CAN CONTRACEPTION CONTROL DEER POPULATIONS IN THE UK?

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1] Introduction and history

Populations of wildlife species can reach densities that become undesirable as a result of many possible factors. There may be an abundance of food or an absence of predators, the species may be non-indigenous or feral and have no natural competitors; it may thrive on intensive food crops or benefit from artificial provision from suburban gardens, waste or amenity plantings. The species may be confined to an enclosure or exhibition or be limited to an island. Under these circumstances an alternative to mass killing is as a means of population control is an attractive concept [Baker, Wild, Conner et al, 2002; Grandy & Rutberg, 2002; Naugle, Rutberg, Underwood et al, 2002], not least because of public sentiment, but also because of the impracticality of the use of firearms or traps in some circumstances and the welfare concern surrounding the use of poisons [Curtis, Pooler, Richmond et al 2002; Hardy, Pekin & de Have 2002; Nettles, 1997].

Since the mid twentieth century research has been directed at the development of agents that safely limit the fertility of targeted wild animals and of systems to deliver these agents to sufficient numbers of the target species to achieve population control [Harder & Peterle, 1974; Plotka & Seal 1989; Tyler, 1967]. Recent research and effort has been concentrated on immunocontraception, which appears to offer efficiency, specificity and safety to the target species, without risk to other species or to the environment [Grandy & Rutberg, 2002; Muller, Warren & Evans, 1997]

2] Specific population problems with deer populations

The most recently published data for deer in the UK show large increases in populations of muntjac [Muntiacus reevesi], roe [Capreolus capreolus], sika [Cervus Nippon] and fallow deer [Dama dama] between 1995 and 2006, with red deer [Cervus elaphus] populations remaining stable [Tracking Mammals Partnership, 2007]. These figures concur with the findings of other workers, who report that deer in the UK have expanded in both numbers and range in the last quarter of the twentieth century [Ward, 2005;

Staines & Ratcliffe 1987]. Similar increases are reported from areas of the USA, particularly the north-east and west coasts, where densities of white-tailed deer [Odocoileus virginianus] as high as 90 per km sq have been reported [Connover, 1997; Naugle et al 2002]. These deer are increasingly urban in habitat and cause significant difficulties with road traffic, crop damage, damage to native vegetation, garden and ornamental damage and scavenging [Rudolph, Porter & Underwood 2000; Connover 1997, Rutberg & Naugle 2007]. In Great Britain such urban populations have not yet been seen, but there is longstanding concern about the impact of deer on the natural and the agricultural environment [Putman 1985; Staines 1985]; there has been at least one report of deer dying of apparent starvation in a lowland wood when the population reached a saturation level [Cooke Green & Chapman 2001] and starvation is a factor in the winter die-off that is a feature of upland deer populations [Ross 1986]. Increasing rural and urban deer populations may be implicated in the epidemiology of diseases transmissible to domestic ruminants, especially bovine tuberculosis [Delahay, Smith, Barlow et al 2007] and of diseases transmissible to humans [White 1998]. It is clear that in urban situations, enclosed exhibition collections or in parks with a high public profile the use of firearms to control deer may be unpalatable to the general public or simply unsafe. The possibility of contraceptive control may appear to be a perfect solution [Naugle et al 2002; Shideler, Stoops, Gee at al 2002].

3] Possible contraceptive agents

The use of toxic chemicals to control deer number by poisoning will not be considered in this article.

3.1. Steroidal hormones

Derivatives of the female sex hormones oestrogen and progesterone have been used to control fertility in deer [Greer, Hawkins & Catlion1968; White, Warren & Frayer-Hosken 1994; Harder & Peterle 1974; Warren, Frayrer-Hosken, White et al 1997] and have more recently been proposed as contraceptives for African large mammals and Australian marsupials [Graham, Webster, Richards et al 2002; Nave, Coulson, Short et al 2002]. The mode of action is by means of regulation of the ovarian cycle, so that treated females fail to come into fertile oestrus. The exogenous hormone in effect tricks the pituitary control of reproductive function into behaving as if the animal is either pregnant or in a state of prolonged anoestrus. Treated females therefore do not exhibit normal breeding behaviour when steroidal hormones are used. Steroidal administration is essentially a hormone medication [Warren et al 1997].

