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Effect of the GnRH vaccine GonaCon on the fertility, physiology and behaviour of wild boar

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Abstract. Fertility control has the potential to be used as an attractive alternative to lethal methods for limiting population growth in overabundant species. This study tested the effectiveness and potential side effects of the single-dose gonadotrophin-releasing hormone (GnRH) vaccine GonaCon on the physiology and behaviour of two groups of captive female wild boar in two sequential trials (Trial 1 and Trial 2). Following vaccination with GonaCon, data on contraceptive effectiveness were recorded as well as data on time budget, social rank, bodyweight, haematology and biochemistry. The concentration of GnRH-antibody titres peaked 2–6 weeks after vaccination and remained relatively high 12 weeks after vaccination. In Trial 1, all control females and none of the treated females gave birth. In Trial 2, faecal progesterone of treated females decreased to basal levels within a month of vaccination. No differences in time budget, social rank and blood parameters were observed between treated and control females. Bodyweight increased more in treated females than in controls. These results indicated that GonaCon can suppress reproduction of wild boar with no significant short-term effects on behaviour and physiology. GonaCon can be regarded as an effective, humane and safe contraceptive for managing wild boar populations.

Introduction

The effective, humane control of overabundant populations of mammals is one of the most debated issues in wildlife management. New restrictions on the use of toxicants, together with growing public antipathy towards lethal control, place increasing constraints on management options (Lurz *et al*. 2002; Fagerstone *et al*. 2002; Grandy and Rutberg 2002). Fertility control has been suggested as a viable and publicly acceptable method to reduce the size and growth of wildlife populations (e.g. Barlow 2000; Merrill *et al*. 2006; Herbert *et al*. 2006; Ramsey 2007). In particular, recently formulated immunocontraceptive vaccines offer great promise for the potential control of overabundant populations and diseases (e.g. Miller *et al*. 2004*a*; Jewgenow *et al*. 2006). Immunocontraception is achieved by exposing an animal to a foreign substance (antigen) that stimulates the animal's immune system to produce antibodies. The design of these vaccines mimics the outer structure of many pathogens that stimulate the production and release of antibodies that in turn neutralise proteins or hormones essential for reproduction (Miller *et al*. 2000; Delves *et al*. 2002). Once exposed to the vaccine, an animal will usually retain a complement of antibodies to ward off future exposures.

Early immunocontraceptive vaccines were delivered as a primer shot followed by a booster injection and had limited practical applications in wildlife management (Curtis *et al*. 2002). Recently developed immunocontraceptive vaccines can be delivered as a single injectable dose and induce infertility for several years thus making field applications more practicable (Miller *et al*. 1999; Miller *et al*. 2004*a*). Gonadotrophin-releasing hormone (GnRH) vaccines interfere with the function of the GnRH that regulates the reproductive hormones (Miller *et al*. 2003; Killian *et al*. 2006). In females, the suppression of the GnRH stops ovulation and the oestrous cycle, and reduces the production of oestrogen and progesterone from the ovaries. In males the suppression of the GnRH reduces the production of testosterone and the size of the testes. GnRH vaccines have been successful in reducing fertility in most mammals (e.g. Curtis *et al*. 2002; Miller *et al*. 2003, 2004*b*; Nash *et al*. 2004; Levy *et al*. 2004). However, many of these studies have not investigated in detail the potential side effects of these vaccines on the physiology and behaviour of treated animals. Potential side effects of immunocontraceptives include an increase in bodyweight and in time spent feeding, changes in social rank, aggressiveness, spatial and social behaviour, as well as changes in biochemical and haematological values (e.g. Dunshea *et al*. 2001; Cronin *et al*. 2003; Jacob *et al*. 2004; Killian *et al*. 2006; Ramsey 2007). If fertility control is used in wildlife management, the potential side effects of each contraceptive should be investigated and weighed against the benefits derived from the use of that particular fertility-control agent.

The present study aimed at investigating the effectiveness and potential side effects of a GnRH vaccine, GonaCon, on wild boar (*Sus scrofa*). GonaCon is a single-dose, injectable GnRH vaccine that contains a new adjuvant (i.e. a compound that improves the immune response, causing higher levels of antibodies) called AdjuVac™. As GnRH-specific antibody titres have been shown to peak ~12 weeks after vaccination with GonaCon (Killian *et al*. 2006), short-term potential side effects of this vaccine should be investigated within this period. The reproductive physiology of female wild boar is characterised by a series of oestrus cycles between late autumn and spring, followed by a summer anoestrus

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period (Mauget 1982). The concentration of the steroid hormone progesterone is relatively high during the luteal phase that follows ovulation and low during the follicular phase that precedes ovulation and during anoestrus.

