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Foreword to the Special Issue on 'Fertility control for wildlife in the 21st century'

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ABSTRACT

The economic and environmental impacts of wildlife are increasing in parallel with renewed public interest in non-lethal methods, such as fertility control, to manage these impacts. The Wildlife Research 2008 Special Issue on Fertility Control for Wildlife (Vol. 35) published following the 6th International Conference on Fertility Control for Wildlife held in 2007 in York, United Kingdom, reported studies on the effects of contraceptives on individual animals and populations, with most papers focusing on ungulates. In the past 15 years, significant progress has been made in developing novel contraceptives for wildlife and in designing methods to deliver these agents. Concurrently, the general debate on wildlife management has widened to include public attitudes and perceptions of novel and traditional methods, animal welfare issues, costs, feasibility, and regulatory and ethical issues. These developments have broadened our understanding of contexts and species for which fertility control could be employed, either as a stand-alone method or to complement other population management options. These topics were reflected in the presentations given at the 9th International Conference on Wildlife Fertility Control, held in Colorado Springs (USA) in 2022. Here, we introduce a special issue featuring selected presentations from the 2022 conference. These studies showcase the wide spectrum of topics that covered novel contraceptives tested on several species, ranging from mice to elephants. They also illustrate new methods to deliver contraceptives, models on the impact of fertility control on populations, feasibility, cost of practical applications of fertility control, discussions on animal welfare and human dimension of these approaches.

Keywords: abundance, applied ecology, contraception, fertility control, population control, population management, reproduction, wildlife management.

Introduction

Most of the economic and environmental impacts of wildlife are due to populations of native and non-native invasive species exceeding their carrying capacity or their so-called social tolerance and thus being referred to as overabundant (Carpenter *et al.* 2000; Drijfhout *et al.* 2020). Examples of overabundant wildlife include wild equids in the United States, African elephants (*Loxodonta africana*), peri-urban marsupials in Australia, primates in Africa and Asia, wild pigs (*Sus scrofa*), deer, urban pigeons (*Columba livia*) and rodents worldwide (e.g. Massei *et al.* 2015*a*; Wimpenny *et al.* 2021; Massei and Boyles Griffin 2022; Ruscoe *et al.* 2022; Delsink *et al.* 2023). Traditional lethal approaches to mitigate human–wildlife conflicts are often not sufficient to reduce local wildlife numbers and their impacts, as shown by the fact that many overabundant species are expanding despite intense lethal control (Massei *et al.* 2015*a*; Valente *et al.* 2020). In parallel, public antipathy toward lethal methods, driven by animal welfare concerns, human safety, environmental impact of toxicants and shifts in public attitudes about wildlife, has fostered interest in the use of fertility control to manage locally overabundant wildlife (Asa and Moresco 2019; Jacoblinnert *et al.* 2022; Massei 2023).

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Collection: Fertility Control for Wildlife in the 21st Century

In 2008, Wildlife Research published a Special Issue on Fertility Control based on papers presented at the 6th International Conference on Fertility Control for Wildlife held in York (UK) in 2007 (Cowan and Hinds 2008). The Special Issue centred on research concerning the effects of contraceptives on individual animals and on populations, with most of the papers focusing on ungulates, such as white-tailed deer (*Odocoileus virginianus*), wild boar and free-roaming horses (*Equus caballus*).

In the past 15 years, significant progress has been made in the field of wildlife fertility control, showcased at the following three subsequent international conferences: the 7th International Conference on Wildlife Fertility Control in Jackson Hole (Wyoming, USA, 2012); the 8th in Washington, DC (USA, 2017); and the 9th in Colorado Springs (Colorado, USA, 2022). Interest in this area was also highlighted by the founding in 2016 of the Botstiber Institute for Wildlife Fertility Control (BIWFC), which is dedicated solely to advancing the use of reproductive management as part of an integrated approach to mitigate human–wildlife conflicts and promote coexistence worldwide through education, outreach, and engagement (https://wildlifefertilitycontrol.org/about-botstiber-institute-for-wildlife-fertility-control/, accessed 29 October 2023). Critically, the past decade saw the global public debate on wildlife management broadened to incorporate stakeholders' attitudes and perceptions of novel and traditional wildlife management methods, animal welfare issues, costs, feasibility, and regulatory and ethical issues. This debate, in turn, has generated a more comprehensive understanding of contexts and species for which fertility control could be employed, either as a stand-alone method or to complement other population management and site-specific conflict-resolution methods. These topics were reflected in the varied themes discussed during the 9th International Conference on Wildlife Fertility Control, organised by the BIWFC in Colorado Springs (USA) in 2022. Featuring studies selected from those presented at the conference, this special issue highlights the recent progress made in research on wildlife fertility control, including the growing spectrum of state-of-the-art developments in this area.