3.2. Immunological agents providing reversible contraception

3.2.1. Porcine Zona Pellucida [PZP] vaccination.

The zona pellucida [ZP] is one of the layers surrounding the mammalian ovum after it is released from the ovary; it consists of a matrix of glycoprotein, with which the sperm must bind in the first stage of fertilisation [Dunbar, Kaul, Prasad et al 2002]. Females may be immunised against their own ZP proteins by administration of similar ZP proteins from other species, which are sufficiently foreign to stimulate an immune response, but sufficiently similar to result in circulating antibodies that attack the natural ZP proteins of treated female. Porcine ZP [PZP] has been found to be most efficient in many species and has been widely used because of availability. PZP may be natural [extracted from pig ova], genetically engineered or synthesised [Dunbar et al 2002].

The contraceptive effect of PZP vaccination is to block fertilisation by interfering with sperm binding to the ovum. Treated females will therefore continue to cycle and to exhibit reproductive and mating behaviour, but will fail to conceive [Fraker, Brown, Gaunt et al 2002; Shideler et al 2002; Muller et al 1997; Killian, Thain, Diehl et al 2007]. A second effect of the administration of ZP antigens is a direct effect upon the tissues of the ovary and reproductive tract by an unexplained mechanism; this effect varies greatly between species and may cause long term infertility [Dunbar et al 2002; Muller et al 1997]. Initial work with PZP vaccines in deer used two injections with a variable interval between the two to achieve contraception [Curtis et al 2002; Naugle et al 2002; Shideler et al 2002]. Recently single-injection commercial products have been marketed using PZP vaccination as their basis for contraception in a variety of species and they have been used successfully in some deer species [Fraker et al 2002; Fraker & Bechert 2007; Rutberg & Naugle 2007; Turner, Rutberg, Naugle et al 2007].

3.2.2. Sperm protein vaccination.

Anti-sperm antibodies may be produced by the administration of selected sperm proteins to both males and females. The effect in females is to cause dysfunction in several of the stages of sperm migration and fertilisation in the reproductive tract. In males there may be direct effects upon spermatogenesis and upon sperm survival in the vas deferens and epididymis [Muller et al 1997]. There has been little work on anti-sperm vaccines at field trial level in mammals, although Muller et al [1997] report that such vaccines have been researched in white-tailed deer.

3.2.3. Pituitary hormone analogues

The pituitary gland, situated below and in intimate contact with the mid brain, secretes a number of hormones that control the mammalian endocrine system. The pituitary is itself regulated by neuropeptides secreted by the hypothalamus in the brain. The axis between the hypothalamus, the pituitary and the gonad is fundamental in the regulation of reproductive function. One particular peptide, Gonadotrophin Releasing Hormone [GnRH], is a key regulator of the pituitary control of both testicular and ovarian activity. By vaccinating animals with a GnRH analogue, antibodies are produced to the endogenous GnRH and the pituitary control of reproduction is disrupted [Baker, Wild, Connor et al 2004; Curtis et al 2002; Muller et al 1997]. The hypothalamus-pituitary-gonad linkage is essential for normal reproductive function in both mammalian sexes and a disruption of this linkage will affect both males and females [Botha, Schulman et al 2007]. Various GnRH analogue vaccines have been produced, including long acting single-injection preparations and these have been shown to be effective in a variety of mammals, including some deer species [Baker et al 2002, Baker et al 2004, Baker, Wild, Hussain et al 2005, Curtis et al 2002, Naugle et al 2002]. Commercial long acting GnRH vaccines are in production and in the process of product licensing [Asa & Boutelle 2007, Fagerstone, Miller, Eismar et al 2007; Miller, Fagerstone & Killian 2007]. The predicted effect of GnRH vaccines on treated females is to suppress cycling by blocking the surges of luteinising hormone [LH] and follicular stimulating hormone [FSH] from the pituitary [Baker et al 2002].

