

# Feasibility of applying contraception for reducing crop damage by avian pest species in Uruguay – Final Report

30 May 2014

Michael L. Avery, PhD  
US Department of Agriculture  
National Wildlife Research Center

## Project overview:

In April 2014, the USDA National Wildlife Research Center (NWRC) and the Uruguayan Board of Oilseed Crops (MTO - Mesa Tecnológica de Oleaginosos) entered into a cooperative research agreement (14-7412-1012-RA) to assess the feasibility of implementing contraception methods to manage bird pest populations and reduce crop damage. Under the terms of this agreement, NWRC is to provide MTO with three products: (1) **Work plan**, which was already submitted and adopted as part of the cooperative agreement; (2) **First report**, which was submitted and includes an initial assessment of the feasibility of using contraception to manage Uruguayan bird pests and which also summarizes progress toward development of a Memorandum of Understanding between NWRC and the National Agricultural Research Institute of Uruguay (INIA); and (3) **Final report**, this document which presents an overall feasibility assessment and recommendations for applying avian contraception to reduce crop damage caused by monk parakeets and eared doves in Uruguay.

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## EXECUTIVE SUMMARY

Crop damage by birds in Uruguay is an ongoing problem. The monk parakeet (*Myiopsitta monachus*) and the eared dove (*Zenaida auriculata*) are the principal species of concern. Current methods of crop protection include lethal management options which appear to be of limited value in reducing damage, and which generate concern for their potential negative environmental consequences. Contraception has been proposed as an alternative to lethal control to manage these pest populations. Previous research using the contraceptive **diazacon** demonstrated the possibility of reducing annual reproductive output of monk parakeet populations in the US by about 60%. No similar information is available regarding contraception effects on eared doves or closely related species. Monk parakeets in Uruguay usually form discrete colonies in *Eucalyptus* groves where they build and maintain nests year-round. Eared doves occupy large traditional nesting colonies from which they might travel extensively each day seeking food and water. Outside the breeding season, doves may use alternate roosting sites and form enormous temporary feeding flocks which can decimate crop fields. Based on (1) previous successful contraception research with monk parakeets, and (2) the species' relatively sedentary behavior, application of avian contraception in Uruguay should focus initially on the monk parakeet. At the same time, acquisition of essential baseline information should be initiated in physiological and behavioral trials with captive eared doves. These will provide data necessary to develop application strategies for eared dove population management. Long-term population reduction combined with effective use of farm-level crop protection methods, such as chemical repellents, will protect vulnerable field crops from serious damage by parakeets and doves.

## INTRODUCTION

Bird damage to crops occurs worldwide. In South America, eared doves (*Zenaida auriculata*), monk parakeets (*Myiopsitta monachus*), and dickcissels (*Spiza americana*) are frequently associated with serious economic losses (Bruggers and Zaccagnini 1994, Bruggers et al. 1998, Basili and Temple 1999). Depredations in Uruguay can be locally severe and can affect soybean, sorghum, sunflower, and rice among other crops (Rodríguez et al. 1995, Canavelli et al. 2008, Vitti and Zuil 2012, Bernardos and Farrell 2013).

Producers in Uruguay have a range of non-lethal management options for reducing avian crop damage at the farm level, including management of waste grains, falconry, nets, acoustic deterrents, and chemical repellents (Rodríguez *et al.* 2011, 2012, 2013). Successful bird damage management generally requires use of multiple methods in an integrated pest management strategy. Various factors will impact the effectiveness of any control effort. These factors include the timing of the management plan, the consistency with which the management plan is applied, the availability of alternate foods for the birds, and the size of the depredating bird population.

In some situations, the bird population inflicting damage on a particular farm is too large to be controlled effectively by non-lethal methods. Lethal control of pest birds is very restricted in Uruguay. There is a government-sponsored program to reduce some monk parakeet populations by spreading toxic grease around the entrance holes of their nests. This program is carried out by trained applicators under contract to the government. No avicide is registered or available for general public use, but the Ministry of Agriculture can issue special permits for lethal control of specific bird species under specific circumstances.

An alternative to lethal control for reducing wildlife populations is the use of chemosterilants or contraception to lower the birth or hatching rate within the target population. Thus recruitment is reduced, and over time the population shrinks. This concept is not new, but wildlife applications have become more common in recent years as biologists, managers, and the public seek more humane, non-lethal approaches to wildlife population reduction which minimize impacts to non-target species. The purpose of this study is to determine whether it is feasible to use contraception in Uruguay for effectively reducing crop damage caused by eared doves and monk parakeets.

The feasibility assessment presented in this report is based on my personal research experience with avian contraceptives, a thorough review of the available information on avian contraceptives (Appendix A), and an in-country consultancy during which I was able to discuss the problem of bird damage in Uruguay with numerous parties and to visit nesting

colonies and crop field sites. Limitations to this feasibility evaluation are related to lack of information on various topics, which will be made explicit in the following sections.

## SELECTING A CONTRACEPTIVE

Options for an avian contraceptive are few. In the US, two compounds have been tested extensively. Nicarbazin (NCZ) is currently registered with the USEPA by Innolytics LLC as a reproductive inhibitor (OvoControl®) for management of Canada goose (*Branta canadensis*) and rock pigeon (*Columba livia*) populations (Bynum et al. 2005, Avery et al. 2008a). Field studies showed that use of OvoControl G immediately prior to and during the breeding season reduced numbers and hatchability of eggs laid by Canada geese (Bynum et al. 2007). There has been no controlled field evaluation of OvoControl P in the US, but anecdotal reports indicate successful reductions of urban rock pigeon populations in many locations. Advantages of NCZ are that it is non-toxic, it is cleared from the body within approximately 48 h, and the infertility effect is reversible. A major disadvantage for field applications is that it has to be fed daily prior to and during egg laying. Otherwise, the NCZ titer in the blood will rapidly fall below its effective level.

