AN EVALUATION OF THE SUITABILITY OF CONTRACEPTIVE METHODS IN GOLDEN-HEADED LION TAMARINS (*LEONTOPITHECUS CHRYSOMELAS*), WITH EMPHASIS ON MELENGESTROL ACETATE (MGA) IMPLANTS: (I) EFFECTIVENESS, REVERSIBILITY AND MEDICAL SIDE-EFFECTS

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Abstract *Animal Welfare 2000, **9:*** 251-271

Finding a responsible method of population control that does not compromise animal welfare is a pressing problem for zoological institutions and conservation breeding programmes. This is exemplified by the conservation breeding programme of the golden-headed lion tamarin, Leontopithecus chrysomelas. *The number of golden-headed lion tamarins in captivity is currently being limited by, among other means, the use of contraception. We have conducted a study on the effects of contraceptive methods used in golden-headed lion tamarins. Data were collected through the distribution of a survey. The use of Melengestrol acetate (MGA) implants in females was by far the most widespread contraceptive method. It was very effective in preventing reproduction, provided that females were not pregnant at the time of implantation. Pregnancies that had commenced before MGA implantation were carried to term and resulted in viable infants, as far as noted. However, the degree of reversibility was very low and, if females did conceive after MGA implantation, infant survival was lower than expected. The widespread use of MGA implants in golden-headed lion tamarins (and probably other species) should be seriously reconsidered. Alternative methods of population control should be investigated. Possible options include the use of other contraceptive methods, limiting the number of offspring through natural factors and the use of euthanasia under very strict conditions. Animal welfare implications associated with the use of euthanasia are discussed.*

Keywords: *animal welfare, callitrichids, contraception, euthanasia, golden-headed lion tamarins, population control management*

Introduction

Controlling the number of animals to be maintained in captivity has become an inevitable aspect of zoo management and conservation breeding programmes. Zoos and institutions holding animals are frequently faced with the problem of surplus animals. Every successful conservation breeding programme will one day reach a point where sufficient or too many animals have been bred (Leus 1999). Finding population control methods which satisfy both the desires of the institutions and the objectives of the programmes, without compromising the health and welfare of the animals involved, is not always easy. This is, among other examples, illustrated by the chain of events guiding the objectives for the conservation breeding programme for the golden-headed lion tamarin, *Leontopithecus chrysomelas*, a callitrichid primate endemic to the Atlantic coastal rain forest of eastern Brazil.

Classified as one of the world's most endangered primates, due to the destruction of its original habitat by human interference, a metapopulation management plan, including captive breeding, was set up in the early 1980s in order to secure the survival of the species. Its aim, analogous to that of the conservation breeding programme for the golden lion tamarin, *Leontopithecus rosalia*, was to create a stock of animals, destined for later reintroductions (Kleiman *et al* 1986; Kleiman & Mallinson 1998). Given the high potential reproductive output of this species (due to regular twinning and multiple litters per year), the world captive population increased rapidly from 222 animals on 31 August 1988 (Mace 1988) to 575 animals on 31 December 1993 (De Bois 1994a,b). At the *2nd Symposium on Leontopithecus* (24–27 May 1994, Ilheus, Bahia, Brazil), it was announced that censuses had led to the discovery of new populations of free-ranging golden-headed lion tamarins (Pinto & Tavares 1994; Van Elsacker & De Bois 1995; Pinto & Rylands 1997). Counts suggested that there were still 6000 to 15 500 tamarins left in the wild, only 520 of which were living in protected areas (Pinto & Rylands 1997; Ballou *et al* 1998). These findings altered the priorities of the management plan.

Current management efforts are concentrating on increasing the size and number of protected areas and preserving their integrity (Ballou *et al* 1998). There is at present no potential for the reintroduction of captive animals. Consequently, the objective for the captive population is now to reduce its size to the minimum required to reach the genetic goal of 90 per cent retention of genetic diversity for 100 years, because of: i) competition for enclosure space with other callitrichid species; ii) increasing difficulties in finding sufficiently qualified institutions to house animals; and iii) the likelihood of a continued substantial input of orphaned animals from the wild (Ballou *et al* 1998). Reduction of the size of the captive population can be accomplished by limiting the number of breeding pairs of golden-headed lion tamarins. Several techniques can and have been used to meet this goal, such as the formation of single-sex groups, the prolonged residence of offspring in their natal group and hormonal or surgical contraception (De Bois 1994a; Sainsbury 1997). These measures have already yielded observable effects: in 1994 and 1995 the population increased by only 6 per cent and 5 per cent respectively (De Bois 1995; 1996) while in 1996 a decrease of 4 per cent occurred (Leus 1998).

Melengestrol acetate (MGA) implants (E Plotka, Marshfield Medical Research Foundation, Wisconsin, USA) are currently the most widely used contraceptive method in golden-headed lion tamarins, golden lion tamarins and many other primate and felid species (Ballou 1996; DeMatteo 1997; Sainsbury 1997). The American Zoo and Aquarium Contraception Advisory Group (AZA CAG) recommends them as the most appropriate contraceptive method in several primate and non-primate species (DeMatteo 1997). However, the effectiveness, reversibility, medical consequences and impact of MGA implants on individual behaviour and group stability have never been investigated in golden-headed lion tamarins (or many other species). Delays in resuming reproduction or even complete failure to reproduce after implant removal have been described in cattle (Zimbelman *et al* 1970) and lions, *Panthera leo* (Seal *et al* 1975). Several reports point to possible malignant effects on female reproductive organs, which might affect reversibility (Goeldi's monkey, *Callimico goeldii*, and squirrel monkey, *Saimiri sciureus*, [Murnane *et al* 1996]; common marmoset, *Callithrix jacchus*, [Möhle *et al* 1999]; felids [Seal *et al* 1976; Cohnen 1995; Harrenstein *et al* 1996]; several other primates [DeMatteo 1997)]). An increase in body weight and symptoms of diabetes have also been noted (Portugal & Asa 1995; Hayes *et al* 1996; Glatston 1998; Möhle *et al* 1999). Follicular development after MGA contraception does not seem to be impaired in felids or common marmosets (Kazensky *et al* 1998; Möhle *et al* 1999). Hardly any information exists on the effects of other contraceptive methods, such as castration or tubal ligation (DeMatteo 1997).

