FINAL REPORT

OLYMPIC NATIONAL PARK

SCIENTIFIC PANEL REVIEW

The Applicability of Contraceptives
in the Elimination or Control of Exotic Mountain Goats
from Olympic National Park

January, 1992

Panel Members:

Richard A. Fayrer-Hosken
Dr. Richard A. Fayrer-Hosken

Robert A. Garrott
Dr. Robert A. Garrott

Jay F. Kirkpatrick
Dr. Jay F. Kirkpatrick

Robert J. Warren
Dr. Robert J. Warren, Panel Leader
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I. EXECUTIVE SUMMARY

A five-member panel of scientists (wildlife biologists, reproductive physiologists, and veterinarians) conducted an independent, on-site review to evaluate the potential for contraceptives to eliminate or control mountain goats in Olympic National Park. All panel members were experienced in experimental applications of the latest contraceptives to free-ranging wild or feral animal populations.

The panel spent six days on-site, during which they were taken on aerial tours via helicopter and shown mountain goats and a variety of mountain goat habitat. Numerous meetings were held with NPS personnel at the park to discuss policy and administrative matters, previous mountain goat research and management efforts in the park, and the panel's task and report. The panel was featured at a public meeting held during one evening at the park headquarters. The meeting included a question-and-answer session for the public and interviews with local television and newspaper media representatives. The panel wrote their draft report on-site. The panel considered the following items in their review: the latest developments in contraceptive research; access and delivery constraints in remote, mountainous terrain; a ban on helicopter-assisted capture of goats; time and cost efficiency; prospects for permanently sterilizing goats, preferably with only one, remotely deliverable treatment; animal health concerns and potential side effects; personnel and visitor safety concerns; the results of previous contraception research and population control modelling with goats in the park; and the likelihood of success when contraceptives are applied at the population level.

The panel concluded that there currently are no remotely deliverable
contraceptives or sterilants available that have been proven to provide long-term infertility or permanent sterility in mountain goats. Even if such contraceptive or sterilant agents were available, the panel believes treating mountain goats in the park with these agents would represent a very expensive, never-ending program that, at best, would only partially control the population. Therefore, despite the fact that each member of the panel is personally committed to developing non-lethal control techniques for wildlife, they came to the unanimous conclusion that lethal shooting appears to be the only feasible option for use in eliminating mountain goats in Olympic National Park. Indeed, even with the use of lethal shooting, it likely will be very expensive and difficult to totally eliminate goats from the park.

II. INTRODUCTION

A. Justification and objectives

Several agency publications and scientific papers have described the potential ecological effects of non-native mountain goats (Oreamnos americanus) in Olympic National Park (ONP) (Houston et al. 1986, 1991; Houston and Stevens 1988; ONP 1981, 1987). Since 1981, the National Park Service (NPS) has conducted a capture-and-removal program to reduce or eliminate this exotic species, and thereby minimize its effect on the native plant and animal communities in the park. The NPS also has conducted pioneering research in field applications of experimental contraceptive and sterilization techniques to control goats in ONP (Hoffman and Wright 1987, 1990). These removal and control programs have been consistent with NPS Management Policies dealing with protection of native animals, threatened or endangered plants and animals, and management of exotic species (NPS 1988). After removal of more
than 400 goats from ONP, management programs were halted in 1990 because of safety concerns for personnel and animals (Machlis et al. 1990).

Prior to any further mountain goat management activity in ONP, the NPS will prepare a draft Environmental Impact Statement (EIS) in cooperation with the U.S. Forest Service (Olympic National Forest) and the Washington Department of Wildlife for public review in 1992. To aid in the information-gathering process of the EIS, a panel of expert scientists was selected to conduct an independent, on-site review and evaluate the potential for contraceptives to eliminate mountain goats in ONP. The scientific panel was asked to consider: access and delivery constraints in ONP's remote and mountainous terrain, a ban on helicopter-based capture of mountain goats, time and cost efficiency of remotely delivered contraceptives in ONP, feasibility and likelihood of success when applying contraceptives at the population level, prospects for permanent sterility in treated mountain goats, animal health concerns and potential side effects, pre-application testing required with captive goats, and human safety concerns.

B. Scientific panel selection and composition

Panel members were selected by Mr. Bruce B. Moorhead (Wildlife Biologist, ONP) and Dr. Robert J. Warren (Panel Leader) from a list of nine potential participants using the following criteria: 1) having personal research experience in applying contraceptives to free-ranging wildlife or feral animal populations; 2) having personal research experience in the latest contraceptive technologies; and 3) having bio-medical experience with wildlife. The panel was designed to consist of a diversity of wildlife biologists, reproductive physiologists, and veterinarians who have national,
professional recognition in these areas. Individuals were selected so as to complement, but not duplicate, each other's expertise. Biographical summaries for the five panel members are provided in the Appendix of this report.

Briefly, Dr. Fayrer-Hosken is a reproductive physiologist and veterinarian who has conducted research with implantable contraceptives and immunocontraception in captive deer and horses. Dr. Garrott is a wildlife ecologist and certified wildlife biologist who has conducted population-level evaluations of the demographic and economic consequences of contraceptive management of feral horse populations. Dr. Jessup is a wildlife veterinarian and certified wildlife biologist who has conducted research on wildlife capture, treatment, and relocation (including mountain goats in ONP), reproductive control in wild deer populations, and experimental trials with contraceptive techniques in captive deer. Dr. Kirkpatrick is a reproductive physiologist who has conducted pioneering research on contraceptive steroid applications in feral horses, and has recently applied immunocontraceptives to free-ranging feral horses and several species of ungulates in captivity. Dr. Warren is a wildlife physiologist and certified wildlife biologist who has conducted research with implantable contraceptives and immunocontraceptives in captive deer and free-ranging feral horses.

C. Organization of the panel's report

The body of this report is organized as follows: 1) Any technique designed to eliminate or control mountain goats in ONP must be applied from a helicopter. Therefore, a section has been included on aerial operations. 2) The panel then considered two possible goals for the mountain goat management program in ONP—complete elimination or population control. The final
sections of the report provide comments regarding interim control measures, conclusions, literature cited, and appendix. For the purposes of this report contraception is defined as reversible inhibition of reproductive success; sterilization is defined as permanent inhibition of reproductive success.

