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Comparative effects of GnRH and porcine zona pellucida (PZP) immunocontraceptive vaccines for controlling reproduction in white-tailed deer (*Odocoileus virginianus*)

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Fawning rates and mating behaviour were compared between white-tailed deer (*Odocoileus virginianus*) treated with GnRH and porcine zona pellucida (PZP) immunocontraceptive vaccines from 1997 to 2000. Female deer from a herd of 102 deer at Seneca Army Depot, near Romulus, New York, were treated with prime and booster injections of PZP ($n = 22$) or GnRH vaccine ($n = 32$), or remained untreated as controls ($n = 34$). During the summers after booster treatment, observed fawning rates for adult female deer were similar for both PZP-treated (0.10–0.11 fawns per female) and GnRH-treated (0.13–0.22 fawns per female) female deer, and were significantly lower ($t = -8.93$ and $t = -9.73$; $P \leqslant 0.0005$, respectively) than those observed for control female deer (1.22–1.38 fawns per female). During the second (0.36 fawns per female) and third summers (0.61 fawns per female) after the last booster injection, GnRH-treated female deer still produced significantly fewer fawns than did the controls (1.38 and 1.31 fawns per female, respectively). In one breeding season after treatment, five of 18 (28%) females vaccinated with PZP produced fawns, similar to the rate for GnRH-treated females (29%). In addition, females treated with GnRH had fewer oestrous cycles per female (0.06, $P \leqslant 0.05$) than did either control (0.22 cycles per female) or PZP-treated deer (0.36 cycles per female). Initial PZP treatment followed by a booster dose 5–7 months later reduced fawn production and prolonged the breeding season as females repeatedly returned to oestrus, similar to results reported in other studies.

Introduction

White-tailed deer (*Odocoileus virginianus*) densities have reached unprecedented levels in some suburban communities (Curtis and Richmond, 1992) and deer populations in North

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America are still increasing. Safety concerns and ethical issues have rendered deer population regulation via managed recreational hunting impractical in many residential areas, and have increased interest in the use of non-lethal methods, such as immunocontraceptive vaccines for controlling birth rates in deer (Warren *et al.*, 1995; Miller, 1996; Curtis *et al.*, 1997; Cowan *et al.*, in press).

Fertility control as a tool in wildlife management has been the subject of research for many years (Harder and Peterle, 1974; Kennelly and Converse, 1997) with variable results (Bomford, 1990; Turner *et al.*, 1997; Warren *et al.*, 1997). Porcine zona pellucida (PZP) has been the most commonly used immunocontraceptive antigen for fertility control in female mammals (Sacco, 1987) and has been administered experimentally to > 70 species of wild mammals, including several captive ungulates (Kirkpatrick *et al.*, 1997; Miller *et al.*, 2000a). The continuing expansion of humans into deer habitat and vice versa has resulted in much recent research with PZP vaccines being focused on widespread and growing concerns with deer in suburban settings (Turner *et al.*, 1992, 1996; McShea *et al.*, 1997; Underwood and Verret, 1998).

A second immunocontraceptive antigen, GnRH, has been shown to have potential for fertility control in domestic animals (Jeffcoate *et al.*, 1978, 1982; Adams and Adams, 1992; Brown *et al.*, 1994; Meloen *et al.*, 1994), companion animals (Ladd *et al.*, 1994), and a variety of wildlife species including Norway rats (*Rattus norvegicus*, Miller *et al.*, 1997), African elephants (*Loxodonta africana*, Brown *et al.*, 1993), rainbow trout (*Oncorhynchus mykiss*, Riley and Secombes, 1993) and the marmoset monkey (*Callithrix jacchus*, Hodges and Hearn, 1977). GnRH has been evaluated for efficacy in captive white-tailed deer (Killian, 1998; Miller *et al.*, 2000b); however, little research has been conducted with GnRH vaccines in free-ranging white-tailed deer.

The issue of remotely delivering an immunocontraceptive antigen and following that event with timely delivery of booster doses to the same free-ranging animal is an obvious challenge (Rudolph *et al.*, 2000). PZP booster injections were delivered by dart rifle during early autumn 1997 before the breeding season, 5–7 months after the initial injection. We hypothesized that a similar reduction in fawning rates would be observed for PZP-treated deer and GnRH-treated females that received both prime and booster doses a few weeks apart in autumn 1996.