Wild boar was used as a model species because of its worldwide distribution, high reproductive rate and impact on human interests. Eurasian wild boar have been introduced in North and South America (Barrett 1978) and occur in Australia and New Zealand as feral pigs (Choquenot *et al*. 1996). In the USA feral pigs currently occur in 26 states and their range is still expanding (Engeman *et al*. 2003). This species has a higher reproductive potential than most large mammals and can adapt to a wide range of environmental conditions (Hone 1995; Massei *et al*. 1996, 1997). This results in very high local densities with negative impact on rural and conservation interests (Singer *et al*. 1984; Engeman *et al*. 2003; Massei and Genov 2004). Although wild boar and feral pigs can be controlled through hunting, it is essential to evaluate different options to manage overabundant populations particularly in urban and/or protected areas where culling is unfeasible or undesirable.

The aims of this study were: (1) to establish the effectiveness of a single dose of GonaCon to induce infertility in captive wild boar, and (2) to assess the potential side effects of GonaCon on the physiology and behaviour of individual wild boar.

Methods

Study animals and plan of work

The study was carried out at the Central Science Laboratory's Animal Unit in two sequential trials. In Trial 1 wild boar females ($n = 12$) were obtained from a local farm in April 2004 and housed in three interconnected outdoor paddocks (each 77 × 24 m). All the boar were 2 years old and had already given birth to at least one litter. Animals were fed on commercial pig diet (Pigbreed Classic Nut Diet, BOCM Pauls Ltd, Selby, Yorks.) and offered *ad libitum* water. Six weeks after arrival all females were equipped with coloured ear-tags for individual identification. Six females were unexpectedly found to be pregnant and births occurred in early July. All the piglets were removed by a veterinarian within 3 days of birth. On 17 August 2004 females were randomly assigned to Treatment group ($n = 6$) and injected with 1000 μg of GonaCon, or to Control group ($n = 6$) and injected with the adjuvant only. Each group comprised 3 previously pregnant and 3 non-pregnant females. Two adult males were introduced in the paddocks on 18 November 2004. Data on physiology and behaviour (listed below) were collected during the prevaccination (July–August 2004) and postvaccination (August–November 2004) periods.

Trial 2 was designed to replicate Trial 1 and to monitor the effects of GonaCon on the reproductive cycle of wild boar. In Trial 2, 18-month-old wild boar females ($n = 12$) of proven fertility were obtained in October 2005. On 26 April 2006 females were randomly assigned to Treatment group ($n = 6$) and injected with the 1000 μg of GonaCon, or to Control group ($n = 6$) and injected with a saline solution. Data on physiology and behaviour were collected during the prevaccination (November 2004 – April 2005) and postvaccination (May 2005–August 2005) periods.

Effectiveness of the GnRH vaccine to induce infertility

The effectiveness of the vaccine to induce infertility was determined by collecting the following data: (1) immune response to the vaccine, assessed by measuring serum antibodies to the GnRH vaccine; (2) concentration of faecal progesterone, used as an indicator of cycling, pregnancy and maintenance of pregnancy; and/or (3) reproductive output.

In Trials 1 and 2 blood samples were collected at vaccination and 6 and 12 weeks after vaccination. In Trial 2 serum samples were also collected 2 weeks after vaccination. The concentration of GnRH-antibody titres in serum was measured as in Levy *et al*. (2004). All data analyses were carried out in GENSTAT 9.2 (Payne 2003).

As the design was unbalanced (due to the extra collection of data in Trial 2) data were analysed through regression and the results presented as an accumulated analysis of variance to test for differences in concentration of GnRH-antibody titres at different time points.

Faecal samples were collected in Trial 2 from each boar immediately after defaecation once or twice every fortnight from April till October 2006. Samples were dried at 40°C immediately after collection, finely ground, extracted in duplicate with 80% methanol, and then assayed with commercially available, fully validated enzyme-linked immunosorbent assay (ELISA) kits for progesterone (Immunodiagnostic systems Ltd). The lowest detectable level of progesterone was 0.045 ng mL^{-1} at the 95% confidence limit. Cross-reactivity of other hormones with the assay were the following: 17α OH progesterone (0.3%), oestriol (<0.1%) and oestradiol 17β (<0.1%). Results were obtained using a plate-reader (Dynex and Labsystems Multiscan Ascent) with a 450-nm filter and plate-reader software (Revelation 3.0 and Ascent).