Any detrimental effects of contraception, both medical and behavioural, will have serious implications, not only for the objectives of the management plan for the golden-headed lion tamarin (and probably other species) but also for the health and welfare of the animals involved, and thus need to be thoroughly investigated. Therefore, we conducted a study on the effects of contraception in golden-headed lion tamarins. This report presents information obtained from a world survey of all official institutions holding golden-headed lion tamarins, and investigates: i) the methods of contraception used; ii) whether these methods were effective in preventing reproduction; iii) whether hormonal implantations were reversible; iv) whether infant survival, both during and after hormonal implantation, was affected; and v) whether there were any medical side-effects. Information on the endocrinological aspects of using MGA implants, as well as effects on individual behaviour, the occurrence of reproduction in offspring residing in the natal group, the occurrence of aggressive behaviour and group stability will be discussed in a companion paper (De Vleeschouwer *et al* 2000 in press).

Methods

The survey

A survey was designed (see, *Appendix 1*) asking for specific details on both male and female contraception. The present report will discuss the information collected from questions on: i) the method of contraception; ii) instances of loss or removal of hormonal implants (for any reason); iii) the occurrence of reproduction in the treated animal; iv) reversibility of hormonal implantation; v) infant survival during and after hormonal implantation; and vi) changes in the health and physical appearance of the treated animal or any group members. Information obtained on socio-sexual interactions and group stability is presented in a companion paper (De Vleeschouwer *et al* 2000 in press).

The survey was sent to 81 institutions listed as official holders in the *Golden-headed Lion Tamarin* Leontopithecus chrysomelas *International Studbook 9* (Leus 1998). These included 43 European, 26 North American, 7 South American and 5 Asian institutions. Institutions were requested to fill in one questionnaire for each animal ever treated in their institution, including animals that had been transferred to other institutions. In case they did not have or had never had treated animals, they were requested to fill in and return a brief note mentioning this fact. Data collection was completed by the end of December 1997. Some zoos were contacted again in order to complete information on expiry and replacement of contraceptive methods in the course of 1998. Furthermore, information on the reproductive history of animals was available from the computer database of the *Golden-headed Lion Tamarin International Studbook*, maintained by the second author at the Royal Zoological Society of Antwerp, Belgium.

Definitions (adapted from DeMatteo [1997])

Contraceptive bout: the period starting from the day the contraceptive method was first used until the end of that period, as defined below:

For implantations, the end of the bout (the *Implantation bout*) was determined by the date when the implant was either removed, expired (as determined from the assumed longevity of the implant), replaced by the same or another contraception method, lost (loss had to be confirmed), or when the animal died or was transferred to another institution and was lost to follow-up. Longevity for MGA implants was assumed to be about 2 years.

For injections, the end of the bout was determined by the duration of known efficacy or the recommended interval between consecutive injections. For Depo-Provera™ (medroxyprogesterone acetate; Coopers-Pitman-Moore, Crewe, UK), this interval was 30–90 days (Porton *et al* 1992).

For other irreversible methods (eg sterilization), the end of the bout was determined by the death of the animal or the transfer of the animal to another institution where it was lost to follow-up.

Stillborn infant: an infant that was reported as stillborn by the institution or in the international stud-book, or for which birth date and death date listed in the international stud-book were the same.

Live born infant: an infant that was reported as born alive or that survived for at least 1 day after birth.

Statistical analysis

In order to investigate the survival of infants born to females that had been implanted, we counted the number of stillborn and live born infants of the same females before, during and after MGA implantation. We used a chi-square test to compare the observed numbers of stillborn and live born infants during and after implantation with the expected numbers. These expected numbers were calculated based on the number of stillborn and live born infants before implantation. Comparing the same females, controlled better for the effects of variables such as sibling rearing experience and parity of the breeding animals. Infant survival is significantly higher for females with experience in rearing siblings and in multiparous females (De Vleeschouwer unpublished data 1997). If there is an effect of these variables on infant survival, we would expect a higher mortality *before* implantation rather than during or after, contrary to expectations if implantation increased infant mortality. This is because the births before implantation also include first births, when the animals involved have the least experience with rearing infants, and fewer helpers are available.

Mean litter sizes before and after MGA implantation were compared using a *t*-test for paired samples.

Results

Use of contraceptive methods

Table 1 contains information on the number of institutions responding to the survey and their use of contraception. If institutions reported not using contraception, this was mostly because they were housing only single-sex groups, because of ethical reasons or because they were only housing animals required to breed for the conservation programme.

Table 1 Use of contraceptive methods in captive golden-headed lion tamarins worldwide.

Region	No institutions involved	No institutions responding	Reported not using contraception	Reported use of contraception
Asia	5	3	2	1
Europe	43	38	27	11
North America	26	16	8	8
South America	7	7	7	0
Total	81	64 (79%)	44 (54%)	20 (25%)

Of the 64 institutions responding to the survey, 20 reported using contraception. These supplied information on the use of contraception in 44 females and 4 males. Fifty-six MGA implants were used in 39 females. Of these 39 females, 31 were implanted once, 5 were implanted twice, 2 were implanted four times and 1 female was implanted five times. Furthermore, one female was implanted and subsequently underwent a hysterectomy. Depo-Provera™ injection was used in one female, who was given an MGA implant afterwards. One female was sterilized. Two more females were implanted with chlormadinone acetate implants (GS implant; Teikokuzouki Co Ltd, Tokyo, Japan). Contraception in males consisted of two vasectomies, one castration and one epididiectomy.

