UPDATED REVIEW ON THE FEASIBILITY OF USING FERTILITY CONTROL TO MANAGE NEW JERSEY BLACK BEAR POPULATIONS

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EXECUTIVE SUMMARY

The New Jersey Division of Fish and Wildlife (NJDFW) manages its black bear population using an integrative management approach that incorporates several different strategies, including education, control of human-derived food, research, response to conflict incidents, and population control. In 2006, a comprehensive evaluation of fertility control as a management option for black bears, initiated by former DEP Commissioner Campbell, concluded that it was unsuitable and not cost effective for managing black bears in New Jersey. However, the latest version of the New Jersey Comprehensive Black Bear Management Policy (CBBMP 2015) recommended that NJDFW continue to review current research on alternative methods for population control, including fertility control. This review serves to fulfill that recommendation and build on the previous evaluation conducted in 2006.

Based on this current review, it is clear that while substantial progress has been made in developing successful fertility control programs for certain wildlife species, serious limitations to the implementation and effectiveness of these programs still remain, and will likely always remain, particularly for free-ranging black bears. These include: prohibitive

- A long-lasting contraceptive agent that avoids the repeated stress on animals and high cost of re-treatment still has not been adequately developed,
- fertility control programs are expensive, especially for species such as black bears that require trapping, immobilizing, and handling large numbers in the field,
- monitoring and evaluating the effectiveness of fertility control programs in free-ranging populations is challenging and expensive,
- fertility control requires treating a large proportion of reproductive females in the population, which is extremely difficult in open populations where immigration and emigration rates are high,
- fertility control alone takes a long time to effectively reduce population size and associated conflict and damage activities,
- impacts of contraceptive agents on the health, behavior, and population ecology of treated animals are still largely unknown, and
- no contraceptive agent has regulatory approval for free-ranging black bears.

Since fertility control is not a feasible option for large-scale black bear management in New Jersey, NJDFW should continue to focus on other aspects of their Comprehensive Black Bear Management Policy (2015), particularly improving control of human-derived food and reducing the size of their black bear population (via hunting). Recent research has shown that these strategies in particular are most effective for reducing population size and human-bear conflicts in New Jersey. Careful monitoring and evaluation of these efforts (i.e., hunting and reduction of human-derived food) should continue as well.

INTRODUCTION

New Jersey uses a multifaceted approach to managing its black bear population, with the goals of ensuring a continued, sustainable population, providing for adequate recreational opportunities, including hunting and viewing, minimizing bear-human conflict, and managing public safety concerns. No single management option is best for every circumstance (NEBBTC 2012), thus New Jersey's Comprehensive Black Bear Management Policy (CBBMP), which was revised and updated in 2015, outlines an integrative approach to black bear management using several strategies, including education, control of human-derived food, research, response to conflict incidents via lethal (depredation permits, euthanasia) and non-lethal (aversive conditioning) options, and hunting. Other options, such as relocation and fertility control, have been deemed unsuitable and not cost effective for reducing black bear populations or managing conflict incidences (Fraker et al. 2006; NEBBTC 2012; CBBMP 2015). Nevertheless, the 2015 CBBMP recommended that "DFW should continue to review current research on alternative population control techniques, such as fertility control."

As a result of the 2005 CBBMP (Wolgast et al. 2005), the DEP's Division of Science and Research commissioned a thorough review of wildlife fertility control options, which resulted in a comprehensive evaluation of fertility control as a management option for black bears (Fraker et al. 2006). This study concluded that fertility control is very unlikely to be a feasible means of managing black bear populations in New Jersey. This current review is designed to build on the Fraker et al. (2006) review and provide additional information and research on the subject of black bear fertility control in the 12 years since this original review was conducted.