A REML (Residual maximum likelihood) analysis was used to test the effects of time (date), treatment and time × treatment on the $\log_{10}$-transformed concentration of progesterone. As the sampling dates were not equally spaced and collection dates were not the same for all animals (due to the difficulty of collecting samples regularly from all the females) the REML analysis used a power model.

Effects of the GnRH vaccine on behaviour and physiology

The potential effects of the GnRH vaccine on the behaviour of the wild boar were assessed by collecting data during 3-h observation sessions carried out once or twice every fortnight. Each session started at 0800–0830 hours, just after the animals had been fed. A pilot test indicated that observations carried out in the afternoon resulted in similar behavioural patterns. During a session, the behaviour of each animal was recorded every 10 min and attributed to one of the following activities: feeding, walking, standing, sleeping/lying, wallowing, and 'other' (carrying sticks, defaecating/urinating, sexual behaviour such as mounting or sniffing of genitals). During each session all agonistic interactions were also recorded and the identity of the animal initiating or receiving an agonistic interaction noted. Agonistic interactions were defined both as fights, which involved physical contacts between animals, and 'displacement', in which one boar walked straight towards another, causing the latter to move away. In each trial, data from these sessions were allocated to pre- and postvaccination periods.

A Principal Component Analysis (PCA) was used to summarise the time spent in different activities for treated and control animals during the pre- and postvaccination periods. The scores of individual wild boar on the first principal component (PC) were used in a repeated-measures REML using Wald statistics and assuming uniform correlation structure over time. For all the analyses, observation dates were aligned at vaccination day in the two trials. For each dataset, a REML analysis was carried out to test for the effect of trial, treatment (treated versus control) and vaccination period (before and after vaccination). By looking at the effect of interaction between vaccination period and treatment the REML investigated whether the effect of treatment was genuine or was due to differences in time only.

The same REML analysis was used on the proportion of time animals spent being active and on social ranks. The social rank of each animal was obtained by the Barrette and Vandal (1986) index:

$$\text{Rank} = (\text{number of AI initiated} + 1)/(\text{number of AI received} + 1)$$

where AI = agonistic interaction. On each date, social ranks ranged from 1 to 12 (12 indicating highest rank) and these ranks were used for the analyses.

Data on bodyweight, haematology and serum biochemistry, collected at vaccination and 6 and 12 weeks after vaccination, were used to determine whether GonaCon affected the physiology of wild boar. Differences in bodyweight between groups were analysed by an Analysis of Covariance (ANCOVA). Data were $\log_{10}$-transformed and the initial weight, recorded at vaccination, was used as covariate.

From the serum samples collected at vaccination and 6 and 12 weeks after vaccination the following biochemical parameters were recorded: α-, β- and γ-globulins, ionised calcium, albumin, urea, creatinine, alkaline phosphatase (ALP), aspartate aminotransferase (AST), γ-glutamyl transferase, sodium, potassium, calcium, bile acids and inorganic phosphate. The following haematological parameters were recorded: haemoglobin, packed cell volume (PCV), red blood cell count, white blood cell count, mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, neutrophils and lymphocytes.

Data from the biochemistry and haematology from the three collection dates (vaccination, 6 and 12 weeks after vaccination) were summarised by a PCA. The effects of trial, time, treatment, and their interaction on the first Principal Component scores were tested by a Split-Plot (repeated-measures) analysis. As the first principal component did not explain much of the variation, Split-Plot ANOVAs were also used to test for the effects of trial, time (vaccination, 6 and 12 weeks after vaccination), treatment and their interactions on individual biochemical and haematological variables. The study was carried out under a UK Home Office licence, in accordance with the *Animals (Scientific Procedures) Act 1986*.

Results

Effectiveness of GonaCon to induce infertility

The analysis of the immune response to GonaCon in Trial 1 showed that 6 weeks after vaccination all the treated wild boar had developed anti-GnRH titres (Fig. 1). The concentration of antibody titres differed between trials ($F_{1,25} = 32.71$, $P < 0.001$) and with time ($F_{2,25} = 3.92$, $P = 0.03$). Results from Trial 2 also showed that anti-GnRH antibody titres occurred 2 weeks after vaccination (Fig. 1).

In March–April 2005 all six control females in Trial 1 produced litters of 7–9 piglets each. None of the six treated females gave birth. In Trial 2 progesterone levels changed with time ($\chi^2 = 83.83$, d.f. = 10, $P < 0.001$), treatment ($\chi^2 = 5.26$, d.f. = 1, $P = 0.02$) and time × treatment ($\chi^2 = 45.83$, d.f. = 10, $P < 0.001$) (Fig. 2), indicating that vaccination with GonaCon affected progesterone levels. The patterns of progesterone concentration showed that control females were cycling before and after vaccination until the summer anestrus occurred. Progesterone in treated females showed similar patterns to that of control females but appeared to be suppressed within a month of vaccination with GonaCon (Fig. 2).