Loss, removal and effectiveness of MGA implants

Figure 1 summarizes the responses obtained for 56 MGA implants that were used in golden-headed lion tamarins. Of these 56 implants, 5 (8.9%) were explicitly reported as being lost (ie not found when the animal was examined), and 9 (16.1%) were removed before the expected expiry date of 2 years. (This involved 2 implants being removed within 10 days of surgery because of infection at the implant insertion site, 5 implants being removed because it was advised that the animal should breed again, and 2 removals for medical reasons because an ultrasound investigation had revealed minor uterine changes.) Finally, 26 implants were reported as checked and confirmed present and 16 were reported as never checked and assumed present.

In total, 49 MGA implants (Figure 1) remained in place for a sufficiently long period (at least the duration of one pregnancy, ie 130 days [Kleiman *et al* 1988]) to evaluate the effectiveness of the procedure in terms of preventing pregnancies. In two of these cases (4.1%), the females started breeding within 2 years of implantation (ie before the expected expiry of the implant). Recalculating from the birth date, conception had occurred after implantation. This involved one case in which the presence of the implant was never checked, so implant loss could not be excluded. In the other case, the presence of the implant was confirmed so this can be considered a case of implant failure. In total, in 9 out of 56 implants (16.1%), infants were produced as the result of what can be considered unplanned pregnancies: these involve the one case of implant failure, the five cases of reported implant loss, the one case of possible loss, and the two cases of implant removal due to infection.

Reversibility of MGA implantation

Assuming that MGA implants are effective for approximately 2 years, 28 implantation bouts (Figure 1) were available for evaluating whether the female resumed reproduction after the implant had expired or was removed. Two cases were excluded: one because of implant failure and another because the female was housed alone when the implant expired.

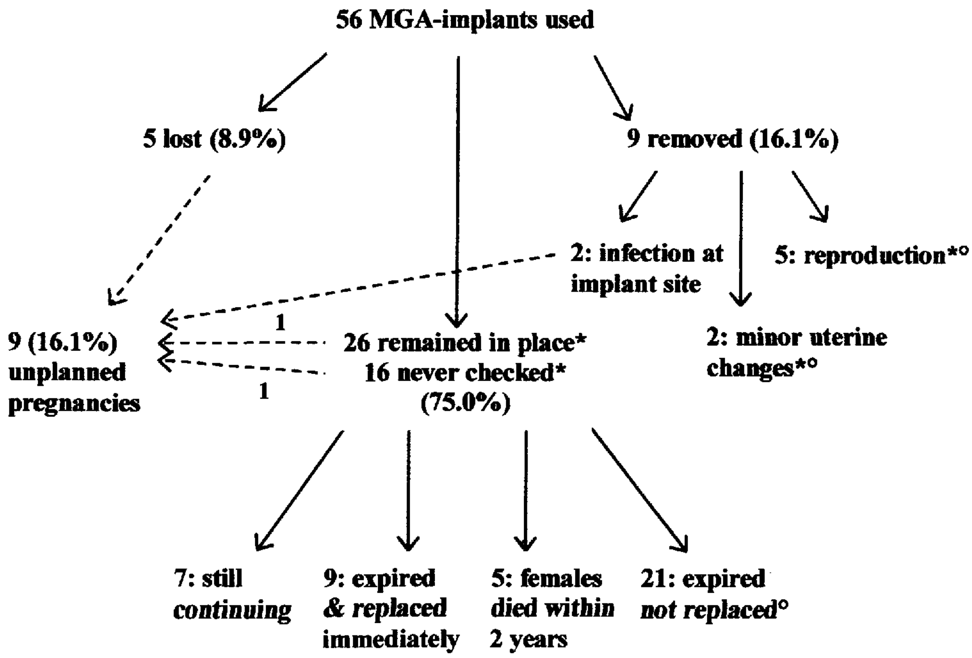

Figure 1 **Summary of findings for 56 MGA implants used in golden-headed lion tamarins. (* – implant bouts available to assess the success of implantation; ° – implant bouts available to assess the reversibility of implantation. See text for other explanations and definitions.)**

In the remaining 26 cases, only 5 females (19.2%) resumed reproduction. For two of these cases, the implants were explicitly reported as being removed. Recalculation from the date of birth indicated that the two females had conceived at approximately 88 and 154 days after implant removal. In the other three females whose implants expired without being removed, conception occurred at approximately 769, 843 and 867 days after implantation. This suggests that the longevity of MGA implants is no longer than 29 months.

In 9 of the 21 cases where reproduction was not resumed, this might be explained independently of the implant. Social group conditions may have inhibited reproduction in six females: four were housed with a brother, one case involved a mother housed with her son and one a daughter housed in her natal group. This daughter was implanted because of incestuous breeding within her natal group. In three more cases, reproduction may not have resumed because the animals involved could be considered post-reproductive: one female was over 15 years old, another was housed with a male over 15 years old, and a third wild-born female was of unknown age.

For 12 cases there seemed to be no explanation for the lack of reproduction, other than the implantation. These 12 females (46.2%) were all housed with an unrelated male at the end of the implantation bout. Six were multiparous females who had previously bred with the same male partner. Six females were nulliparous, three of which were housed with a male of proven fertility. For nine females, the implantation bout had lasted for 2 years, in one female 19 months and in another 37 months (this female had two consecutive implants of which the second was removed). In the twelfth female, the implant was removed at an unknown date.