The aims of the present study were to compare the efficacy of PZP and GnRH vaccines for reducing fawn production in the same herd of white-tailed deer. Fawning rates and breeding behaviour of PZP- and GnRH-treated female deer were compared between treatments and also with untreated control deer. A direct comparison of these vaccines under similar herd and field conditions provides an optimal setting for determining whether either or both of these immunocontraceptive antigens have potential for further development as a tool for wildlife fertility control.

Materials and Methods

The study was conducted in the quarantine area (QA) of the 4000 ha Seneca Army Depot (SAD) located near Romulus, New York. The 263 ha QA is enclosed by three 2.4 m parallel, security fences and consists of 5% paved roads, railroads and buildings, 17% woodland and 78% open grasslands. Natural forage was abundant, and was further supplemented with apples, apple mash, corn, alfalfa hay and salt to ensure that deer were in good condition during the breeding season and winter months. These food items were strategically placed to serve also as bait sites that were used for darting of deer and behavioural observations.

Experimental animals included 61 adult (≥ 2.5 years) and 27 yearling (1.5 years) female deer, and eight adult and five yearling males. Deer were captured with rocket nets (Hawkins *et al.*, 1968), dart guns (Pneu Dart, Inc., Williamsport, PA) and Clover traps (Clover, 1954) from

Table 1. Immunocontraceptive treatment schedule for female white-tailed deer vaccinated with porcine zona pellucida (PZP) or GnRH antigens at Seneca Army Depot, Romulus, New York from 1996 to 1998

Experimental group	Sample size	Prime dose	First booster	Second booster
PZP	22	6 March – 1 May, 1997[a]	26 August – 28 October, 1997	3 September – 30 October, 1998
GnRH	32	31 August – 9 October, 1996	20 September – 9 November, 1996	10 September – 17 October, 1997

[a]The prime dose of PZP vaccine was injected by hand into female deer at the time of capture and marking. All other vaccinations were delivered remotely by dart-syringe and rifle.

surrounding SAD property during winter and early spring in 1996 and 1997. Deer captured in rocket nets or Clover traps were restrained under the net and immobilized with 2.2 mg xylazine hydrochloride kg^{-1} (Rompun; Miles Laboratories, Shawnee Mission, KS) administered i.m. The antagonist yohimbine hydrochloride (Yobine; Lloyd Laboratories, Shenandoah, IA) was administered i.v. at 0.11 mg kg^{-1} upon release of the deer (Mech *et al.*, 1985). For immobilization with a dart rifle, disposable 2 cc darts with 1.9 cm needles and gelatin collars were used. These syringe darts injected either pure xylazine hydrochloride, or a mixture of xylazine hydrochloride tiletamine hydrochloride and zolazepam hydrochloride (Telazol; Fort Dodge Labs, Fort Dodge, IA) at 2.2 mg kg^{-1}. No antagonist was administered at release when the Telazol mixture was used for deer immobilization. Each deer was fitted with a numbered collar for individual identification before release into the research enclosure.

For the field study, female deer were assigned to GnRH (1996–2000), PZP (1997–2000) or control (1996–2000) groups (Table 1). All vaccine treatments were administered in the hip region either by injection by hand at capture (PZP) or by remote delivery later with self-injecting 1 cc darts (Pneu Dart Inc., Williamsport, PA). In this investigation, a prime dose of PZP vaccine was administered during winter 1997 when deer were food-stressed and more easily lured to bait sites, thereby increasing darting efficiency. Deer were darted from canvas shelters at baited sites (< 35 m) near dawn and dusk, or from a vehicle at night with the aid of a spotlight at distances of 14–45 m along roadsides. All treatments followed positive identification of individual deer.

GnRH experiments

The immunocontraceptive vaccines used in the present study were prepared by L. A. Miller (US Department of Agriculture-National Wildlife Research Center, Fort Collins, CO). The 10 amino acid GnRH was made immunogenic by coupling it to the carrier keyhole limpet haemocyanin (KLH, Miller *et al.*, 2000b). A glycine was added at the C-terminus of GnRH as a spacer, and a cysteine was added to provide a coupling agent to maleimide on KLH. Maleimide-activated KLH was purchased from Pierce Chemical Co. (Rockford, IL) and the C-terminal Cys-GnRH was coupled to the activated KLH following the manufacturer's instructions. Both KLH-maleimide and the peptide were lyophilized and rehydrated in a 1:1 (w:w) ratio for coupling. The 1 cc prime dose of GnRH vaccine contained 65 µg KLH–GnRH in saline mixed with Freund's complete adjuvant (FCA) at a 1:1 ratio (Miller, 1997). The 1 cc booster dose contained 65 µg KLH–GnRH mixed with Freund's incomplete adjuvant (FIA) in a 1:1 ratio. The prime dose (GnRH + FCA) was remotely injected into 32 female deer and the first booster shot (GnRH + FIA) was administered 3–4 weeks later, before the breeding season

during September and October 1996. A second booster dose (GnRH + FIA) was delivered by remote injection during September 1997. No GnRH booster treatment was provided in September 1998 or 1999; however, fawning rates were again monitored in the summer of 1999 and 2000 to determine any residual effects of the GnRH vaccine in female deer at 1 and 2 years after treatment.