3.3. Immuno-chemical sterilants providing permanent contraception

It is possible to combine toxic chemical molecules with antibodies so that specific cells, such as pituitary or ovarian cells are targeted and permanently ablated. These combinations rely upon the immunological specificity of the antibody and in theory present no risk to other species or other tissues. A combination of GnRH antibody and potent plant cytotoxin has been successfully experimentally tested in dogs, cats, sheep and deer [Nett & Webber 2007].

4] Effects and side effects of wildlife contraceptives

4.1. Environmental effects.

Steroidal contraceptives present significant risks of pollution and persistence in both the environment and the food chain. They are not easily digested or metabolised and continue to have effects in predators. [Harder & Peterle 1974; Warren et al 1997; White et al 1994]. For these and other reasons, little current attention is directed at steroids as contraceptive agents in wild animals, although they are successfully used in zoos and in limited situations where wildlife species are easily captured for treatment and are not subject to predation [Hyndes, Handasyde, Shaw et al 2007]

PZP molecules are proteins and GnRH molecules are smaller subunits of peptides. Both are conjugated with larger immunogenic proteins to produce the active vaccine and both are in turn mixed with adjuvants to prolong and increase the immunogenic effect. There is no persistence of the immunologically active components in the environment and no risk of onward transmission through the food chain as the antigens are destroyed by normal digestion. Once effectively delivered to the target animal, immunocontraceptives present no risk to the environment or to non target species. [Muller et al 1997; Miller et al 2007].

The single dose immunocontraceptive vaccines are provided with long term efficacy either by means of the incorporation of an adjuvant, or by manufacturing the antigen in a slow release polymer [Nettles 1997; Turner et al 2007]. Early commercial single dose vaccines used Freunds Complete Adjuvant [FCA], but this has now been replaced in both PZP and GnRH vaccines with a commercial alternative [Miller et al 2007]. Licensing authorities are reluctant to approve the use of FCA in commercial products because of cross reaction with the intra-dermal tuberculin test [Nettles 1997]. The current adjuvant is modified from a commercial Johnes disease mycobacterial vaccine [Fagerstone, Miller, Eisemann et al 2007] and may not be approved for use in the UK except under experimental conditions [Peters AR, personal communication].

4.2. Intended and desirable contraceptive effects.

Since the mid 1990s very effective contraception has been achieved in a wide range of wild and feral animal species using immunocontraceptive vaccines. Given two injections of first generation PZP vaccines, followed by annual boosters, the fertility of feral horses [Equs caballus] was reduced by 95% [Kirkpatrick 1995], of white-tail deer by 80% [Curtis et al 2002] and of Tule elk [Cervus elaphus] by 90% [Shideler et al 2002]. In all these examples, fertility returned to the majority of treated females when vaccination ceased, although the interval to return to breeding varied. In the same way first generation GnRH vaccines achieved very high contraception rates when given as two initial injections followed by annual boosters to white-tail deer, with favourable return to fertility later [Curtis 2002]. In these studies initial injections were administered by hand or by jab-stick when the animals were restrained. Free ranging white-tail deer were successfully contracepted by darting in an urban situation between 1993 and 1997, administering two initial dart doses and annual boosters. Treated females had a fawning rate of 31 fawns per 100 does after the first year, which decreased to 17.6 fawns per 100 does overall during the study. The normal fawning rate in untreated does was 85 fawns per 100 does [Naugle, Rutberg et al 2002].