Wildlife fertility control: what has happened since 2008?

Despite being organised during the pandemic, which hindered travelling and attendance for researchers from several countries, the 2022 Colorado Spring Conference brought together 120 attendees from 14 countries, with a total of 40 oral presentations and 12 posters. The theme of the conference,' *Creating Connections*, was intended to lay the foundation for more effective and pervasive collaboration among all wildlife practitioners, including biologists, social scientists, wildlife managers, government agencies, non-governmental organisation (NGOs), policymakers, legislators, and others.

The main progress on wildlife fertility control in the past 15 years, highlighted in the three international conferences and in a plethora of publications, has occurred in the following areas: (1) registration of new drugs; (2) research on an increased range of wildlife and free-roaming domesticated animal and livestock species; (3) development of methods to deliver contraceptives; (4) development of theoretical models exploring the effects of fertility control on population size in different contexts and at different scales; and (5) human dimension aspects and stakeholder engagement.

Product registrations since 2008 include the following injectable immunocontraceptives: the porcine-zona pellucida (PZP)-based ZonaStat-H and ZonaStat-D, registered in the USA for use in wild equids and cervids respectively, and GonaCon-Equine, GonaCon-Deer and GonaCon-Prairie Dog, registered in the USA for use in white-tailed deer, wild equids, and prairie dogs (*Cynomys* spp.). A study presented at the conference on the use of the ZonaStat-D to manage an urban population of native Columbian black-tailed deer (*Odocoileus hemionus columbianus*) showed that treatment of 63% of the does decreased fawn abundance by 58% after 1 year (Hering *et al.* https://wildlifefertilitycontrol.org/wp-content/uploads/2022/05/ICWFC-2022-Program-Book.pdf, accessed 27 October 2022). The study concluded that immunocontraception, in tandem with methods to decrease deer access to supplemental urban food sources, shows promise for cost-effective non-lethal population control.

Studies on GonaCon presented at the conference focused on the use of this vaccine to manage populations of free-roaming cattle (*Bos taurus/Bos indicus*) in Hong Kong (Massei *et al.* 2015*b*, 2018; Pinkham *et al.* 2022, https://www.youtube.com/watch?v=d2BHEUJv4eA, accessed 27 October 2022) and on two pilot trials to test the effectiveness of this contraceptive on peri-urban wild boar in Spain (Lopez-Bejar *et al.* https://www.youtube.com/watch?v=25ugjuPDTIE, accessed 27 October 2022) and non-native hippopotamuses (*Hippopotamus amphibius*) in Colombia (Bruemmer *et al.* https://www.youtube.com/watch?v=trQWX0Wfkos, accessed 27 October 2022). The GonaCon study (Shiels *et al.* 2024) included in this Special Issue was conducted on black-tailed prairie dogs (*C. ludovicianus*) in areas where this native keystone species is associated with zoonotic disease transmission and crop and property damage. These animals live in colonies in urban and suburban settings and their presence and persistence in these landscapes is welcomed by conservationists and citizens that often oppose the use of lethal population control methods to mitigate the impacts of prairie dogs. The study showed that treatment with GonaCon induced infertility that lasted 1 year, with a juvenile density of prairie dogs three times higher in control than in GonaCon-treated sites 1 year after treatment. Two years later the juvenile density did not differ between control and GonaCon-treated sites, and the study concluded

that this approach could be considered to treat whole colonies of prairie dogs in areas where lethal control is unacceptable.

