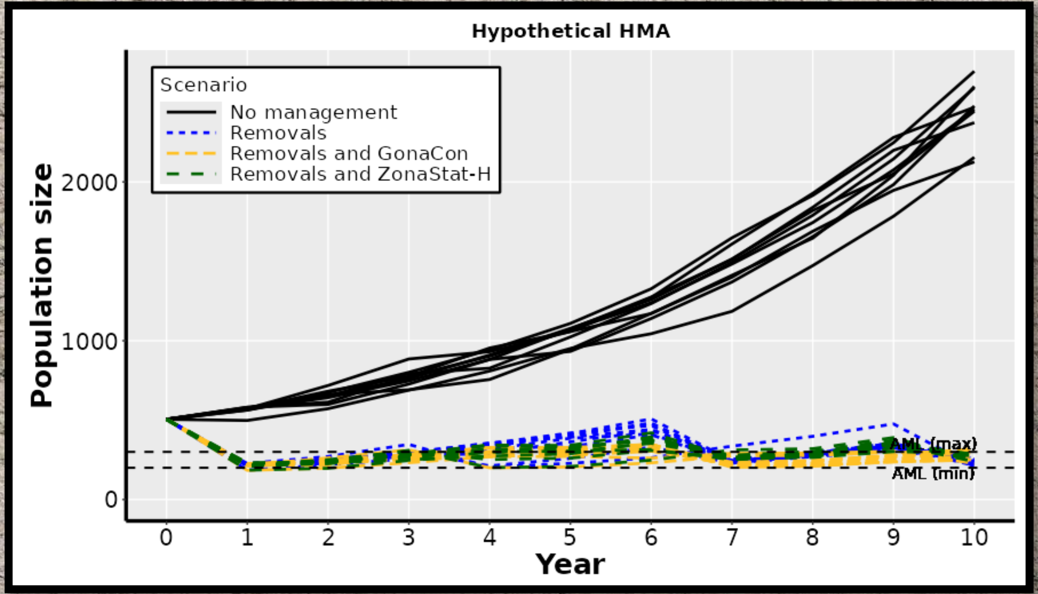
U.S. Department of the Interior
Bureau of Land Management

PopEquus Modeling

WHB Advisory Board, January 2025



Desatoya HMA, Nevada. BLM Photo: John Axtell, 2020

2023 Recommendation #3. **The board recommends that the BLM** and the USFS present at the next board meeting plans that determine ecosystem health and population stabilization by **choosing two HMAs**/Territories each **and demonstrating how the PopEquus model can be utilized to attain desired management outcomes**, as well as what those outcomes would be.

BLM Response: …**PopEquus is being used** to compare and contrast how effective and expensive it would be to achieve stable populations within AML, using different management scenarios...**After decision records are final for two of those HMAs, they will serve as the type of demonstration projects that the board is recommending**…where aerial surveys are the method of choice, those will be used annually to assess foal to adult ratios and population growth rates…**The BLM will report back to the board annually on** the population status of these two HMAs, and **the extent to which the population trends are or are not consistent with projections from PopEquus**.

Outline

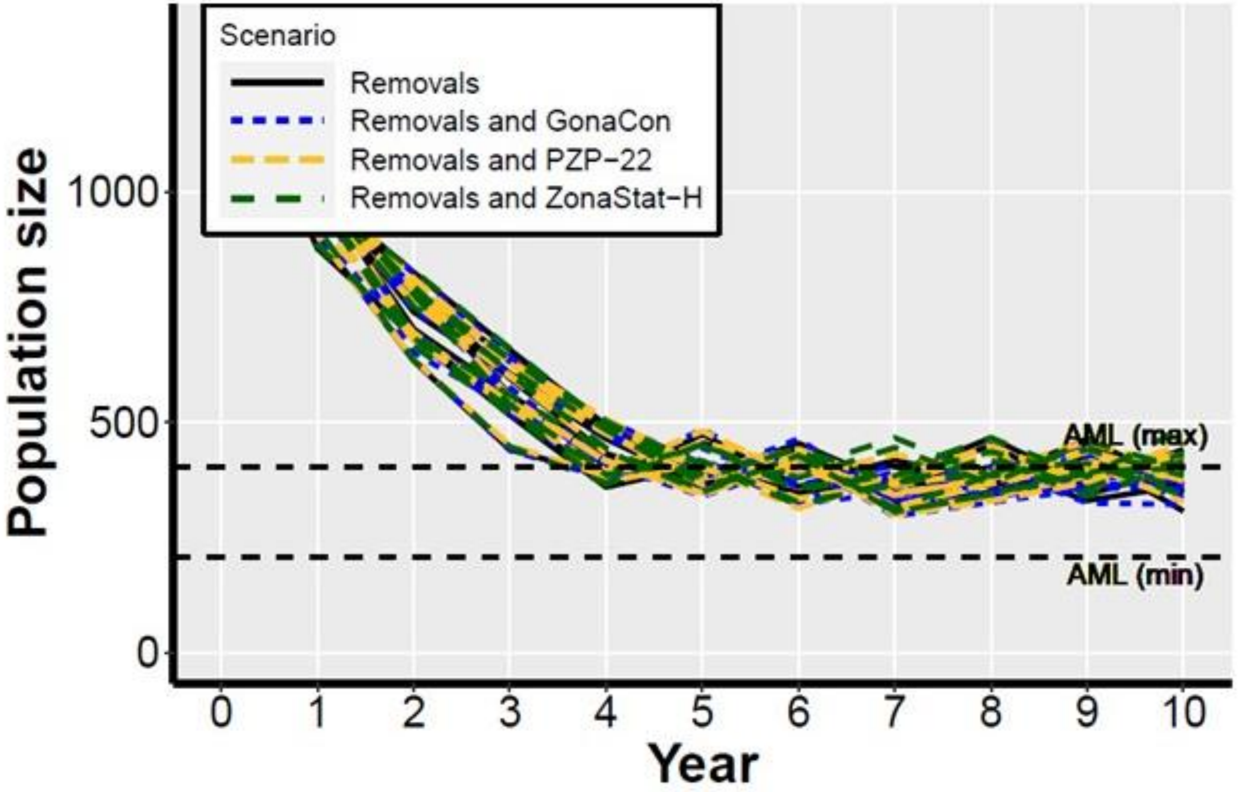
1. PopEquus model use in NEPA analyses & Demo