LIMITATIONS OF FERTILITY CONTROL METHODS FOR BLACK BEARS

Fertility control for wildlife remains an active area of research. While substantial progress has been made on programs with free-ranging populations of wild horses (Gray et al. 2010; Ransom et al. 2011), bison (Duncan et al. 2013; Duncan et al. 2017), and, to some extent, white-tailed deer (Rutberg and Naugle 2008; Gionfriddo et al. 2011; Rutberg and Pereira 2017), limitations to the implementation and effectiveness of these programs remain. Some of these limitations include: 1) development of contraceptive agents that are safe and effective for the specific species of interest and require only a single dose or treatment, 2) costs associated with delivering contraceptive agents (including capture and handling of animals, generally multiple times), 3) time required to effectively reduce populations and conflict/damage activities using fertility control methods, 4) determining impacts of contraceptive agents on the health, behavior, and population ecology of treated animals, and 5) hurdles associated with regulatory approval of contraceptive agents (Fagerstone et al. 2006; Fraker et al. 2006; Liu 2011; Turner and Rutberg 2013; Massei and Cowan 2014). These limitations are even more pronounced when considering fertility control options for free-ranging black bears.

DEVELOPMENT OF SAFE, EFFECTIVE, SINGLE-DOSE CONTRACEPTIVE AGENTS FOR BLACK BEARS

Currently, no safe and effective contraceptive agents have been adequately developed and tested specifically for free-ranging black bears. Only four published studies have directly tested various

fertility control methods on American black bears (Jewgenow et al. 2001; Frank et al. 2005; Lane et al. 2007; and Brito et al. 2011). All of these studies were conducted on a small sample of captive bears, and no field testing of any kind has been carried out on free-ranging black bear populations. Fraker et al. (2006) outlined two methods under "active consideration" for fertility control in black bears - zinc gluconate (Neutersol®) for treatment in males (Brito et al. 2011), and porcine *zona pellucida* (PZP) vaccines for treatment in females (Frank et al. 2005; Lane et al. 2007).

Although zinc gluconate (Neutersol®) has been FDA-approved for use in young dogs, Brito et al. (2011) tested the treatment in eight captive adult male black bears and found no reduction in testosterone secretion and continued sperm motility in all but one of the treated bears, indicating it is unlikely to result in complete sterility. Further, testicular lesions and abnormal seminiferous tubules also were found in the treated bears from this study. Cavalieri (2017) found that zinc gluconate treatments are most suited for use in companion animals, and that the need for "careful" and "slower speed of administration" would hamper application within even the domestic cattle industry, making application to free-ranging black bear populations a virtual non-starter. More pointedly, an effective fertility control strategy for bears must target females, not males due to the larger home range size of males and the ability of males to inseminate multiple females (Fraker et al. 2006). Treating even upwards of 80-90% of males in the population may have little to no effect on reproductive rates.

PZP vaccines have proven effective in several mammal species, including black bears, but are currently limited by the need to provide occasional booster immunizations, which is prohibitive for large, free-ranging populations of animals that are difficult to capture (e.g., black bears; Fraker et al. 2006). Frank et al. (2005) found the PZP vaccine to be highly effective in captive bears, though questions of the timing of doses, type and dosage of adjuvants, and long-term side effects (i.e., safety) remained. Lane et al. (2007) tested a single-dose PZP formulation on 22 captive female black bears, and while treated females produced no cubs during the one-year study, effectiveness and safety of the treatment beyond one continuous breeding season is unknown. The Humane Society of the US began a study in 2004 to test PZP on five captive female black bears in New Jersey, but the study was terminated after one year. Results from the first year were that both control sows both gave birth, while 1 of 3 PZP-treated sows gave birth (W. Rives and A. Rutberg, pers. comm.). Larger, longer-term studies in captive black bears would need to be completed to determine the safety and effectiveness of PZP vaccines over long periods, followed by additional field trials to determine the safety, effectiveness, and population impacts in free-ranging populations.