III. AERIAL OPERATIONS

A. Risk assessment

Whether the goal of elimination of mountain goats by shooting, or control of populations by contraception, or a combination of these methods is selected for ONP, most of these activities will need to be conducted from a helicopter. Commercial, light-observation helicopter performance characteristics and uses have been reported by Jessup (1983), but the most versatile and maneuverable small commercial helicopter for steep-terrain flying in ONP appears to be the Hughes 500D. Although helicopters are used frequently by Federal and state wildlife agencies, there are finite risks of accident, injury, and fatality associated with their use (Machlis et al. 1990). In regard to capture operations in ONP the panel quotes from Machlis et al. (1990), "the most important of the physical hazards to personnel are death or severe injuries that can result to capture team members. These may occur during helicopter accidents and their greatest risk is during pursuit and landing/hovering operations. Hazards unique to this project include physical harm from jumping out of a hovering helicopter, possible helicopter accidents during toe-in and one-skid landings, falls while crossing rough terrain, helicopter crashes during dangerous flying conditions, accidents while using the net-gun, injury while restraining a goat, and accidental exposure to chemical immobilization agents."
The Machlis et al. (1990) report did not evaluate specific risk associated with mechanical failure or pilot error. As helicopter mechanical failure can occur at any time, and the chance of a failure increases with increased number of rotor-hours, the number of rotor-hours required for any program is an index to the chance of mechanical failure-associated accidents. The Machlis et al. (1990) report also noted that "most helicopter pilot errors (84%) occur during takeoff, approach, and landing phases" and that "increased flight experience was observed to increase the rate of helicopter pilot errors rather than decrease rates as expected." This again suggests that the higher the number of rotor-hours used over the longer period of time, the greater are the risks of serious accident. In 15 years of field work using the helicopter for habitat survey, wildlife census, capture and relocation, and vaccination programs (i.e., hundreds of rotor-hours), Dr. Jessup has seen four helicopter crashes involving state wildlife agency employees. Two were caused by mechanical failure and two were apparently the result of pilot error. These resulted in seven fatalities, two serious injuries, and four minor injuries (personal communication, D.A. Jessup).

Low ground clearance flying and flying in rough terrain for any reason carry inherently greater risks than high ground clearance flying and flying over open, flat terrain where there are numerous potential landing sites. As noted above, high risks are associated with helicopter landings in rough terrain where wind, weather, and footing are unpredictable. Very high risks are associated with toe-in landings, one-skid landings, and hover exits (jumps). In January 1990, the Office of Aircraft Safety (Department of Interior) issued an Operating Procedures Memorandum for helicopter toe-in and one-skid landings. These new procedures prohibit such landings unless
specific exemptions are obtained. This action, plus concern for human safety as detailed in a recent risk assessment (Machlis et al. 1990), increasing mountain goat mortality rates in ONP capture operations, and costs associated with capture have all effectively eliminated large-scale, helicopter-based capture as a management tool for mountain goats in ONP.

B. Practicality for elimination or control in ONP

Detailed safety and cost concerns associated with helicopter/net-gun capture of bighorn sheep (*Ovis canadensis*), which are similar to those in ONP, were recently published by Jessup et al. (1988). These concerns over safety and cost are likely to be greater when applied to goat elimination or control in ONP. The very steep (nearly vertical) terrain in much of ONP offers very few alternate landing sites in case of a helicopter mechanical failure in any portion of a operation. Aerial shooting of mountain goats from a helicopter without removal of the carcasses requires a brief, close approach to an individual animal and the discharge of a firearm in close proximity to rough, steep terrain, but it does not require prolonged close pursuit, one-skid landings, toe-in landings, or hover exits.

Administration of an contraceptive/sterilant by dart or biobullet (BallistiVet, Inc., Minneapolis, MN) requires closer pursuit and approach to an individual goat for somewhat longer periods of time than does aerial shooting, but would also not require toe-in landings, one-skid landings, or hover exits. Depending on the type of contraceptive/sterilant chosen, its efficacy, mode of delivery, and other parameters, it is most likely that close helicopter pursuit for delivery to an average of 300-400 goats would be required for a period of at least 10 years (approximate goat life expectancy),
with periodic follow-up operations. Lethal shooting should require only 1-2 years of intense helicopter operations, and close pursuit of 300-400 goats with several short follow-up actions (30-40 goats) in subsequent years.

Elimination of mountain goats by lethal shooting would likely carry significantly lower risks and costs than population control by contraception or capture-and-removal methods. The amount of helicopter time necessary to remotely treat goats with a contraceptive/sterilant agent undoubtedly will be much greater than compared to lethal shooting. The panel estimates that aerially delivered contraceptives/sterilants may cost as much as 10 times more than lethal shooting. Helicopter capture costs for the mountain goat management program in ONP were approximately $100,000 in 1988 and 1989; it is expected that a lethal shooting operation might cost about the same amount, or slightly more. Helicopter costs for an aerial contraception/sterilization program could cost as much as $1-2 million. These estimates do not include personnel costs, drug supplies, equipment, etc. All of these are likely to be 10 times greater in cost for contraception/sterilization as opposed to shooting. In addition, for the reasons stated above, one could also expect 10 times the risk of a serious or fatal helicopter accident.

The success of mountain goat elimination by lethal shooting or control by remotely delivered contraception/sterilization depends largely on sightability of individual animals. Although this varies by season, vegetation type, slope, aspect, and weather conditions, Houston et al. (1991) have estimated sightability of mountain goats in ONP to average 66-70%. As mountain goats are harassed and selectively removed or vaccinated, sightability will be reduced further. Forward-Looking-Infra-Red (FLIR) technology may increase sightability of mountain goats in brush or forest
cover, because it can display the differential heat content of animals, surrounding vegetation, snow, or terrain. FLIR units designed for helicopter use are commercially available.