Diazacon was registered with the USEPA in the late 1960s as Ornitrol®, an oral contraceptive for rock pigeons. Diazacon reduced egg laying and egg hatchability in pigeons (Woulfe 1968), but the pigeon is a year-round breeder and long-term use of the compound might have undesirable side effects (Lofts et al. 1968). The registration was cancelled in 1993. The chemical structure of diazacon is similar to cholesterol, and it inhibits formation of pregnenolone, the parent compound of steroid hormones, preventing synthesis of testosterone and progesterone which are essential for reproduction (Miller and Fagerstone 2000). The effects of diazacon are not permanent, but it does persist in the body and its effects can last several months.

Interest in diazacon has surfaced in recent years as a possible means to control the growth of monk parakeet populations in the US (Avery et al. 2006). In trials with captive monk parakeets, diazacon treatments for 10 days suppressed reproduction for the entire breeding season (Yoder et al. 2007). Treated birds exhibited no side effects. In a follow-up field trial in south Florida, productivity of monk parakeet colonies exposed to diazacon-treated bait was reduced 60% compared to colonies not exposed to diazacon (Avery et al 2008b). Diazacon appears to pose no hazard to predators that might consume parakeets treated with the chemical (Yoder 2011).

***Diazacon is preferable to nicarbazin for the present proposed use primarily because it has an excellent track record with the monk parakeet, one of target species. Also, it does not require constant feeding; one 10-day exposure period lasts the entire breeding season which is a major advantage for field use.***

## FEASIBILITY AT DIFFERENT LEVELS

There are differences between the two target species in the degree of knowledge we currently have with regard to contraception in general and diazacon specifically. The following table summarizes the state of knowledge and my judgment on the feasibility question at increasing levels of effect:

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Response variable	Feasibility	
	Monk parakeet	Eared dove
Physiological effects	YES	Probable
Bait acceptance (individual)	YES	Probable
Bait acceptance (colony)	Probable	???
Colony size reduced	Probable	???
Population reduction	???	???
Crop damage reduction	???	???

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For example, I am very confident that for individual monk parakeets, contraception with diazacon bait will be feasible because we have already demonstrated that to be the case for parakeets in the US. The same will probably hold true for eared doves, but the requisite studies have not been performed, so I cannot say with certainty. On the other hand, we have no prior information on either species regarding the likelihood that contraception can be applied successfully to reduce population size. A population can be defined as a collection of colonies occupying a given geographic area. If sufficient numbers of colonies are successfully treated, then the accumulation of those results should produce a response at the population level. Studies have not been conducted for a long enough time over sufficiently broad areas to make clear whether or not reduction of population size would be possible.

The ultimate purpose of this proposed management plan is crop damage reduction. But the link between population reduction and damage reduction is difficult to establish. This link will be facilitated if the foraging patterns of the targeted dove and parakeet colonies are known. Such information is most reliably obtained through studies of birds equipped with transmitters which allow biologists to know the exact locations of their study animals. Knowledge of which farms are damaged by doves or parakeets from specific colonies will enable researchers to monitor those farms and measure whether there is actual damage reduction as the contraception program is implemented at the target colonies. Lack of a one-to-one relationship between target colonies and farms means that damage reduction will be much more difficult to detect.

***Given current knowledge, the feasibility of using contraception for population management is greater with monk parakeets than with eared doves.***

## THE SCALE OF THE PROPOSED PROGRAM

Development and implementation of a contraceptive strategy for avian population management requires vision and commitment. An initial development phase (3-5 years) will be followed by several more years of implementation, monitoring, and evaluation. It makes little sense to invest in the program up front with research and initial field experimentation without continuing the support for as long as necessary to achieve the desired impact on the target avian populations. The appropriate duration of an avian contraceptive management program is not evident *a priori*. It will depend on funding availability, the specific objectives of the program, and the responses of the birds to the treatments.

It is important to keep the demographic, geographic, and temporal scale in mind as the various management options are considered. A contraceptive approach to avian population management implies a long term strategy impacting birds regionally, across a broad geographic scale:

Demographic:	Individual (feeding deterrent) -----	Population (contraception)
Geographic:	Local Scale (farm) -----	Large Scale (regional)
Temporal:	Short Term (days) -----	Long Term (years)

This is generally not an approach that can be directed specifically toward bird damage management at a given location or a method that is expected to provide short term relief from depredating birds. Damage at the farm level is more effectively addressed by one or a combination of the available methods that immediately affect the feeding behavior of individual birds on-site. Chemical repellents, visual scare devices, auditory deterrents and many other tools are used to provide immediate relief from the actual depredating flocks.

Because of the long-term nature of contraception management, it might require several years before it will be possible to document success (i.e., population reduction). This could produce feelings of failure or inadequacy on the part of the personnel carrying out the program as well as the producers for whom the program is designed to help. Expectations must be realistic. And intermediate measures of success should be built into the program so that incremental progress can be documented. Such intermediate performance measures could include quantifying nest contents to document reduced egg-laying or quantifying numbers of recently fledged young birds in the treatment areas.

***Contraception is a long-term management strategy that will require persistence and commitment to carry out successfully.***

## SIMULATION MODELING

Simulation modeling can provide insight into the long term responses of wildlife populations to management scenarios and perhaps lend some guidance to the duration of an avian contraception program. Pruett-Jones et al. (2007) devised a model which simulated growth of the monk parakeet population in the US. They constructed their model based on data from monk parakeet populations in Argentina. Then they imposed two management strategies to evaluate the separate effects of trapping/removal (= mortality) and nest destruction (= contraception) on the growth of the simulated population. Their analyses indicated that lethal control of 20% of the parakeets annually caused the simulated population to decline by approximately 80% over 10 years. Destruction of 50% of the nests each year, which can be regarded as equivalent to contraception, resulted in the simulated population declining by approximately 50% over 10 years (Pruett-Jones et al. 2007). The authors did not simulate the combined effects of lethal control and nest destruction, but there is no doubt that a management strategy which combines them would accelerate population decline. They conclude (Pruett-Jones et al. 2007, p.35) that "...control of monk parakeets will likely require an integrated approach including ... long-term population reduction through trapping or chemical sterilization."

