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History of the Science of Wldlife Fertility Control: Reflections of a 25-Year International Conference Series

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Abstract The science of wildlife fertility control originated in the mid-twentieth century, out of a growing need for alternatives to lethal controls for selected wildlife populations, where traditional lethal controls were no longer legal, wise, safe or publicly acceptable. Until late in the century the science was uncoordinated and without significant funding or cooperation among investigators. A 25-year conference series brought scientists engaged in this endeavor together, from around the world and set the stage for more rapid development and research support. In rapid fashion, steroid related efforts gave way to contraceptive vaccines and gonadotropic-releasing hormone (GnRH) agonists and by the turn of century actual successful management of certain species was well underway. This included wild horses, urban deer, captive zoo populations, and even African elephants. However, an unanticipated backlash from state and federal wildlife agencies, and some animal protection groups slowed progress, particularly in application of the science to free-ranging wildlife populations. Today the science has progressed to the point where actual management could alleviate many problems but the sociopolitical dimensions of this science have slowed progress and thrown up many non-scientific hurdles (state legislation in particular). This short history presents a classic case of a general public and political system that cannot keep pace with new scientific developments.

Keywords: *contraception, fertility control, wildlife*

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1. Introduction

The management of wildlife populations by means of fertility control is a concept born in the mid-20th century, largely in response to increasing human-wildlife conflicts and changes in social norms regarding the stewardship of wildlife. Urbanization and modern agricultural development had earlier led to the reduction of predators. Consequently, regulated hunting and trapping emerged as a policy designed to replace predators as population control devices and as management tools. Dwindling wildlife resources and the loss of habitat led to the creation of reserves and parks, and special legislation that protected certain species from traditional lethal controls. Examples would include wild horses protected by the Free-Roaming Wild Horse and Burro Act of 1971, or wapiti or elephants inhabiting national parks, or enabling legislation for new national parks that protect certain species that would generally not be protected, or even zoological gardens, where unregulated reproduction can lead to "surplus" animals and massive ethical problems associated with the disposition of these animals [1].

Prior to human intervention wildlife populations were controlled by two natural processes including mortality control and fertility control. When animal populations exceeded the carrying capacity of their environment animals died from starvation and disease as well as predation. At the same time, high densities among wildlife populations led to a decrease in reproductive success; animals delay the age at which they will first breed, they produce fewer offspring and juvenile mortality increases.

Humans have chosen to impose artificial mortality control on wild populations through regulated hunting, trapping and poisoning and this has been accepted as "normal", or acceptable human activity and with many species this approach continues to be the primary management tool. In recent history, however, increasing urbanization, the withdrawal of private lands from the public hunting domain, regulatory prohibitions on the use of poisons and trapping, low fur prices and changing public attitudes about lethal wildlife control have reduced the effectiveness of mortality control as a management tool for many species in various settings. Thus, we now face exploding populations of some adaptable or highly protected species but without acceptable management tools with which to protect environment and animals alike. These events and factors are generally recognized as the impetus behind the emergence of the concept of wildlife fertility control [2,3].

The concept of human-induced fertility control, however, is still often considered “bizarre” or “unnatural” and the reasons for this perception are not well understood. It may have something to do with the simplicity or relatively lower cost of mortality control, or something as simple as a cultural mindset based on long-standing traditions. It may be related to the perception that a new paradigm might have an impact on the economics associated with various traditional mortality control methods. Regardless of the answer to this question, the public and various governmental agencies have arrived at a point in time when safe, humane, and publicly acceptable wildlife management is beginning to be viewed as more acceptable.

Prior to 1987, isolated studies and trials with wildlife contraception occurred, but with little public interest or agency funding and almost nothing in the way of innovative science. The first attempts, in the 1950s and 1960s focused on small rodents, deer and birds. By the 1970s, research on deer expanded, and research on wild horse fertility control began but in the latter case never reached the publication stage in that decade. These efforts were joined by attempts at managing captive exotic species in zoos with contraception (these early attempts are reviewed in [4,5]. Virtually all of these early attempts were characterized by reliance on reproductive steroid hormones, synthetic and natural, to cause contraception. There was little forethought regarding environmental issues, regulatory requirements, delivery issues, or extra-contraceptive effects on the target species, let alone cultural and political issues. Much of this lack of coordination and progress derived from a paucity of funding and scientific collaboration within this area of research, although some of it resulted from a lack of field experience by the laboratory scientists focused on contraceptive drugs [6].