2. Monitoring / assumptions used in PopEquus
   Annual herd growth rates
   Fertility control efficacy


BLM Photo: Paul Griffin

1.A. PopEquus in NEPA *(USFS Devil's Garden)*

A graph of population size through time can be used to visualize effects of management alternatives on population size. Different colored lines indicate management alternatives simulated by the user; for each alternative, individual lines are different simulation replicates, that vary due to random chance. Dashed horizontal black lines indicate the minimum and maximum target population size range (i.e., AML).



	Alternative 1	Alternative 2	Alternative 3	Alternative 4
PopEquus Projections	Eighty percent (80%) probability reaching AML in 10 years with 1,640 horses gathered, 1,067 removed, and 302 mares treated.	Thirty percent (30%) probability reaching AML in 10 years with 1,659 horses gathered, 1,156 removed, and 255 treated.	Eighty percent (80%) probability reaching AML in 10 years with 1,640 horses gathered, 1,067 removed, and 302 mares treated.	Fifty percent (50%) probability reaching AML in 10 years with 3,169 horses gathered, 1,101 removed, and 1,161 mares treated.

Table 17: Cost Analysis using PopEquus Model Simulation over 10 Years

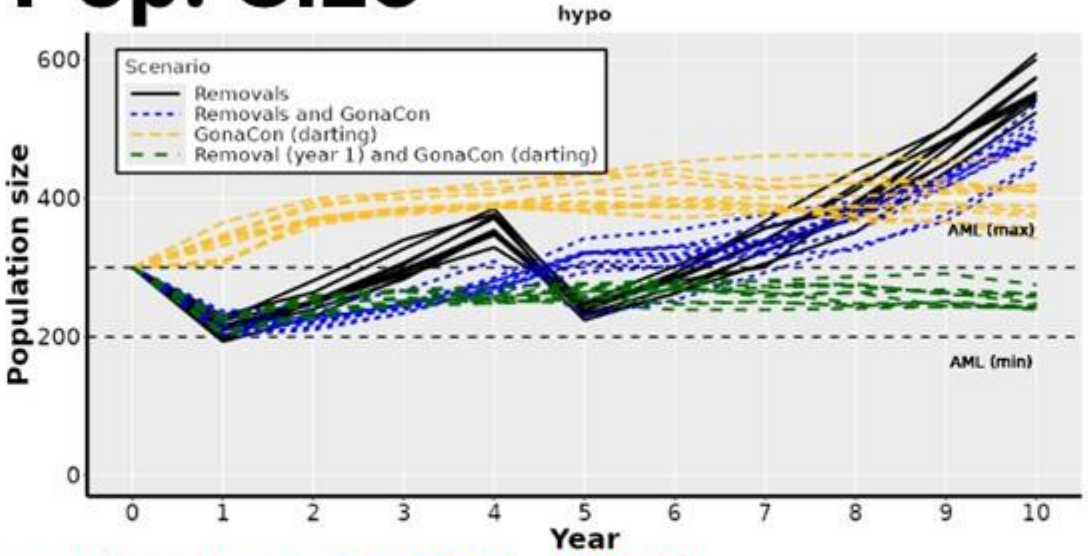
Management Alternative	On-Range Cost ($ million)	Off-Range Cost ($ million)	Total Cost ($ million)
Alternative 1 Proposed Action	1.84	5.63	7.47
Alternative 2 – Modified 2013 TMP	1.87	5.81	7.69
Alternative 3 – Established AML, Limited Fertility Control	1.84	5.63	7.47
Alternative 4 – Sustain Current WH Population, Limited Fertility Control	3.06	5.35	8.41