It would be useful to apply simulation modeling to explore additional management scenarios involving contraception. In particular, a simulation model for eared dove population management would be valuable. Its life history pattern is very different from the monk parakeet, so results from the parakeet model are not directly applicable to the eared dove. Furthermore, it would be instructive to examine explicitly the combined impacts of lethal control and contraception in each of the target species.

***Simulation modeling could potentially provide useful insights into long-term population management through the application of contraception.***

## COSTS AND BENEFITS

Justification for a particular management program often resides in cost-effectiveness or a positive benefit-cost analysis. It is difficult to apply such a test to the proposed program because there is insufficient data to quantify benefits of population reduction and, by extension, reductions of crop damage. Estimating the benefits of applying any crop protection method requires information relating to the amount of damage inflicted to the crop by the target species, and the efficacy of the particular crop protection method in reducing the damage. There are limited data on the amount of crop damage caused by populations of eared doves and monk parakeets in Uruguay. In 2011, losses in soybean exceeded \$1 million on an area of about 100,000 ha, based on the amount that had to be resown due to eared dove damage to sprouts (MTO, unpubl. data). In another study on 14 fields (10 to 60 ha), damage to sprouting soybean ranged from 1.4 to 11.7% of the plants (E. Rodríguez, unpubl. data). Information on the efficacy



of the proposed avian contraception approach for reducing crop damage is non-existent. Without these data, cost-effectiveness cannot be determined at this time.

Costs associated with the proposed avian contraception program will include increased research infrastructure to carry out studies supporting application to eared doves. The remaining costs associated with the developmental stage principally comprise personnel and travel expenses. Enumeration of these costs requires more knowledge of Uruguayan cost structure than I possess.

The cost and availability of diazacon, the proposed contraceptive agent, must also be considered. The costs (in US dollars) for diazacon bait used in field trials conducted during 2006-2007 in south Florida for monk parakeet management were:

site	nests	bait eaten	diazacon				sunflower		total cost	
			g/site	rate (g/g)	g/site	\$/kg	\$/site	\$/kg	\$/site	\$/site
1	21	6630	0.0005	3.32	5000	16.6	5	33.15	49.75	2.37
2	13	4030	0.0005	2.02	5000	10.1	5	20.15	30.25	2.33
3	20	4740	0.0005	2.37	5000	11.85	5	23.7	35.55	1.78
4	27	5720	0.0005	2.86	5000	14.3	5	28.6	42.9	1.59
5	17	3450	0.0005	1.73	5000	8.65	5	17.25	25.9	1.52
6	37	5520	0.0005	2.76	5000	13.8	5	27.6	41.4	1.12
<b>MEAN</b>	<b>23</b>	<b>5020</b>	<b>0.0005</b>	<b>2.51</b>	<b>5000</b>	<b>12.55</b>	<b>5</b>	<b>25.1</b>	<b>37.65</b>	<b>1.64</b>

Thus, on average, treatment of six monk parakeet colonies (135 nests) with diazacon-treated sunflower bait cost \$1.64/nest. This cost does not include personnel or travel costs. The cost of the diazacon itself was \$5000/kg at that time. Currently, USDA/NWRC is negotiating with a Chinese supplier, and the eventual price is likely to be somewhat lower (J. Eisemann, NWRC, personal communication). We do not have similar estimates for eared dove applications. In the short term, obtaining diazacon-treated bait from USDA/NWRC at a negotiated cost would seem to be a viable option.

*At this time, we lack crucial information to evaluate the actual cost-effectiveness of contraception as a potential avian population management tool for crop protection in Uruguay.*

## PROGRAM ADMINISTRATION

The avian contraceptive management program currently under consideration is beyond the scope of local authorities to administer. Such an effort seems more appropriately funded and managed by an agency of the national government, possibly coordinated through the Ministry of Agriculture. This should help to assure financial stability and promote confidence in the administration and implementation of the program. Important partners in a wildlife contraceptive program will include the National Agriculture Research Institute, commodity groups such as MTO, farmer groups, academia, and conservation organizations. A public outreach campaign will inform residents about the objectives and goals of program to minimize the chances of misinformation.

It should be expected that proposing a large scale avian contraceptive program will generate skepticism, and possibly active opposition. Objections will be raised on scientific grounds, which make it imperative that a sound, defensible experimental protocol be developed, reviewed, and carried out, with no shortcuts taken. As the program is implemented, it will likely be scrutinized by the public, by the press, and by the scientific community. This scrutiny should be anticipated, and appropriate pro-active measures should be available to explain and support the rationale of the avian contraception management program.

***Coordination and administration of the proposed avian contraception program should be at the national level, and its implementation should proceed on a sound scientific basis.***

## HISTORICAL VIEW

In 1991, eminent British ornithologist Dr. Chris Feare stated unequivocally that development of contraception as a method for population management of bird pests in Uruguay and Argentina would be an unwise use of time and resources (Feare 1991). He raised several pertinent arguments against the feasibility of a contraceptive approach. With the benefit of present-day knowledge and based on my personal experience working in this subject area, I reach different conclusions. My responses Dr. Feare's objections to the use contraception (underlined) are:

Contraception is not selective- The contraception baiting strategy will include measuring bait consumption and numbers of birds daily so that the amount of bait deployed can be adjusted to the number of birds at the bait site. The birds will also be conditioned to expect the bait at certain time of day which will help ensure that leftover bait is minimal. Non-target exposure will never be eliminated, but an appropriate bait delivery strategy can reduce exposure. Non-target animals that consume the contraceptive bait will not be killed; at worse, they will be unable to reproduce during that breeding season.

One dose is not sufficient – This is true; diazacon treatment requires several days of exposure, but this is not a problem. The birds will be conditioned to feed at the bait site daily and will consume the necessary dose over a period of 10 days. Thereafter, the birds will be unable to reproduce for the year.