Despite this lack of coordination and professional collaborations that are found in most other scientific endeavors, by 1981 several events occurred which raised the public and agency consciousness about the possibilities of this new applied science. The first event was the passage of the Free-Roaming Wild Horse and Burro Act of 1971. This single event set the stage for a future wildlife dilemma of unprecedented proportions and brought the concept of fertility control to wildlife managers in a way that had heretofore been missing. The legislation provided almost complete protection to an extremely fecund and adaptable wildlife species living on public lands, with no natural controls, and it took only a few years for the dimensions of the problem to become recognized. An estimated 17,000 wild horses in 1971 soon grew to more than 50,000 horses by 1980.

The second significant event, in 1977, was the financial investment in wild horse fertility control research by the managing agency, the Bureau of Land Management (BLM) in the amount of about $200,000. This level of funding for wildlife contraception was unheard of at the time and nothing drives scientific interest more than money. Now many more scientists were paying attention.

The third landmark event, in 1980, was the involvement of the National Academy of Sciences/National Research Council (NAS/NRC) in wildlife fertility control issues. The BLM, now facing a serious problem with growing wild horse populations, commissioned the NAS/NRC to study the issues of the wild horse management problem and make recommendations for solutions. One of the most prominent recommendations that emerged from that study [7] was an increased emphasis on fertility control research as a potential management tool. This in turn led to more federal research money ($750,000 this time), predictably more interest from the scientific community, and more research activity. Despite these events, research through the mid-1980s, remained focused on steroids and hands-on delivery and while some results were promising pharmacologically, most were impractical from a safety, logistical or regulatory point of view.

The fourth landmark was the formal organization of a Contraceptive Advisory Group (CAG) by the accrediting agency for zoological parks, the Association of Zoos and Aquariums (then the American Association of Zoos and Aquariums), as a means of developing new fertility control approaches for captive wildlife and promoting their use in captive settings. A framework – uncoordinated to be sure – was now in place to bring the concept of wildlife contraception to the public eye.

2. The Birth of the Confernce Series in Wildlife Fertility Control

In November 1987, an event took place that would more or less provide a concise and accurate history of the relatively new science of wildlife fertility control for the next quarter century. The First International Conference on Fertility Control in Wildlife was organized and took place in Philadelphia, although it was known then as the Symposium on Contraception in Wildlife.

The motivation behind that inaugural meeting was born out of Penn State philosophy Professor Cohn’s frustration at being unable to stop a deer hunt in Ridley Creek State Park in Pennsylvania, a Philadelphia suburb. She had tried presenting information about deer population dynamics including compensatory reproduction, and had persuaded two of the three townships within which the park is located to pass resolutions to investigate and perhaps use contraception. Even a victory in the courts was not sufficient: the hunt was allowed to take place on the automatic appeal of the Pennsylvania Game Commission.

Professor Cohn then decided to harness the power of science, naively believing that the factual data of science could not be ignored. After all, her undergraduate students constantly asserted, "Science proves that..." without having any idea how science might attempt to establish factual information. Dr. Cohn was aware that there had been an unpublished and unsuccessful effort to use fertility control deer on Angel Island, CA, and she knew that there were at least a handful of scientists engaged in research in wildlife contraception. While one scientist's data might be questioned, she reasoned, it might also be assumed that this could not happen with the presentation of data from numerous scientists who had come together at a conference. The conference generated a lot of interest, and is described below. All the papers from the conference were edited by scientists and published. Dr. Cohn felt that it was very important that new data, observations and hypotheses be widely available so that they could be read and criticized if necessary. Knowledge needs to be communicated if it is to be acted upon.

Perhaps a there is a shorter answer to the question of why the conference on contraception was desired. It could be said that the motivation for the conference was based on two beliefs that may not be true; 1) that most people are reasonable and 2) that reasonable people can change their views and perhaps even their behavior on the basis of factual information revealed by the scientific method.