PopEquus (live demonstration)

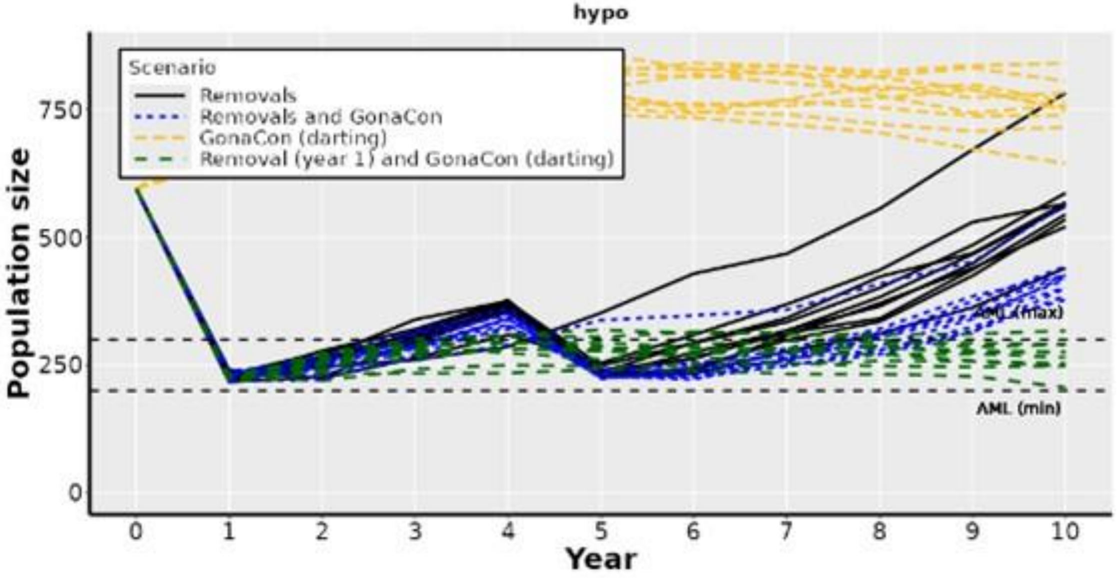
https://rconnect.usgs.gov/popequus/

One variable at a time: Starting Pop. Size

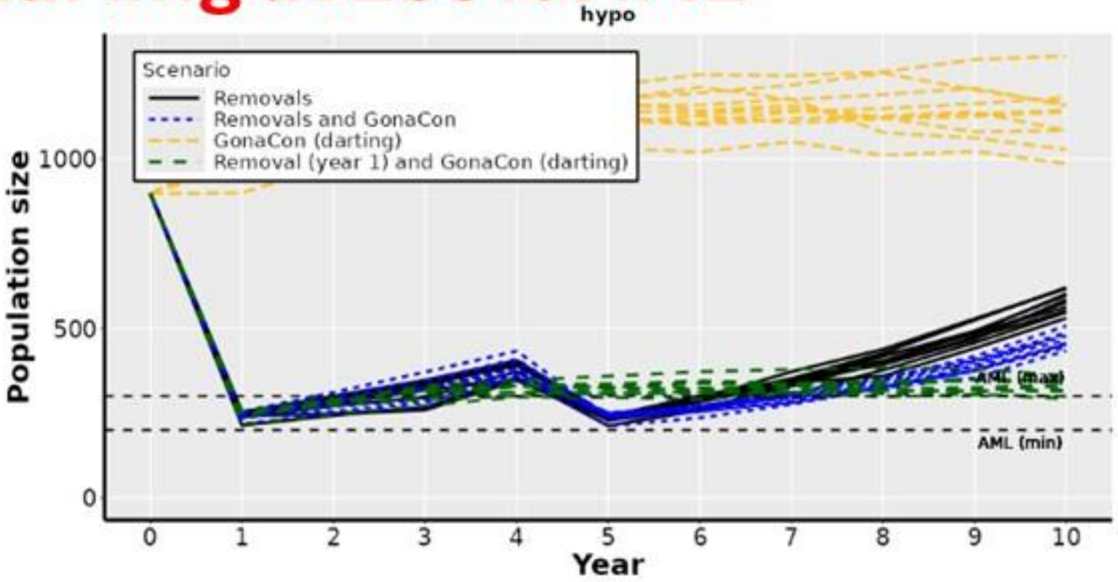
Starting at 100% AML →



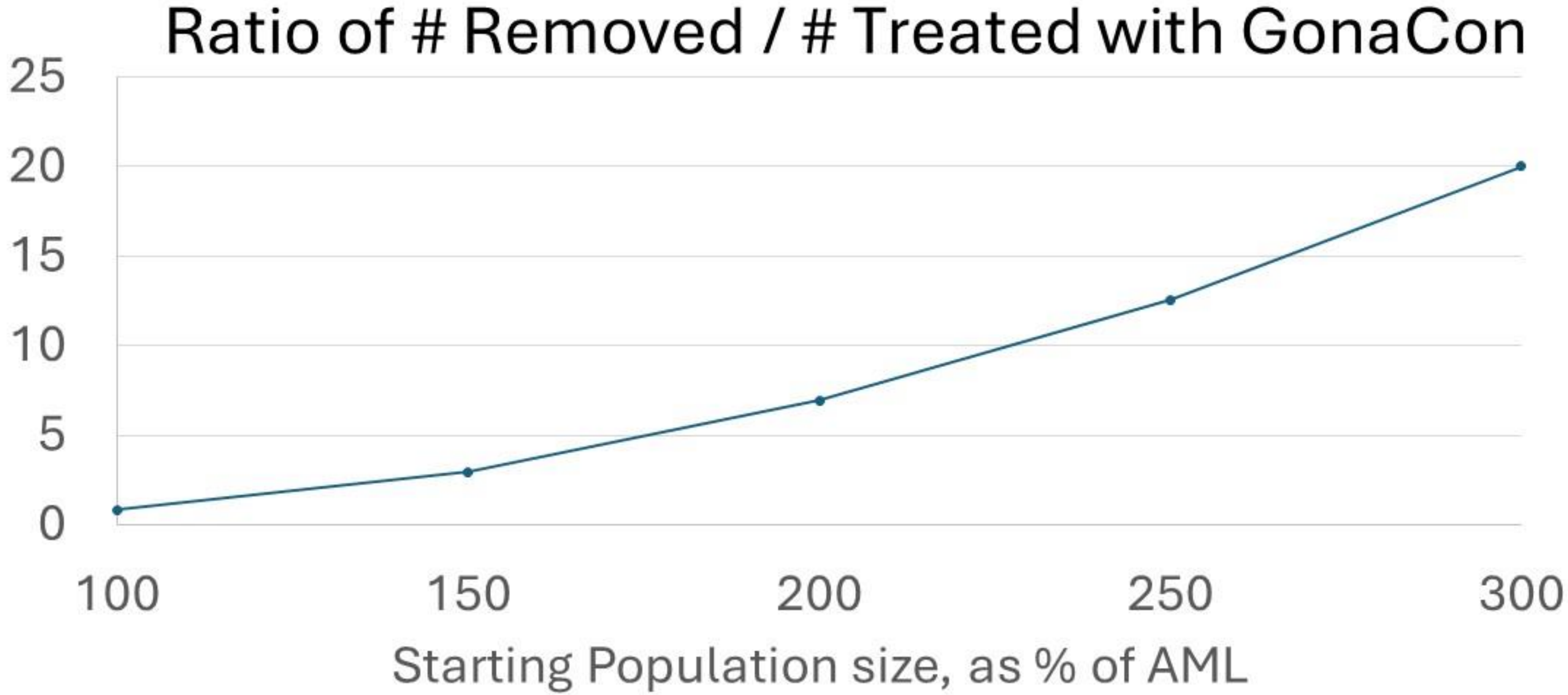
← Starting at 200% AML



Starting at 300% AML →



One variable at a time: Starting Pop. Size



Hypothetical HMA. Results here are just showing a Removals + GonaCon Alternative, with removals in years 1 & 5.

1.B. PopEquus assumptions: "Mechanics"

rconnect.usgs.gov/popequus/

USGS
science for a changing world

PopEquus 1.0.2 | Basic Tool | Advanced Tool | User Manual | Mechanics | Exercises

This page describes the mechanics of how horse population projections are performed by the ***PopEquus*** simulation tools and how management actions, such as fertility control treatment, are simulated in that framework.