IV. GOAT ELIMINATION AS A GOAL

A. Feasibility

The panel members agree unanimously that current contraceptive or sterilant technologies will not eliminate mountain goats from ONP within an acceptable time period that is necessary to avoid possible adverse ecological impacts of this exotic herbivore to native plant communities and rare plant species in the park. Justification for this statement is: 1) current, remotely deliverable contraceptives/sterilants are not 100% effective in all individual animals treated; 2) current technologies require at least one annual retreatment regime; 3) it is nearly impossible to treat 100% of the individuals in a particular population; 4) any individuals left untreated can reproduce and add new individuals to the population, which will then need to be eliminated in the future.

At best, currently available contraceptives/sterilants could be used to: 1) maintain a population at a stable level, 2) reduce the rate of population increase, or 3) slowly reduce population numbers over a long period of time (i.e., the life expectancy of a mountain goat; possibly as long as 10-15 years). Ultimately, lethal shooting would be required to eliminate the remaining individual mountain goats in ONP; however, National Environmental Policy Act (NEPA) compliance would require extensive public review and comment on an EIS prior to implementing any lethal elimination program. During this period, the mountain goat population would continue to increase, thereby
making their ultimate elimination more costly and difficult (see Section VI below).

B. Demographics and population applicability

The prospect that contraceptive/sterilant technologies can be successfully employed to eliminate mountain goat subpopulations is limited at best and, in all likelihood, is unattainable. In order to eliminate a subpopulation, a contraceptive/sterilant agent would have to be 100% effective (i.e., inhibit reproduction in every animal treated) and be deliverable to 100% of the target subpopulation. At present, no contraceptive/sterilant technologies have been proven to be 100% effective and it is unreasonable to assume that such technologies will exist in the foreseeable future.

Delivery of a contraceptive/sterilant agent to mountain goats is a formidable task because of the vastness, inaccessibility, and ruggedness of the terrain in ONP. These characteristics dictate that any broad-scale application of contraceptive agents will require intensive use of helicopters as the delivery platform. The successful use of helicopters for capture/removal of mountain goats in ONP demonstrated that contraceptive/sterilant agents can be successfully delivered. However, individual animals commonly elude darting by evasive behavior and the use of terrain and vegetation cover.

Another factor affecting the potential for delivery is the difficulty of detecting animals. Houston et al. (1991) estimated that only 66-70% of the mountain goats were detected in aerial census surveys during July in ONP. This estimate is corroborated by the results of numerous studies of large mammals in mountainous terrain where from one-third to one-half of the animals

Thus, there are three factors that limit the level of treatment attainable: 1) the efficacy of the contraceptive/sterilant agent, 2) the proportion of the animals that are detected, and 3) the proportion of the animals detected that can be darted successfully. The multiplicative effect of these factors can be demonstrated with a simple example. A highly optimistic scenario for treating the ONP mountain goat population would be a contraceptive treatment efficacy of 95%, with 90% of the mountain goats being detected, and 90% of the detected animals being darted successfully. The level of treatment would then be calculated as \((0.95)(0.90)(0.90) = 0.77\). Thus, under a "very-best-case" scenario, the NPS could expect approximately one quarter of the population (i.e., 1.00 - 0.77) to continue to remain reproductively active, and thereby assure persistence of the population.

If a "one-shot" permanent sterilant were used for a period of 3-5 years, it may be possible to treat nearly all goats in the population. This certainly would result in the suppression of reproduction below natural attrition, thereby causing the population to decline over a long period of time. The treatment program would have to be continued at a maintenance level in order to identify and treat any reproductively active individuals that may have immigrated from populations along the periphery of ONP. This immigration would undoubtedly occur, and small groups of mountain goats may go undetected for several years. Currently, there are no proven "one-shot" permanent sterilants that can be delivered remotely. All remotely deliverable contraceptive agents today require an annual retreatment. The need for annual treatments and the limited treatment levels likely attainable in the
population suggest that, at best, current contraceptive technologies would suppress the reproductive rates to the extent of stabilizing the mountain goat population in ONP.

V. GOAT POPULATION CONTROL AS A GOAL

A. Manipulating demographic parameters

The dynamics of a population are driven by four demographic processes—reproduction, survival (mortality), immigration, and emigration. Manipulating any of these processes can have an effect on population dynamics and, hence, can be used as a management tool. The effectiveness of manipulating the various processes with respect to impacts on the dynamics of a population are quite different. The limited data available on the movements of the ONP mountain goat population indicates that the park population is composed of 21 subpopulations. In some of these subpopulations, moreover, there is free exchange of goats across the eastern park boundary. Such movements will influence the dynamics of subpopulations in these areas and will complicate treatment efficacy in regard to goat population elimination or control. Therefore, any management actions aimed at population control should focus on manipulating reproduction and/or survival. Manipulating survival removes animals from the population and also decreases recruitment if reproductive-age females are removed. Thus, population management focused on removal of animals is the most effective way to control the mountain goat population. However, the NPS can no longer effectively capture and remove animals due to recent restrictions on helicopter operations (see Section III above). Therefore, the only practical technique available for manipulating survival is lethal shooting of goats.
Manipulating reproduction reduces recruitment, but does not eliminate animals from the population. Hence, reproductive manipulation can never be as effective in population control as manipulations of survival. There are a number of contraceptive technologies that could prove to be effective in suppressing reproduction in mountain goats. The applicability and efficacy of technologies for controlling the population, however, will be dependent entirely on the ability to treat a large proportion of the population (Garrott 1991).

B. Potential contraceptive agents and sterilants

If the alternative goal of population control is chosen instead of elimination of goats, there are several potential agents which may have management value. Bomford (1990) and Kirkpatrick and Turner (1991) provide very thorough reviews of the contraceptive technologies that have potential applicability in wild and free-ranging animals. In writing this section, the panel assumed that any potential contraceptive or sterilant selected, for control purposes, must be delivered remotely from a helicopter with a minimal risk to other park animals or people. Current ONP policies and constraints prevent large-scale capture of goats, thereby eliminating "hands-on" application of contraception/sterilization agents.