More progress has been made testing various PZP formulations in other free-ranging species, including wild horses, bison, and to some extent white-tailed deer. Gray et al. (2010) tested a single-dose PZP formulation, SpayVac®, on a population of free-ranging wild horses and found that although fertility was reduced over the course of the three year study, fertility rates remained at 37-50%, potentially leaving population growth rates excessively high. Similarly, Roelle et al. (2017) tested two formulations of SpayVac® on a population of captive feral horses and found fertility rates of 13.3%, 46.7%, and 43.3% in years one through three, respectively, in one of their treatment groups. Duncan et al. (2013) found reduced calving rates in a free-ranging bison population following repeated injections of PZP over three years. One advantage of fertility

control programs in free-ranging ungulates such as wild horses and bison is the relative ease (compared to black bears, or even white-tailed deer) of rounding up large numbers for subsequent boosters or impact evaluation (Turner and Rutberg 2013). Continuing progress needs to be made in extending the effectiveness of single-dose inoculations over longer time periods (> 5-7 years) before these methods will be worthwhile and effective in large-scale populations of free-ranging black bears.

Rutberg and Pereira (2017) are currently testing a single-shot PZP formulation in an "open" white-tailed deer population in upstate New York, where movements of deer are not as tightly restricted. Understanding how immigration and emigration affect the effectiveness of fertility control is especially important for application in large, free-ranging, open wildlife populations. Since the start of the study in 2014, 69 adult females have been captured and treated (> half of the adult female population on site), with known fawning rates of 11.8% (2/17 treated deer) in year one, and 20% (1/5 treated deer) in year two. Vaccination appears to be reliable for approximately two years and booster vaccinations were applied to all recaptured deer after 2.5 years (A. Rutberg, pers.comm.).

The Rutberg and Pereira (2017) study highlights many of the challenges with field application of fertility control methods, particularly in open populations, including time and effort necessary to capture and treat animals. It took approximately 16 weeks over the first three years of the study to capture 69 deer (just over 50% of the adult female population; Rutberg and Pereira 2017). The percent of the population that needs to be inoculated in order for fertility control methods to be effective varies widely by site as well. A. Rutberg (pers.comm.) estimates that ~50% of the population must be treated to stabilize population growth, and upwards of 60-80% would need to be treated to achieve population reduction. K. Frank (pers.comm.) estimates that > 65% of the population must be treated to achieve population reductions in wild horses. Similar rates have been estimated in other studies as well (Garrott 1995; McCullough 1996; Seagle and Close 1996; Hobbs et al. 2000). Even if long-lasting contraceptive agents are successfully developed for black bears, which would still require much additional testing both in captive and field settings, the time and effort involved in trapping, immobilizing, handling, and treating a large enough proportion of free-ranging bears to be effective for population control would remain largely prohibitive.

Evaluating the efficacy of contraceptive agents also can be very challenging in field applications of fertility control methods. Often, treated individuals die, disappear, or are not easily recaptured, making data collection for determining immune response, health impacts, and other factors difficult if not impossible (Turner and Rutberg 2013). Different individuals may be captured and sampled each year, leading to fluctuating sample sizes and inconsistencies in data collected. Studying behavioral impacts and changes in population dynamics (birth and survival rates, changes in movement and activity patterns, etc.) as a result of fertility control efforts is even more complicated, challenging, and costly to study in free-ranging populations in general.

Other options for fertility control in female black bears were also reviewed by Fraker et al. (2006), but none were deemed to be feasible for large-scale fertility control of free-ranging black bears. GnRH vaccines (e.g., GonaCon™) have made progress over the past 10 years, but again show limited effectiveness over longer time frames and also require booster vaccinations,

limiting their application in free-ranging black bear populations (Fraker et al. 2006). A review by Kirkpatrick et al. (2011) also found potential safety issues with GnRH vaccines for treating pregnant individuals of certain species, as well as side effects and behavioral effects that were not found with PZP. More recently, studies of GnRH vaccines have successfully been carried out in other species (white-tailed deer – Miller et al. 2008; Gionfriddo et al. 2011; wild boar - Massei et al. 2012; eastern fox squirrels - Krause et al. 2015), but these studies have largely been limited to smaller, closed or captive populations. Gray et al. (2010) tested GonaCon™ in a population of free-ranging feral horses and found reduced fertility rates for three years; however, fertility still remained between 39-42% over the course of the study, which would still leave population growth rates untenably high. Gionfriddo et al. (2011) found similar results in a small, fenced population of white-tailed deer. Application of GnRH treatments to free-ranging black bear populations, as with PZP, would require years of additional testing both in captivity and in the field.