Population projection

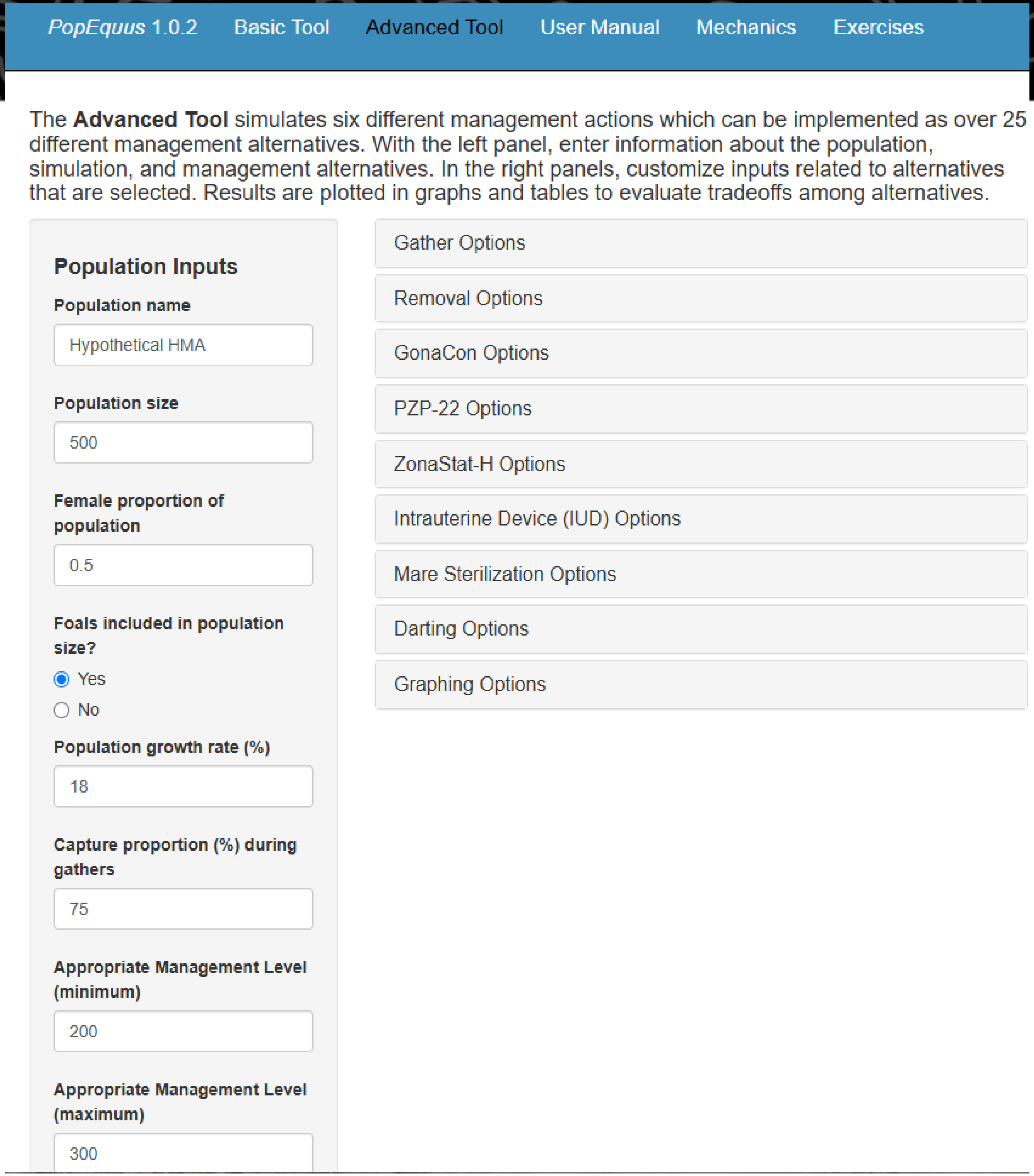
The ***PopEquus*** application projects horse populations through time using matrix multiplication (Caswell 2001). It conceptualizes horse population structure using an **age-based, two-sex, post-breeding census population model**, where horse populations have 21 age classes for each sex: one age class for each year of age from 0 (foals) to 19 years old, and a final stage with all individuals ≥20 years old. During a given time-step, individuals in each age class have a probability of surviving and transitioning to the next age class, until they reach age 20; all individuals ≥20 years old are modeled as a single stage class with a probability of surviving and staying within that stage. Females of age ≥2 years old have a probability of reproducing (foaling) and recruiting individuals into the foal age class. Individuals that do not survive and transition during a time-step are assumed to have died.

The model uses demographic matrices containing population vital rates (age-based survival and reproductive rates) to project populations (**Table 1**). Some demographic matrices are based on studies of wild horse populations from western North American ecosystems (Berger 1986, Garrott and Taylor 1990, Jenkins 2002, Roelle et al. 2010). Other matrices were built to approximate the wide range of potential **population growth rate (λ)** values experienced by horses (range: 0.84–1.39) (Ransom et al. 2016). In total, the model uses ten demographic matrices representing variable demographic conditions that might be experienced by horse populations in space and time. Each demographic matrix yields a different deterministic value of λ. Seven of the matrices create λ values ranging from 1.066-1.196 (i.e., 6.6-19.6% increases in population size per year). Two matrices yield larger λ values (1.231, 1.317) that might occur during years or in places with particularly high productivity. One matrix yields a λ value of 0.53, where the population decreases in size (approximately halves); this might happen during years where environmental conditions cause extremely low adult survival, such as during an unusual blizzard event (Garrott and Taylor 1990). Populations are projected by multiplying a demographic matrix by a population size vector, which is a single column, 42-row describing the number of female and male horses in each age classes in a given year (below).