Of all contraceptive agents and sterilants available, only the following ones may be of potential use in ONP: 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); 2) melengestrol acetate (MGA, a synthetic progestin); 3) Norgestomet (a synthetic progestin currently utilized in the food-animal industry); 4) sperm acrosomal
membrane protein (SAMP) immunization (this stimulates antibodies against the sperm cell surface proteins which results in infertility in the male and female); 5) porcine zona pellucida (PZP) glycoprotein immunization (this stimulates antibodies to the host animal's oocyte zona pellucida and leads to infertility by either blocking fertilization or reducing the number of oocytes in the ovary); and 6) gonadotropin releasing hormone (GnRH) conjugated to a cellular toxin (this destroys the pituitary and chemically castrates the male or female animal). The contraceptive/sterilant agents and the routes of delivery are listed in Table 1, are described in detail in Section V, D, and are compared to each other in Table 2. In the absence of proven efficacy in mountain goats of any agent or procedure, the panel recommends a minimal clinical simulation (pen trials) of a captive population prior to field tests.

Table 1. Current remotely deliverable contraceptive/sterilant agents for reproductive control in mammals.

<table>
<thead>
<tr>
<th>#</th>
<th>Agent</th>
<th>Route of delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Hormonal:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gonadotropin releasing hormone (GnRH) analog</td>
<td>Biobullet implant</td>
</tr>
<tr>
<td></td>
<td>Megestrol acetate (MGA) - implanted</td>
<td>Biobullet implant</td>
</tr>
<tr>
<td></td>
<td>Megestrol acetate (MGA) - microencapsulated</td>
<td>Dart</td>
</tr>
<tr>
<td></td>
<td>Norgestomet - implanted</td>
<td>Biobullet</td>
</tr>
<tr>
<td>2</td>
<td><strong>Protein antigens:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acrosomal membrane proteins - adjuvanted</td>
<td>Dart</td>
</tr>
<tr>
<td></td>
<td>Acrosomal membrane proteins - microencapsulated</td>
<td>Biobullet</td>
</tr>
<tr>
<td></td>
<td>Zona pellucida glycoproteins - adjuvanted</td>
<td>Dart</td>
</tr>
<tr>
<td></td>
<td>Zona pellucida glycoproteins - microencapsulated</td>
<td>Dart</td>
</tr>
<tr>
<td>3</td>
<td><strong>GnRH-conjugated pituitary toxin</strong></td>
<td>Dart</td>
</tr>
</tbody>
</table>
C. Remote delivery systems

There are only two remote delivery systems for contraceptives/sterilants that apply to mountain goats. These include the biodegradable "biobullet" and self-injecting darts fired from a capture gun. The biobullet is a hollow, 0.25-caliber bullet manufactured from compressed food-grade material (hydroxypropyl cellulose; Kirkpatrick and Turner 1991). The biobullet, which contains a freeze-dried contraceptive vaccine or steroid hormone (in a free state, packed in a silastic tube, or in the form of a slow-release microcapsule) is designed to lodge in the muscle. Previous research indicates the dangers of infection and trauma are minimal. Several researchers have used this method to successfully treat free-ranging wildlife with vaccines (Goodloe et al. 1988, Davis et al. 1991). This method also is used in the routine administration of vaccines to livestock (BallistiVet Inc., Minneapolis, Minn.). Once the biobullet is lodged, degradation occurs within 24 hours and the agent, in this case a contraceptive, is released for pharmacological action. Maximum capacity for the biobullet is 125 mg, with a maximum effective range of 40 m. An advantage of the biobullet is that minimal tissue trauma occurs at the point of impact. Two potential disadvantages are that the light weight biobullet may have difficulty in penetrating the dermal shield of the mountain goats and the prop-wash from the helicopter blades can alter the biobullet's trajectory.

A variety of commercially available or custom-made, self-injecting darts and delivery guns are available. A modified rifle propels projectiles (darts) with either a blank cartridge or compressed CO₂. The darts are designed to deliver liquids (1-15 ml capacities) intramuscularly and are made of plastic or metal. The dart injects the contraceptive agent by compressed air or a
small powder charge. In the case of contraceptive delivery, the needles on these darts have a very small barb, which permits the dart to fall out within minutes or hours after delivery (Kirkpatrick et al. 1990). The major disadvantages of the dart are 1) they remain in the environment after delivery, 2) prop-wash from the helicopter blades can alter the dart's trajectory, and 3) some darts can cause greater tissue damage when compared to the biobullet.

D. Specific agents

1. GnRH analog

Description: Gonadotropin releasing hormone (GnRH) is a hypothalamic hormone decapeptide that stimulates pituitary cells to release follicle stimulating hormone (FSH) and luteinizing hormone (LH). FSH and LH stimulate the reproductive functions of the ovary or testes. GnRH normally binds to certain pituitary cells and stimulates an intracellular second messenger system which results in the release of LH or FSH. The GnRH analog will strongly suppress the cellular release of FSH and LH after attachment to the pituitary cells. This results in a selective suppression of FSH and LH, and thus a hormonal castration of both males and females.

Effect on the food chain: None

Use to date: None

Application schedule: Unknown

Cost: Unknown

Future: This technology is purely in the developmental stages.

Applicability to mountain goats: Animals should become sterile with this therapy, and would demonstrate no reproductive activity. However, an
unknown retreatment schedule would be necessary.

2. Melengestrol acetate/megestrol acetate

Description: These two closely related compounds are synthetic progestins which can be delivery orally, by implant, or by injection. They cause a suppression of estrus and ovulation in the female (Sokolowski and van Ravenswaay 1978). Among ungulates, MGA implants have been used successfully to inhibit reproduction in deer (Bell and Peterle 1975, Plotka and Seal 1989), domestic goats (personal communication, U.S. Seal), and mountain goats (Hoffman and Wright 1990). MGA could be delivered remotely in two ways. It could be delivered remotely as a silastic implant within a biobullet. In deer, a 150 mg implant of MGA (Bell and Peterle 1975) in a silastic implant was sufficient to suppress estrus for 3 to 5 months. Current biobullet technology permits remote delivery of MGA in a similar dosage. Based on work in a variety of domestic animals, administration to males may result in a temporary but significant reduction in the sperm cell concentration and a loss in aggressive behavior associated with breeding behavior.