PZP experiments

Female deer ($n = 22$) were immunized with purified PZP, which was prepared by and purchased from B. S. Dunbar (Baylor College of Medicine, Houston, TX; Skinner *et al.*, 1994). The 1 cc prime dose of PZP vaccine consisted of 0.5 cc saline containing 65 μg PZP mixed with 0.5 cc FCA. Similarly, a 1 cc booster dose contained 65 μg PZP in 0.5 cc saline mixed with 0.5 cc FIA at a 1:1 ratio. The prime dose (PZP + FCA) injection was administered by hand at the time of capture during late winter 1997 (February–April), as deer were readily caught at bait sites during the winter. The effectiveness of a prolonged period between administration of the prime and the initial booster dose was determined by administering the initial booster (PZP + FIA) by remote injection 5–7 months later in September 1997. A second booster treatment (PZP + FIA) was delivered by dart-rifle in September and October 1998. These deer were monitored for mating and subsequent fawning activities from autumn 1997 to summer 2000.

Fawn observations

Fawn searches were conducted in the 263 ha enclosure each day from May to September 1997–2000. Maternity was determined on the basis of repeated observations of fawns following females and by females displaying maternal behaviour toward fawns. A minimum of three doe–fawn interactions was used to determine parentage. Parturition dates were initially based on fawn motor skills and size at first observation relative to fawns of known age (McShea *et al.*, 1997). In September, October and December of each year, fawns were captured and removed from the research enclosure. These fawns were classified by age on the basis of incisor development (Severinghaus, 1949). Adjustments to initial estimated parturition dates were made on the basis of incisor development.

From 1996 to 1998, observations of deer breeding activity were conducted each day at dawn and dusk from mid-October until all males had shed their antlers (early March 1997 and late March 1998). A female was considered to be in oestrus when she was observed being tended (Hirth, 1977) or mounted by a male. The breeding season was divided into five, 1 month periods beginning with the date on which a male was first observed tending a female. If the oestrous cycle overlapped two periods, the doe was placed only in the earlier period.

For analysis of parturition and dates of observed oestrus, the Wilcoxon rank sum test (Z) or Kruskal–Wallis test (chi-squared) for multiple groups were used. All percentages were subjected to angular (arcsine) transformation (Steele and Torrie, 1960) before ANOVA.

Results

Fawn production

Only four of 32 (13%) and four of 30 (13%) GnRH-treated female deer produced fawns in 1997 and 1998, respectively (Table 2). None of nine GnRH-treated yearlings, and only four of 23 (17%) GnRH-treated adults, produced fawns in 1997. The apparent value of providing a booster treatment is shown by comparing fawn production in boosted, sexually mature adults with those deer that did not receive the booster. During the fawning seasons of 1997 and 1998

Table 2. Fawn production for female white-tailed deer treated with porcine zona pellucida (PZP) or GnRH immunocontraceptive vaccines, and for control females at Seneca Army Depot, Romulus, New York from 1997 to 2000

Experimental group	Year	Sample size (yearlings:adults)		Percentage producing fawns (yearlings:adults)		Total fawns produced (yearlings:adults)		Avearge number of fawns per female (yearlings:adults)	
PZP	1998	3	19	33	11	1	2	0.33	0.11
	1999	–	20	–	10	–	2	–	0.10
	2000[a]	–	18	–	28	–	5	–	0.28
GnRH	1997	9	23	0	13	0	5	0.00	0.22
	1998	–	30	–	13	–	4	–	0.13
	1999[b]	–	28	–	29	–	10	–	0.36
	2000[b]	–	28	–	57	–	17	–	0.61
Control	1997	15	19	53	79	12	26	0.80	1.37
	1998	–	27	–	81	–	33	–	1.22
	1999	–	16	–	88	–	22	–	1.38
	2000	–	13	–	85	–	17	–	1.31

[a]PZP-treated female deer that received their last booster injection in autumn 1998, so that fawning rates for summer 2000 occur > 20 months after treatment.