Effects of GonaCon on behaviour and physiology

In both trials, no limping, hunched posture or any other behavioural sign of distress were observed in both treated and control wild boar following treatment with the vaccine or with the adjuvant.

The first Principal Component summarising the time budget of treated and control females, explained 75.25% of the variability and contrasted 'eating' with 'sleeping'. The second Principal Component, explaining 17.80% of the variability, contrasted 'eating' with 'standing' and 'walking'. Time budget was influenced by vaccination period ($\chi^2 = 28.97$, d.f. = 1, $P < 0.001$) and by trial ($\chi^2 = 43.30$, d.f. = 1, $P < 0.001$) but was not affected by treatment ($\chi^2 = 0.29$, d.f. = 1, $P = 0.59$) and by treatment × vaccination period ($\chi^2 = 0.02$, d.f. = 1, $P = 0.87$). This confirmed that the differences in behaviour of the two groups before and after vaccination were due to a time effect rather than to an effect of treatment with the vaccine.

For both treated and control females differences in behaviour over time, as indicated by the first PC, were mainly due to a

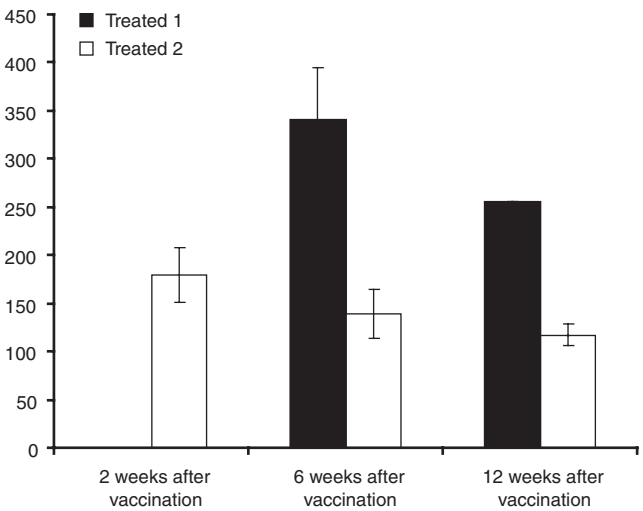

Fig. 1. Mean gonadotrophin-releasing hormone (GnRH) antibody titres (±s.e.) of female wild boar treated with GonaCon in Trial 1 (Treated 1, $n = 6$) and Trial 2 (Treated 2, $n = 6$).

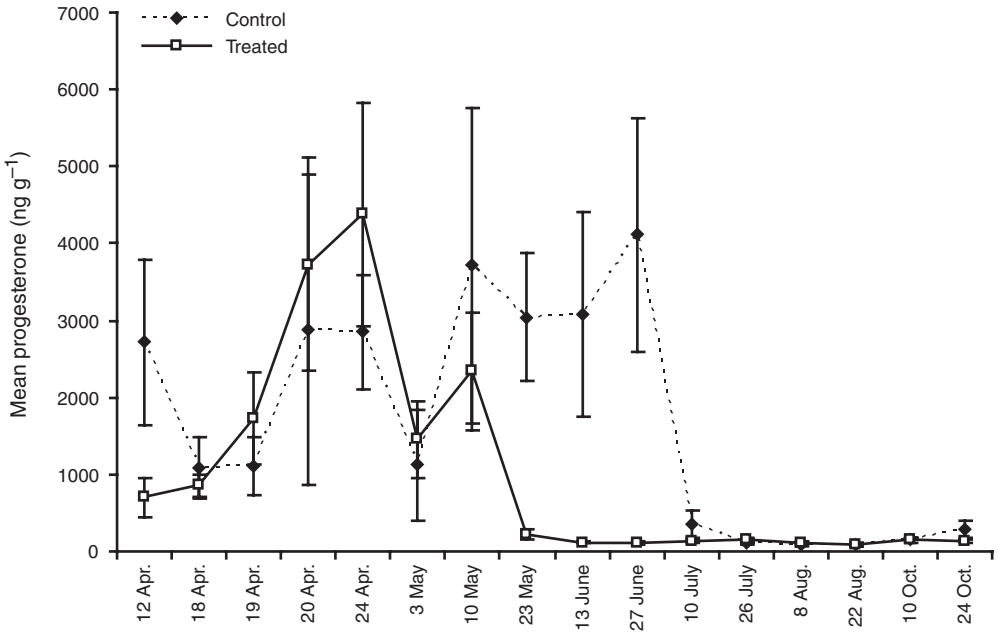

Fig. 2. Mean faecal progesterone concentration (±s.e.) in wild boar females treated with GonaCon and in control females in Trial 2. Vaccination with GonaCon was conducted on 26 April 2006. Regular increase and decrease in progesterone indicates that females are cycling before entering the summer anoestrus.