MGA also may be incorporated into biodegradable microcapsules, which can be delivered by darting. The microencapsulation coats the hormone in a biodegradable, non-toxic lactide material. This coat erodes on contact with tissue fluids, which causes a sustained release of the hormone. Microencapsulation has been used to deliver other reproductive steroids to wildlife (Kirkpatrick et al. 1982; Turner and Kirkpatrick, 1982, 1991) and humans (Singh et al. 1989). The microcapsules are suspended in a carrier (carboxymethyl cellulose) and are injected intramuscularly.

Effect on the food chain: MGA is a progestin and, as with all steroid
hormones, it will accumulate in body fat, which will allow entry into the food chain after consumption.

Use to date: Subdermal MGA implants have been used successively to control reproduction in individually treated female mountain goats (Hoffman and Wright 1990); however, its efficacy at the population level has not been evaluated.

Application schedule: The maximum effective range of the biobullet is 40 m. The mountain goat breeding season is a discrete period in the fall. A MGA biobullet administered at this time may result in effective contraception in individually treated females for that particular breeding season.

Three to 5 ml of the microencapsulated MGA is remotely delivered by a dart. Remote delivery often is difficult in cold weather, because the cold increases the viscosity of the carrier and makes injection difficult. Also, microcapsules settle out of suspension 5-10 minutes after loading the dart. Annual boosters of microencapsulated MGA would be necessary.

Cost: MGA biobullet implants cost about $25 per administration dose. Microencapsulation of MGA is expensive (the cost would be approximately $100-300 per administration dose, depending on the ease of encapsulation).

Future: MGA incorporation into a biobullet may be possible by the Fall of 1992. Microencapsulated MGA could be made available by the Fall of 1992.

Applicability to mountain goats: This is the only chemical contraceptive agent that has been evaluated successfully in mountain goats (Hoffman and Wright 1990); pharmacological applicability is high, although remote delivery requires annual administration, and its efficacy at the population level has not been evaluated.
3. Norgestomet

Description: Norgestomet is a synthetic progestin (11-methyl-norprogesterone acetate) designed and marketed for the synchronization of estrus in domestic livestock. It has been used in cattle, sheep, and domestic goats. Norgestomet is approved for use in food animals and has a zero withdrawal time (no measurable tissue residues immediately after withdrawal of the drug). In these animals it has been administered via subcutaneous implants to suppress ovulation (Synchromate-B). Recently, Norgestomet (42 mg dose) has been complexed into silastic rods and incorporated into biobullets (personal communication, D.A. Jessup).

Effect on the food chain: None or minimal

Use to date: The Norgestomet biobullet is currently being evaluated in captive deer (personal communication, D.A. Jessup).

Application schedule: Each year prior to the breeding season.

Cost: Norgestomet biobullet implants cost about $10 per administration dose.

Future: At the present time, Norgestomet has only been delivered via biobullet to an experimental group of captive deer, but the silastic implant should be effective for 6 months. This period would be more than adequate to suppress estrus each year during the relatively short breeding season of mountain goats.

Applicability to mountain goats: Norgestomet efficacy in mountain goats is unknown. Remote delivery of Norgestomet via biobullet will result in intramuscular administration, instead of subcutaneous administration, with unknown efficacy.
4. Sperm acrosomal membrane proteins

Description: The sperm acrosomal membranes cover the head of the sperm cell and participate in the sperm-egg interaction and zona pellucida penetration. Antibodies raised against sperm acrosomal membrane proteins (SAMPs) in the male would lead to infertility as a result of sperm cell and epididymal damage. Antibodies raised against SAMPs in the female would result in infertility as a result of disruption of the fertilization process. Antisperm antibodies are a primary cause of infertility in humans (Cunningham et al. 1991)

Effect on the food chain: Animals immunized with SAMP would not pose a threat to the food chain and there is no withdrawal period. As with all proteinaceous vaccines, neither the antigen nor the antibodies produced against it can survive digestion after oral ingestion.

Use to date: Vaccinations to date have resulted in infertility in the guinea pig (Primakoff et al. 1988) and mouse (Yan et al. 1990).

Application schedule: The vaccine is currently administered with an initial double vaccination followed by annual booster vaccinations.

Cost: About $20 per administration dose.

Future: The vaccine is currently being evaluated by Drs. Fayrer-Hosken and Warren for contraceptive use in female and male white-tailed deer. As is the case for porcine zona pellucida vaccines, the SAMPs could be delivered in an adjuvanted or microencapsulated form in either biobullets or darts.

Applicability to mountain goats: To date, no studies have evaluated SAMP efficacy in mountain goats, but data derived from other ungulate species suggests significant merit for this revolutionary technology and a rather high probability of success in individually treated mountain goats.
5. Porcine zona pellucida

Description: The mammalian egg is surrounded by a non-cellular membrane known as the zona pellucida (ZP). The ZP consists of three glycoproteins (ZP1, ZP2 and ZP3). ZP3 is postulated to be the sperm receptor (Florman and Wassarman 1985). Injections of porcine ZP (PZP) cause the female to raise antibodies against the three glycoproteins.

Effect on the food chain: The animals immunized with PZP do not pose a threat to the food chain and there is no withdrawal period. As with all proteinaceous vaccines, neither the antigen nor the antibodies produced against it can survive digestion after oral ingestion.

Use to date: Among ungulates, PZP has been shown to be an effective inhibitor of fertilization in horses (Liu et al. 1989; Kirkpatrick et al. 1990, 1992), white-tailed deer (Turner et al. 1992), Przewalski's horses, sika deer, sambar deer, axis deer, and banteng (personal communication, J.F. Kirkpatrick). Trials are currently underway with West Caucasian tur, muntjac deer, Himalayan tahr, llamas, and hippopotamuses.

Application schedule: The PZP is administered remotely by dart and the current regime requires two initial administrations 3-4 weeks apart followed by an annual booster.

Cost: About $20 per administration dose as currently used (Kirkpatrick et al. 1990). Microencapsulation of PZP is expensive (the cost would be approximately $20-100 per administration dose, depending on the ease of encapsulation).

Future: Currently a single-dose, initial inoculation (microsphere form) is under development and will be available in 12 months. Research is currently investigating a single-administration vaccine with an effective
period of 2 years.