Three more products have been registered since 2008, including two oral contraceptives for rodents, ContraPest® and EP-1, and a new formulation of nicarbazin for pigeons. Applications of these products have been reported in several publications (reviewed in Jacoblinnert *et al.* 2022 and in Massei *et al.* 2023) and discussed in three conference presentations, one focussed on rodent contraceptives (Belmain https://www.youtube.com/watch?v=8o8jWIHgq_g, accessed 27 October 2022), and two on nicarbazin-based contraceptives for pigeons (Pellizzari https://www.youtube.com/watch?v=OsoRDQh6oxg, and Wolf https://www.youtube.com/watch?v=MRdLkJ_UagQ, accessed 27 October 2022). ContraPest®, which is based on a combination of two active ingredients, 4-vinylcyclohexene diepoxide and triptolide (Witmer and Raymond-Whish 2021), was registered in the USA for black rats (*Rattus rattus*) and Norway rats (*Rattus norvegicus*). EP-1, which is a combination of two synthetic hormones, levonorgestrel and quinestrol, was registered in Tanzania for multimammate mice (*Mastomys natalensis*) and has been shown to inhibit fertility in many rodent species in China, Tanzania, Zambia, Ethiopia and Indonesia in either or both captive and field trials (reviewed in Jacoblinnert *et al.* 2022 and in Massei *et al.* 2023). A new formulation of nicarbazin, which is the active ingredient of an oral contraceptive for pigeons already commercially available in Italy as a veterinary medicine (Ovistop®) and in the USA as a biocide (Ovocontrol®), was registered in Belgium under the name of R-12. The study by González-Crespo (2024) on the use of Ovistop® for urban pigeons, showcased in this Special Issue, demonstrated that this contraceptive causes a significant steady decrease in local pigeon abundance over 8 years. Most crucially, the study estimated the cost of this treatment and investigated the potential uptake of Ovistop® by non-target bird species, concluding that intake by non-target birds was negligible and that in two thirds of the municipalities the initial cost of using this contraceptive was halved after 3 years of treatment.

The past 15 years have also seen the development of novel methods to deliver oral contraceptives to wildlife. These delivery methods are crucial to ensure that only target species access the contraceptive-treated bait as many fertility control inhibitors have the potential to affect multiple species. For instance, the boar-operated system (BOS) has been proven effective in the UK and in the USA to deliver baits to wild boar only (Massei *et al.* 2010; Campbell *et al.* 2011) and selective feeders have been designed to deliver contraceptives to invasive non-native monk parakeets (*Myiopsitta monachus*) (Anderson *et al.* 2023) and grey squirrels (*Sciurus carolinensis*) (Beatham *et al.* 2021). Similarly, ContraPest® is delivered as a liquid in a tray placed inside a box; this approach has the dual function of minimising uptake by non-target species and avoiding that rats move the bait outside the feeder.

As more oral contraceptives become available for wildlife applications, understanding factors that affect patterns of individual and population bait uptake is essential to maximise consumption of these agents by the target species. The study by Beatham *et al.* (2024), featured in this Special Issue, showed that season, feeder density and grey squirrel density are important factors affecting bait uptake, with more squirrels consuming bait from three feeders per hectare than from one per hectare, and with a higher proportion of animals feeding on bait in summer than in winter.

Assessing contraceptive efficacy and costs of their delivery is another crucial aspect of practical applications of fertility control. The study by Coulson and Wilson (2024), included in this Special Issue, focused on evaluating capture efficacy, contraceptive efficacy and population-level outcomes of a subdermal levonorgestrel implant on two peri-urban populations of eastern grey kangaroos (*Macropus giganteus*). Delivery efficiency, expressed as number of kangaroos caught-per-unit effort, was greater from a vehicle than on foot. Treatment efficacy was high, inducing infertility in 86–100% of the females treated. In one population, fertility control held population density at a moderate level for 3 years, but for the second population, located on a larger, open site, the authors concluded that culling might be required to complement fertility control. Two additional presentations introduced studies focused on remote delivery of contraceptives for equids via darts (Hart, https://www.youtube.com/watch?v=lMl2_hNjJxM, accessed 27 October 2023) and on devices designed to deliver oral contraceptives to primates (Hill https://www.youtube.com/watch?v=DjMkpkUIRyM, accessed 27 October 2023).