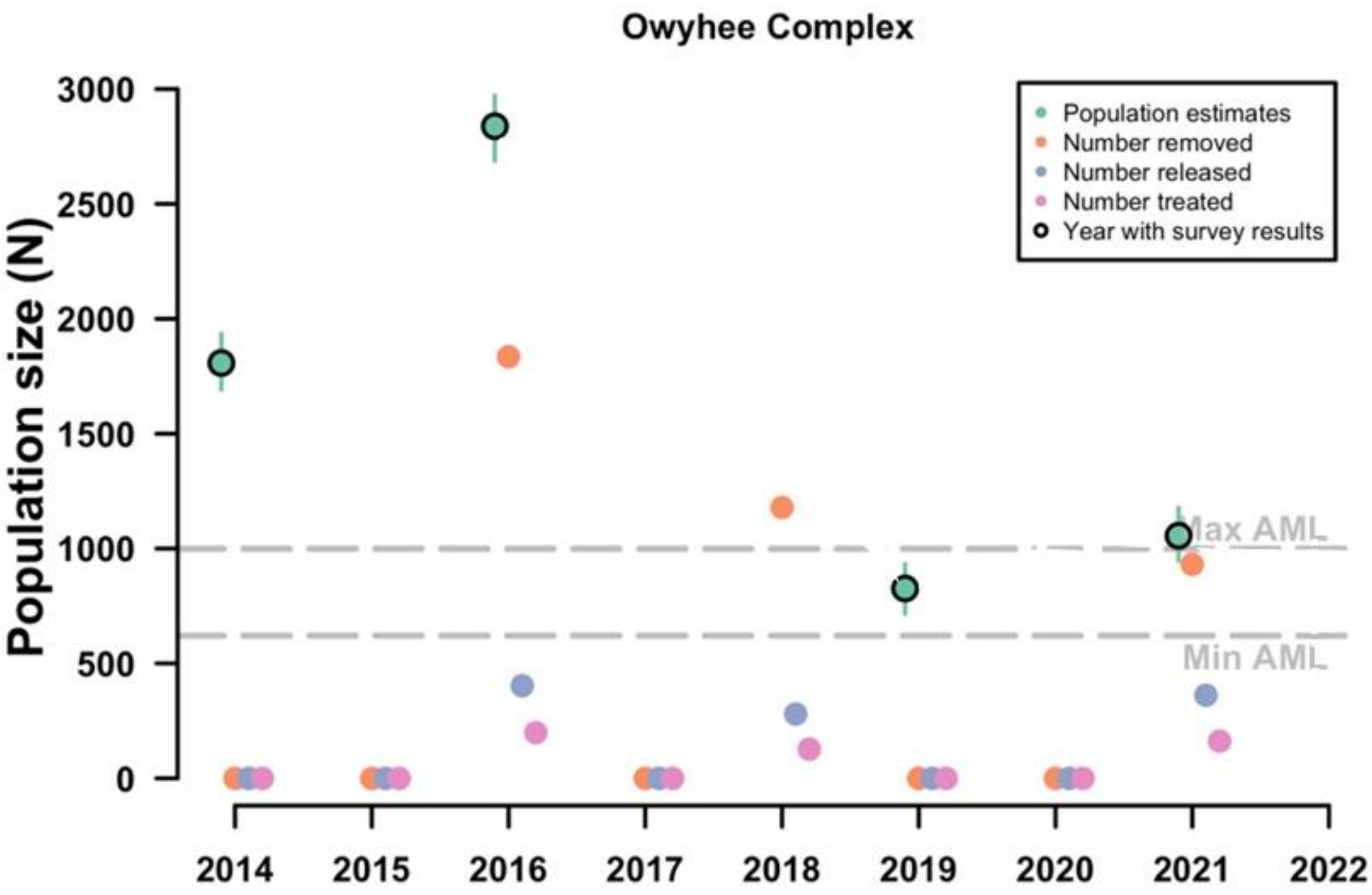
Table 1: Population vital rates and demographic matrices used to project horse populations with the ***PopEquus*** simulation tool. The 'Summary' tab summarizes all population vital rates (**survival, S; reproduction, R**) and resulting measures of deterministic population growth rates (λ) from ten demographic matrices used to project horse populations. Reproduction of females (i.e., foaling) is denoted by the variable R. **Additional tabs** (e.g., '**Matrix 1**') include the exact demographic matrices used by the application. Each demographic matrix is a square matrix with 42 rows and 42 columns that correspond to 21 age classes for **females (F)** (age 0-20+) and **males (M)** (age 0-20+). Columns and rows are labeled by **F** for females, **M** for males, and numbers to represent ages (e.g., **F1 is 1-year old females**). Each matrix cell describes probability that an individual will transition (or reproduce) from column state to row state during one time step. For example, in Matrix 1, the value in column 1, row 2 (0.948) is the probability that an age 0 female that will survive and transition to become an age 1 female at the end of the year. Values along the subdiagonal describe the transition rates (i.e., survival) among age classes. Alternatively, horizontal values in rows 1 and 22 of columns 1-21 describe reproductive rates from the column state to the row state. For example, in Matrix 1, the value in column 4, row 1 (0.244) describes the rate at which age 3 females