Applicability to mountain goats: Thus far no trials or tests have produced evidence of PZP efficacy in mountain goats, but data derived from other ungulate species suggests significant merit for this revolutionary technology and high probability of success in individual mountain goats.

6. GnRH-conjugated pituitary toxin

Description: A method which is currently under investigation and may provide sterilization with a single dose (i.e., "one shot") is injection of a pituitary cell toxin conjugated to gonadotropin releasing hormone (GnRH). Gonadotropin releasing hormone is a hypothalamic hormone decapeptide that stimulates pituitary cells to release follicle stimulating hormone (FSH) and luteinizing hormone (LH). FSH and LH stimulate the reproductive functions of the ovary or testes. GnRH normally binds to the pituitary cells and stimulates an intracellular second messenger system which results in the release of LH or FSH. The working hypothesis is that a cellular toxin complexed to GnRH will destroy the FSH- and LH-producing cells after attachment of the conjugate. This results in a selective removal of the pituitary gonadotrophs and thus hormonal castration of both males and females.

Effect on the food chain: Unknown

Use to date: None

Application schedule: Potentially deliverable via darts.

Cost: Unknown

Future: This technology is purely in the developmental stage and initial results of preliminary treatments in deer may be available by 1993. This technology may present significant operator risk because the conserved
nature of GnRH (i.e., GnRH is identical in all mammalian species) would mean that accidental human administration could result in sterilization.

Applicability to mountain goats: Animals should become sterile with this therapy, and would demonstrate no reproductive activity.

Table 2. Synthetic matrix scores of different contraceptive/sterilant agents listed according to their order in the text.

<table>
<thead>
<tr>
<th>Contraceptive</th>
<th>Availability</th>
<th>Delivery</th>
<th>Cost</th>
<th>Risk</th>
<th>Duration</th>
<th>Sex</th>
<th>Final score</th>
</tr>
</thead>
<tbody>
<tr>
<td>GnRH analog</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>48.00</td>
</tr>
<tr>
<td>MGA - implant</td>
<td>5</td>
<td>10</td>
<td>9.75</td>
<td>10</td>
<td>5</td>
<td>7.5</td>
<td>47.25</td>
</tr>
<tr>
<td>MGA - microsphere</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>7.5</td>
<td>5</td>
<td>7.5</td>
<td>37.00</td>
</tr>
<tr>
<td>Norgestomet</td>
<td>10</td>
<td>10</td>
<td>9.75</td>
<td>10</td>
<td>5</td>
<td>7.5</td>
<td>52.25</td>
</tr>
<tr>
<td>Sperm antigens</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>7.5</td>
<td>4</td>
<td>10</td>
<td>40.50</td>
</tr>
<tr>
<td>Zona pellucida</td>
<td>10</td>
<td>5</td>
<td>9.8</td>
<td>7.5</td>
<td>3</td>
<td>5</td>
<td>40.30</td>
</tr>
<tr>
<td>Pituitary toxin</td>
<td>0</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>48.00</td>
</tr>
</tbody>
</table>

* Availability - Scored from 0 (completely unavailable at the present) to 5 (available within 1 year) to 10 (currently available).
  
  b Deliverability - Scored from 0 (undeliverable from a helicopter) to 5 (deliverable with moderate difficulty) to 10 (deliverable from a helicopter with no difficulty).
  
  c Cost - Scored from 0 ($1,000/goat) to 10 (no cost), in $100 increments.
  
  d Risk to target animals - Scored from 0 (greatest risk, i.e., potential death directly or indirectly) to 5 (moderate risk, i.e., infection or trauma that would lead to significant debilitation) to 0 (minimal risk, i.e., infection or trauma that would not result in any significant debilitation).
  
  e Duration - Scored from 0 (1 application/3 months) to 5 (1 application/12 months) to 10 (1 application/3 years or longer).
  
  f Sex - Scored from 5 (effective in one sex only) to 10 (effective in both sexes).
  
  g "MGA - implant" is megestrol acetate delivered via biobullet implantation.
  
  h "MGA - microsphere" is microencapsulated megestrol acetate delivered via dart.
VI. NECESSITY OF INTERIM CONTROL MEASURES

The panel was concerned that recent progress achieved by NPS personnel in reducing the mountain goat population in ONP may be lost by annual incremental population increases in the interim time period (probably several years) during which a final EIS is approved. In particular, no action to control mountain goat population increases during the EIS approval process will necessarily require a much greater, final control effort. As a result, there will be more human risk, and ultimately more mountain goats will have to be killed or treated with contraceptives/sterilants, if and when, a lethal shooting or contraception/sterilization program is finally implemented.

VII. CONCLUSIONS

The scientific panel members assembled for this review have all had a diversity of research experience in the area of non-lethal control of overabundant wild and free-ranging animal populations. As such, these scientists are all involved in research designed to develop alternatives to lethal shooting as a means of controlling certain animal populations. Despite the commitment of each panel member to this area of research, and with the hope that future research results will provide non-lethal means of controlling these populations, the panel nonetheless came to the unanimous conclusion that current contraceptive or sterilant technologies will not eliminate mountain goats from ONP. The panel reached this conclusion in light of detailed considerations as described in the previous six sections of this report.

Lethal shooting may be a feasible option for the elimination or control of mountain goats in ONP. Destruction of individual animals with a firearm is an effective population control option. When carried out properly by a
marksman, shooting from a helicopter, although not popular with the public, can be considered humane. Treatment obviously is permanent, costs are relatively low, effectiveness is high, and hazards to NPS personnel are minimized (because effective ranges are greater than for dart guns). Lethal shooting also can avoid several issues of concern, such as side effects to non-target animals, FDA approval, annual retreatment with contraceptives, and helicopter prop-wash interference with dart delivery. The single disadvantage to shooting is public reaction to the destruction of goats.

It is likely that research developments within the next 10-20 years may provide a "one-shot" permanent sterilant that may be applicable for mountain goat management in ONP. However, even if such a sterilant is developed in the future, it will likely never eliminate mountain goats from ONP (see Section IV above). Indeed, even with the use of lethal shooting, it will likely be very expensive and difficult to totally eliminate mountain goats from ONP (see Section III, B above).