The development of long-lasting, single-dose immunocontraceptive vaccines has made great progress since 2000. Fallow deer were successfully contracepted for more than three years by a single injection of long-acting PZP vaccine, with over 90% efficiency [Fraker, Brown et al 2002]. The fertility of white tail deer was reduced from 83% in untreated does to 11% after one single injection of an alternative PZP product, which only increased to 25% after two years, with no further injections [Turner, Rutberg, Naugle et al 2007]. Long acting GnRH vaccine has now been shown to provide contraception for prolonged periods given as a single dose to white-tail deer [Fagerstone, Miller, Gionfroddo et al 2007] and an alternative product has achieved almost complete contraception in Rocky Mountain elk for one full year after a single dose given either by injection or by dart [Baker et al 2004, 2005, Conner Baker et al 2007]. There is some evidence that GnRH vaccines are marginally more effective in young female deer and that PZP vaccines better in older animals [Curtis et al 2002], which accords with findings in domestic cattle and sheep [Brown et al 1994, Evans et al 1994].

Effective contraception by injection or by darting has significantly reduced or even eliminated population growth in wild free-ranging elephants [Loxodonta Africana], gray seals [Halichoerus grypus], white tail deer, Rocky Mountain elk, feral horses, lions [Panthera leo], cheetahs [Acinonyx jubatus], koalas [Phascolartos cinereus] and kangaroos [Macropus giganteus] [Fraker & Bechert 2007; Turner et al 2007; Herbert & Vogelnest 2007; Delsink, Kirkpatrick, van Altena et al 2007; Bertschinger, de Barros, Trigg et al 2007; Killian et al 2007; Conner et al 2007; Greenfield, Handasyke, Shaw et al 2007; Wilson, Coulson et al 2007]. Captive populations of many ungulate species have been effectively controlled by immunocontraception injection of females. These animals include black tail & mule deer [Odocoileus hemionus], sika deer, Reeves muntjac, wild boar [Sus scrofa], several antelope species, Javan banteng [Bos javanicus] , thar [Hemitragus hylocrius] and others, although the dose of antigen required, the interval of booster doses and the length of time to return to fertility has been very variable [Lamberski Frank Robin et al 2007, Asa 2007, Penfold, Jocle, Trigg et al 2007, Fraker & Bechert 2007]

4.3. Undesirable effects in the target females

Female deer contracepted with PZP vaccines continue to cycle and show normal reproductive behaviour. They are herded, attended and covered by fertile males in the normal way. This is predictable, as contraception effectively occurs at the stage of fertilisation; they do not therefore become pregnant or cease to show oestrus. The effect of this is to prolong the rut in white tail deer, fallow deer and Tule elk, although researchers have noted that mature bucks and bulls cease to rut and contraceptive females are attended by young males in the later part of the prolonged rutting period [Curtis et al 2002; Fraker et al 2002; Shideler et al 2002]. As the contracepted females repeatedly cycle, they receive more attention throughout the rut than untreated females and in some studies treated female deer were in poorer condition after the rut than the pregnant controls. Later in the annual cycle the contracepted females were in better condition than the does that had delivered fawns and lactated [Mc Shea et al 1997; Fraker et al 2002; Baker et al 2004].

In the case of GnRH analogue vaccines, the predicted suppression of breeding behaviour in treated female deer because of ovarian inactivity has not been found to occur. Using both short acting, double dose GnRH preparations and single dose long-acting products treated female deer have continued to show normal breeding behaviour during the rut. This is despite basal levels of LH and ovarian hormones, indicating no follicular development. It is believed that the behaviour is stimulated by very low background levels of oestrogen in the absence of progesterone [Baker et al 2002]. Treated females may actually show increased sexual activity as untreated females become pregnant in the course of the rut [Baker et al 2004]. There is conflicting evidence about whether GnRH vaccines prolong the breeding season in deer, an effect reported regularly with PZP vaccines [Gray & Cameron 2007; Powers Baker, Connor et al 2007]. With both PZP and GnRH vaccines given in the short acting form, treated females are effectively contracepted for one year and then may start rutting earlier the following year, although their fertility will be reduced. This may simply be a factor of them being in better condition because they have not been suckling a fawn [Mc Shea et al 1997; Curtis et al 2002].

