March 18, 2022

Genetic augmentation of grizzly bears in the Greater Yellowstone Ecosystem: Pilot Program

Rationale and process

Montana Fish, Wildlife and Parks proposes considering and ultimately adopting a process that would assist the long-term genetic health of the grizzly bear population in the Greater Yellowstone Ecosystem (GYE) via the occasional translocation of non-conflict grizzly bears in the Northern Continental Divide Ecosystem (NCDE). This draft document lays out the processes required to allow this to occur, how we envision field operations to follow from that, and also provides the biological rationale for taking this action. Although this program would best be integrated within a comprehensive, statewide grizzly bear plan, progress on that plan is currently delayed. This initiative is consistent with what we anticipate a statewide plan would call for, and is also consistent with long-term direction we believe USFWS favors. A more detailed step-down providing guidance for field operations is currently in the discussion stage, and will be distributed after appropriate consultations

Briefly, biologists have long recognized the long-term risks that wildlife populations face when they are isolated from other populations. The importance of ultimately providing biological connectivity between bears in the GYE and those further north has been recognized for many years (e.g., Allendorf and Servheen 1986). Because both the GYE and NCDE populations of grizzly bears have expanded in abundance and distribution, they are closer to becoming connected via natural movements of bears than at any time during at least the past 50 years. Natural movements of bears into the GYE have been recognized as desirable by Montana Fish, Wildlife and Parks for many years (Dood et al. 2006, MFWP 2013:41), management zones committed to by federal and state managers are intended to facilitate occasional migration (NCDE Subcommittee 2021), and conflict prevention and reduction activities continue that may ultimately allow these movements to occur. Whether or not migrant grizzly bears move into Yellowstone and ultimately contribute genetically, FWP, in cooperation with others, can undertake measures that would, if successful, have a similar biological effect.

1. FWP would, on an on-going and continuing basis, translocate conflict-free bears from other populations in Montana to pre-selected and pre-approved areas within the GYE. Areas chosen for release would be those judged most likely to allow individuals to meet their biological needs without conflicts with humans, and also most likely to encounter and breed with individuals of the opposite sex.
2. Trapping would be conducted to capture and move bears as resources allow.
3. The sex/age of bears that would be augmentation candidates, exactly where they would be released within the GYE, and whether there are times of year when augmentation would be inadvisable are biological considerations that are crucial to the ultimate success of the initiative. Members of the Interagency Grizzly Bear Study Team (IGBST), as well as field-level bear managers in the NCDE are currently considering these biological aspects (see other document).

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4. Bears whose presence is deemed to have greater biological value to the source population than the GYE would not be considered candidates for this program.
5. FWP or USFWS staff in northwestern Montana would coordinate with counterparts in the GYE on the details of transportation and release.
6. The frequency with which such animals would become available would vary annually, and not be predictable. The expectation is that approximately 2 to 4 candidate bears would become available and be moved every 10 years. There would be no additional expectations or requirements for the timing beyond that. For example, if opportunities presented themselves, > 1 bear might be moved in any given year; conversely, a few years might pass with no good opportunities.
7. This magnitude of capturing and moving bears would result in approximately 3 to 6 bears being moved to the GYE per grizzly bear generation (see below). If one-half of the bears moved stayed in the Yellowstone, survived long enough to reproduce, and produced (or sired) a cub that survived to adulthood, approximately 1.5-3 effective migrants per generation would gradually be added to the Yellowstone population. (See below for additional information and justification).
8. If subsequent monitoring (see below) indicated the need for additional bears, additional trapping would be considered. If subsequent monitoring indicated greater fidelity and survival among augmented bears than anticipated, fewer might be moved.
9. All individuals translocated would be fitted with a GPS collar, micro-chipped, and tissues for DNA monitoring would be obtained. The IGBST (or cooperating staff) would track any translocated individuals as part of their routine telemetry monitoring program. Attempts would be made to continue monitoring females post-denning, to document presence of litters. We anticipate, however, that direct observation of offspring from augmentees will be difficult and incomplete. Thus, the genetic monitoring program that is currently in place would continue to document and quantify any reproductive contribution from translocated animals.
10. Translocated individuals would be considered experimental[1] animals, and either moved or euthanized should they cause conflicts with humans.
11. For any translocated individuals that survive and remain in the GYE Demographic Monitoring Area (DMA) at least 1 year, that year's allowable mortality limit for that gender for the GYE (as per the GYE Conservation Strategy) would be increased by one[2] to account for the unanticipated addition of that individual, reinforcing that the augmentation is for genetic, not demographic purposes.
12. As per the NCDE Conservation Strategy, a bear removed from within the NCDE DMA would count against the NCDE's mortality limit (albeit could be accompanied by an asterisk to clarify that the bear might not have died, thus helping inform a potential programmatic review).

Required permissions and suggested processes/protocols

[1] Not to be confused with the legal definition of an "experimental population" in ESA 10(j) sense.

[2] This paragraph has not yet been endorsed by USFWS or the Yellowstone Ecosystem Subcommittee, so may yet change.