Given that implants which have not been removed might still be effective, we also restricted the analysis to seven cases for which implant removal was explicitly reported. In two cases, females did resume reproduction (28.6%), while reproduction was not resumed in the other five (71.4%).

Infant survival and MGA implantation

As calculated retrospectively from the date of parturition, 9 females were implanted while pregnant. Two of these females were excluded because their pregnancies were the result of incestuous matings, which might have lowered infant survival. Pregnancies of the remaining 7 females before implantation had resulted in 70 infants of which 10 were stillborn and 60 live born. All 10 infants born to these females during implantation were live born. The difference in the number of stillborn and live born infants before and during the implantation bout was not different from expectation (chi-square = 1.63, $df = 1$; ns). Thus, the survival of infants born to females who conceived before implantation was not negatively affected.

Of the five females which resumed reproduction after the implantation bout, one was discarded because it involved mother-son incestuous breeding. Table 2 contains information on reproduction in the remaining 4 females. Forty infants were born to these females before implantation, 4 of which were stillborn and 36 live born (see Table 2). Of the 25 infants born after contraception, 6 were stillborn and 19 live born. These numbers were significantly different from expectation (chi-square = 5.44, $df = 1$; $P < 0.02$). Although the number of females is small, the results seem to indicate that more stillbirths occur after a female has been implanted. In two of the four females, these stillbirths occurred in the first litter after implantation. Moreover, mean litter size after implantation was significantly lower than before implantation ($t = 18.3$, $df = 3$, n = 4; $P < 0.0005$).

Medical side-effects of MGA implantation

Changes in medical conditions were reported for only 9 of the 39 implanted females. Two females suffered severe hair loss on the chest, as well as on the waist and tail, but hair growth was restored after some months. Two females seemed to have become heavier but no exact body weights were given. Two females died during the implantation bout, one from a chronic gut infection and one from pseudo-tuberculosis. These deaths are probably unrelated to the use of the implant. The autopsy for this latter animal (implanted for 1 year) revealed an apparently normal uterus and ovaries. For three females, the surveys reported the results of an ultrasonography. 'Minor uterine changes' were reported for two females at respectively 11 months and 5 years after implantation (this latter female had five consecutive implants). These females' implants were removed as a consequence of these findings (Figure 1). The third female had four consecutive implants. The surveys report, 'a pen-sized firm mass in abdomen, suspect it is in uterus', during a medical examination performed 4.5 years after the first examination. A second examination at 6.4 years after the first implantation revealed 'suspect mild decidualization in uterus.'

Effects reported for other contraceptive methods used in females

The two females with chlormadinone implants, the sterilized female, the hysterectomized female and the female who received a Depo-Provera™ injection did not give birth during their respective contraceptive bouts. The two implantation bouts are still ongoing, so there are no data on reversibility for this contraceptive method. The female who received a Depo-Provera™ injection was separated from her male partner 2.5 months after the injection. She subsequently gave birth to two stillborn infants sired by her son about 637 days after the

Table 2 Reproductive data for four females which conceived after MGA implantation.

Female[1] (Implant date)	Reproduction before implantation			Reproduction after implantation		
	Birth date	Litter size	Stillbirths	Birth date	Litter size	Stillbirths
113 Amiga	09/09/86	2	0	26/07/93	1	1[2]
(1st implant 09/06/89;	19/03/87	2	1	22/02/94	1	0
replaced 12/07/91; 2nd	30/07/87	2	0	03/07/94	1	0
implant removed	09/12/87	1	0	12/11/94	2	0
15/10/92)	20/04/88	2	0	20/04/95	2	0
	29/08/88	2	0	15/11/95	2	0
	15/11/88	1	1[2]	29/04/96	2	0
	24/03/89	2	0	20/09/96	1	0
				29/01/97	1	0
Mean ± SEM		**1.75 ± 0.46**			**1.44 ± 0.53**	
123 Bahia	30/11/86	2	0	29/05/92	1	0
(implanted 03/09/89;	13/04/87	1	0	18/06/95	1	1
implant removed	24/08/87	1	0	17/11/95	1	1
24/10/91)	24/02/88	2	0	14/04/96	1	0
	05/07/88	1	0			
	03/03/89	1	0			
	06/08/89	1	0			
Mean ± SEM		**1.29 ± 0.49**			**1.00 ± 0.00**	
141	09/05/87	2	0	±01/08/95	1	1
(implanted 01/12/92;	08/03/89	2	0	10/04/96	2	0
implant not removed)	12/09/89	2	0			
	14/03/90	2	0			
	23/07/90	2	1			
	20/07/91	1	0			
	27/04/92	1	1			
	10/09/92	2	0			
Mean ± SEM		**1.75 ± 0.46**			**1.50 ± 0.71**	
166 Flame	21/11/89	1	0	23/07/93	1	0
(implanted 05/02/91;	10/04/90	2	0	21/01/94	1	1
implant not removed)				08/06/94	2	0
				± 07/09/94	1	1[3]
Mean ± SEM		**1.50 ± 0.71**			**1.25 ± 0.50**	

[1] Numbers and names according to the international stud-book (Leus 1998).
[2] Female aborted non-full-term foetus.
[3] Female aborted foetus during first third of pregnancy.

injection. This is long after expiry of the contraceptive injection, which lasts only 30–90 days. It is likely that reproduction between the mother and her son was socially inhibited, which explains the long period between expiry of the injection and parturition.

No medical side-effects were reported for any of these females.

Effects reported for contraceptive methods used in males

One litter of infants was produced in the case of the epididiectomized male: it was suspected that some residual viable sperm was left, resulting in the pregnancy of the breeding female (sexual interactions between the breeding female and the epididiectomized male, including full copulations, still occurred after surgery; De Vleeschouwer *et al* 2000 in press). In the case of the two vasectomized males and the castrated male, no births occurred during their respective contraceptive bouts.