Female deer immunised during pregnancy with both PZP and GnRH vaccines showed no alterations in gestation length, offspring health or offspring survival rates and no differences in general social behaviour has been observed [Powers et al 2007; Baker et al 2004; Curtis et al 2002]. Long term studies of contraception in stable social groups of deer have not been conducted, but the studies in feral horses indicated that longevity of mares contracepted for several years is significantly increased [Kirkpatrick 2002; Turner & Kirkpatrick 2002] giving rise to a completely new cohort of aged but healthy females. The same may be expected in deer [Cowan & Massei 2007] and will affect social group dynamics and the long term effects of the contraceptive programme. There is some concern that in long lived, strongly bonded species, such as the elephant the presence of some neonates, juveniles and sub-adults is essential for normal social structure. In these species 100% contraception may be undesirable [Delsink, Kirkpatrick, van Altena et al 2007]. Other authors have questioned whether breeding success, or being pregnant are determining factors in social status amongst females in a social group and whether contracepted females are condemned to perpetual low ranking. This seems to be the case in wolves, but has not been studied in deer [Davis & Pech 2002].

More pertinent to the possible application of immunocontraception to deer is the reported interspecies variability. Using both PZP and GnRH vaccines the doses, responses and required booster intervals were far from consistent. Reeves muntjac appear to require very frequent boosting of PZP vaccines in comparison with other deer and Sambar [Cervus unicolor] failed to respond at all and were not contracepted [Lamberski et al 2007; Asa & Boutelle 2007, Penfold et al 2007]

Specific pathology is reported in a few deer treated with long term single dose immunocontraceptives, including local abscessation at the site of the injection and ovarian pathology. It is thought that the adjuvant incorporated into the vaccine is principally responsible; these reactions occur at very low levels [Dunbar et al 2002, Naugle et al 2002, Powers et al 2007].

<u>4.4. Effects in males of the target species</u>

As GnRH is essential to both male and female reproductive function, it is likely that administration of GnRH analogue vaccines to males will have significant effects. Administered to pre-pubertal white tail deer, these vaccines delay puberty considerably, although the treated bucks proceed to achieve normal testosterone levels and normal antler growth by the age of three years [Miller, Fagerstone, Rhyan et al 2007]. A commercial GnRH vaccine is licensed and on sale in Continental Europe specifically to delay puberty in male fattening pigs, which are effectively chemically castrated up to killing age to prevent boar-taint of the meat. This commercial vaccine has been used successfully to control breeding in free ranging mares [Botha et al 2007]. In captive collections of zoo animals, GnRH vaccine has been successful in reducing aggressive behaviour in males, by means of the suppression of testicular activity [Asa & Boutelle 2007]. Interestingly, in some bovid species the effect is to abolish aggression but increase bodily condition and paradoxically slowly to increase basal testosterone, testis size and sperm count [Penfold et al 2007]. Given to adult male deer, GnRH vaccines interfere with seasonal hormonal cycles, affecting rutting, antler growth and antler shedding [Fraker MA, personal communication].

4.5. Population effects

Immunocontraception is effective in reducing fertility in deer to a considerable extent, but a reduction in fertility may not reduce population [Davis & Pech 2002, Kirkpatrick & Turner 2007]. There have been few studies of long term contraception in populations of deer. One notable project shows that population decrease is possible over a twelve year period with very intensive effort including annual vaccination by dart of as many females as possible and with other management changes such as the prohibition of artificial feeding [Rutberg & Naugle 2007]. In this project white tail deer in a suburban environment on an island were contracepted between 1993 and 2005. For the first five years of the study populations continued to increase by 11% per year and then decreased by 16% annually as the effect of the contraception and management changes took effect. The authors of the report describe this as a modest reduction of population in a suburban environment, where deer movements are limited by environmental or behavioural considerations. In another island situation with fallow deer, treated does were rendered infertile by immunocontraception, but the reduction of population continued to be by means of shooting [Fraker et al 2002]. In both studies the treated deer were either marked or individually identified to prevent repeat dosing of the same females.