Animal welfare aspects of fertility control are also an area of research that has expanded, with some stakeholders querying the physiological and behavioural welfare effects of this approach (Hampton *et al* 2015; Asa and Moresco 2019; Massei 2023). One session of the conference was dedicated to the potential effects of contraceptives on animal welfare, with talks on optimising population density for wild animal welfare and on measuring the welfare impact of fertility control (Hecht, https://www.youtube.com/watch?v=iVwPV6eKY6A; Browning https://www.youtube.com/watch?v=KnzzlQOMy0k; accessed 29 October 2023).

From a theoretical perspective, the past decade saw significant development in software and modelling tools, which allowed the evaluation of the impacts of fertility control, alone or in conjunction with other methods, on population size. For instance, adding fertility control to culling was predicted to reduce wild pig abundance substantially more than was culling alone, particularly in areas open to immigration (Pepin *et al.* 2017). Similarly, a model comparing the effectiveness of fertility control and culling to reduce grey squirrels suggested that, when applied to low-density populations after short-term culling, population reduction using contraceptives could be achieved within the same timescale as that from continuous culling alone, but with a

substantially lower cost (Croft *et al.* 2021). Building on these results, another paper featured in this issue (Croft and Massei 2024) modelled the effects of coordinating landscape-scale control of grey squirrels by accounting for the potential of landowners' different attitudes to population control. The results suggested that with complete coordinated control, culling was generally faster and more cost-effective than was contraception. However, when differences in public acceptance of methods were considered, reducing the spatial coverage of population management, contraception appeared to maintain greater population reductions than did lethal control.

Presentations at the 2022 conference highlighted significant changes in policy and public acceptance of fertility control for some iconic species such as African elephants. The paper by Delsink *et al.* (2024) illustrated how fertility control has gained support as a legitimate method for managing populations of elephants in reserves in South Africa. These findings were echoed in other presentations on wild equids in the USA (Boyles Griffin https://www.youtube.com/watch?v=lCjGYhgOi44, accessed 27 October 2023) and on hippopotamuses in Colombia (Bruemmer https://www.youtube.com/watch?v=trQWX0Wfkos, and Clifford https://www.youtube.com/watch?v=D-BOyi1qXMw, accessed 27 October 2023).

Looking ahead

Work on wildlife fertility control is underway in many studies around the world (Asa and Moresco 2019; Jacoblinnert *et al.* 2022; Massei *et al.* 2023). Novel oral contraceptives and formulations are being tested, practical obstacles of delivering these agents to adequate proportions of target species are being overcome with creative solutions, and large-scale trials are underway to test the feasibility and suitability of fertility control applications to mitigate human–wildlife conflicts, and to quantify the monetary and welfare costs of such actions.

Among the new lines of research, attention to gene drive-based contraceptives is growing, as highlighted in four talks presented at the 2022 conference on this approach (Piaggio, https://www.youtube.com/watch?v=mV90Bl-OSEY; Delborne, https://www.youtube.com/watch?v=zkILjpXKcWw; Hartley https://www.youtube.com/watch?v=wMfV4g_Q_0Q; Whitelaw, https://www.youtube.com/watch?v=7ULMluhGIYs accessed 28 October 2023). Gene drive-based contraceptives raise a number of ethical and ecological concerns in addition to those already expressed by some stakeholder groups on methods to manage wildlife. These concerns include questions about the ethics of engineering a wild species, the potential environmental consequences on species behaviour and ecosystem dynamics and the possible spread of effects well beyond the specific targeted location (Brossard *et al.* 2019).

Emotions and polarised views on wildlife management are increasingly driving public choices about wildlife management (Wieczorek Hudenko 2012; Jacobs and Vaske 2019). One conference presentation (Carlisle, https://www.youtube.com/watch?v=8VBqgsIVrRQ accessed 28 October 2023) highlighted how we should be careful not to make assumptions about stakeholders' values, attitudes and beliefs about wildlife management. We anticipate that human dimensions, and in particular public perceptions of wildlife fertility control as a means of mitigating human–wildlife conflicts, will remain a primary focus for the field in the future. Addressing issues raised by stakeholders and decision-makers and finding ways to effectively engage and educate wildlife managers, policymakers and the public about this growing field of wildlife management will be a high priority and a significant challenge over the next decade.

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