Annual herd growth rate

PopEquus allows values from 0-32%



Example herd size monitoring data



Growth rates: Time series analysis

(preliminary. from: Folt et al., 2024 presentation at 'The Wildlife Society')

>30 populations (HMAs or complexes) in >70 HMAs

>120 simultaneous double-observer aerial surveys

Approx. 18-20% average growth w/o treatments

All herds had mean growth rate over 5% per year

… some over 25% per year

- Fertility control measurably reduces growth rate
- Low but measurable density dependence

Fertility control efficacy

PopEquus expectations for GonaCon-Equine Vaccine, *after* Baker et al. 2018, 2023

(foaling rates here assume a 75% background)

1 dose ➔ 37% lower foaling in 2nd year after treatment *(i.e., 43% foaling in year 2)*

➔ 29% lower fertility in 3rd year *(i.e., 53% foaling in year 3)*

2 doses ➔ 100% lower foaling in 2nd year *(i.e., 0% foaling)*

➔ 85% lower years 3-5 *(i.e., 11% foaling)*

➔ 50% lower years 6-8 *(i.e., 37% foaling)*

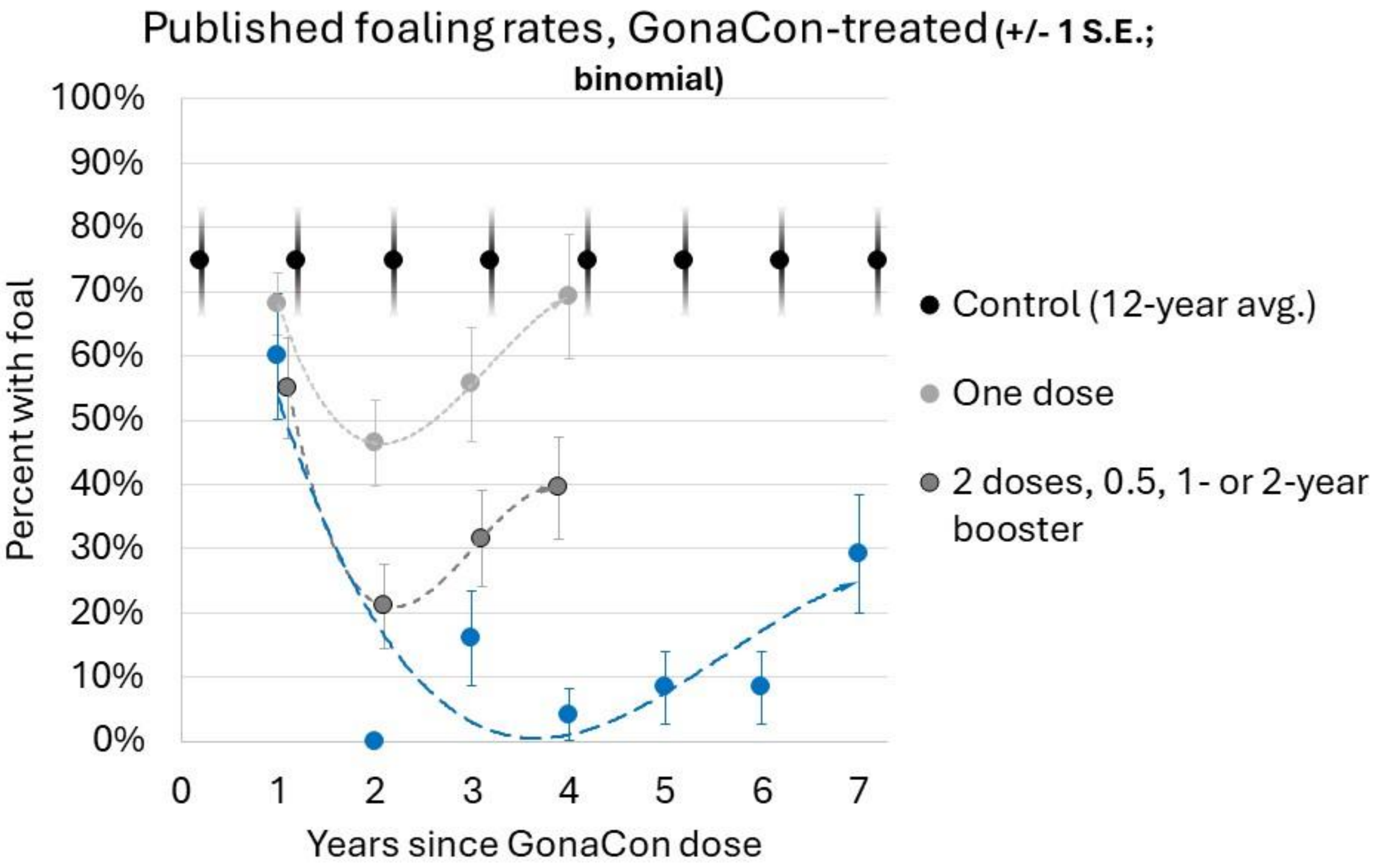
BLM management ~30+ day booster monitoring results