Hormonal implants and IUDs may have potential application in wildlife populations, and have been tried in animals such as horses, but have still not been tested in black bears (Fraker et al. 2006). Safety concerns with these treatments would need to be addressed before application in free-ranging populations, as the synthetic hormones used do not degrade readily and can be transferred through the food chain (Fraker et al. 2006). Fraker et al. (2006) also reviewed surgical sterilization of black bears via vasectomy or tubal ligation as a method of population control. Although largely effective at an individual level, sterilizing a large enough proportion of the population to effectively reduce birth rates is largely time- and cost-prohibitive. Boulanger et al. (2012) estimated costs of US$1000 or more per animal for white-tailed deer. In addition, these methods involve surgical experience and expertise that wildlife agency personnel generally do not have, as well as veterinary oversight, which is not readily or consistently available to most wildlife agencies. Finally, invasive surgery poses an increased risk of infection, mortality, and other complications, particularly when conducted in field settings.

COSTS ASSOCIATED WITH FERTILITY CONTROL METHODS FOR FREE-RANGING BLACK BEARS

Although prices of contraceptive agents themselves are relatively low (e.g., $2-10/dose for GonaCon™ and $24/dose for the PZP formulation ZonaStat-H), costs to capture and mark each animal and the cost of equipment and personnel required to carry out vaccinations can be excessively high (Massei and Cowan 2014; Naz and Saver 2016). Turner and Rutberg (2013) highlight the challenges of accessing animals for contraceptive treatments in the field, including costly and time-intensive capture via helicopter roundups or use of bait stations for remote darting. In the case of free-ranging black bears, remote darting is not a feasible option, and targeted trapping efforts would need to be carried out, likely over several months across several years, in order to access enough animals for treatment. Unique marking of treated animals, ideally with radio or GPS collars to facilitate recapture, is also necessary to assess the effectiveness and impacts of treatment efforts. Between 2001 and 2014, New Jersey Division of Fish and Wildlife (NJDFW) captured and handled between 215-364 bears annually (including recaptures) during their active research phase (CBBMP 2015). Given an estimated cost of $2,000 to handle an individual bear (CBBMP 2015), this would lead to capture costs ranging from $500,000-$750,000 annually to access approximately 10% of the total black bear population in

New Jersey for contraceptive treatment. Much of this cost would be wasted as well, since treatment would only be applied to females and approximately half of captures would be males. Further, upwards of 50% of a population needs to be treated for population stabilization (A. Rutberg, pers.comm.), requiring these costs and efforts to be increased even further. The need for such extensive capture efforts makes large-scale contraceptive treatment of free-ranging black bears largely cost-prohibitive and inefficient for population control or reduction.

TIME REQUIRED TO EFFECTIVELY REDUCE POPULATIONS AND CONFLICT/DAMAGE ACTIVITIES USING FERTILITY CONTROL METHODS

In general, fertility control methods are not able to produce rapid reductions in population size, and do not resolve human-wildlife conflict issues since nuisance animals still remain in the population after treatment (Fagerstone et al. 2002; Hristienko and McDonald 2007). Unlike direct removal options such as hunting, which is the most cost-effective and efficient option for reducing human-bear conflict and managing high-density populations, fertility control does not reduce current population size (NEBBTC 2012).

Fertility control alone cannot reduce populations faster than the natural mortality rate, making hunting much more timely and efficient for reducing populations, and potentially conflict issues, to target levels (Bradford and Hobbs 2008; McLeod and Saunders 2014). Hunting efforts, however, must be continued indefinitely in order to maintain populations at these levels. If and when lifetime contraceptive agents are developed, fertility control may actually become more efficient at minimizing treatment efforts and stabilizing populations over the long-run (Hobbs et al. 2000; Zhang 2000; Bradford and Hobbs 2008). Caution must be used in this instance, however, as lifetime contraceptive agents may increase extinction risk due to low or non-existent birth rates (Bradford and Hobbs 2008).