change in eating and sleeping patterns. In Trial 1, both groups spent progressively more time eating and less time sleeping as autumn approached (Fig. 3). In Trial 2, both groups spent progressively less time eating and more time sleeping as summer approached. Accordingly, the proportion of time spent active differed with trial ($\chi^2 = 21.79$, d.f. = 1, $P < 0.001$) and vaccination period ($\chi^2 = 21.85$, d.f. = 1, $P < 0.001$) but was not affected by treatment ($\chi^2 = 0.95$, d.f. = 1, $P = 0.33$) and by treatment × vaccination period ($\chi^2 = 0.01$, d.f. = 1, $P = 0.91$).

Social ranks varied with treatment ($\chi^2 = 11.29$, d.f. = 1, $P < 0.001$) and treatment × trial ($\chi^2 = 5.37$, d.f. = 1, $P = 0.02$) but not with trial ($\chi^2 = 0.57$, d.f. = 1, $P = 0.45$), vaccination

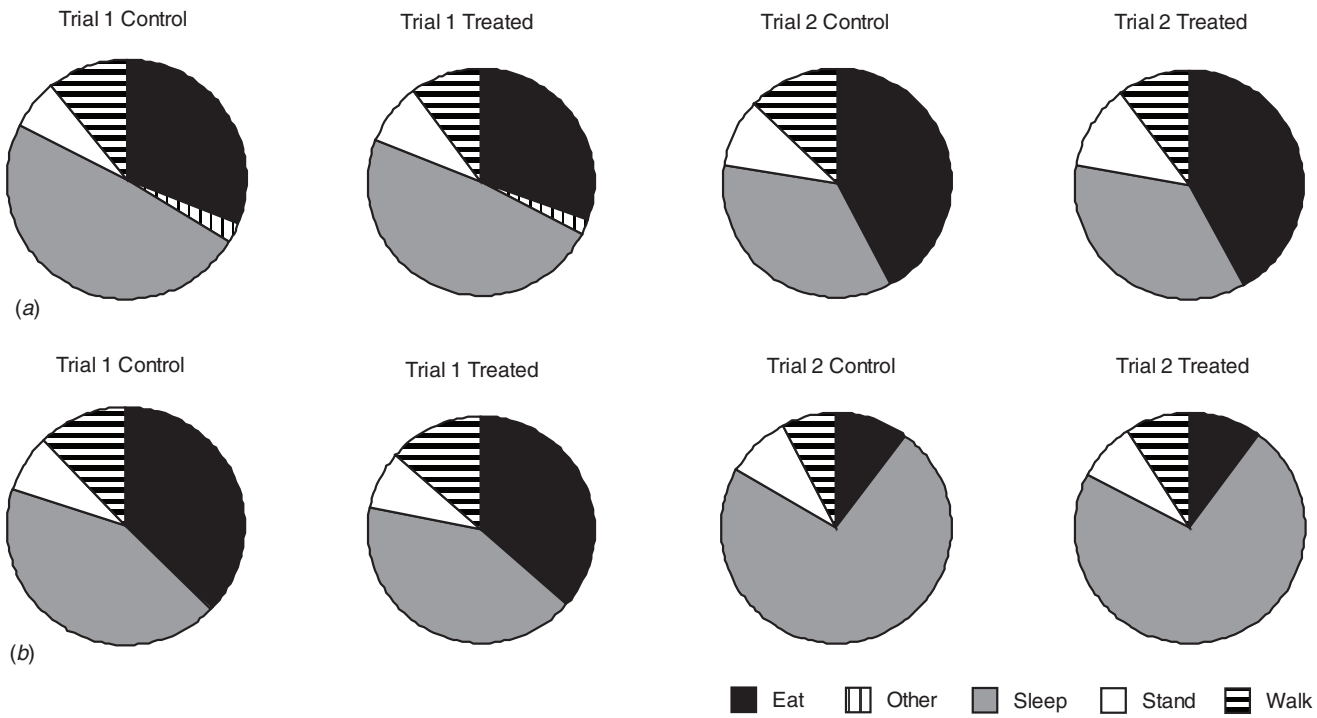

Fig. 3. Time spent in different activities by four groups of wild boar females ($n = 6$ per group) (*a*) before and (*b*) after treatment with GonaCon. In Trial 1 prevaccination was in July–August 2004 and postvaccination in August–November 2004; in Trial 2 prevaccination was in November 2005–March 2006 and postvaccination was in April–August 2006.

