Pages 237-246 *in* Proceedings of the 2000 Annual Conference of the Society for Theriogenology, 2 December 2000, San Antonio, Texas, Society for Theriogenology, Nashville, Tennessee (*www.therio.org*).

OVERVIEW OF FERTILITY CONTROL IN URBAN DEER MANAGEMENT

Robert J. Warren
Daniel B. Warnell School of Forest Resources
University of Georgia
Athens, GA 30605-2152

Introduction

Overabundant white-tailed deer (*Odocoileus virginianus*) populations have become a significant problem in many areas of the United States. Problems associated with overabundant deer herds include adverse effects to ecological communities, economic losses from crop damage, damage to landscape plantings, damage to vehicles and injuries to humans from collisions between deer and vehicles, and concern over tick-borne diseases. Two publications present comprehensive overviews of the problems associated with deer overabundance and various programs that have been employed to manage these overabundant deer herds (McShea et al. 1997*a*, Warren 1997).

The term "urban deer" has been used to describe deer that have adapted readily to urban and suburban habitats throughout many portions of North America (McAninch 1995). In many of these areas, public opposition, municipal ordinances, or concerns for human safety often prohibit the use of lethal methods (e.g., hunting or sharpshooting) for controlling urban deer populations. Therefore, interest in the potential use of fertility control as a non-lethal method of controlling deer in these areas has increased dramatically in recent years (Warren 1995).

Fertility control may seem to be a logical alternative method for controlling urban deer populations; however, the practical and logistical difficulties of administering fertility control have prevented this method from being used routinely by wildlife managers. The objectives for this paper are to review published research on deer fertility control methods, consider the applicability of fertility control methods to urban deer management, and discuss advantages and disadvantages of the different methods. Extensive research on wildlife fertility control is available in several published conference proceedings (Walters 1990, Cohn et al. 1996, Australian Society for Reproductive Biology 1997, Kreeger 1997, Curtis and Warren 1998), as well as in one annotated bibliography (McIvor and Schmidt 1996).

Applicability of Fertility Control in Deer

At the outset, it is vitally important to distinguish between applying fertility control methods to deer in captive studies versus small-scale field experiments versus routine management of free-ranging deer populations. Achieving fertility control in captive deer or in small-scale field experiments is not an accurate predictor of the success of fertility control at the population level in a free-ranging deer herd (Underwood and Verret 1998). Changes in the number and composition of deer populations are dynamic and occur as the result of a multitude of factors, only one of which is reproduction. Any reductions in a particular deer herd's density because of reduced fertility could be offset by increased survival of fawns produced by fertile females in the population or by immigration of deer from areas surrounding the treated area. Recent research with a free-ranging suburban deer herd has shown that fertility control may be applicable only to localized herds with less than 100 females (Rudolph et al. 2000).

A second important consideration regarding the applicability of fertility control in urban deer is the treatment of males versus females. Most research in this area has been directed toward controlling fertility in females. The polygamous breeding behavior of deer makes male-based fertility control ineffective at the population level. In other words, only a few untreated, fertile males in an urban deer population would be capable of breeding most of the females in that area. Thus, it would be necessary to treat all of the males in a population to prevent fawn production.

Fertility Control Terminology

The term contraception refers to the prevention of conception by either stopping ovulation or fertilization. Contraception is usually temporary. Fertility often returns after treatment is stopped. On the other hand, the term sterilization refers to an inability to reproduce and usually refers to permanent infertility. The term contragestation refers to an interruption of gestation or pregnancy after conception (i.e., an abortion). The term fertility control is used collectively to refer to all methods of inhibiting reproduction (i.e., contraception, sterilization, and contragestation). There are basically four general methods of fertility control that have been tested and may be applicable to urban deer—surgical sterilization, synthetic steroid hormones, immunocontraception, and contragestation.

Surgical Sterilization

Surgical sterilization requires capture of individual deer and application of field surgery, usually by a licensed veterinarian. Both of these requirements increase the cost of this method of fertility control and create concerns over animal stress. Surgical sterilization has the distinct advantage of being permanent. Ovariectomy would remove the major source of reproductive steroid hormones (estrogen and progesterone), which would alter behavior of the female. Alternatively, ligation of the oviduct would sterilize the female without altering behavior; however, the females would repeatedly cycle for up to seven estrous cycles per breeding season (Knox et al. 1988). Extending the breeding season in deer may be of concern in terms of prolonging the increased activity associated with rut (see Immunocontraception Section below). There is one published account of surgical sterilization having been used to control a small (<20), captive deer herd at a zoo in Milwaukee, Wisconsin (Frank et al. 1993).