[b]GnRH-treated female deer that received their last booster injection in autumn 1997, so that fawning rates in summer 1999 occur > 20 months after treatment, and those in summer 2000 occur > 32 months after the last booster injection.

after booster treatments during the previous autumn, only eight of 62 females (13%) treated with GnRH produced fawns and only one of the eight females produced twins. During summer 1999, after one breeding season without a booster, eight of 28 (29%) adult females previously treated with GnRH produced fawns and of these, two does produced twins, which is the common litter size for adult females in good health (Verme, 1969). In the second breeding season after treatment, 16 of 28 females (57%) bore fawns. During these same four reproductive seasons, 110 fawns were produced by control does (n = 38 in 1997; 33 in 1998; 22 in 1999; and 17 in 2000; Table 2).

For females treated with PZP, three of 22 (14%) and two of 20 (10%) produced offspring during 1998 and 1999, respectively. One of three (33%) PZP yearlings and two of 19 (11%) PZP adults produced fawns in the summer of 1998. During the reproductive seasons immediately after booster treatments the previous autumn, none of the PZP-treated females that produced fawns had twins. One breeding season after treatment, five of 18 females (28%) bore young, which was similar to the rate for GnRH-treated females (29%).

During summers immediately after autumn booster treatments, fawn production for both GnRH- and PZP-treated females was significantly lower than that of control females ($t = -8.93$; $P < 0.0005$ and $t = -9.73$; $P < 0.0005$). In addition, in the second reproductive season after booster injections, GnRH- and PZP-treated females still produced significantly fewer ($P < 0.0005$) fawns than did the controls.

There was no difference in parturition dates between 1997, 1998 and 1999 (chi-squared = 1.58; 2 df; $P > 0.1$; Table 3) among control females, as most fawns were born before 1 July. Fawning dates for the GnRH- and PZP-treated females were later in 1998 than for the 1997 GnRH group (chi-squared = 8.34; 2 df; $P \leq 0.03$) and later than the control groups in 1997 and 1998 (chi-squared = 3.87; 1 df; $P \leq 0.05$). There was no difference in parturition dates between any of the three groups in 1999 (chi-squared = 0.00; 2 df; $P > 0.995$).

Table 3. Parturition dates for female white-tailed deer treated with porcine zona pellucida (PZP) and GnRH immunocontraceptive vaccines, and for control females, at Seneca Army Depot, Romulus, New York from summer 1997 to 1999

	Parturition dates				
Experimental group	Before 15 June	15 June – 1 July	1 – 15 July	15 July – 1 Aug	1 – 15 Aug
PZP					
1998	1	1	1	0	0
1999	1	0	1	0	0
GnRH					
1997	4	0	0	0	0
1998	0	1	1	1	1
1999[a]	5	2	1	0	0
Control					
1997	10	10	3	0	0
1998	13	7	3	0	0
1999	9	5	0	0	0

[a]GnRH-treated female deer that received their last booster injection during autumn 1998.

Table 4. Observed dates for the resumption of oestrous cyclicity in female white-tailed deer treated with porcine zona pellucida (PZP) and GnRH immunocontraceptive vaccines, and for control females, at Seneca Army Depot, Romulus, New York during 1997 and 1998

		Occurrence of oestrus				
Experimental group	Year	November	December	January	February	March
PZP	1997	2	2	3	1	0
	1998	4	10	3	2	1
GnRH	1997	0	1	1	0	0
	1998[a]	4	1	0	0	0
Control	1997	2	3	1	0	0
	1998	4	0	0	0	0

[a]GnRH-treated female deer that received their last booster treatments during autumn 1997.

Mating activity

There was no difference in observed timing of oestrus for the control females between 1997 and 1998, or for the PZP-treated females between 1997 and 1998 ($Z = 1.49$, $P = 0.136$ and $Z = 0.406$, $P = 0.682$, respectively; Table 4). However, females treated with GnRH for a second year cycled later than females in their first year of treatment with GnRH ($Z = 1.93$; $P = 0.05$). Observed oestrous cyclicity for PZP-treated females was significantly later than that for control females ($Z = 2.62$; $P = 0.009$) and marginally later than that for GnRH-treated females ($Z = 1.78$; $P = 0.075$). In 1997, females treated with PZP showed significantly more mating activity (0.36 oestrous cycles per doe) than those treated with GnRH (0.06 oestrous cycles per doe) and control females (0.22 oestrous cycles per doe).