Damage to specific farms cannot be traced directly to colonies given the contraceptive - This could be true, particularly for eared doves which apparently have a wide daily foraging range. It might be necessary to conduct telemetry studies to identify specific farms damaged by birds from a given colony. For monk parakeets this is not as much of a problem because they are more sedentary and their feeding locations are likely more readily identifiable.

Not enough adults will be treated for contraception to have an effect - This is simply a matter of effort. The contraceptive approach is a long-term strategy. Given time and sufficient geographic scope, target bird populations will be reduced, and crop damage will decrease as a result. This pre-supposes existence of a centrally controlled, coordinated baiting effort that will assure appropriate coverage.

***Development and implementation of a contraception management approach to avian population reduction include inherent uncertainties, but such issues can be successfully addressed.***

## PROPOSED RESEARCH PLAN

This analysis concerns two bird species which cause serious damage to crops in Uruguay. Although the monk parakeet and the eared dove cause similar problems, their behavior and ecology are very different. Therefore it seems reasonable to treat them separately with regard to the feasibility of using contraception as a population management tool.

**Monk Parakeet.** To some extent, the monk parakeet is already being managed in Uruguay through the application of toxic grease in the nesting colonies. For example, from late 2012 through 2013, approximately 12,000 nests received toxic grease treatment within the Departments of Canelones, Colonia, San Jose, Flores, and Durazno, a combined area of 32,000 km<sup>2</sup> (S. Contarín, Uruguay Ministry of Agriculture, unpubl. data). It is not clear how much crop damage is prevented by the use of this lethal control program.

In the US, the monk parakeet has been the subject of a multi-year research effort to develop and implement diazacon as a practical oral contraceptive to use as part of an overall parakeet management strategy (Yoder et al. 2007, Avery et al. 2008b). Analyses of monk parakeets in the US demonstrated that their biology in the US is the same as that in the native range of South America (Avery et al. 2012). Thus, findings from research performed on parakeets in

the US should be directly applicable to parakeets in Uruguay. This is important because considerable resources and effort have already been expended on contraceptive development in the US; this effort will not have to be duplicated for application to monk parakeets in Uruguay.

Personnel in Uruguay can use the information already developed in the US on contraceptive baits, dosage levels, and application strategies to initiate field trials. The principal question to answer is whether parakeets can be attracted to bait stations. This proved to be possible in the US, but it has to be demonstrated in the Uruguayan field situation, and the baiting strategy perhaps modified as needed. The basic procedure was outlined in the First Report, but is presented here for convenience:

Monk Parakeet – field trials to verify bait acceptance and efficacy.

1. Select 6 nesting colonies to be study sites; record numbers of active nests and parakeets at each site.
2. Before the breeding season, establish bait stations at each site.
3. Monitor the bait stations with motion-activated cameras to estimate visitations by parakeets and use by nontarget species; measure bait consumption.
4. Apply contraceptive-treated bait, continue to measure bird activity and bait consumption for 10 days.
5. After the breeding season, determine the number of parakeets and number of active nests at each site, and compare this to initial conditions.
6. Repeat for year two and three. Expand to other sites if possible.

These initial field trials should be carried out for at least 3 years so that the long-term effects of the treatment on the test colonies can be detected and quantified. If possible, it would be informative to include three colonies where lethal control is currently used for comparison to the contraception sites. The lethal control sites would be monitored for active nests and numbers of parakeets in the same manner as the sites receiving contraceptive bait. To carry out the proposed field trials, research personnel dedicated to the project will be required: one research biologist to oversee and coordinate the research; and three field teams (one team per treatment site), each composed of an experienced technician and a trainee.

**Eared Dove.** There is currently no official effort to manage or reduce the eared dove population in Uruguay. And there is no existing information on the critical aspects of contraceptive use as it relates to eared doves. This means that considerable development effort will be necessary to quantify physiological and behavioral responses of eared doves to diazacon and to diazacon-treated bait. There will be a need for a series of trials using captive birds, followed by field trials in selected sites. The proposed 5-year development plan is outlined here, based on information contained in the First Report:

Eared Doves – acquire basic information on physiological effects, bait acceptance, and efficacy in pen and field trials

Years 1 and 2

1. Construct aviary large enough to hold 30 testing cages.
2. Trap and maintain doves in captivity in pairs.
3. Conduct food preference and food consumption trials.
4. Evaluate effectiveness of diazacon as a contraceptive using the monk parakeet dose rate and exposure period as models.
5. Compare productivity (number of eggs, number of chicks) of treated pairs and untreated pairs in the cages.

Year 2

6. Map the locations of eared dove colonies.
7. Conduct flight pen study of feeding activity of doves in small flocks (20-25) to estimate bait consumption (three replicates).

Years 3, 4, and 5

8. Locate roost/nest colonies, select three for treatment and three as untreated control sites; establish bait plots near the colonies.
9. Present untreated bait and monitor with cameras to quantify eared dove visitation rates and presence of non-target species on bait plots. By using bait plots near the target colonies, we increase the chances that birds visiting the bait plot are from the target colony. We will attempt to follow flight lines to confirm that there is a connection between the bait site and the colony.
10. When dove use of bait plots is satisfactory, offer treated bait at three sites for 10 days.
11. For each roost/nest colony, quantify number of eggs per nest in colony and/or the ratio between juveniles and adults trapped on the bait plot to determine efficacy.

There are many points along the proposed development process where progress could be interrupted or halted. For example, the candidate compound, diazacon, might be highly toxic to doves, or the doves might not eat the diazacon-treated bait. If the contraceptive trials with captive doves proceed well, then the crucial test will be to identify roosting/nesting colonies for treatment and to demonstrate that birds from these sites can be attracted to bait plots established nearby. Moreover, the timing of treatment will be crucial because the birds must be exposed to the contraceptive prior to ovulation to ensure reproduction is prevented.