Synthetic Steroid Hormones

Exogenous synthetic steroid hormones cause contraception through the process of negative feedback within the female's endocrinological system. The hormones (e.g., synthetic progesterone and/or estrogen) are either ingested or implanted subcutaneously. They then produce sufficient circulating levels of these hormones to block or inhibit the release of gonadotropin releasing hormone (GnRH) from the hypothalamus and follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from the pituitary gland, which are necessary for normal ovarian activity, ovulation, and pregnancy.

Orally administered, synthetic steroids can inhibit ovulation in female deer, but in practice these are not feasible because they require daily oral exposure. Roughton (1979) showed that oral melengestrol acetate (MGA), a synthetic progesterone, was an effective antiovulatory agent in captive white-tailed deer, but daily treatment was required. Harder and Peterle (1974) also showed oral treatment or intramuscular injection with diethylstilbestrol (DES), a synthetic estrogen, was not an easily administered method of contraception in deer. Microencapsulation of DES, allowed oral treatment intervals to be extended to 17 and 30 days, but still required high doses to be effective and was not readily accepted by the deer (Matschke 1977*a*).

Subcutaneous hormone implants have prevented pregnancy in female deer. Bell and Peterle (1975) reduced reproductive rates by using silastic-silicone rubber tubing implants containing MGA and DES. Matschke (1977*b*, 1980) examined fertility control in deer with silastic implants of DES and a synthetic progestin (DRC-6246). Calculated release times for DES were 1-2 years versus 3 years for DRC-6246

(Matschke 1977*b*); however, in a field trial, suppressed reproduction only lasted for 2 years before depletion of the hormone occurred (Matschke 1980).

Plotka and Seal (1989) showed that implants containing MGA provided at least 2 year's infertility when applied to nonpregnant captive deer. However, when applied to five pregnant does during winter, pregnancy was not interrupted and the implants had to be removed, after which one of the treated females died. Plotka and Seal (1989) recommended that pregnant deer not be treated with MGA implants unless pregnancy is first terminated.

Levonorgestrel (LNG) is an implantable progestin that provides effective, long-term (>5 years) contraception in humans (Diaz et al. 1982). Contraception of deer for >5 years from one LNG treatment might seem more practical for controlling deer populations. However, two studies with LNG implants in captive white-tailed deer have shown this technique to be ineffective. Plotka and Seal (1989) implanted five does with a single homogenous silastic-silicone rod containing 200 mg LNG; three of the five does became pregnant. White et al. (1994) used the technique as it is applied in humans, which consists of 216 mg of LNG sealed inside six small silastic-silicone tubes. White et al. (1994) compared six versus nine LNG implants (containing a total of 216 versus 324 mg of LNG) in female adults and fawns. Despite significant release of LNG from both doses of implants, White et al. (1994) observed that three of five implanted adults and one of two fawns that survived 2 years post-implantation became pregnant.

Norgestomet (NGM) is a synthetic progestin marketed for synchronizing estrus in domestic livestock. It has been applied remotely via "biobullets" (i.e., needle-less, intramuscular implants; Kesler et al. 1998) as a contraceptive in white-tailed deer (DeNicola et al. 1997*a*) and black-tailed deer (*Odocoileus hemionus*) (Jacobsen et al. 1995). In both species of deer, NGM was nearly 100% successful in preventing pregnancies for 1 year. Therefore, annual treatments would be required to maintain control over deer reproduction.

Currently, there are no synthetic steroid hormone contraceptives that have been approved by the U.S. Food and Drug Administration (FDA) for use in white-tailed deer, although NGM has been approved and is commercially available (Syncro-Mate B®) for use in cattle (Kesler 1997). Therefore, this method of fertility control for deer can currently be used only in controlled experiments approved by the FDA. Synthetic steroid hormones are orally effective, and therefore, have the potential for secondary, nontarget organism effects.

Immunocontraception

The basic principle of immunocontraception is to inject an animal with a vaccine to stimulate its immune system to produce antibodies against a protein (i.e., antigen) involved in reproduction. The antibodies produced then interfere with the function of the protein in the reproductive process, thereby resulting in contraception. Fertility can resume after exposure to the antigen has ceased and the antibody titers decrease (Muller et al. 1997). The proteins usually are mixed with an adjuvant to increase their immunogenicity. Vaccines used in this manner are proteinaceous reproductive hormones (i.e., GnRH, FSH, LH), or the proteins surrounding the sperm or ovum, or proteins involved in implantation (Miller et al. 1998). Other hormones (i.e., melatonin, estrogen, progesterone) can be also be used in these vaccines, but they must first be conjugated to another compound to make them immunogenic.