Eighteen papers were presented and for the most part the symposium could be characterized as a historical overview. The proceedings were ultimately published as a book [8]. The technology presented at this conference was dominated by reproductive steroids (11 of 18, or 61% of the papers). Some small progress had been made with wild horses, and the real or potential target animals expanded to include urban deer, African lions, mountain goats and Golden Lion Tamarins, as well as a variety of exotic species in zoos. In no case were data presented to suggest the successful manipulation of any wildlife *population* through fertility control. Much of the information presented was derived from human research and application of the steroid contraceptives to various laboratory species in research settings and most of the work presented focused on efficacy. But several papers explored dimensions of this science that would emerge in later years and drive future research. Dr. George Kollias [9], of Cornell University, presented a paper that explored the risks of steroid treatments, a paper that would presage the passing of this approach to wildlife contraception in later years. Dr. Brian H. Vickery [10], then of Syntex Research, presented a paper on the use of luteinizing hormone releasing hormone (LHRH) analogues to suppress fertility in dogs, and this approach would become a major player in captive wildlife fertility control in the future. Drs. Allen Hunter and Ann Byers [11], then of the IUCN Conservation Breeding Specialists Group, presented a paper on immunological intervention of reproduction, something that would, one day, blossom into the single largest and most effective approach to wildlife contraception. But Drs. Hunter and Byers did not know that in 1987. Their presentation derived its information from human and laboratory animal research and included discussions of sperm-specific antigens, zona pellucida antigens on the ovum, and gonadotropin-releasing hormone (GnRH) antigens, and how vaccines against these components of the reproductive system might have some utility for wildlife management. One paper that has largely been lost to history was an actual attempt at reducing fertility in wild horses on Cumberland Island National Seashore, GA, using a vaccine against GnRH. The outcome of the research, presented by Robin Goodloe, [12], then of the University of Georgia, was less than successful, but the work marks the very first time that such an approach was used to attempt to control reproduction in wildlife. Finally, Dr. Cheryl Asa [13], (now the chairperson of the Association of Zoos and Aquarium's Contraceptive Advisory Group, at the St. Louis Zoo) presented a paper that discussed the importance of understanding the behavioral effects of contraceptives in wildlife. That too would become a much larger issue in future years. Other topics were germane to the subject of wildlife contraception, but only really reflected some history, or parallel research with lab animals or humans. But, it was a start and the history was in print. The audience was eclectic and represented a modest mix of interested biologists, representatives of the animal protection community and a few state wildlife agency representatives. Most importantly, it brought together most of the active scientists in the field and potential funding sources for future research under a single roof for the first time.

It is worth noting that, in the preface to these proceedings, Dr. Cohn asked what would later become a disturbing and profound question. At that time there were some twenty years of published research on the subject of wildlife fertility control yet almost no public knowledge of it. "*Once cannot help but ask why these research findings have been so little disseminated to the general public*", Dr. Cohn pondered. Twenty-five years later the same question is being asked.

3. A Futuristic View of the Science and a Little Progress in the Field

Two years later, the Second International Conference on Fertility Control in Wildlife (known at that time as "Fertility Control in Wildlife Conference") was held in Melbourne, Australia. This conference was largely inspired by growing concerns over Australian non-native species such as foxes, horses, water buffalo, rabbits and even urbanizing native kangaroo populations. Both the tone of the meeting and the audience were markedly different from the first conference. The sponsors and the general audience were dominated by the animal welfare community and in large part, the topics reflected ethics, philosophy, prospective ideas for the future and a small but initial presentation of actual results from the field. The topic of the ethics of wildlife fertility control made its initial appearance in this field of endeavor, and established the philosophical foundation for finding non-lethal approaches. Of the 30 papers given, 7 were in the area of animal welfare. It was now recognized that the topic of wildlife fertility control evoked substantial issues of ethics and even philosophy. On the last morning of the conference, held at the University of Melbourne, protestors showed up and put an exclamation point on the ethical facets of this topic.