One of the vasectomized males died 3 months after the vasectomy due to liver cell degeneration and focal necrotic hepatitis, unlikely to be related to the surgical procedure. No medical side-effects were reported for the other males.

Discussion

This study demonstrates that:

i) Contraception in golden-headed lion tamarins is largely accomplished through MGA implants in females.
ii) Instances of loss, forced removal or confirmed failures of MGA implants known to be present are rare. If they remain in place, MGA implants are highly effective at preventing reproduction provided that the females are not pregnant at the time of implantation. Pregnancies that have already started before implantation are carried to term and the survival of infants born from such pregnancies is not negatively affected.
iii) Reversibility after implantation with MGA is very low, and, if reproduction is resumed, there is some evidence for a higher frequency of stillborn infants than before implantation.
iv) Medical side-effects of MGA implants seem to be infrequent, but for some females uterine changes have been reported.

The database from the present study can be considered to give a representative view of the use of contraceptive methods in golden-headed lion tamarins. The response rate was 79 per cent, which is very high. The database on contraception maintained by the AZA CAG lists the use of 39 MGA implants, 1 Depo-Provera™ injection and 1 ovariohysterectomy in golden-headed lion tamarins (DeMatteo 1997). The present study obtained information on 56 MGA implants (including nearly all of those listed by AZA CAG), all information on other contraceptive methods listed by AZA CAG and information on the use of two more contraceptive methods in females. In addition, the limited use of contraception in males was reported.

The low probability of loss, forced removal, or failure and the low frequency of medical side-effects all seem to promote MGA implants as an acceptable method of controlling population growth. However, the very low reversibility and the possible higher occurrence of stillborn infants should give serious reasons for concern. It is unclear whether the higher proportion of stillborn infants is really due to implantation, since the stillbirths did not always occur in the first litter after implantation. Mean litter sizes were also lower in females which resumed reproduction after MGA implantation. It may be that these females have a lower ovulation rate or that they resorb one embryo early in pregnancy. However, the effect of age cannot be excluded since all females were older when resuming reproduction after implantation.

These effects have hitherto not been reported for MGA implants in golden-headed lion tamarins, although problems with reversibility have been mentioned for other species (DeMatteo 1997). The possible pharmacological or pathological reasons for these problems are as yet unclear. Uterine changes that might impair reversibility have been reported for Goeldi's monkeys, squirrel monkeys, several other primate species and some felids (Seal *et al* 1976; Harrenstein *et al* 1996; Murnane *et al* 1996; DeMatteo 1997). In common marmosets, similar changes have been reported but these changes were reversed after implant removal and, overall, did not seem to affect ability to conceive (Möhle *et al* 1999). In the present study, the occurrence of uterine changes was reported for three females on which an ultrasonography was performed. In two of these females, the implant was removed following this diagnosis, but the females did not conceive (one of them was housed with a sibling male). This also suggests a link between the observed uterine changes and the probability of reproduction after implantation.

Several arguments can be advanced to explain the low percentage of irreversibility reported by AZA CAG as opposed to the present study. The AZA CAG restricted its analysis to the cases where implants have been explicitly removed: this points to reproduction being resumed in two out of three golden-headed lion tamarins (DeMatteo 1997). For the present study, it may be argued that since the implants were not always removed, the possibility that they were still effective cannot be excluded. However, even if we restrict our analysis to the seven cases where the implant was explicitly removed, the number of females failing to resume reproduction was very high (71.4%). The data from the females who did resume reproduction point to an implant longevity of, at most, 29 months. This is not much beyond the presumed longevity of 24 months. Moreover, it may take some time for females to conceive after expiry of the implant. Such a delay was apparent in the two females who conceived after their implants had been removed. For those females whose implants expired but were not removed, and for which reproduction was not resumed, the period elapsed since implantation ranged from 32.4 to 77.1 months.

One advantage of the present study is that the circumstances under which the animals were housed at the time when reproduction should have been resumed were known in more detail than mentioned in the AZA CAG report (DeMatteo 1997). Investigation of the age and social housing of the animals points to a possible reason in some cases of irreversibility. Being housed with a sibling may be cited as one reason for the absence of breeding in some females, due to the existence of a behavioural 'incest taboo' (Carroll 1989; Heistermann *et al* 1989). However, in golden-headed lion tamarins, incestuous breeding between siblings housed outside their natal family is very likely to take place if appropriate measures to prevent it are not taken (Leus 1998; Price 1998). In fact, incestuous breeding may be more frequent in this species than in other callitrichids (Price 1997; 1998). Moreover, the females involved were all implanted because they had been mating incestuously under the same social conditions that prevailed at the end of the implantation bout. It is thus unlikely that the lack of breeding in these females after implantation may be accounted for by the existence of an 'incest taboo'.

Animal welfare implications

Although the above explanations may account for some observed failures of reproduction, the arguments offered are questionable and unlikely to explain many of these failures. There was no clear reason why some 46.2 per cent of the females did not resume reproduction. It would be unacceptable – both from an animal welfare perspective and the objectives of a conservation breeding programme – to ignore the existence of the problem merely for matters of a methodological nature or definitions. Unless reversibility in these cases is really established, as evidenced by reproduction, one cannot afford to consider the problem as less serious than presented here. When taking the decision to use MGA implants, one must be aware that this method may in fact be irreversible, just like a surgical procedure such as vasectomy or sterilization. This is likely to be unacceptable for the objectives of the conservation breeding programme, since these animals may be needed for breeding in the future. Therefore, the widespread use of MGA implants in this species should be seriously reconsidered and only advised if there is a considerable chance that the animals involved will never be required to breed again. Moreover, if implants are removed or expire, the female should be allowed time to start reproducing again in order to assess reversibility, instead of immediately being re-implanted. The contraception of daughters housed in their natal group has been proposed by Price (1998) as a means of preventing incestuous breeding. However, the degree of incestuous breeding by daughters in their natal group seems to be very low, even after contraception of the breeding female (Leus 1998; De Vleeschouwer *et al* 2000 in press) and even though, in lion tamarins, daughters are physiologically fertile (French *et al* 1989; Van Elsacker *et al* 1994). Given the effects on reversibility, the implantation of females merely to prevent conceptions that are very unlikely to happen should be discouraged.