To carry out the proposed project, a research biologist is needed to oversee and coordinate activities. The trials with captive birds will require an experienced technician and a trainee. For field trials, there will be a field crew for each study site; each crew will have an experienced technician or biologist as team leader, with 2 or 3 technicians to assist.

The lack of previous contraception research with eared doves increases the uncertainty of this management approach for this species. There is no way to know for sure if the technique will be effective without conducting the necessary stepwise research as prescribed.

*Appropriate multi-year commitments of resources and personnel are essential. Field research of contraceptive application for monk parakeets can be initiated relatively soon because the basic research has already been performed in the US. For eared doves, the development process will take longer as additional information must first be obtained in a series cage and pen trials using captive birds before field applications can proceed.*

## RECOMMENDATIONS

### General recommendations:

- Commit to a 5-year research plan to develop avian contraceptive methods.
- Select diazacon as the contraceptive chemical of choice.
- Arrange with USDA/NWRC to provide diazacon-treated bait for testing.
- Develop simulation models for eared dove and monk parakeet to evaluate population management options and goals.
- Consider a collaborative project with Argentina on eared dove ecology and management to complement the contraception research.

### Specific recommendations for Monk Parakeet contraception research:

- Increase personnel to meet increased research workload.
- Proceed with field trials for 3 years to verify bait acceptance and document efficacy.
- Aggressively implement large scale operational program if field trials prove successful. Train and add personnel proportionally to operational needs.

### Specific recommendations for Eared Dove contraception research:

- Invest in infrastructure (cages, lab space, flight pen), equipment, and personnel to conduct research for contraceptive development.
- Conduct cage and flight pen trials with captive birds to determine parameters for successful contraception in eared doves.
- Select appropriate test sites and apply contraception bait in field situations to document field efficacy.

## ACKNOWLEDGMENTS

This project was supported through APHIS Agreement 14-7412-1012-RA between USDA/National Wildlife Research Center (NWRC) and the Uruguayan Oil Seed Board (Mesa Tecnológica de Oleaginosos; MTO). I am particularly grateful to Ing. Agr. Roberto Verdera, Ing. Agr. MSc. Enrique Fernández, and Ing. Agr. MSc. Sergio Ceretta for their hospitality and insights into the problems of bird damage to crops in Uruguay. Mrs. Carolina Balestra (MTO) and Stephanie Kozar (NWRC) provided administrative support throughout the project. I am especially indebted to Dr. Ethel Rodríguez (MGAP) for her advice and encouragement at every stage of this project, and for sharing her wealth of knowledge on the management of Uruguayan bird problems. Lourdes Olivera and Guillermo Tellechea, members of Dr. Rodríguez's staff, graciously provided technical and logistical support.

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## Appendix A. Review of Contraception as an Avian Crop Damage Management Tool

Prepared by  
Michael L. Avery, PhD  
U.S. Department of Agriculture  
National Wildlife Research Center

### **1.0 Introduction**

Wildlife managers often seek to reduce problem wildlife populations. Reasons for this include crop damage reduction, endangered species protection, control of zoonotic disease, and human safety. Population reduction requires that losses, through mortality and emigration, exceed recruitment, through reproduction and immigration. Contraception impacts this equation by lowering the recruitment rate. The degree to which the recruitment rate is lowered will determine the effectiveness of contraception as a population reduction tool.

The interest in potential applications of contraception to wildlife species has increased greatly in recent years as managers seek new tools for addressing problems caused by over-abundant wildlife populations (Fagerstone et al. 2006). The interest has spurred research into effectiveness of various infertility compounds and methods on individual animals (Fagerstone et al. 2010). Most of the research emphasis has been directed toward mammalian species, such as deer and horses (e.g., Kirkpatrick et al. 1990, Killian et al. 2004, Killian et al. 2006). Many of the mammalian infertility treatments entail injection of the contraceptive into individual animals. Furthermore, there has been very little long-term evaluation of the population-level response to these treatments. Consequently, the majority of the wildlife contraception research to date does not directly apply to the problems of pest bird management. There is an obvious need for research that (1) addresses specific pest bird species of interest, (2) is oriented toward field studies, (3) assesses population-level effects, and (4) adopts a long-term management perspective.

This review focuses on fertility control in birds, for which there is considerably less information than for mammals (Bomford 1990, Fagerstone et al. 2010). First, the advantages and disadvantages of fertility control for wildlife management are briefly presented. Then the various factors that affect the decision on whether or not to apply contraception are discussed. Finally, the biological factors important to effective use of contraception for wildlife population management are addressed and considered in context of potential for use in Uruguay.

### **2.0 Positive aspects of contraception for wildlife management**

**2.1 Public acceptance.** Contraception can be viewed as an alternative to lethal control for possible reduction of wildlife populations which have grown too large. Lethal control of wildlife is often controversial, even when it is conducted according to humane guidelines. Increasingly,

there is desire by the public for alternatives to traditional lethal control options. Contraception is a non-lethal approach that has broad (but not universal) support with the general public, and among conservation and animal rights organizations. Public perception seems to favor prevention of births rather than increased mortality for management of over-abundant wildlife populations.

2.2 Safer than toxicants. Contraceptives are designed to prevent reproduction, not to kill the target animal. It is inevitable that some non-targets will be exposed to the contraceptive treatment despite careful planning and testing of baiting practices. The worst outcome from such events, however, will be temporary contraception, not mortality. The risk to non-target animals is loss of a breeding opportunity, not death. Thus, the safety margin for a contraceptive is greater than for a toxicant when it comes to non-target hazards.

2.3 Flexibility of use. Contraceptive dose and delivery can be designed for species-specific applications. The timing of use, type of bait, placement of bait, and other important factors are all subject to manipulation by the user. Because of the increased safety margin compared to toxicants, contraceptives can potentially be applied in a broader range of management situations. Specific requirements will vary from case to case, but the options for using infertility agents to manage wildlife populations are greater than for lethal control.