On the scientific side, three dimensions of the meeting are notable, all of which would have far-reaching effects in future years. First, Dr. Hugh Tyndale-Biscoe, of the Australian agency CSIRO, presented a paper on the potential for genetically modifying non-pathogenic and species-specific bacteria and viruses to incorporate genes for molecules that would express themselves and subsequently interfere in some manner with reproduction [14]. Dr. Chris Langford, of the Australian Veterinary Research Institute followed up with more details about viral vectored contraceptives. This new and interesting concept reared its head in Melbourne.

The second interesting and significant dimension of this meeting was two papers on actual successful fertility control in large wildlife, outside of zoos. One was focused on captive white-tailed deer [15], and the other on wild horses [16], in the field. Both studies involved remote zona pellucida vaccination, using small darts. The horse paper represented the first successful attempt to inhibit fertility in large free-ranging animals without the dangers and expense of capture. A keynote address by Jurrien

Dean, of the U. S. National Institutes of Health, emphasized the potential for zona pellucida antigens for contraceptive vaccines. In only two years, the subject of immune contraception, introduced by Drs. Hunter and Byers, in Philadelphia, had moved closer to center stage in terms of potential and actual successful research.

The third dimension of the conference, subtle as it was at the time, also set the stage for future issues in the field. Dr. Mary Bomford, of the Bureau of Rural Resources in Canberra, began to represent certain agency biases against wildlife fertility control [17]. The concerns were mostly speculative, based on generalized demography, theoretical contraceptive efficacies, and modeling, all without supporting data, but the larger picture of negative attitudes about the wildlife fertility control, by certain government agencies was a message read by the more attentive. The proceedings of this conference were never published formally but exist as a compiled record of papers, thus the references above reflect the same topics, some of which were published in journals immediately following the conference.

4. Turning the Corner from Steroids to Immunocontraception

The third international Conference on Fertility Control in Wildlife (then known as "Contraception in Wildlife Management") was held in Denver, in September 1993. Over 30 papers were given and 20 papers were published in the proceedings [18] at a conference sponsored by a government agency – the United States Department of Agriculture (USDA) – a first. It was now clear that government agencies recognized the discipline and that alone gave the science of wildlife fertility control more legitimacy. The large number of oral papers – more than were published as a USDA Technical Bulletin – suggested increased interest in the subject by a wide spectrum of groups.

Several dimensions of this conference are worth reporting in the historical march of the science. First, the population modelers arose. Here was a topic that, as presented, more or less predicted failure, or at least expressed great skepticism for those entering the field with contraceptives. The models created just didn't instill much confidence that a free-roaming population of long-lived wildlife could be managed successfully with fertility control. The models presented, however, utilized generalized demography and lacked site-specific details of the populations and had an almost complete absence of real contraceptive data (which in fairness, didn't exist then). Nevertheless, this did not help move the science forward. Interestingly, none of the modeling papers given at the conference were published in the proceedings, but one appeared later in a journal [19].

Dr. Hugh Tyndal-Biscoe, of CSIRO, and several other Australians reinforced the idea of viral-vectored immunocontraceptives that was born in Melbourne, three years earlier [20,21,22]. It was clear that Australia was now going to pursue wildlife fertility control with some vigor and that it would be focused on genetically modified organisms (GMO). The audience, which was the largest of the seven conferences to date, was uncomfortable with this approach. How would the vector organisms – viruses – be prevented from mutating (for which they are notorious)? How could these vectors be controlled once they were released into the environment? How could they be prevented from infecting non-target but related species, i.e., foxes and dogs? It became obvious to all in attendance that Australian scientists did not perceive facing the same regulatory hurdles that existed in the U.S., and that they were undaunted by the challenges. Nevertheless, the direction for Australian wildlife fertility control for the next 15 years was established.

Nine, or almost one half of the published papers focused on immunocontraception, while only two papers addressed steroids. The corner had been turned. If there were to be a future for wildlife contraception it would be with vaccine-based contraceptives rather than steroids, at least outside of zoos. Once again, porcine zona pellucida dominated immunocontraception. Dr. Bonnie Dunbar, of Baylor School of Medicine and the leader in the field at that time, led the charge for PZP [23]. However, only two papers, one on deer [24], and one on horses [25] reported progress with use in the field and that was a continuation of the work reported at Melbourne three years earlier. Field-level application was just not occurring despite the flurry of research activity in labs, pens and corrals.