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Permissions and approvals

1. USFWS approves all relocations and translocations of grizzly bears in the contiguous 48 states. With limited exceptions, grizzly bears have not previously been moved from one "ecosystem" to another. To expedite real-time decision making, an omnibus approval of this program from USFWS is part of this process.

2. Landowner approval. FWP only releases grizzly bears where the landowner has provided pre-approval. Although there is no particular reason to consider 'northern' grizzly bears differently from those coming from closer by, because this would be a new program we would anticipate obtaining specific approval from landowners in the GYE (typically USFS) for releases of these bears.

3. Newly enacted legislation requires the Montana Fish and Wildlife Commission to pre-approve sites for any grizzly bear releases that would occur within Montana. A list of 32 potential relocation sites in the GYE (anticipating possible relocations of conflict animals) was presented to the Commission for consideration on October 28, 2021 and approved on February 4, 2022.

4. FWP operates its grizzly bear conflict response program under annually renewed memoranda of agreement with the USFWS; thus, no new permits or addenda to these annual agreements would appear to be required.

Suggested processes and protocols

Because this program, while considered informally for decades, has never previously been implemented and because grizzly bear management is highly scrutinized, thorough consideration of field protocols should first occur.

1) Release locations have been be considered and screened from biological and management perspectives at a coarse geographic scale. The initial biological questions "Who (which kinds of bears), where (where captured, where released), and when?" are inter-connected, and thus were considered comprehensively. The group drafting this "protocols" document has considered release areas within the Demographic Monitoring Area of the GYE.
2) A draft protocol document was led by the IGBST and is now in the hands of land managers. We anticipate an iterative process, with the document improving as more expertise is added.
3) The protocols will be presented to both the GYE and NCDE subcommittees of the IGBC to consider objections or suggested revisions. Public input would be solicited at this point, and the document subsequently revised to reflect it.
4) Jurisdictions whose approval would be required are now being approached, with the draft protocol that integrates biological, logistical, and social/political considerations. At present, it is unclear whether this would require formal MOU with other jurisdictions.

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5) Draft and finalize additional language to the GYE and NCDE Conservation Strategies to incorporate agreed-upon protocol (this step probably would not be required prior to any field work).

Documentation and History

Similar programs have been considered in the past but not yet implemented. The "Final Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Area" of March 2007 (since superseded by the one signed by participants in December 2016) noted that migration of grizzly bears into the GYE could occur either via natural movements or artificial transplantation. In the proposed delisting rule of 2007, USFWS pledged to "*continue efforts to reestablish natural connectivity, but our partners…* [presumably including MFWP]*… will transplant one to two effective migrants per generation if no movement or genetic exchange is documented by 2020*…". USFWS further stated that "*Augmentation is proposed as a precautionary measure based on the recommendations of Miller and Waits (2003, p. 4338) to maintain current levels of genetic diversity, should grizzly bear movement into the GYA not occur over the next 20 years*."

The USFWS (2021:181) also contemplated possible translocation, suggesting confidence that "…*translocation, if necessary, will address the ability of future GYE bears to adapt evolutionarily*". Regarding accountability and monitoring, USFWS (2021:181) stated that "*The IGBST also monitors genetic diversity of the GYE grizzly bear population so that a possible reduction in genetic diversity will be detected and responded to accordingly with translocation of grizzly bears into the GYE originating from another population in the lower-48 States. In addition to possible translocations, measures described in the 2016 GYE Conservation Strategy are and will continue to be used to promote genetic connectivity through natural movements. These measures include habitat protections, population standards, mortality control, outreach efforts, and adaptive management*."

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Detailed biological background

Grizzly bears living in the GYE have been isolated from other grizzly bear populations possibly for over 100 years, and thus the genetic effects of small population size raise concerns. No immigrants into the GYE population have been documented to date (Haroldson et al. 2010; M. Haroldson, USGS, pers. comm., 2021), and heterozygosity and allelic diversity are lower than most other North American grizzly bear populations for which data are available. However, these 2 metrics of genetic diversity declined very slowly if at all from 1985 to 2010. The rate of inbreeding has been very low since 1985, and no physiological, behavioral, or demographic effects indicative or associated with inbreeding have been detected. Importantly, estimates are that effective population size (the summary metric best suited to consider genetic effects) has increased over the estimates of 1910-1960, continued to increase during 1985-2007, and is well above the level where the short-term effects of reduced genetic diversity (i.e., inbreeding, genetic drift) would be expected.

Thus, all indications are that Yellowstone grizzly bears are genetically well-adapted to their existing environment and facing no immediate threat related to population genetics. However, the Yellowstone population is sufficiently small from a genetic perspective that isolation from other populations poses risks for its *long-term* viability (> 100 years). Although no genetic issues currently limit the ability of grizzly bears in Yellowstone to survive and reproduce normally, their ability to respond evolutionarily to unknown future environmental or other challenges may be limited by low allelic diversity combined with isolation. Thus, introduction of genetic material from other grizzly bear populations would reduce the long-term risks associated with loss of allelic diversity in the Yellowstone grizzly bear population.