### **3.0 Potential problems of contraception for wildlife management**

3.1 Population response time lag. An infertility treatment produces effects that will be manifested in the future. The affected animal still exists in the population. It will continue to eat or damage resources. Presumably it will live its normal lifespan. The true effect of the treatment only occurs when the animal attempts to reproduce. The affected animal is rendered incapable of contributing offspring to the population. Cumulative effects on many animals across years produce a slowly declining population because recruitment no longer keeps pace with mortality. The lag time from treatment to effect will depend on the proportion of affected animals in the population and the rate of immigration of new animals into the population. The lack of immediate population decline or reduced crop damage might prejudice farmers against the use of contraceptive methods.

3.2 Availability of compounds. The number of potentially useful oral contraceptive drugs is limited. In the USA, the only avian contraceptive currently registered for use by the USEPA is nicarbazin, which is sold under the trade names OvoControl G® for geese and OvoControl P® for pigeons. Diazacon is under development as a contraceptive for monk parakeet population management, but registration with the USEPA has not yet been accomplished.

3.3 Target specificity. The oral antifertility compounds that have been tested and found effective are not species-specific. Any animal that ingests sufficient amounts of the drug will be

affected. Thus, for efficient use against target animals and for reduction of non-target impacts, the contraceptive delivery system must be crafted carefully to exploit unique aspects of the behavior of the target species (Yoder and Miller 2006).

3.4 Density-dependence. The dynamics of wildlife populations are complicated. Many aspects of population biology can be density-dependent. This means that as the number of animals decreases, through whatever means, there are compensatory changes in factors such as territoriality, survival, and reproduction (Ransom et al. 2014). In the context of contraception, as numbers of offspring produced by treated animals are reduced, greater opportunities are created for untreated animals to have larger broods and for those offspring to obtain more resources, increasing chances of survival. Some studies of relatively small, closed wildlife populations have documented population reduction through fertility control (e.g., Rutberg and Naugle 2008), but empirical studies of free-ranging wildlife are needed to evaluate fully the long-term population-level impacts of contraception.

3.5 Lack of a track record. Virtually no study has demonstrated that fertility control can resolve population-level problems caused by wildlife species. Research on wildlife contraceptives has focused successfully on identifying and testing efficacy of compounds at the individual level. However, the true value of a contraceptive management approach is judged by the impact that it would have on the population, and by extension, on the damage that the population causes. Modeling can provide valuable insights into population-level impacts (e.g., Dolbeer 1998), but empirical verification is essential. Otherwise, acceptance of fertility control as a viable wildlife management option will be difficult to achieve among professional managers.

#### 4.0 **Factors of Importance When Considering Contraception**

It is important to state clearly what the contraceptive program is expected to accomplish.

Objectives of the project might include one or more of the following:

- Reduce or slow the growth of pest population
- Reduce crop damage caused by pest population
- Reduce costs of animal damage control
- Apply humane, socially acceptable methods

In most cases, reducing the growth of the pest population is not the ultimate objective, but it is usually a means to an end. Agricultural applications are concerned with reducing the amount of damage. This is often linked to population reduction, but not necessarily. Regardless of how the objectives are framed, achieving one or more of the objectives will depend on a number of factors, including the following.

4.1 Availability of suitable compounds. The options for avian contraceptive compounds are very limited. Fagerstone et al. (2010) list only three possible chemicals for consideration.

4.1.1 **Conjugated linoleic acid (CLA)** has been shown to increase live weight gain and to improve feed efficiency in rats, mice and chickens (Chin et al. 1994, Park et al. 1997). It is a common additive in poultry feed, and there is increasing evidence of its health benefits to humans (Pariza 2004). CLA has also been evaluated as an avian infertility agent (Cook et al. 1996). The effects of CLA are specific to birds, and the effects are not permanent in individual breeders. CLA induces mortality of embryos in fertile bird eggs by altering the fatty acid composition of the egg yolk (Aydin et al. 2001). Aydin and Cook (2006) report that CLA increased embryonic mortality in pigeon eggs up to 100% after breeding birds fed 10 weeks on feed treated with 0.5% CLA. Diets containing 3% CLA produced 100% embryonic mortality in fertile eggs of *Coturnix coturnix japonica* after 6 days of exposure (Aydin and Cook 2004). There has been no definitive field evaluation of this compound, and it is not clear what the optimum exposure period or dietary CLA concentration should be to achieve embryonic mortality in other avian species.

4.1.2 **Diazacon** has a chemical structure similar to cholesterol (Miller and Fagerstone 2000). It inhibits formation of pregnenolone, the parent compound of steroid hormones, preventing synthesis of testosterone and progesterone which are essential for reproduction. The effects of diazacon are not permanent, but it does persist in the body and its effects can last several months. Diazacon was registered with the USEPA in the late 1960s as Ornitrol®, an oral contraceptive for rock pigeons (*Columba livia*). Diazacon was effective in reducing egg laying and egg hatchability in pigeons (Woulfe 1968), but the pigeon is a year-round breeder and long-term use of the compound is expensive and might have undesirable health effects (Lofts et al. 1968). The registration was cancelled in 1993.

Interest in diazacon has surfaced in recent years as a possible means to control the growth of monk parakeet (*Myiopsitta monachus*) populations in the US, where these birds nest on electrical utility structures and cause power outages (Avery et al. 2006). In preliminary trials, diazacon was effective in reducing egg laying, egg fertility and egg hatchability for 2–4 months in coturnix quail (*Coturnix coturnix*) after feeding on it for 10–14 days (Yoder et al. 2004). Diazacon affected both sexes, producing testosterone decline in males and progesterone decline in females (Yoder et al. 2004). In other trials with captive monk parakeets, diazacon treatments for 10 days suppressed reproduction for the entire breeding season (Yoder et al. 2007). Treated birds exhibited no side effects. In a follow-up field trial in south Florida, productivity of monk parakeets exposed to diazacon-treated bait was reduced 60% compared to parakeets not exposed to diazacon (Avery et al 2008b). Diazacon appears to pose no hazard to predators that might consume parakeets treated with the chemical (Yoder 2011). Despite the apparent

effectiveness and safety of diazacon as a contraceptive for monk parakeets, it currently is not registered with the USEPA.