Finally, the political dimensions of wildlife fertility control rose up and made their presence known. The general public in attendance was dominated by groups and individuals interested in urban deer fertility control. This issue had been energized by the work of Dr. John Turner and colleagues, in this conference and earlier in Melbourne. Various state fish and game agencies were also well-represented and pushing back. It became clear that lines were being drawn between hunting and contraception, whether or not the issue had substance. In a larger sense, clear lines were being drawn between the traditional wildlife management fraternity and animal welfare community. The subject of wildlife fertility control was now becoming polarized. Perhaps the most telling paper was presented by two representatives of the Colorado Division of Wildlife, Bruce Gill and Michael Miller [26]. The paper was titled "Thunder in the distance: the emerging policy debate over wildlife contraception". They accurately, and prophetically predicted this policy debate would be "*anything but tranquil*". What started out to be a conceptually simple scientific challenge in Philadelphia, six years earlier, was now a raging political/cultural bull, looking for someone to gore.

5. On the Great Barrier Reef

Great Kepple Island rests amidst the Great Barrier Reef, off the east coast of Australia, and it was the setting for the Fourth International Conference on Fertility Control in Wildlife, in 1996, and now moving closer to a standard conference title – Fertility Control for Wildlife Management. Twenty-five papers were given and 33 posters were presented. The proceedings were published in the journal *Reproduction, Fertility and Development* [27]. Once again the primary sponsors were government agencies, CSIRO and the Australian Academy of Science, signaling more governmental interest in the topic. And once again, most papers reflected laboratory-level research, some modeling, and increased emphasis on

GMOs. Ethics were addressed again. The primary papers on field applications were the PZP work with wild horses and white-tailed deer [28], the same ones featured at Denver and Melbourne. The significance of these papers was the initiation of actual *management* of wild horses and deer – as opposed to just field research on efficacy and safety - with a PZP vaccine. While research continued, contraceptive management was now a reality. In general, however, the conference emphasis was on perceived pest species rather than valued wildlife.

The GMO research was in high gear, but confined to Australia. Viral vectors, attenuated bacterial vectors, recombinant myxoma and herpes viruses, were all discussed as possible vectors for rabbits, foxes, brushtail possums, and a few other species [29]. Few concerns were expressed about this approach.

Immunocontraception now dominated (almost one-fourth of all papers) and only two papers (6%) were directed at steroids. One interesting new wrinkle was a paper on the genetic engineering of plants, to deliver immunocontraceptives [30]. The most negative view of fertility control in wildlife came from Dr. Victor Nettles, wildlife disease specialist at the University of Georgia [31]. He posited many potential health and genetic hazards to wildlife as a result of fertility control, but provided no relevant data to support the contention. He also defended traditional lethal control methods, and his claims would linger for another 15 years despite a lack of supporting evidence. What was becoming clear from these conferences was that whatever made it into print had a long half-life. Nevertheless, at this point in time the opposition coming from traditional lethal control advocates was basing its objections on perceived scientific grounds.

6. Africa and Progress in the Field

The Fifth International Conference on Fertility Control in Wildlife was held in the Kruger National Park in South Africa, in August 2001, largely prompted by the initiation of elephant fertility control research in that country. Twenty papers were given (no posters) and they reflected the changing nature of wildlife fertility control. The proceedings were published in the journal *Reproduction*, as a supplement issue [32]. The biggest and most significant trend reflected by this conference was the actual practical application of contraceptives to free-ranging wildlife. Of 20 total papers, 9 of them were devoted to actual field applications. There were 7 reports using PZP on horses, wapiti, deer and African elephants, and two dealing with GnRH blockers in deer and wapiti.

Four features of this conference signaled significant and positive change in the larger field of wildlife fertility control. The first was the increased emphasis on field applications at the population level (all with PZP). This included the first demonstration that entire populations – wild horses and urban deer in this case – could be altered through fertility control [33,34]. The second highlight was the introduction of African elephant fertility control, reflecting research studies completed in the Kruger Park and the beginning of actual management of elephants in game parks [35]. This was a major step forward for the field and developed new interest, probably because of the iconic nature of elephants. It is also worth mentioning that elephant fertility control reached the management level faster than with any other species. At this point urban deer, wild horses and African elephants were actually being managed, officially, by various agencies.