DeNicola et al. (1996*b*) treated white-tailed deer with remotely delivered immunocontraceptive vaccines containing human chorionic gonadotropin (hCG) or LH, but did not observe reduced fertility. The immunocontraceptive that has been tested most successfully in deer has used the zona pellucida (ZP) as the antigen (Kirkpatrick et al. 1996). The ZP is a series of glycoproteins surrounding the ovum that is important in sperm-egg binding during fertilization. Injections of immunocontraceptives containing ZP cause the female to produce antibodies to ZP, which then interfere with normal fertilization. Turner et al.

(1992) successfully used porcine zona pellucida (PZP) vaccine as an immunocontraceptive for white-tailed deer. Their vaccine was delivered remotely via syringe-darts; however, multiple booster injections were required. This requirement limits the practicality of using this contraceptive vaccine in free-ranging deer populations. Recent advancements in research with PZP have included microencapsulation of the booster vaccinations so that only one vaccination per year is required; however, results to date have not been favorable (Turner et al. 1996)

Some research has been conducted to develop an oral delivery method for immunocontraceptive vaccines (Miller et al. 1998). Conceptually, a genetically modified bacterium or virus serves as a live vector to orally deliver a genetically engineered immunocontraceptive vaccine to deer. Obviously, such a contraceptive technology would greatly improve the cost and time efficiency of applying immunocontraceptives to free-ranging deer populations. However, there are concerns regarding nontarget organism effects. Much more research is necessary before this technology can be considered even for field-testing.

Immunocontraceptive techniques have numerous advantages over synthetic steroid hormone contraceptives for use in deer. Immunocontraceptives can be delivered remotely, which makes them more feasible for application in the field than methods that require capture and handling of individual deer. Also, a protein-based vaccine likely would be deactivated if ingested orally by nontarget organisms in contrast to the persistent tissue residue that often characterize the synthetic steroids. Digestion of the vaccine after oral ingestion likely would prevent unintentional transfer up the food chain to carnivores or humans.

Immunocontraceptives have a number of disadvantages. Currently, there is no commercial source for ZP or the PZP vaccine, although research is underway to develop recombinant ZP (Skinner et al. 1994). In addition, the only PZP vaccine formulations for which successful results have been published include Freund's Complete Adjuvant (FCA; a mixture of oil, water, and killed bacterial proteins). Tests in deer with PZP vaccine formulations using two other synthetic adjuvants (Carbopol 934P® or synthetic trehalose dicorynomycolate) have been unsuccessful (Thiele 1999, Walter 2000). Use of FCA in the vaccine can result in a false positive test in animal health assessments for tuberculosis. The FDA has not approved the PZP vaccine for routine use in the management of urban deer populations. Given the experimental nature of the PZP vaccine and the FCA adjuvant, the FDA requires a site-specific Investigational New Animal Drug (INAD) authorization (Kesler 1997) before it can be applied in field experiments. The FDA also requires all animals treated with PZP vaccine to be marked as "Experimental Animal: Do Not Consume".

Currently, PZP vaccine containing FCA must be injected in liquid formulation. Remote delivery is possible using commercially available syringe darts. However, remotely delivered syringe darts may have disadvantages. Their accuracy depends on the quality of the equipment and the experience and skill of the user. Also, missed darts may not be recovered and could remain in the environment as a potential human exposure hazard (especially for curious children).

One other disadvantage of the PZP vaccine is that it must be applied during spring and summer before the breeding season. During this time of the year, it is difficult to attract deer to bait stations because of abundant natural foods. Lower baiting success decreases the applicability of PZP vaccine to deer in a particular population. Recent research (Thiele 1999), however, has demonstrated that it is possible to administer the initial vaccination much earlier, even as early as when the females are fawns.

Another disadvantage of the PZP vaccine is that treated females display recurrent estrous cycles. McShea et al. (1997*b*) treated adult female white-tailed deer with PZP immunocontraceptives and noted that they continued to display estrus as late as March. Prolonging the breeding season in this manner can disrupt normal intersexual behavior and may indirectly increase deer-vehicle collisions. Deer are most active during the breeding season (Ozoga and Verme 1975) and, as a result, deer-vehicle collisions usually increase dramatically during autumn (Allen and McCullough 1976). Research is needed to determine whether prolonging the breeding season by PZP immunocontraception will increase deer-vehicle collisions.