4.1.3 **Nicarbazin (NCZ)** is approved by the US Food and Drug Administration for control of coccidiosis in broiler chickens. NCZ also causes reduction in hatchability and egg-laying by increasing permeability of the membrane between the egg white and egg yolk, thereby preventing development of the embryo (Jones et al. 1990). Ideally, the female bird lays eggs and incubates them, but the eggs never hatch. Advantages of nicarbazin are that it is specific to egg layers, it is cleared from the body within approximately 48 h, and the infertility effect is reversible. A disadvantage of the compound is that it has to be fed daily prior to and during egg laying. Otherwise, the NCZ titer in the blood will fall below its effective level. Nicarbazin was tested by the National Wildlife Research Center (NWRC) and subsequently registered with the USEPA by Innolytics LLC as a reproductive inhibitor (OvoControl®) for management of Canada goose (*Branta canadensis*) and rock pigeon populations (Bynum et al. 2005, Avery et al. 2008a). Field studies show that use of OvoControl G immediately prior to and during the breeding season can reduce numbers and hatchability of eggs laid by Canada geese, thereby reducing recruitment of goslings into resident populations (Bynum et al. 2007). Controlled field evaluations of OvoControl P have not been conducted, but anecdotal reports indicate successful reductions of urban rock pigeon populations in many locations in the US.

Interfering with egg laying or the hatchability of the egg can be used to reduce reproductive capacity in birds. Egg addling, including shaking or oiling the eggs in the nest, effectively reduces egg hatchability (Pochop et al. 1998). Egg oiling with corn oil is allowed by the USEPA and is used to reduce reproduction in Canada geese and gulls (*Larus* sp.). However, this method is labor intensive and probably useful only in small areas.

4.2 Delivery system. There are two important components of an effective contraceptive delivery system. First, delivery to the target species must be emphasized. Second, the delivery system should be designed to minimize exposure of non-target animals to the contraceptive.

4.2.1 Contraceptives for free-ranging bird populations are most effectively delivered orally, via food or water. Prior to operational use, the appropriate dose levels and bait formulations need to be developed. Testing of candidate doses and formulations on captive birds will be necessary, especially as new target species are identified.

Appropriate facilities must be available for housing, maintaining, and testing the species of interest. Caging requirements, both for maintaining the animals and for testing the animals, will vary depending upon the species' behavior and natural history. In addition, access to analytical chemistry resources will be important so that the nominal treatment

levels applied to bait can be verified, and so that chemical residues in tissues of the treated animals can be determined.

Bait acceptance is sometimes a problem, which will interfere with effective bait delivery. Prior to field application, testing of candidate bait matrices should occur so that rejection of the bait can be avoided. Cage or pen testing of target species should approximate as closely as possible the actual conditions in the field. For example, if the target species normally feeds in flocks, then pen testing should involve groups of birds, not individuals. If the target species normally feeds on the ground, then the bait formulation and the pen trial evaluations should reflect the ground-feeding behavior.

4.2.2 In addition to effective contraceptive delivery to the target species, potential impacts to non-target animals should be incorporated into development of the delivery system. Selection of the bait type and presentation of the bait (e.g., on the ground or elevated) should take into account the habits and preferences of likely non-target animals, to the extent possible. Preliminary testing in the field is recommended to document the identity and frequency of non-target animals accessing the proposed bait site and consuming the bait. Monitoring of bait sites during this pre-baiting phase is best accomplished with motion-activated cameras for accurate documentation of animal behavior. Pre-baiting can last several days, or until there is reliable visitation by large numbers of target animals. The bait site might have to be moved to an alternate location if evidence from the pre-baiting period shows insufficient interest by the target species, or if too many non-target animals are regularly attracted to the site.

Species-specificity can sometimes be achieved by exploiting unique behaviors of the target animals. For example, to deliver diazacon-treated bait to monk parakeets, we designed a feeder that takes advantage of the parakeet's acrobatic climbing ability. In this design, a wire cage surrounds the bait tray and discourages other species. But parakeets are not dissuaded. They are able to climb around the barrier and readily access the bait tray.

#### 4.3 Rapid and Durable Treatment

There is currently no compound under development or consideration that would produce lifetime infertility for a pest bird species. In cage trials, diazacon produces infertility for a breeding season in monk parakeets. Thus, its use in any field application would necessitate annual exposure prior to the breeding season, early enough to prevent ovulation and fertilization. The contraceptive benefits of nicarbazin do not persist because the compound is cleared from the bird's body within approximately 48 hours. So, unless the animal is exposed almost daily to the chemical, the amount of nicarbazin retained is not sufficient to interfere with reproduction.

#### 4.4 Non-target Impacts

As with a toxicant or any chemical applied to control pest species, the use of contraceptives should avoid impacting non-target animals. A major advantage of nicarbazin is its safety. This compound is used extensively in poultry feed for control of coccidiosis. There is no record of human health issues associated with this use. Nicarbazin has been determined safe for mammals and for target and non-target bird species (Bynum et al. 2005). The risk of non-target impacts from the use of nicarbazin as a wildlife contraceptive seems remote. Diazacon is somewhat more problematic in that health effects have been noted in animals exposed for extended periods to the compound (Yoder et al. 2004). But in open feeding situations, captive and free-flying monk parakeets consumed contraceptive doses of diazacon-treated bait, but they did not ingest harmful amounts (Yoder et al. 2007, Avery et al. 2008b).