The third significant feature of this conference was a clear warning, by C. K. Williams, of CSIRO, in Australia about the seemingly insurmountable regulatory hurdles facing GMO research [36]. By this point in time, most of the scientific arguments swirling about wildlife fertility control had been answered and a new approach – regulation - was necessary if the concept was to be minimized by those opposed. Beyond that, an astute member of the audience, paying close attention to the paper by Williams, might have seen the writing on the wall and the beginning of the end for GMO research.

A fourth feature, that also presaged the future in this field, was increased emphasis on the development of a single inoculation, long-lasting immunocontraceptive, by Dr. John Turner [37]. It was becoming clear that it was not enough to just be able to successfully apply fertility control to wildlife populations, but that the process now had to be cheaper and more convenient. This was, in a way, an admission that the concept of wildlife fertility control was a reality. It is worth noting that the conference itself was delayed for over an hour when an elephant knocked down a power line!

7. Jolly Old England

The Sixth International Conference on Fertility Control in Wildlife was held in York, UK, in September 2007. It was sponsored by still more government agencies (Cooperative Research Centre for Invasive Animals, Central Science Laboratories of UK, and the Department for Environment, Food and Rural Affairs, of UK), reflecting growing interest within governing bodies. The proceedings were published in the Australian journal *Wildlife Research* [38].

Forty-four papers were given and 11 posters presented (although only 14 papers were published) and three trends were most obvious. The first was the continuing trend of field applications of fertility control to wildlife, including deer, horses, and elephants. Progress was being made in actually getting contraceptives to the field to solve problems.

The second clear trend was the collapse of the genetically modified organism approach to wildlife fertility control, more or less predicted by C. K. Williams, in the previous conference, in Kruger Park. Regulatory hurdles proved too much to overcome. Only the work of a New Zealand Group, using a nematode vector common to brushtail possums and some other marsupials remained [39]. After a 15 year run, the concept of GMOs as delivery vectors died a regulatory death.

The third clear trend was the emergence of two new immunocontraceptive approaches. Including a novel PZP formulation and two GnRH vaccines as major players. SpayVac®, a liposomal PZP formulation, produced by a proprietary Canadian company, GonaCon®, a GnRH vaccine developed by the USDA/NWRC specifically for deer, and Improvac®, a GnRH vaccine produced by Pfizer and tested on horses all made dramatic appearances in this

conference and suggested a shift in approaches [40,41,42]. Two of them, SpayVac® and GonaCon® made a case for a single inoculation long-duration and new emphasis on native PZP, in the form of a potential long-acting pellet reinforced a changing paradigm in wildlife fertility control. In 1987, at the first conference in this series, the paradigm was reflected by the question, "Can we manage wildlife populations by means of fertility control?" By 2007 that question had been answered in the affirmative, but now the question changed. "Can we do this easier and cheaper?" The search for a one-inoculation, long-acting contraceptive was underway and showing promise.

8. The Greater Yellowstone Ecosystem

The Seventh International Conference on Fertility Control in Wildlife was held in Jackson Hole, Wyoming, in 2012, and marked the 25th anniversary of this conference series. The proceedings were published in a supplement to the *Journal of Zoo and Wildlife Medicine* [43]. Forty-six papers were given (and 18 published as full papers and 28 abstracts) and four trends became clear and marked the emerging history of this arcane science.

The first was the increasingly large role of GonaCon®, not just in the United States, but also in Europe, Mexico, New Zealand and Australia. The vaccine had originally been developed for deer, but politics (see below) prevented practical application, so the agency, USDA, sought out other applications, including bison, horses, wild pigs, feral goats, wapiti and feral dogs. However, only one application, feral goats in Wales, was conducted at the population level [44]. There was however, a cautionary note expressed in one paper, regarding the ubiquitous nature of the mammalian GnRH receptor and the extra-reproductive effects of blocking GnRH, spearheaded by the work of Dr. Donal Skinner [45].