Because of the close genetic similarity between the different species of the genus *Leontopithecus* (golden lion tamarin, golden-headed lion tamarin, black lion tamarin [*L. chrysopygus*], black-faced lion tamarin [*L. caissara*]; Forman *et al* 1986), MGA implantation in the other species of lion tamarins may cause the same problems of irreversibility. MGA implantation in golden lion tamarins is even more widespread than in golden-headed lion tamarins (DeMatteo 1997). The AZA CAG report mentions that 8 out of 13 golden lion tamarins whose implants were removed did not resume reproduction (DeMatteo 1997). This seems indicative of a comparable problem. A similar study to this one, investigating details of social housing and age, would yield the necessary information to assess the severity of the problem in golden lion tamarins. As for black lion tamarins, the first cases of MGA implantation are now taking place. The metapopulation management plan for this latter species involves the captive and wild population being managed as one, with frequent transfer of animals in both directions (Valladares-Pádua & Cullen 1994; Ballou *et al* 1998; Padua & Ballou 1998). In this way, the number of animals to be maintained in captivity can be lower than for the other species, while still meeting the genetic goals of the metapopulation management plan (Padua & Ballou 1998). If females in captivity have been implanted, and this implantation has the same effect as in golden-headed lion tamarins, this may result in the reintroduction to the wild of females who are no longer capable of reproduction. This is a problem applicable to both black and golden lion tamarins, since reintroductions of the latter species have already taken place (eg Beck *et al* [1991]). One would need to reassess the reversibility of hormonal implantations on a case-by-case basis, and only reintroduce animals still capable of reproduction. However, this would result in an increasing number of infertile animals in captivity, which would have only a very limited value for the conservation breeding programme. The captive population, including that of golden-headed lion tamarins, is supposed to fulfil a role as a buffer for the future (in case reintroductions become necessary again). It also has important educational value (to improve the public's awareness) and, through scientific research, may contribute to the knowledge of the biology of the species, which may provide further beneficial insights for the management of the wild population (IUDZG/CBSG 1993; Van Elsacker & De Bois 1995). *The World Zoo Conservation Strategy* lists conservation, education and scientific research as the main initiatives by which zoos can play a role in conserving the earth's wildlife and biodiversity (IUDZG/CBSG 1993). Housing an increasing number of captive infertile animals, due to the continuing use of MGA implants, even with knowledge of the negative side-effects, cannot be accepted, whether viewed from the objectives of a conservation breeding programme or from the function of modern zoological institutions as conservation centres.

Nevertheless, a certain control on the number of lion tamarins in captivity is inevitable, since the potential reproductive output of this genus is very high due to regular twinning and multiple litters per year. If the current population of golden-headed lion tamarins were allowed to grow at an annual rate of 25 per cent, there would be 2000 tamarins within 5 years and 6000 within 10 years (Leus 1999). This growth rate was easily achieved during the 1980s when the use of contraception was still limited. Finding suitable institutions to house these animals is already becoming a problem and will be even more so in the future, if the population continues to grow. Putting animals in inferior conditions is unacceptable in terms of welfare. Separating the sexes and leaving offspring in their natal groups for as long as possible are only temporary solutions which relieve some problems but are insufficient to deal with all surplus animals. Moreover, although a unisex group is a natural form of social organization that also occurs in the wild, it is unlikely that animals spend a prolonged period of their life in these types of associations (Dietz & Baker 1993; Dietz *et al* 1996). Polyandrous groups are a natural and stable form of social organization, which frequently occur in the wild (Dietz *et al* 1996). However, very few cases exist in captivity. This could be another way of dealing with certain surplus males.

There are two main options for controlling the number of tamarins in captivity while not using MGA implants. One is to use other contraceptive methods, such as Norplant™ (Wyeth, Maidenhead, UK), Depo-Provera™ injections, immunocontraception, etc (for a review see Sainsbury [1997]; Glatston [1998]). The present study, however, demonstrated that these methods have seldom been used, and there is hardly any knowledge on reversibility or other side-effects. They should, therefore, be used with caution. More research is needed before they can be advised for widespread use. An investigation of factors such as the impact of light regimes and variables relating to diet which might induce the natural pattern of seasonal reproduction, or the potential of food with a natural contraceptive effect (such as papaya or leaves from the mangosteen fruit tree; Graeme Martin personal communication 1999) might also reduce the number of offspring born to a certain breeding pair and allow contraception to become more limited with time.

The other option is to allow the use of euthanasia as a method of controlling the number of surplus animals *under very strict conditions* (Sainsbury 1997; Glatston 1998). There are certain welfare arguments in favour of euthanasia as a population management method. In golden-headed lion tamarins and, more generally, all callitrichids, social organization, reproductive behaviour and infant care patterns are very complex and closely interrelated. Allopaternal care, regular twinning, the instant resumption of fertility after parturition, the monopolization of reproduction in one female, the reproductive inhibition of offspring in their natal group and delayed dispersal of offspring all lead to the very typical group structure of a nuclear or extended family (eg Dunbar [1995]; Solomon & French [1996]). Given this close interrelationship between infant care and many aspects of their social system, one might wonder whether it is acceptable to prohibit such an essential part of these primates' social life, as is the case when reproduction in the breeding female is inhibited.