Theoretical models have been devised to predict the effects of wildlife contraception. Factors that need to be incorporated in the models include the natural longevity of the species, the rate of predation, the recruitment rate by breeding and the effect of contraception upon female survival. These models seem to show that deer are relatively poor candidates for population reduction by means of contraception: "*Contraceptives may be effective in reducing populations of short lived species with a high natural mortality…. in long lived species with low mortality the best anyone can expect is short term zero population growth with a very intense effort over a very long time necessary to achieve reductions"* [Kirkpatrick 2002].

A long term study of feral horses on Assateague Island USA over a 13 year period achieved zero population growth in two years by means of PZP vaccines given annually to each mare. It took a further 8 years to achieve a decline in population from 175 animals to 150 and a further 3 years to reduce the numbers to 135. Each mare was individually identified and immunised annually. The slow decline in population was caused by increasing condition in the mares, reduced mortality and significantly increased longevity [Kirkpatrick & Turner 2007; Turner & Kirkpatrick 2002].

The possibility of selection against immunocompetency within populations has been raised. If the healthiest and most immunologically active individuals respond best to immunocontraception, and if these individuals also have the best capacity to mount resistance to infection and disease, might immunocontraception select against these animals and eliminate their genes from the population over time? Might the weak, unhealthy individuals that fail to respond to the immunocontraception be selected as the breeding stock? [Nettles 1997; Muller et al 1997]. Current workers believe that there is no evidence of this [Kirkpatrick JF, personal communication], but there has been no study of sufficient length or breath to answer the question.

5] Delivery systems

5.1. By injection or by dart

All the current and recent effective immunocontraception in deer has been delivered to individual animals by means of injections or darts. Almost all the published studies that demonstrate efficacy in deer report that the PZP or GnRH vaccines were administered by injection by hand to deer confined in races or crushes, herded into buildings, netted from helicopters or darted from very close range [Baker et al 2002, 2004, 2005; Curtis et al 2002; Fraker et al 2002; McShea et al 1994, 1997; Powers et al 2007; Shideler et al 2002]. Even in the few studies of immunocontraception in freely ranging deer populations, the deer were either caught for their initial injections [Fraker et al 2002; Shideler et al 2002], were lured to within close range of hides at feeding stations for darting at ranges of 5-25 metres [Naugle et al 2002; Rutberg & Naugle 2007] or were darted at close range from behind stalking horses [Shideler 2002]. No author reports administering a dart to deer at a range greater 35 metres by daylight or 45 metres at night with a lamp and these distances were only reported in the case of deer confined within a boundary fence [Curtis et al 2002]. Horses may be darted up to 50 metres [Turner & Kirkpatrick 2002]

Contraceptive injections appear to have a greater efficiency and to reduce the fertility rate more if they are administered by hand rather than by dart [Thiele 1999 cited by Naugle et al 2002; Shideler et al 2002; Turner et al 2002. This may be because of the failure rate of darts to deliver the full dose: one third of the darts administered by Baker et al [2005] to sedated Rocky Mountain elk at close range failed to deliver fully. Systems to inject depot combinations of long acting contraceptives by dart are currently not 100% reliable [Turner et al 2007].

5.2. Oral bait

Contraception by bait has been achieved in birds, marsupials and rodents, although the active agents currently used are not immunologically mediated [Lapidge & Humphries 2007; Mayle 2007]. Bait delivered contraception is controversial, since species specificity is difficult to achieve and there is inevitable environmental contamination [Grandy & Rutberg 2002; Gynn 1997]

There are no reports of oral delivery systems to achieve contraception in deer.

5.3. Vector delivered vaccines.

A great deal of research effort and funding has been directed towards the possible development of viral vectored vaccines for control of rodent pests in Australia. The objective was to conjugate the vaccine to an infectious agent such as a non pathogenic virus so that the spread of the virus also spread the vaccine. [Singleton, Farroway, Chambers et al 2002; Williams 2002]. This work has now been terminated after much opposition and limited success [Grandy & Rutberg 2002; Hinds, Hardy & Peacock 2007].