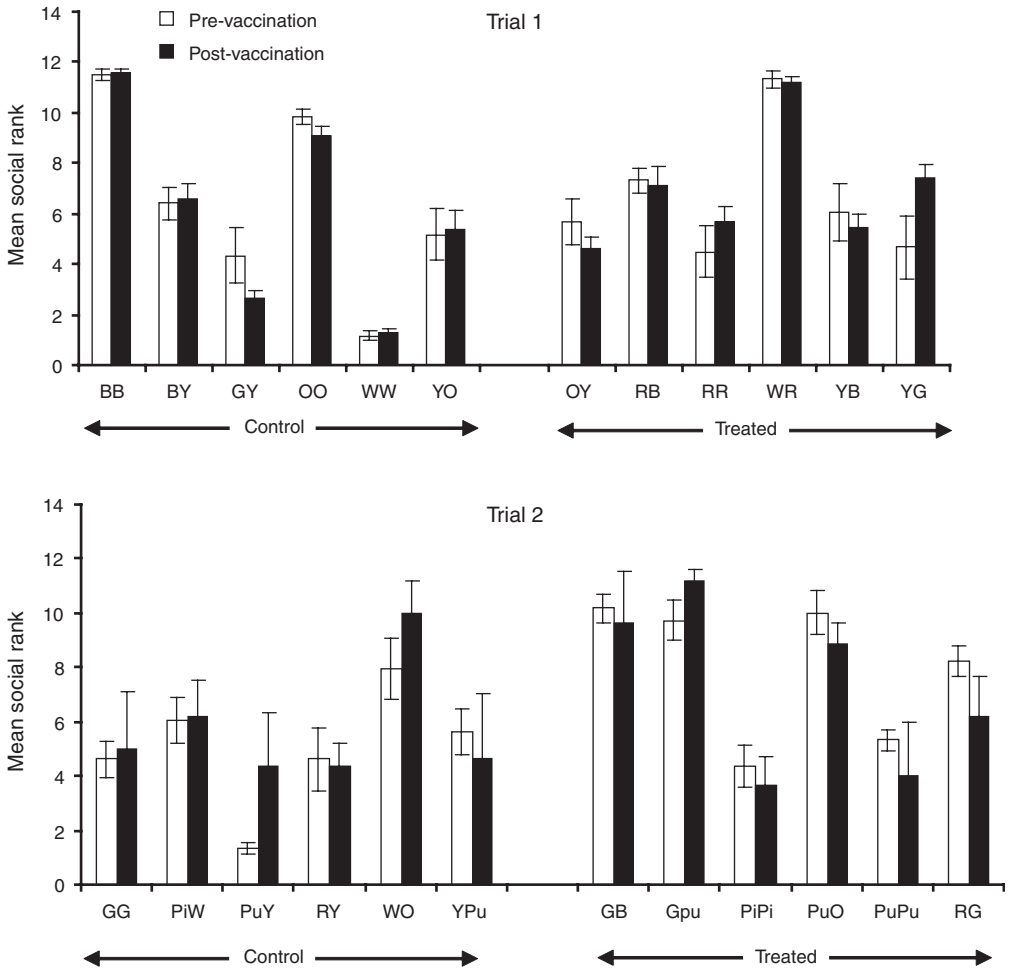

Fig. 4. Mean social rank (±s.e.) of individual wild boar females in Trial 1 and Trial 2 before and after treatment with GonaCon. Codes under each column refer to the identity code of each female. Highest rank is 12.

period ($\chi^2 = 0.11$, d.f. = 1, $P = 0.74$), or treatment × vaccination period ($\chi^2 = 0.26$, d.f. = 1, $P = 0.61$). This indicated that, overall, animals in treated groups had higher ranks than controls but that vaccination had no effect on social rank as control and treated wild boar maintained their rank throughout the trials (Fig. 4).

Bodyweight increased with time in both groups. Twelve weeks after vaccination the bodyweight of treated wild boar in both trials (mean weight in Trial 1 = 119.3 ± 22.2 (s.d.), mean weight in Trial 2 = 91.4 ± 11.0) had increased more that that of controls (mean weight in Trial 1 = 115.5 ± 8.8, mean weight in Trial 2 = 86.4 ± 19.9) (ANCOVA: $F_{1,20} = 8.30$, $P < 0.009$).