The second trend was the expansion of actual management with native, remotely-delivered PZP for species as diverse as elephants, bison, horses, and deer. Almost 15% of the total papers involved native PZP and actual management of wildlife populations. Bison represented the newest application at the population level [46]. One fascinating advance was an orally-delivered contraceptive for rodents [47], the first practical oral contraceptive for mammals.

The third trend was the acknowledgement that politics and culture was the single largest barrier to widespread application of fertility control to wildlife. The conference's introduction, the closing summary paper, and another three published papers all were directed at the political barriers [3,48,49]. While science marched onward, and technological advances occurred, both state and federal obstruction to the concept was delaying application to real-world problems. The obstruction was carefully defined [3] and focused on barriers that come from polarized philosophies, and cultures, or what might be labeled "uncomfortable knowledge" (hunting and traditional lethal controls versus contraception and the perception of animal welfare intrusions into traditional management approaches to wildlife) and merely represented a continuation but growing trend, first predicted in the third conference [26]. Few paid attention to that warning almost two decades before and now the price was being paid. Unprecedented in this conference series was the total absence of attendees representing state and federal fish and wildlife agencies. Science was making progress, but polarization, culture and the resulting politics were preventing practical application, both in the U.S. and abroad.

The final, and somewhat positive trend was the U. S. federal approval and registration of three wildlife contraceptives, including OvoControl®, for pigeons, GonaCon®, for deer and native PZP, under the name ZonaStat-H®, for horses. Originally, back in the 1980s, USDA was tasked with regulatory authority for wildlife contraceptives, but because pregnancy is not a disease, they jettisoned that responsibility and handed it off to the Food and Drug Administration (FDA). FDA kept the science going through Investigational New Animal Drug Exemptions (INADs), but it was clear that the immense expense of getting formal FDA approval for wildlife contraceptives rendered their regulatory involvement impractical. This reflected the lack of commercial value of the entire wildlife contraceptive endeavor. There were political pressures directed at FDA as well, from opposing forces, and in the end FDA handed the regulatory authority over to the U. S. Environmental Protection Agency (EPA). FDA retained regulatory authority over companion animal and captive (zoo) animal fertility control but divested itself of responsibility for free-ranging wildlife. But nothing is so simple, and the EPA registered wildlife contraceptives as "pesticides", a label that frightens the public and annoys animal advocates and is being grasped by some agencies to prevent or delay application to wildlife.

This conference also distilled still a third strategy shift by opponents. Scientific objections failed to stop progress, and interference at the regulatory level failed, so now states were throwing up legislative hurdles [50]. The bird contraceptive OvoControl® is a classic example [48]. While the various state agencies approved the oral contraceptive for pigeons (not a game bird), they would not approve it for geese (a game bird). In the case of deer, several states had already created legislative bans or hurdles to the use of fertility control and one (Nebraska) even went so far as to amend its constitution to discourage wildlife fertility control. This does not bode well for the future of the field.

9. Conclusion

This is, briefly, a historic journey through the science of wildlife fertility control, as reflected by the seven international conferences over a quarter century. Gone are the steroids, and genetically modified organism delivery schemes. Immunocontraceptives are here to stay, in a variety of forms but dominated by GnRH and PZP vaccines, and the science has actually arrived at a point where limited management of wildlife is underway, and successful. A few papers on oral delivery of contraceptives may represent the next big step in this science, but more regulatory hurdles will keep that progress painfully slow. While scientific advances continue, the biggest hurdles are now clearly cultural and political and dominated by restrictive state legislation. As is most often the case, science outpaces public

understanding, social acceptance, cultural change, government inertia and political courage, and that is clearly the case with wildlife fertility control. Much of the fault for this chasm between the state of the science and actual application must lie with the scientists and advocates. Public relations in this arena have been abysmally lacking, reflecting on Professor Cohn's voiced concern in 1987. The public still knows little about the science and what public information has been produced has largely been from opposing forces and can be characterized as the "social promotion of ignorance" [50], replete with misinformation, opinion, and strategic omissions. Nevertheless, the field pushes forward and increasing public awareness and advocacy pushes back against the political barriers.

Compete of Interests

The authors have no competing interests.

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