The panel would like to commend the NPS staff at ONP for their past research and management efforts with mountain goats. The panel was extremely impressed by the level of commitment demonstrated by these professionals. For numerous years, and often under conditions of great personal risk, they have attempted to apply non-lethal procedures, which were both expensive and experimental, in their efforts to control the mountain goat population in the most humane manner possible.
VIII. LITERATURE CITED


IX. APPENDIX

A. Biographical sketches for the panel members

1. Richard A. Fayrer-Hosken

Current Position:

Assistant Professor, Department of Large Animal Medicine, College of Veterinary Medicine, University of Georgia

Education:

B.S. (Zoology and Entomology), Rhodes University, 1975
B.V.S. (Veterinary Medicine), University of Pretoria, 1981
Ph.D. (Reproductive Physiology), University of Georgia, 1987

Professional Society Memberships:

Society for Study of Reproduction
Society for Theriogenology
American Society of Andrology
International Embryo Transfer Society
American Veterinary Medicine Association
Florida Veterinary Medicine Association
Georgia Veterinary Medicine Association

Areas of Specialization:

Reproductive physiology; veterinarian - licensed to practice veterinary medicine in Georgia and Florida.

Past Research Experience:

Dr. Fayrer-Hosken has conducted extensive work with in vitro fertilization and sperm-egg interactions of domestic species. He and Dr. Warren are currently investigating the integrated contraceptive control of white-tailed deer using hormonal and immunological (antigenic) methods. This research is focusing on the molecular basis of fertilization and how this technology can control (enhance or inhibit) fertility. In addition, he has evaluated the specific content of the zona pellucida in female deer and horses, and the sperm molecules associated with the sperm-egg interaction.
2. Robert A. Garrott

Current Position:
Assistant Professor, Department of Wildlife Ecology, University of Wisconsin

Education:
B.S. (Wildlife Biology), University of Montana, 1976
M.S. (Wildlife Management), Pennsylvania State University, 1980
Ph.D. (Wildlife Conservation), University of Minnesota, 1990

Professional Society Memberships:
The Wildlife Society
Society for Conservation Biology

Areas of Specialization:
Wildlife ecology, wild mammal population dynamics, and wildlife management; Certified Wildlife Biologist (The Wildlife Society).

Past Research Experience:
Dr. Garrott has extensive experience in studies of large mammal population dynamics and has conducted field-oriented research programs in Alaska, Antarctica, Montana, Colorado, and Nevada. Since 1985, he has been a member of an interdisciplinary team that has been conducting research on the development and application of contraceptive techniques for feral horse populations in the western United States. Dr. Garrott has conducted modelling studies to evaluate the demographic and economic consequences of a wide variety of management alternatives for controlling feral horse populations.

3. David A. Jessup

Current Positions:
Wildlife Veterinarian, International Wildlife Veterinary Services; Veterinary Medical Officer, Wildlife Investigations Laboratory, California Department of Fish and Game; Adjunct Assistant Professor, Department of Immunology and Microbiology, University of California--Davis; and Visiting Lecturer, Department of Epidemiology and Preventive Medicine, University of California--Davis

Education:
B.S. (Zoology), University of Washington, 1971
D.V.M., Washington State University, 1976
M.P.V.M., University of California, Davis 1984
Professional Society Memberships:

The Wildlife Society
Wildlife Disease Association (Vice President)
American Association of Wildlife Veterinarians
American Association of Zoo Veterinarians
United States Animal Health Association

Areas of Specialization:

Wildlife diseases and immobilization; veterinarian - licensed to practice veterinary medicine in Washington, Oregon, and California; Certified Wildlife Biologist (The Wildlife Society).

Past Research Experience:

Dr. Jessup has conducted extensive research on wildlife capture, treatment and relocation; and the diagnosis and management of wildlife health problems, especially infectious diseases. He was involved in the early mountain goat capture and relocation efforts in Olympic National Park. He recently re-evaluated those capture operations. Dr. Jessup has had experience in the recognition and management of Johnne's disease at Point Reyes National Seashore, pneumonia and other diseases of bighorn sheep in the Lava Beds, Death Valley and Joshua Tree National Monuments. He was involved in efforts to relocate excess deer from Angel Island State Park, California and to evaluate control options for deer on this park. Recently, he has had experience with reproductive control of wild deer populations, experimental trials with contraceptive techniques, and biobullet vaccination.

4. Jay F. Kirkpatrick

Current Positions:

Senior Staff Scientist in Endocrinology, Deaconess Research Institute; Associate Professor, Department of Biological Sciences, Eastern Montana College; and Research Associate, Toledo Zoo

Education:

B.S. (Biological Sciences), Pennsylvania State College, 1962
M.S. (Biological Sciences), Pennsylvania State College, 1962
Ph.D. (Reproductive Physiology), Cornell University, 1971

Professional Society Memberships:

Society for Experimental Biology and Medicine
Society for Study of Reproduction
American Association of Zoological Parks and Aquariums
ZooMontana Zoological Society
Areas of Specialization:

Reproductive physiology; non-capture methods for the study of reproduction in wildlife and wildlife contraception, particularly as it applies to feral horses, deer, and captive exotic ungulates in zoos.

Past Research Experience:

Dr. Kirkpatrick has conducted extensive research on animal physiology and endocrinology. He conducted the pioneering research on contraception of feral horses in the western United States. Dr. Kirkpatrick has recently applied immunological contraception to feral horses on Assateague Island National Seashore, to feral donkeys on Virgin Islands National Park, and to captive white-tailed deer. He also has conducted a study of reproductive self-regulation in bison on Yellowstone National Park.

5. Robert J. Warren

Current Position:

Associate Professor, School of Forest Resources, University of Georgia

Education:

B.S. (Zoology/Wildlife Ecology), Oklahoma State University, 1974
M.S. (Wildlife Management), Virginia Polytechnic Institute and State University, 1976
Ph.D. (Wildlife Biology), Virginia Polytechnic Institute and State University, 1979

Professional Society Memberships:

The Wildlife Society
Southeastern Section, The Wildlife Society (President)
Georgia Chapter, The Wildlife Society
Wildlife Disease Association
American Society of Mammalogists

Areas of Specialization:

Physiology, nutrition, ecology, and genetics of wildlife populations;
Certified Wildlife Biologist (The Wildlife Society).