#### 4.5 Cost-effectiveness

Determining the cost and benefit of a management program based on contraception will require a long-term viewpoint. The results of such a management approach will not be immediately obvious. Use of contraceptives requires a commitment to treatment and monitoring that is measured in years, not days, weeks, or months. Furthermore, cost effectiveness will depend upon the amount and the value of the resource that is protected. The value of the crop saved from damage because of the contraceptive treatment must exceed the costs of application. This presumes that methods are available to detect and measure damage caused by the target species. Even if the contraception technology is already available, the costs of applying and implementing the program might be great. Such determinations will have to be made case-by-case in consideration of the objectives of the management program.

#### 4.6 Safety

Trials with target species to establish appropriate dosages need to be conducted to minimize the risk of birds receiving a toxic dose. In addition to being safe for target animals, contraceptives should not have adverse effects on non-target animals. Use of oral bait delivery systems offers a way to treat larger, free-roaming populations at lower cost, but there is increased risk of unintentional exposure of non-target species to the treatment. Nicarbazin has been used by the poultry industry in numerous countries for many years. It has no effects in mammal species and is safe for both target and non-target bird species, even at higher doses than needed to cause the contraceptive effect (Bynum et al. 2005). Diazacon, as a cholesterol inhibitor, could cause health effects in either target or non-target species if fed for extended periods (Yoder et al. 2004). In open feeding trials with captive and free-ranging monk parakeets, no adverse effects have been noted using diazacon-treated baits (Yoder et al. 2007, Avery et al. 2008b).

### **5.0 Importance of Avian Biology**

The reproductive biology of the target species is an important factor in development and application of reproductive inhibitors to manage populations of free-ranging wildlife. Population reduction via fertility control is most feasible for species that breed at an early age,



produce numerous offspring annually, provide limited amount of parental care, and have short life spans (Fagerstone et al. 2006, MacDonald and Wolf 2013). In general, this means that reproductive control will be most effective in managing species such as rodents or bird species with high reproductive rates and low survival. Reproductive control will typically be less efficient than lethal control in managing populations of larger species such as raptors, vultures, and geese that typically have small clutch sizes and begin to reproduce when 2–4 years old. Dolbeer (1998) used population models to compare the relative efficiency (i.e. percentage decline in population size relative to number of animals sterilized or removed) of reproductive control and lethal control in managing wildlife populations. He concluded that for animals that first breed at three years of age, lethal control will always be more efficient than contraception for reducing populations, regardless of the adult survival rate (Dolbeer 1998). In general, this means that contraception will be most effective in managing species with high reproductive rates and low survival rates. For example, theoretical models predict that if 70% of rats can be sterilized for three generations (one year), the population will be almost eliminated, whereas a similar effort using lethal control allows the population to rebound to its original size (Knippling and McGuire 1972).

The monk parakeet and eared dove (*Zenaida auriculata*) are the avian crop pest species of principal interest in Uruguay. These species differ somewhat in their natural history and behavior. Key aspects of eared dove biology appear to be uncertain, but comparisons using data from the mourning dove (*Zenaida macroura*), a closely related North American species, might be appropriate (Table 1). Compared to monk parakeets, the doves are characterized by high productivity, early age of first breeding, short lifespan, and low annual survival. Such attributes are characteristic of species for which contraception is most suited as a population management tool (e.g., Dolbeer 1998). Further investigation is needed to determine whether it is feasible to employ contraceptive strategies for successful management of a wide-ranging species prone to extreme population outbreaks, such as the eared dove (Bucher and Ranvaud 2006). The monk parakeet does not exhibit attributes as conducive to management with fertility control as the dove species (Table 1). Nevertheless, investigations of monk parakeet management at electric utility facilities in south Florida, USA demonstrated that nest productivity of parakeet populations were reduced by almost 60% with the contraceptive diazacon (Avery et al. 2008b). The challenge in Uruguay will be to adapt the contraceptive approach to agricultural environments. The overarching objective is to reduce crop damage, not just to reduce population size.

## **6.0 Contraception or Lethal Control?**

Wildlife population management plans must take advantage of as many tools or methods as possible. The integration of multiple lethal and non-lethal methods will usually produce more satisfactory results than reliance on a single management approach. Contraception and lethal control are not mutually exclusive, but in fact should be considered complementary. Both

approaches have a role in population management of problem species, but they are most effective when used in concert. Fertility control might be best used as a means to stabilize population size or slow population recovery after conventional lethal methods, implemented by trained and licensed professionals, have reduced the population to a desired level. Such a program should be carefully planned, and would preferably be developed in consultation with appropriate wildlife, agricultural, environmental, and conservation agencies or departments. Public outreach is also critical so that there is clear understanding as to what is being done, why it is being done, and what the expected outcome will be.

Fertility control by itself is generally not an efficient means to reduce population size. As Kirkpatrick (2002) noted: “*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*”.

## **7.0 Summary**

Research on fertility control for wildlife population management has advanced considerably in recent years, and there is growing public interest and support for alternatives to lethal control of over-abundant pest species. In limited trials, conjugated linoleic acid has shown some potential for inducing embryonic mortality. At this stage, however, there is too little information available to recommend it as a realistic management option. The two compounds that are currently viable options for avian contraception are nicarbazin and diazacon. Each of these compounds has been researched and tested extensively, and nicarbazin is currently registered in the USA for management of goose and pigeon populations. Diazacon is not currently registered, but was at one time, and recent trials in south Florida have demonstrated its efficacy for fertility control in monk parakeets. It must be cautioned that contraception will likely not by itself be a solution to crop damage situations. Furthermore, agricultural producers might be unwilling to accept having to wait years before a population reduction occurs and crop damage abates. A more likely scenario for wildlife contraception is as part of an integrated management plan to maintain a pest population at an acceptably low level after it is reduced by trained professional experts using conventional methods. Implementation of such a management approach will require extensive knowledge of the target species (e.g., food preferences, movement patterns, reproductive biology) to develop efficacious means of delivery and to avoid adversely impacting non-target species. Cost-effectiveness will depend on the specific circumstances and objectives of each management situation.

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