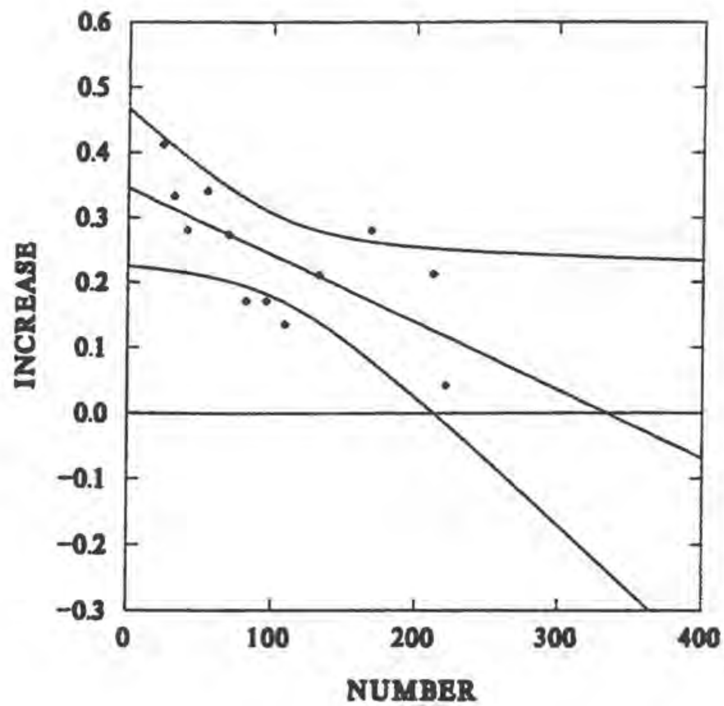

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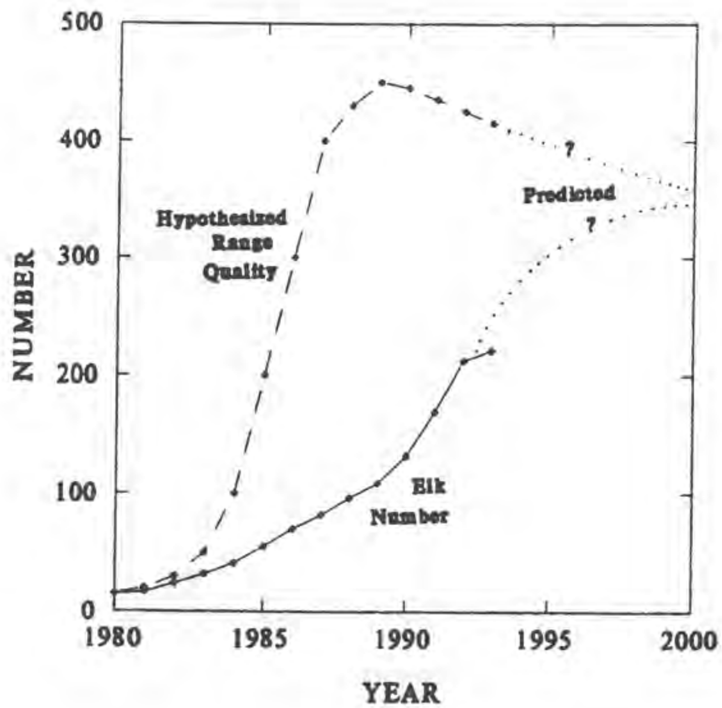

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