The PCA on the biochemical variables showed that the first PC explained 32.30% and the second PC 15.13% of the variation. The factors that contributed most to the first PC were α-, β- and γ-globulins, ALP, bile acids and inorganic phosphate. Overall, the biochemical values were affected by time ($F_{2,37} = 48.99$, $P < 0.001$), trial ($F_{1,20} = 575.80$, $P < 0.001$), time × trial ($F_{2,37} = 12.69$, $P < 0.001$) and time × treatment ($F_{2,37} = 3.85$, $P = 0.03$), but not by treatment ($F_{1,20} = 0.02$, $P = 0.88$).

Most individual biochemical variables were affected by time but not by treatment or by time × treatment interaction. Bile acids and sodium were the only parameters affected by time × treatment interaction. Six weeks after vaccination, bile acids decreased in treated females (average = 20.9 ± 15.1 (s.d.) μmol L^{-1}) but remained stable in controls (average = 34.2 ± 13.6 μmol L^{-1}) and sodium remained stable in treated females (average = 138.4 ± 12.1 mmol L^{-1}) but decreased in controls (average = 134.9 ± 10.1 mmol L^{-1}).

The PCA on the haematological variables showed that the first PC explained 30.37% and the second PC 22.32% of the variation. The factors that contributed most to the first PC were haemoglobin, PCV, red blood cells and neutrophylls. The haematological values were not affected by time ($F_{2,39} = 2.13$, $P = 0.13$), trial ($F_{1,20} = 3.06$, $P = 0.09$) or treatment ($F_{1,20} = 0.05$, $P = 0.83$) but were affected by time × trial ($F_{2,39} = 6.31$, $P = 0.004$) and time × treatment interaction ($F_{2,39} = 0.09$, $P = 0.91$). Some haematological variables were affected by time and none was affected by treatment or time × treatment interaction.

Discussion

This study indicated that the GnRH vaccine GonaCon has potential as an effective, humane contraceptive for controlling fertility in wild boar. The results suggested that the only effect of GonaCon is to maintain treated animals in anoestrus, without any other significant effect (besides a modest increase in bodyweight) on their physiology and behaviour in the three months following vaccination.

The response of anti-GnRH titres found in this study was similar to that found in feral pigs (Miller *et al*. 2003; Killian *et al*. 2006). When tested in deer, coyotes, feral pigs, wild horses and bison, GonaCon induced similar levels of GnRH antibody titres and caused infertility for 1–4 years (Miller *et al*. 2000; Curtis *et al*. 2002; Killian *et al*. 2006; Perry *et al*. 2006). In addition, preliminary results (in preparation) on data collected on the wild boar in this study indicated that the vaccine is effective for several years.

Although in the present study the concentration of antibody titres showed a significant drop with time, differences between trials were much greater than difference due to time from vaccination. This could indicate that treating females in different parts of the year, i.e. during summer anoestrus (Trial 1) or in early spring (Trial 2) when all the females were reproductively active and cycling, might affect the response of the immune system to the vaccine. If this hypothesis was confirmed in future studies, this might indicate that using GonaCon in specific periods of the year might enhance the immune response to the vaccine.

Wild boar are seasonally polyoestrous throughout most of the year with the exception of summer and early autumn when animals enter a period of anoestrous (Henry 1968; Mauget 1982). Within each oestrus, a 5-day follicular phase, characterised by low progesterone levels and culminating with ovulation, is followed by a 16-day luteal phase during which the *corpus luteum* produces progesterone. The faecal progesterone levels observed in this study (Trial 2) indicated that all animals were ovulating before treatment and had a period of anoestrus in summer. In treated females, progesterone levels showed that GonaCon became effective within one month from vaccination. Thereafter, progesterone levels were consistently maintained low but detectable. Similarly, mares (*Equus caballus*) treated with a GnRH vaccine showed one oestrus before ovarian activity ceased within 2–4 weeks of vaccination (Tshewang *et al*. 1997; Dalin *et al*. 2002). A reduction of progesterone and other steroid hormones (e.g. luteinising hormone and oestradiol) to basal levels was also found in bison (*Bison bison*) treated with GonaCon (Miller *et al*. 2004*b*) and in mares treated with a GnRH vaccine (Dalin *et al*. 2002; Elhay *et al*. 2007). This suggested that treatment with GonaCon suppressed, but did not completely block, the production of these hormones. The fact that steroid hormones may still be available to the body after treatment with the GnRH vaccine has positive implications for the welfare of theses animals, since lack of these important hormones can have potentially wide-ranging effects on animal health.