Allowing reproduction and euthanasia of surplus offspring may *only* be considered under very strict conditions, such as when the group becomes too large for the enclosure, when it becomes unstable, or when an animal is evicted. The stud-book keeper might then advise whether the animal is needed for breeding or for companionship. Only if this is not the case and if a sufficient number of siblings are left, either in the family group or in breeding situations, might the stud-book keeper allow euthanasia. Permission of the latter person would in any case be necessary (in the case of lion tamarins only after additional permission from IBAMA – the Brazilian authorities, who are the legal owners of all lion tamarins in captivity [Kleiman & Mallinson 1998; Leus 2000]).

Euthanasia might be a beneficial option in terms of animal welfare. Given current medical procedures, euthanasia is unlikely to cause pain and the animal is unaware of its impending fate. It causes no more pain or distress than the capture of an animal for routine procedures such as medical injections or anaesthesia. The parents can continue to reproduce and care for infants, which significantly adds to their well-being in captivity. Offspring can easily remain in their natal group until a certain age, and are able to fulfil their natural role as infant caretakers. In this way, natural group dynamics are respected and the array of natural behaviours, already inevitably limited by the constraints of captivity, is not reduced any further. The public is, moreover, presented with a more accurate view of a lion tamarin's social life and, in this way, the captive population is better able to fulfil its role in education. Moral and public objections to euthanasia are likely to present a major obstacle. A thorough explanation of the role of zoological institutions, the problems they encounter, their underlying reasons and the chosen solutions, is, therefore, necessary. However, one needs to weigh the welfare of the animals against possible consequences of a negative public opinion.

Given the high reproductive turnover of golden-headed lion tamarins, allowing full reproduction would result in an exceedingly high number of animals to be euthanased – something likely to pose moral and ethical problems to the people involved. The number of offspring born to a breeding pair may be limited by certain factors such as short-term contraception or factors relating to food availability and light regime (see above). In this way, euthanasia might provide a very selective, yet strictly controlled, option for reaching the goal of responsible population control management.

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APPENDIX 1: Questionnaire on the use of contraception in golden-headed lion tamarins. (Reprinted from the original used in the current study.)

MALE #............
Studbook number: ....
Local ID: ....
House Name: ....
The male was contracepted 0 in your institution
0 in (one of) its previous institution(s)
Date of contraception: ....
Method of contraception: ....
Weight of animal prior to contraception: ....
Group composition at the date of contraception (give studbook numbers of all group members and underline breeding male and female if present): ....

1. CONTRACEPTION PROCEDURE

a. At which stage of the reproductive cycle was the animal contracepted? (eg one week after the last birth)

b. When during the daily activity pattern of the animal was the 'to be contracepted' individual captured and why?

c. On average, what was the total time that the animal was away from the rest of the group for application of the contraception?

2. SUCCESS OF CONTRACEPTION:

a. Did the contracepted male remain sexually active:
- did females present for mating ? YES/NO/UNKNOWN
if yes: give studbooknumber of female(s): ....
- did the contracepted male initiate matings? YES/NO/UNKNOWN
if yes: give studbooknumber of female(s) ....
- did the contracepted male copulate with any female? YES/NO/UNKNOWN
if yes: give studbooknumber of female(s) ....
- when during the contraceptive bout was this sexual activity seen?
0 within three months after contraception
0 between six months and 1 year after contraception
0 between 1 year and 2 years after contraception
0 after 2 years of contraception
if possible, give an approximate of the date of sexual activity:
....

b. Were any OTHER male group members sexually active?
- before contraception of the male: YES/NO/UNKNOWN
if yes: give studbooknumber of male(s) ....
- after contraception of the male: YES/NO/UNKNOWN
if yes give studbooknumbers of male(s) ....
- when during the contraceptive bout was this sexual activity seen?
0 within three months after contraception
0 between six months and 1 year after contraception
0 between 1 year and 2 years after contraception
0 after 2 years of contraception
if possible, give an approximate of the date of sexual activity:
....

c. Were any infants born during the period after the male was contracepted?
YES/NO/UNKNOWN

if yes:
- give the birth date of the infant(s) and the studbooknumber of the mother(s) and possible father(s)
....

- how did the contracepted male react to
- the female that gave birth: ....
- the infant(s) ....
- other male group members ....

d. Did you carry out any physiological evaluation (eg hormone analyses,...) of male and/or female group members? ....

3. SOCIAL STRUCTURE:

a. Did contraception cause changes in:
- the social status of the contracepted male ? *YES/NO/UNKNOWN*
if yes: which changes: ....
- the social status of the other male group members ? *YES/NO/UNKNOWN*
if yes: which males and changes ....
- the social status of the female group members ? *YES/NO/UNKNOWN*
if yes: which females and changes ....
- if applicable, the paternal care of the contracepted male towards infants?
YES/NO/UNKNOWN
if yes: how ....
- if applicable, the paternal care of other group members towards infants?
YES/NO/UNKNOWN
if yes: which group members and how ....

b. Were any individuals expelled from the group after contraception of the male?
YES/NO/UNKNOWN
If yes, give studbooknummer of the expelled individual(s), expelling date(s) and studbooknumber of the aggressor(s) ....

4. MEDICAL CONDITIONS:

a. Were there any changes in the physical appearance of:
- the contracepted male: *YES/NO/UNKNOWN*
if yes: which ....
- the other group members: *YES/NO/UNKNOWN*
if yes: which ....

b. Were there any changes in the overall health of any of the group members after contraception? (eg weight loss/gain, lethargic/overactive, appetite,...)
YES/NO/UNKNOWN
if yes: which ....

c. If the contracepted male died, did you carry out an autopsy?
If yes, please attach the autopsy report if available, or indicate the date and cause of death (if known).
....

d. If the contracepted male was transferred to another zoo, indicate the date of transfer and the zoo to which it was transferred. ....