One other disadvantage of the PZP vaccine is that incomplete vaccinations can result in late-born fawns. Turner et al. (1996) determined that incomplete vaccinations allowed antibody titers to decrease before the breeding season ended, thereby enabling PZP-treated females to conceive in late winter so that their fawns could be born in early autumn. Underwood and Verret (1998) observed late-born fawns in PZP-treated females on Fire Island, New York, and speculated that these fawns could have lower survival potential during harsh winter conditions.

There are at least five published cases of field experiments in which PZP immunocontraception was applied to free-ranging white-tailed deer populations. Peck and Stahl (1997) treated females in a 308-ha metropolitan park in Columbus, Ohio. Walter (2000) treated females in a 67-ha suburban community near Groton, Connecticut. Rudolph et al. (2000) treated females in a portion of a 43-km^2 suburban community in Irondequoit, New York. All three of these studies concluded that PZP immunocontraception was time-consuming and costly (ranging from $802-1,100/treated female). Rudolph et al. (2000) specifically stated that PZP immunocontraceptive vaccines ideally should be applied to isolated deer herds containing fewer than 100 females. The other two published field experiments on PZP immunocontraception (Underwood and Verret 1998, Thiele 1999) were done using volunteers, so costs were much lower (<$50/treated female). The field experiment by Underwood and Verret (1998) observed no decline in the deer population after five years of treating females with PZP vaccine. They concluded, "First, a population decline cannot be effectively achieved unless zero fertility *is* the population goal–and can only be achieved if every female of reproductive age is vaccinated." (Underwood and Verret 1998:44).

<u>Contragestation</u>

Research on contragestation in white-tailed deer has focused on prostaglandin $F_{2?}$ ($PGF_{2?}$). This product is commercially available (Lutalyse®) and has been approved by FDA for synchronizing estrus or terminating pregnancy in cattle and swine intended for human consumption. As approved, $PGF_{2?}$ can be used without a preslaughter drug withdrawal period, thus indicating the lack of any secondary, nontarget organism effects. Although FDA has not yet approved $PGF_{2?}$ for use in deer, which are classified as human food animals, it is likely that it could be approved for routine use in deer. When administered during gestation, $PGF_{2?}$ causes regression of ovarian corpora lutea and a concomitant reduction in blood progesterone concentrations, which induces an abortion (Lauderdale 1972).

Other than the fact that it is commercially available, $PGF_{2?}$ has the advantage that it is applied during winter after females are pregnant. During this time of the year, it is relatively easy to attract deer to bait stations because of prevailing shortages of natural foods. This fact would greatly increase the applicability to more deer in a particular population. Another advantage for $PGF_{2?}$ is that it can be delivered remotely by "biobullet" (DeNicola et al. 1996*a*, Kesler et al. 1998).

Disadvantages associated with the use of $PGF_{2?}$ for fertility control in deer are that females must be retreated annually, because they become pregnant the following year. In addition, abortion of fawn-like fetuses may be unacceptable in some communities. Waddell (2000) treated captive female white-tailed deer with $PGF_{2?}$ during early (5-9 weeks) and late (16-22 weeks) gestation. Fetuses aborted during early gestation were not recognizable, but later in gestation they looked like fawns.

There are at least two published field experiments in which $PGF_{2?}$ was applied in free-ranging white-tailed deer herds. DeNicola et al. (1997*b*) remotely treated 16 adult female deer with $PGF_{2?}$ in a 176-ha facility in Connecticut and terminated pregnancy in all of them. Jordon et al. (2000) conducted a field experiment in two areas (one treated and one control; about 730 ha/each) on Kiawah Island, South Carolina. All free-ranging, female deer seen during a 4-week period in the treated area received remotely delivered biobullets containing $PGF_{2?}$. After two consecutive years of treatment, adult females in the treated area averaged pregnancy rates of 50% compared to 100% in the control area. Population-level effects have not yet been documented during the first 2 years of their experiment (Jordan et al. 2000).

Conclusion

Despite the great interest in fertility control as a means of controlling urban deer populations, much research is still needed before these methods can be used in routine management. It is important that the public be properly informed about the distinction between fertility control in individual deer versus population control in an entire herd. Warren (2000) published a brochure designed to objectively answer the public's questions about fertility control in urban deer management. There is much potential for fertility control to be applicable in the management of urban deer in the future, however, the current state of research in this area has not yet proven the effectiveness of these methods in causing a decline in urban deer populations.

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