Discussion

The results from this study demonstrate successful inhibition of fertility in semi-free ranging white-tailed deer with a remotely delivered GnRH vaccine. The observed fawning rates (0.13–0.22 fawns per female) in the present study were similar to those reported by Miller *et al.* (2000b) for hand-injected, captive deer in Pennsylvania (0.21 fawns per female) with an 88% reduction in fawn births as compared with control females.

PZP treatments with 5–7 months between prime and booster injections markedly reduced fawn production, and reduced the incidence of twin births for those females that produced fawns. PZP treatment also prolonged the breeding season due to an increased number of oestrous cycles in each doe; this finding is similar to results reported in studies with 2–4 weeks between prime and booster injections (Turner *et al.*, 1992, 1996; McShea *et al.*, 1997; Killian, 1998). Miller *et al.* (2000a) also noted that the best immune response to PZP vaccination often occurs in the second year after original antigen exposure and that infertility may be retained for 1–4 years in some females without additional booster treatments.

GnRH and PZP vaccines reduced fawn production in white-tailed deer to a comparable degree. However, the GnRH treatment was apparently more effective for yearling females, and more adult females responded to PZP treatment. Three of the four GnRH-treated adult females that did not respond to vaccine injection and produced fawns in 1997 also produced fawns in 1998, and all four females again produced fawns in 1999. Apparently, either a small proportion of the adult female population did not respond to the GnRH vaccine (Bomford, 1990; Becker and Katz, 1997) or the first, second or both remotely delivered injection failed to deliver a complete dose.

Suppression of reproductive hormones with GnRH may be more effective in yearlings (deer classified as 1.5 years old), which generally ovulate less frequently than do adults (Hesselton and Jackson, 1974), and do not reach full reproductive potential until adulthood (deer classified as 2.5 years or older; Verme and Ullrey, 1984). None of the nine females immunized with GnRH as yearlings produced fawns during their first or second year as adults. Adams and Adams (1992) and Brown *et al.* (1994) reported that immunization of domestic stock against GnRH very early in life (prepubertal) may be more efficacious and longer lasting than immunization later in life. Warren and White (1995) suggested that treating prepubertal fawns may increase the efficiency of a contraceptive management programme.

Contraceptives delivered orally will probably be necessary for practical wildlife management in the future (Warren *et al.*, 1995; Miller, 1996; Curtis *et al.*, 1997; Linhart *et al.*, 1997; Miller *et al.*, 2000a), and, thus, may be administered to deer of all ages via bait consumption. Therefore, it is important for future investigators to examine the potential impacts of immunization on all age classes (fawns, yearlings, adults) of white-tailed deer. However, the risk of unintentional treatment of non-target wildlife species is much greater with oral delivery than for injection or implants (Guynn, 1997). Species specificity could be achieved either by genetically engineering the antigen, or by designing a bait station to exclude non-target animals. Much work is still required to develop safe and effective delivery systems for contraceptive drugs or vaccines (Cowan *et al.*, in press).

Parturition dates for PZP-treated females were not substantially delayed, as all three births occurred before early July. The few deer that did not develop a sufficient antibody response to inhibit reproduction must have conceived on their first or second oestrous cycle. Jackson and Hesselton (1973) reported that 95% of females (including fertile fawns) in New York gave birth before 19 July, which is similar to the results obtained for the control females.

Variation in the response to GnRH among adult females or incomplete injections may also explain the delayed breeding in 1997 and resulting delayed parturition in 1998 shown by

GnRH-treated females. Only two oestrous cycles were observed for GnRH-treated females in 1997; however, the first was not observed until December. Cyclicity in deer in all other experimental groups was first observed in November. If GnRH injections administered in autumn 1996 were incomplete in the four non-responding females and insufficient to block reproduction (all four females fawned in early June), then administration of the third injection to these females in autumn 1997 may have acted as a single-injection treatment. If this was the case, only a short-lived antibody response would be produced and, thus, there would be only a delay in the onset of oestrus and subsequent fawning. Miller *et al.* (2000b) noted variations in antibody titre and immune response for captive female deer treated with GnRH vaccines. These observations were consistent with past immunocontraceptive studies and are thought to be due to genetic differences among individual animals. Feral horses treated with GnRH showed delayed foaling (Goodloe, 1991), and captive red deer stags showed a delayed rut (Atja *et al.*, 1992; Freudenberger *et al.*, 1993). McShea *et al.* (1997) also noted delayed fawning for PZP-treated females that received only a single injection.