Research is continuing into the possible use of a nematode parasite as a vector for immunocontraception in the bushtail possum in New Zealand [Cowan, Grant et al 2007]

There are no reports of vectored contraceptive systems for deer.

6] Costs

The delivery of immunocontraceptive doses to deer is expensive in terms of time and money. In a study of free ranging Tule elk Shideler et al [2002] estimated that the contraception of 43 female elk took more than 20 workers 25 days to achieve and cost some $300 per animal in 2002. Two years earlier, Walter [quoted by Naugle et al 2002] estimated that the contraception of suburban white tail deer cost $220 per doe darted and more than $1000 per doe if capture was necessary for injection. The price of contraceptive agents has reduced in recent years and single dose formulations reduce the need for repeated darting, but costs are still considerable in terms of man-power, time budgets and finance [Miller et al 2007].

7] Future developments under discussion

A promising possible development in wildlife contraception appears to be in the field of "ghost cell" technology, by which vaccines may be delivered orally by "hiding" the vaccine within the cell wall or envelope of dead bacterial cells [Miller et al 2007; Duckworth et al 2007]. This will enable the peptide antigens to be absorbed without digestion by the target animal. The problems of target animal specificity remain and although workers are developing promising species specific systems, for example for wild boar [Massei, Coats & Quy 2007] or for grey squirrels [Mayle 2007], the problem remains that in the case of deer it is inadvisable to vaccinate males with GnRH vaccines [Fraker MJ, personal communication] for reasons given at 4.4 above.

For remote injection the possibility of "bio-bullets" has been considered to increase the distances at which deer may be immunised [Turner et al 2007]. This line of research has made little progress, since projectile and terminal ballistics are extremely complicated. Animals will inevitably be wounded by the impact and penetration of the bullets, in contrast to darts, which penetrate by fine needle, deliver and then fall out.

Summary – Can contraception control deer populations in the UK?

In the light of current knowledge and with a view to imminent developments, the following conclusions may safely be drawn:

- Immuno contraception is very effective in deer. Both PZP and GnRH analogues reduce or abolish fertility in female deer with few side effects upon the treated animals.
- Long term infertility may be achieved with a single dose given to female deer. Even if given during pregnancy there is no effect upon the offspring and the treated females are likely to remain barren for up to five years.
- Studies to date appear to show few adverse effects upon social behaviour in gregarious deer species.
- Contraception will probably increase the longevity of vaccinated deer.
- There are species variations that may affect response in the different species of deer present in the UK.
- Because they are long-lived and suffer low predation/mortality rates deer are considered to be poor candidates for contraceptive control of whole populations.
- Where deer numbers are considered to be too high, contraception will not reduce numbers in the absence of other means of removal until older females die naturally, which may take many years.
- It will be necessary to contracept the majority of females in a given population over a period of 5-10 years before a reduction in the population will be achieved and even then any reductions will only be modest.
- Efficient contraception requires the identification of individual female deer in a given population from year to year.
- Delivery has to be by injection, which may be delivered by hand from a syringe or by dart.
- Current dart systems are not able to deliver at distances at which wild deer can normally be approached in the UK.
- Current dart systems are subject to a significant rate of failure to deliver.
- Immunocontraception by darting or by injection may have a place in *limiting population growth* in enclosed or captive deer herds.

- The possible future developments of “bio-bullets” may have a place in deer contraception, but no such system is close to production and would still require the long term identification of individual deer.
- The possible future delivery of contraception by oral bait is unlikely to applicable to deer because of the adverse effects upon males. It is considered to be almost impossible to devise an oral bait delivery system that is specific to deer and specific to female deer.
- For wild deer populations “Contraception is not a substitute for hunting” [Fagerstone, Miller, Gionfriddo et al 2007].

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