FEMALE #..........

Studbook number: ....
Local ID: ....
House Name: ....
The female was contracepted *0 in your institution*
0 in (one of) its previous institution(s)

Date of contraception: ....
Method of contraception: ....
Weight of animal prior to contraception: ....
In case of implantation:
MGA implant ID number as provided by Dr. Plotka: ....
Dose of contraception in case of implantation or weight of the implant:
....
Group composition at the date of contraception (give studbook numbers of all group members and underline breeding male and female if present): ....

1. General procedure:

a. At which stage of the reproductive cycle was the animal contracepted? (eg one week after the last birth)

b. When during the daily activity pattern of the animal was the 'to be contracepted' individual captured and why? (eg immediately after a suckling bout and after the young(s) has(have) been transferred to another individual)

c. In case of hormonal implantations, describe briefly how and where the contraceptive device was put in place.

d. What was the total time that the animal was away from the rest of the group
- for application of the contraception (the operation itself)?
....
- did you keep the contracepted animal separated in order to let the wound heal?
YES/NO/UNKNOWN
if yes,
for how long ....
did any groupmember remain with her (give studbooknumbers if applicable)?
....

2. Success of contraception:

a. Did the contracepted female remain sexually active:
- did she present for mating ? *YES/NO/UNKNOWN*
if yes: give studbooknumber of male(s) to which she presented:
....
- did any male group member show interest in the contracepted female?
YES/NO/UNKNOWN
if yes: give studbooknumber of male(s): ....
- did the contracepted female copulate with any male? *YES/NO/UNKNOWN*
if yes: give studbooknumber of male(s) ....
- when during the contraceptive bout was this sexual activity seen?
0 within three months after contraception
0 between six months and 1 year after contraception
0 between 1 year and 2 years after contraception
0 after 2 years of contraception
if possible, give an approximate of the date of sexual activity:
....
- were you able to confirm the presence of the contraceptive device at the time of sexual activity
....

b. Were any OTHER *female group members sexually active?*
- before contraception: *YES/NO/UNKNOWN*
if yes: give studbooknumber of female(s): ....
- after contraception: *YES/NO/UNKNOWN*
if yes give studbooknumbers of female(s): ....
- when during the contraceptive bout was this sexual activity seen?
0 within three months after contraception
0 between six months and 1 year after contraception
0 between 1 year and 2 years after contraception
0 after 2 years of contraception
if possible, give an approximate of the date of sexual activity:
....
c. Were any infants born during the period when the female was contracepted?
YES/NO/UNKNOWN
in case the contracepted female gave birth:
- give the birth date of the infant(s) and the studbooknumber of the possible father(s)
....
- was/were the infant(s) healthy? ....
- were you able to confirm the presence of the contraceptive device at the time of conception?
....
- how did the contracepted female react to the infants?
....
in case another female gave birth:
- give the birth date of the infant(s) and the studbooknumber of the possible father(s)
....
- how did the contracepted female react to
- the female that gave birth: ....
- the infant(s): ....
d. Did you carry out any physiological evaluation? (eg hormone analyses,...)
....

3. SOCIAL STRUCTURE:
a. Did contraception cause changes in:
- the social status of the contracepted female? *YES/NO/UNKNOWN*
if yes: which changes: ....
- the social status of the other female group members ?
YES/NO/UNKNOWN
if yes: which females and changes: ....
- the social status of the male group members ? *YES/NO/UNKNOWN*
if yes: which males and changes ....
- if applicable, the maternal care of the contracepted female towards her own infants?
YES/NO/UNKNOWN
if yes: how ....
- if applicable, the care of other group members towards infants?
YES/NO/UNKNOWN
if yes: which group members and how ....
b. Were any individuals expelled from the group after contraception of the female?
YES/NO/UNKNOWN
If yes, give studbooknummer of the expelled individual(s), expelling date(s) and studbooknumber of the aggressor(s) ....

4. Medical conditions:
a. Were there any changes in the physical appearance of:
- the contracepted female: *YES/NO/UNKNOWN*
if yes: which ....
- the other group members: *YES/NO/UNKNOWN*
if yes: which ....
b. Were there any changes in the overall health of any of the group members after contraception? (eg weight loss/gain, lethargic/overactive, appetite,..)
YES/NO/UNKNOWN
if yes: which ....
c. If the contracepted female died, did you carry out an autopsy?
If yes, please attach the autopsy report if available, or indicate the date and cause of death (if known).
....
d. If the contracepted female was transferred to another zoo, indicate the date of transfer and the zoo to which it was transferred.
....

5. Efficiency and reversibility of hormonal implantations
a. Was the implant lost ? *YES/NO/UNKNOWN*
if yes: give cause of loss:
0 removal of group members: (approximate of) day of loss .
....
0 other causes: state cause: ....
(approximate of) day of loss ....
b. If the implant was not lost, did you remove the contraceptive device after some time ?
YES/NO/UNKNOWN
if yes, for what reason? ....
what was the removal date: ....
what was the group composition at the time of removal (give studbooknumbers)
c. Did you replace the first contraceptive device by another one or did you change the method of contraception? *YES/NO/UNKNOWN*
if yes, give the method and date of replacement ....
d. Did the female reproduce after removal of the contraceptive device, and if so, give the date of birth.
....
e. If the contraceptive device was not removed, lost or replaced, did the female start reproducing after some time? *YES/NO/UNKNOWN*
if yes, give the date of birth of infant(s) ....