Females treated with GnRH for a second year and PZP-treated females breeding late in the season showed reduced rates of twin births. This finding may have resulted from decreased sperm production often experienced by males during late winter (Mirarchi *et al.*, 1977; Knox *et al.*, 1988), which may be associated in part with loss of body weight (Gittleman and Thompson, 1988). GnRH can also function as a contragestation agent depending on timing of the vaccine delivery and immune response of the individual deer (Miller *et al.*, 2000b). Therefore, GnRH could have inhibited implantation or even the maintenance of pregnancy in some female deer resulting in fetus resorption and, thus, smaller litter sizes.

GnRH-treated females that did not receive a booster treatment in autumn 1998 showed an earlier onset of oestrus than did GnRH-treated females that received a booster injection immediately before the breeding season. Similarly, 14 of 20 (70%) of the oestrous cycles observed for second year PZP-treated females occurred before the end of December compared with only four of eight (50%) for the first year PZP-treated does. This finding may be attributable to non-parous and non-lactating does entering the breeding season in better body condition and, therefore, showing an earlier onset of breeding activity (Verme and Ullrey, 1984; McShea *et al.*, 1997).

Only eight of 28 (29%) GnRH-treated female deer bore fawns in 1999, indicating that GnRH continued to inhibit reproduction in 71% of females 1 year after treatment. If the four non-responsive GnRH-treated females that consistently produced fawns during the study are excluded, then only four of 24 (17%) of females produced young in the second fawning season after booster treatment. Miller *et al.* (2000b) noted that infertility was directly related to anti-GnRH serum antibody titres above 64 000 with infertility lasting 2 or more years without booster treatment. However, studies in domestic stock revealed that short-term anti-GnRH immunization was reversible (Keeling and Crighton, 1984), and thus unlikely to be accompanied by a prolonged period of reduced fertility after treatment.

Turner *et al.* (1996) reported that PZP-mediated infertility for white-tailed deer was reversible within 2 years for 75% of treated females. In contrast, Miller *et al.* (2000a) observed that PZP produced variable infertility for up to 4 years. Overall, birth rates were reduced by 76% during the 6 year study, and there was an 89% reduction in fawn production during the first 2 years of active immunization. For this captive herd in Pennsylvania, immune responses among deer were variable, especially in the first year of treatment (Miller *et al.*, 2000a).

The obvious impact of a residual effect and the ultimate reversibility of contraception are of considerable importance to population modelling efforts (Barlow, 2000; Hobbs *et al.*, 2000). A predictable natality rate is a cornerstone for accuracy in building and understanding wildlife population models (Courchamp and Cornell, 2000; Hobbs *et al.*, 2000; Cowan *et al.*, in

press). Although Nettles (1997), Kirkpatrick *et al.* (1997) and other workers have alluded to this issue, additional studies of the long-term effects of both PZP and GnRH vaccines, as well as other candidate agents, are needed. In addition, recent modelling of virus vectors and bait delivery for immunocontraceptive agents highlighted the importance of delivery systems to the overall success for field application of fertility control programmes (Courchamp and Cornell, 2000; Cowan *et al.*, in press).

In summary, both PZP and GnRH vaccines were effective for inhibiting reproduction in white-tailed deer when administered as described here. In addition, the GnRH vaccine was responsible for a reduced fawning rate for female deer 1 and 2 years after treatment. Hobbs *et al.* (2000) showed that fertility control with long-lived or irreversible agents may be more efficient than culling for regulation of ungulate populations. However, longer term studies and pathological examination of deer treated with immunocontraceptive vaccines may be required to reveal potential detrimental health effects resulting from interference with the reproductive system of white-tailed deer (Seal, 1991; Muller *et al.*, 1997).

Our experience and data, plus recent reports, indicate that implementation of an immunocontraceptive programme using current protocols, even in a semi-free ranging but enclosed deer herd, would be expensive and perhaps impractical due to high equipment and labour costs (Rudolph *et al.*, 2000; Pooler *et al.*, in press). The need for a single dose, oral contraceptive agent for free-ranging animals has been highlighted in a number of studies (Warren *et al.*, 1995; Miller, 1996; Bradley *et al.*, 1997; Curtis *et al.*, 1997; Linhart *et al.*, 1997). Further research to develop such a single-dose, fertility control agent that can be delivered orally and at lower cost is warranted.

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