Throughout the course of this study, no differences in time budget were observed during the pre- and postvaccination periods between treated and control females, indicating that, at least up to 12–14 weeks after treatment, GonaCon did not affect the behaviour of wild boar. The time spent in different activities by treated and control females changed significantly throughout the year as the animals spent progressively more time feeding and less time sleeping in autumn and winter than in other months. One limitation of these data is that 24-h sessions of behavioural observations would have provided a complete and potentially more accurate representation of time budget. The difficulty of identifying individual animals at night prevented collection of data in 24-h sessions. However, in both trials and across all seasons, the behaviour of all wild boar appeared relatively synchronised. Thus, it is unlikely that major differences in nocturnal behaviour would have occurred. Furthermore, the data collected in this study reflected similar changes in behaviour of free-living wild boar. Time budget in this species follows seasonal patterns and is related to factors such as temperature, humidity, daylength, food availability and mating. For instance, Mauget *et al*. (1984) showed that in summer wild boar spent ~25% of their time feeding compared with 33% in autumn, whilst the time spent sleeping and resting decreased from 58% in summer to 52% in autumn. Similarly, Gerard and Campan (1988) indicated that in autumn wild boar spend relatively more time eating and less time resting compared with summer months.

Studies on the effects of GnRH vaccines on animal behaviour and physiology are still scarce and inconsistent. For instance, treatment of domestic pigs with a GnRH vaccine was associated with an increase in feed consumption, growth and higher deposition of subcutaneous fat in both males and females within 4 weeks of vaccination (Cronin *et al*. 2003; McCauley *et al*. 2003). However, male lambs immunised against GnRH decreased feeding efficiency (expressed as the ratio between weight gain and total food consumed) compared with control animals (Kiyma *et al*. 2000). In the present study, the only indication of an effect of the GnRH vaccine on the physiology of wild boar was a modest increase in bodyweight. If these results were confirmed in natural conditions, this should not necessarily be regarded as a negative side effect of the vaccine, for two reasons. First, the bodyweight of wild boar varies significantly (up to 20–30%) within and between years (Massei *et al*. 1996). Second, the lifespan of free-living wild boar seldom exceeds 2–3 years of age due to hunting pressure (Gerard and Campan 1988) and it is unlikely that small difference in bodyweight could affect survival.

Social rank of treated and control females did not change following vaccination with GonaCon. Hierarchy in pigs housed in groups is relatively stable (e.g. Graves 1984; Brouns and Edwards 1994) and this study demonstrated that, at least in the 12–14 weeks after treatment, vaccination did not affect social ranks. Similarly, Jolly *et al*. (1996) showed that in groups of female brushtail possums (*Trichosurus vulpecula*) treated with a GnRH vaccine, social hierarchies remained unchanged over the 2–4 months after vaccination of the dominant female. If confirmed with free-living wild boar, these results indicate that treatment with GonaCon is unlikely to affect the behaviour and social stability of a group. This is important because other population-management options, such as culling, can disrupt social and spatial behaviour of wild boar (Maillard and Fournier 1995; Sodeikat and Pohlmeyer 2003). When population management is carried out to control the spread of diseases, social and spatial perturbation may lead to increase contact rate between individuals, thus negating the effects of culling. In these instances, fertility control might represent a preferable option to culling (Miller *et al*. 2004*b*).

No difference in blood parameters was observed between treated and control sows, indicating that there were no adverse effects of treatment on overall animal health. The date of collection (time) affected most biochemical and some

haematological variables of both groups, indicating seasonal variation in these variables. Similar results were obtained by Killian *et al*. (2006) for white-tailed deer treated with GonaCon, where the majority of biochemical and haematological parameters did not vary between treated and control animals. The same study also indicated that the only side effect recorded in treated deer was the formation of a granuloma at the injection site, probably associated with the adjuvant and concluded that treatment with GonaCon had no averse effect on deer health.

Increasing numbers of theoretical and empirical models (Hobbs *et al*. 2000; McLeod and Saunders 2001; Smith and Cheeseman 2002; Cowan *et al*. 2006) indicate that fertility control could be as effective as lethal control to reduce overabundant populations. Fertility control appears to have real potential to control populations of wild boar and pigs in situations where culling is not feasible or desirable. Examples include urban areas, protected areas where hunting is not permitted and instances where lethal control could potentially lead to social perturbation.

If the effectiveness and the lack of side effects of GonaCon are confirmed in the long term, the use of this vaccine might be regarded as a feasible option to manage free-living populations of wild boar as well as other overabundant or expanding mammalian species that conflict with human activities.

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