Best estimates are that any long-term genetic risks can be ameliorated by the effective migration into Yellowstone of as few as 1 to 2 animals per generation (10-15 years) if continued indefinitely into the future. Thus, although connectivity is required over the long-term to alleviate risks, such genetic connectivity can be thought of as a slow and continuous trickle of bears rather than a sudden and dramatic increase of gene flow. Recent geographic expansions of GYE grizzly bears in a northwesterly direction, and of NCDE area grizzly bears in a southeasterly direction have increased the probability of natural genetic connectivity in the future. A major impediment to achieving connectivity is Interstate Highway 90, and in particular the rapidly increasing level of human development associated with the greater Bozeman area.

Why do we think that genetic augmentation is necessary, and why do we think the relatively few animals we suggest here will suffice? Consider the question "How many animals are enough to ensure long-term persistence" by focusing on minimizing the chance that erosion of genetic diversity within a small, isolated population will render it unable to evolve, if needed, to changed conditions in the future. We know that larger populations generally have more genetic diversity — more options available from which to develop adaptations to differing conditions — than smaller ones. But how large is large enough to maintain needed evolutionary potential? We don't have the luxury of observing a variety of wild populations subjected to changing conditions to see which ones successfully coped and which did not. Instead, we need to depend on theory, augmented by well-considered simulation models.

In 1980, geneticist Ian Franklin postulated that an effective population of 500 would be large enough to allow beneficial mutations to balance genetic erosion (in particular, "genetic drift") indefinitely, and was thus a useful rule of thumb for answering the question "How many are enough to retain the evolutionary potential to cope with future change" (Franklin 1980)? Since then, some

scientific dispute about the "500 long-term rule" has emerged (Jamieson and Allendorf 2012, 2013; Frankham et al. 2013); FWP agrees with Jamieson and Allendorf (2013) that it retains usefulness in considering long-term needs for population size.

Importantly however, the 500 number refers to the "effective" size, not the number of animals. The effective population size (N_e) is defined as that which will lose genetic variability at the same rate as an "ideal" population[3]. Because in almost all wild populations, N_e is smaller than the actual (census) number of animals (N_c), more than 500 animals would be needed in order to satisfy Franklin's rule-of-thumb. What is the relationship between N_e and N_c in grizzly bears? In reviewing a number of equations relating these 2 quantities at the time, Harris and Allendorf (1989) created simulations of grizzly bear populations, and concluded that, based on demographics and breeding structure, N_e was likely to be in the range of $0.24N_c$ —$0.32N_c$, depending on assumptions used. This suggested that a grizzly bear population would need to number ~ 1,560 to 2,080 to meet Franklin's criterion. Since then, advances in genetics and theory have allowed better and more data-driven estimates of N_e for the GYE grizzly bear population. Kamath et al. (2015), estimated that the N_e/N_c ratio had, in recent years, been between 0.42 and 0.66 (suggesting between 760 and 1,190 bears needed to satisfy Franklin's rule of thumb). Regardless, the long-term need for occasional genetic interchange between geographically discrete grizzly populations has not seriously been questioned by biologists (and is not questioned by FWP).

A related question follows: if a population is isolated but capable of being reached by occasional migrants from another presumably larger and more genetically diverse population, how many migrants are needed to effectively link the two genetically, and how often must such immigrations occur, in order for the entire assemblage to both be genetically secure while retaining any adaptive divergence? Sewell Wright, one of the founders of modern conservation genetics, had proposed decades ago that, under a number of simplifying assumptions, a single migrant per generation would be sufficient to prevent loss of heterozygosity and allelic diversity within a vulnerable subpopulation while still allowing it to respond adaptively to local conditions (Wright 1931). This noteworthy result derives from fact that a single migrant would provide a relatively large infusion of genetic material to a small population, and although it would provide a proportionally smaller benefit to a larger population, the very fact of large size would reduce the need for the immigration. A number of simulation studies later confirmed that the one-migrant-per-generation (OMPG) rule-of-thumb maintained its validity under a variety of assumption violations typical of real-world populations (Mills and Allendorf 1996, Wang 2004), and thus that OMPG, or perhaps slightly more than one, remained a useful long-term goal. A genetic metric to reflect the balancing between assuring that the target population would maintain its evolutionary potential while still maintaining necessary local adaptations is called F_{ST}, which under OMPG would, after a sufficient number of years, equilibrate at 0.2

Of course, a "migrant" in this sense is not merely an animal that travels from one population to another. For it to perform as the OMPG theory predicts, the migrating animal must contribute to the gene pool after arriving, i.e., breed with a resident. Put another way, the 'M' in OMPG must be an "effective migrant". What about the 'G' in OMPG? How long is a generation for grizzly bears? Using similar methods to those used to estimate N_e for Yellowstone grizzly bears, Kamath et al. (2015) estimated it at about 14 years. To date, we have no evidence that any migrants, effective or otherwise, have made it from the NCDE to GYE area populations.

[3] Defined as one with discrete, non-overlapping generations, that doesn't vary in size annually, and in which the contributions of each member to the succeeding generation are randomly distributed (i.e., described by a Poisson distribution).

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