Past Research Experience:

Dr. Warren has worked with a variety of mammalian and avian wildlife species. His past research has focused primarily on physiological indices of nutritional or reproductive status in wild animals. He has conducted a variety of wildlife research on National Park Service areas, to include an
evaluation of the field applicability of biobullet vaccination for the remote delivery of immunocontraceptives to free-ranging feral horses on Cumberland Island National Seashore. More recently, his research has concentrated on white-tailed deer ecological and population characteristics on Catoctin Mountain Park, Cumberland Island National Seashore, and Chickamauga National Battlefield Park. Dr. Warren also has conducted native predator reintroduction research on Cumberland Island National Seashore. He is currently working with Dr. Fayrer-Hosken to experimentally evaluate implantable steroid and immunological contraception in captive deer.

B. Itinerary of the panel's activities and meetings

Saturday, October 19, 1991:

On this day, panel members travelled to Port Angeles, Washington. Drs. Fayrer-Hosken and Warren were accompanied by Bruce Moorhead on a brief auto tour of portions of ONP from Port Angeles to the Hurricane Ridge Visitor Center. All panel members were provided with copies of numerous scientific articles, NPS documents, and agency reports dealing with mountain goats in ONP for their review prior to travelling to the park.

Sunday, October 20, 1991:

During the morning, Richard Olson conducted three helicopter tours with panel members taken in pairs. Dr. Jim Larson (Regional NPS Office) accompanied one of the tours. The aerial tours proceeded up the Elwha River drainage to the interior areas of the park. All panel members were shown a variety of mountain goat habitat and rugged mountainous terrain. Mountain goats were viewed by all panel members during the aerial tours. The helicopter pilot and Mr. Olson simulated the aerial maneuvers that might be used in any attempts to remotely deliver a contraceptive agent to mountain goats in the park.

In the afternoon, the panel met in the park headquarters with the following NPS personnel: Paul Crawford, Maureen Finnerty, Kathrine Hoffman, Roger Hoffman, Doug Houston, Bruce Moorhead, Richard Olson, and Roger Rudolph. The panel was briefed on the following topics: NPS Management Policies regarding exotic species; the past Environmental Assessments for mountain goat management in the park; the proposed interagency EIS process; ecological impacts of mountain goats on the park's native flora; the results of previous research on mountain goat ecology, behavior, and population responses to experimental management efforts; bio-medical experiences with captured goats during previous translocation operations in the park; the results of previous contraception research and population control modelling; and the field constraints (i.e., remote, mountainous terrain, helicopter use, goat behavior) affecting the applicability of contraceptives in the park. Dr. Kirkpatrick
then gave a slide presentation that summarized the latest developments and research results in the area of wildlife contraception.

**Monday, October 21, 1991:**

In the morning, the panel members met to discuss their initial thoughts regarding the control of mountain goats in the park and the purpose of the panel's report. Specific options regarding contraceptive treatment of goats were discussed. Safety, practical applicability, and costs of various contraceptive agents were considered. Dr. Jim Foster attended this meeting.

In the afternoon, the panel met with the following persons: John Aho, Paul Crawford, Jim Foster, Kathrine Hoffman, Roger Hoffman, Doug Houston, Jim Larson, Brian Martz, Bruce Moorhead, Richard Olson, and Gerry Wright. Discussions dealt primarily with the content of the panel's final report as a part of the information-gathering process as required by NEPA. The panel was briefed in preparation for the public meeting to be held later the same day. The panel prepared brief biographical summaries to be handed out at the public meeting.

In the evening, the five-member, scientific panel was featured at a public meeting held at the park headquarters. The following persons attended the public meeting: John Aho, Cathy Sue Anunson, Roger Anunson, Seabury Blair, Jr., Nelson Badingham, Paul Crawford, Sandi Doughton, George Erb, Maureen Finnerty, Kathrine Hoffman, Roger Hoffman, Scott Miller, Bruce Moorhead, Wayne Pacelle. Dr. Warren was introduced as the panel leader. He then described the purpose of the scientific panel review, and introduced the panel members and gave a brief, professional history for each member. He then summarized the panel's activities during the previous two days, and the activities planned for the remaining three days. Dr. Kirkpatrick then repeated his slide presentation summarizing the latest developments and research results in the area of wildlife contraception. The public meeting included a question-and-answer session between panel members and the public that lasted about one hour. Interviews by local television and newspaper media representatives occurred at the end of the meeting.

**Tuesday, October 22, 1991:**

In the morning, the panel members met alone and developed the approach and content for the report, wrote a preliminary outline for the sections of the report, and made authorship assignments. The panel then met with Paul Crawford, Maureen Finnerty, Kathrine Hoffman, Roger Hoffman, Doug Houston, Bruce Moorhead, and Richard Olson. Topics discussed included the panel's concern over the feasibility of complete elimination of mountain goats, the possibility of only controlling certain subpopulations of goats, comments from the public meeting regarding native plants and the exotic status of mountain goats in ONP, and the organization of the written report. Then, in the afternoon and evening, the panel members wrote, compiled, and edited the first draft of the report.
Wednesday, October 23, 1991:

In the morning, the panel completed editing the first draft of the report. The report was then copied and presented to Paul Crawford, Doug Houston, Bruce Moorhead, and Richard Olson for their review. Comments were received from these persons by the afternoon, and that evening the panel revised the report and prepared the second draft.

Thursday, October 24, 1992:

In the morning, the panel met with Paul Crawford, Doug Houston, Bruce Moorhead, and Richard Olson and received their comments on the first and second drafts of the report. Later that morning, the panel again revised the report and prepared the third draft, which was submitted to Superintendent Maureen Finnerty prior to departure from Port Angeles in the afternoon. Dr. Warren then coordinated the final revisions of the written report via correspondence with panel members and NPS personnel at Olympic National Park.