Yearlong contraceptives that require boosting each year require that a large number (upwards of 100% with high survival rates) of adult females be treated to achieve population reduction (Bradford and Hobbs 2008; Grund 2011). Merrill et al. (2006) found that in a closed population of deer, permanent fertility control could begin to reduce a population after 2–3 years, and a population reduction of approximately 60% could be achieved within 10 years if approximately 30–45% of the animals were captured and treated annually. Several studies have suggested using lethal control to reduce population size initially, followed by fertility control to maintain densities at target levels (Hobbs et al. 2000; Merrill et al. 2006). Modeling the impact of fertility control methods on population dynamics can be helpful to determine the most efficient and effective means of meeting population objectives in a specific study area within a set timeframe (Massei and Cowan 2014). Cost, effort, feasibility, and impacts on health and behavior of treated animals must also be considered when determining the most effective options for population control.

Empirical evidence also suggests that long timeframes are needed to achieve population reductions in free-ranging wildlife populations using fertility control. Rutberg and Naugle (2008) documented a 27-58% decline in white-tailed deer over a 5-9 year period following annual treatment of adult females with PZP. Annual treatment of approximately 60-70% of female wild horses on Assateague Island with PZP reduced the population 34% over 18 years (Kirkpatrick

and Turner 2008). In many cases where human-wildlife conflict is high, an 8-10 year timeframe for population reduction (and an assumed, potential reduction in conflict and damage activities) is unacceptable.

DETERMINING IMPACTS OF FERTILITY CONTROL ON HEALTH, BEHAVIOR, AND POPULATION ECOLOGY OF TREATED ANIMALS

Although more recent research into PZP and GnRH formulations show promise as safe and effective fertility control methods in several species (Kirkpatrick and Turner 2008; Fagerstone et al. 2010), studies of long-term health effects, behavior, and social structure have not been adequately carried out or documented, particularly in free-ranging populations (Gray and Cameron 2010). Physiological health effects of various contraceptive treatments include changes in ovarian structure and function, changes in bodyweight or condition, and abscesses or inflammatory reactions to injection sites (Gray and Cameron 2010; Massei and Cowan 2014). Although most of these physiological effects have been minimal, results from many studies are not well documented, and some have been inconsistent. For example, fertility treatments should hypothetically increase body condition in females due to reduced costs associated with reproduction; however, increased body condition was seen in some studies, but showed no change or only temporary change in others (Gray and Cameron 2010). Body condition in male deer should theoretically decrease due to additional energy expenditures associated with prolonged breeding activities, but this has not been documented empirically (Ji et al. 2000; Gray and Cameron 2010; Miller et al. 2013). Hampton et al. (2015) also note that negative effects of capture and handling must also be incorporated into health and welfare considerations of fertility control programs.

Fertility control methods also have impacts on social structure and behavior that have not been widely documented or studied (Gray and Cameron 2010; Massei and Cowan 2014). Behavioral impacts of contraceptive treatments can include changes in sexual activity and mating behaviors, changes in movement and activity patterns, increased aggression, and disruption of social hierarchies or territorial behaviors (Gray and Cameron 2010). Understanding how movement patterns, aggression, and foraging behaviors might change in free-ranging populations as a result of fertility control efforts has key implications in terms of population management and human-wildlife conflict concerns, particularly with species such as black bears, and must be taken into consideration and evaluated as part of the feasibility determination of these efforts. As mentioned previously, studying these impacts can be very challenging in free-ranging populations (Turner and Rutberg 2013; Hampton et al. 2015).

Finally, evaluating population-level effects of fertility control programs is important for understanding efficacy and how programs impact population dynamics over time. There have been several examples of success in reducing population size of free-ranging wildlife species via fertility control methods (Kirkpatrick 2005; Kirkpatrick and Turner 2008; Rutberg and Naugle 2008; Duncan et al. 2017); however, much less has been documented about the impacts of these efforts on population vital rates (e.g., survival, birth rates in untreated individuals, etc.) and demographic parameters (e.g., sex ratios and age distributions). These parameters have important implications on population persistence and health over time (Gray and Cameron 2010; Ransom et al. 2014). Further, evaluating how immigration and emigration impact population parameters

and the efficacy of fertility control options has not been fully explored, and presents an additional challenge in applying these methods to open populations of free-ranging species (Merrill et al. 2006; Rutberg and Pereira 2017). Similarly, understanding selection pressures and genetic changes in populations as a result of fertility control programs is important (and complicated) as well (Ransom et al. 2014).

Since estimating and monitoring vital rates, demographic parameters, and genetic changes in free-ranging populations is so challenging, costly, and time-intensive, population models can provide a valuable tool for determining how fertility control efforts might impact these parameters (Merrill et al. 2006; Turner and Rutberg 2013). Several studies have attempted to model impacts of fertility control efforts on such parameters (Hobbs et al. 2000; Zhang 2000; Merrill et al. 2006; Rutberg and Naugle 2008; Bradford and Hobbs 2008; Grund 2011), though model assumptions and inputs are often simplified and limited, making results from these models limited as well. For example, ecological feedbacks that may compensate for (or enhance) reductions generated by fertility control efforts, as well as immigration, emigration, and stochastic variations of weather, food production, and environmental changes may have a major impact on model results (Rutberg and Naugle 2008; Ransom et al. 2014), yet these factors are rarely incorporated into predictive models. It is important to note that the challenges of evaluating population-level impacts are not unique to fertility control methods, but extend to other management strategies as well, including hunting.

REGULATORY HURDLES ASSOCIATED WITH APPROVAL OF CONTRACEPTIVE AGENTS

Reproductive inhibitors for use in wildlife and feral animals are now regulated by the Environmental Protection Agency under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). State wildlife agencies must also be consulted regarding the use and testing of contraceptive agents in free-ranging wildlife (Fagerstone et al. 2010). Currently, only two immunocontraceptives are approved for use in certain species of free-ranging wildlife – GonaCon® and ZonaStat-H. Others are currently in various phases of the registration process, but are currently not available for widespread use. Registration of a contraceptive “pesticide” by the EPA requires submission of a series of studies on product chemistry, toxicity, non-target hazards, environmental fate and efficacy, thus the EPA registration process can take several years, if not decades depending on financial, logistic, and other constraints (Fagerstone et al. 2010; Rutberg 2013). Approval of an effective contraceptive agent for use in free-ranging black bears will require extensive additional testing in both captive and free-ranging populations.

CONCLUSIONS

Much progress has been made in the past 12 years in developing effective methods for managing certain wildlife populations using fertility control, but this option remains unsuitable and uneconomical for free-ranging populations of black bears. Many of the complex biological, technical, and legal issues outlined by Fraker et al. (2006) still exist today, including:

- A long-lasting contraceptive agent that avoids the repeated stress on animals and high cost of re-treatment still has not been adequately developed,

- fertility control programs are expensive, mainly due to the effort required to capture and recapture animals, as well as monitor and evaluate effectiveness,
- fertility control still requires treating a large proportion of reproductive females in the population,
- fertility control alone takes a long time to effectively reduce population size and associated conflict and damage activities,
- impacts of contraceptive agents on the health, behavior, and population ecology of treated animals are largely unknown, and
- no contraceptive agent has regulatory approval for free-ranging black bears.

Although development of longer-lasting, safe vaccines and regulatory hurdles may be resolved over the next several years or decades, the following issues with using fertility control to manage free-ranging populations of black bears will likely never go away:

- Trapping, immobilizing, and handling large numbers of black bears in the field will always be expensive,
- treating a large enough proportion of females in open populations where immigration and emigration rates are high will always be extremely difficult,
- fertility control methods will always be slow (no faster than natural mortality rates) to reduce population size, and
- fertility control methods will never be able to directly and immediately address conflict and damage issues

Thus, fertility control is not a feasible option for large-scale black bear management in New Jersey. The New Jersey Division of Fish and Wildlife should continue to focus on other aspects of their Comprehensive Black Bear Management Policy (2015), particularly improving control of human-derived food and reducing the size of their black bear population (via hunting). Raithel et al. (2017) recently showed that both of these strategies have been effective for reducing human-bear conflicts in New Jersey. Careful monitoring and evaluation of these efforts (i.e., hunting and reduction of human-derived food) should continue.

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