About 15+% without foals in 2nd season

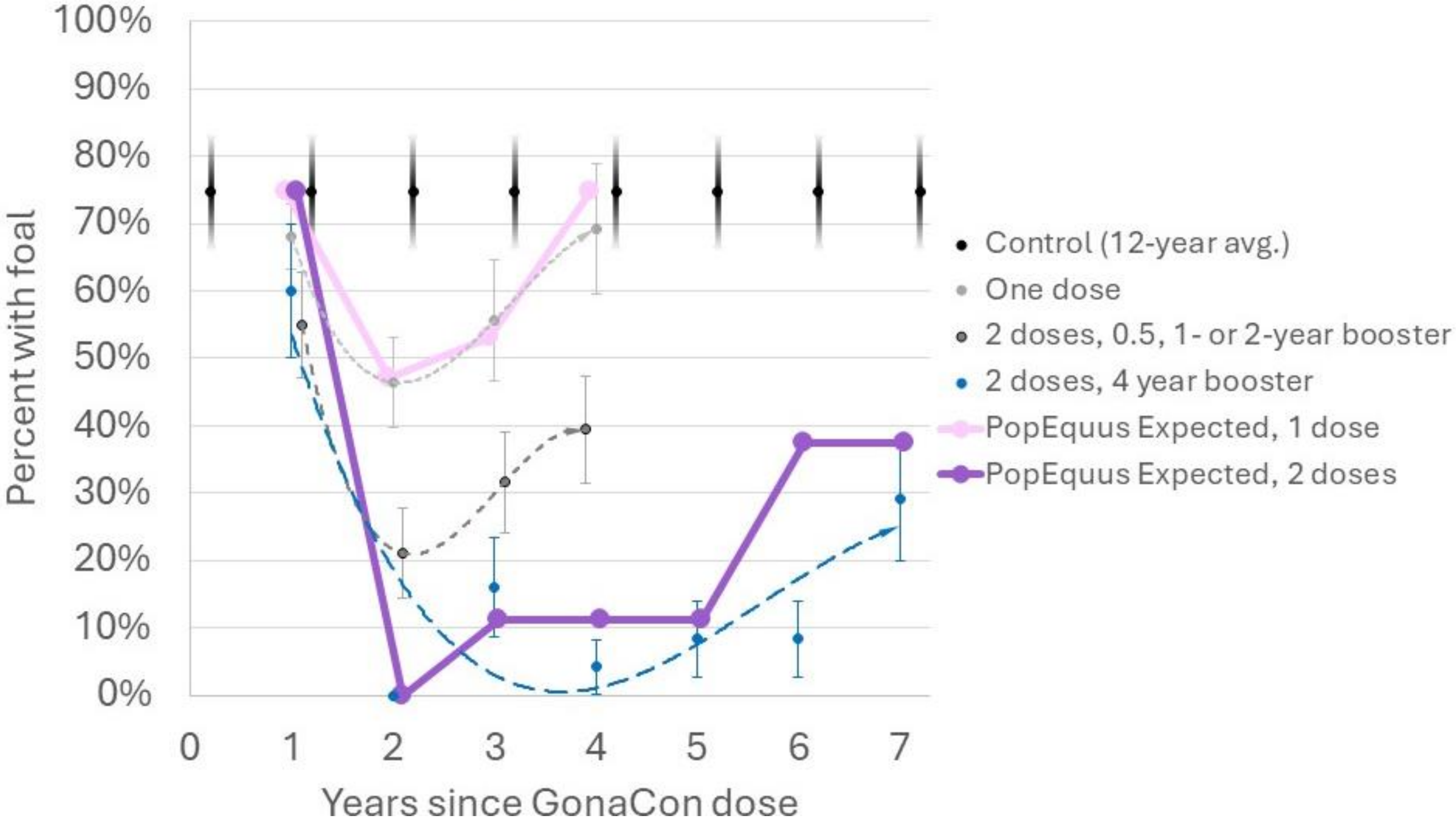
About 30% without foals in 3rd season

About 45% without foals in 4th season

i.e., an increasing return to fertility over time

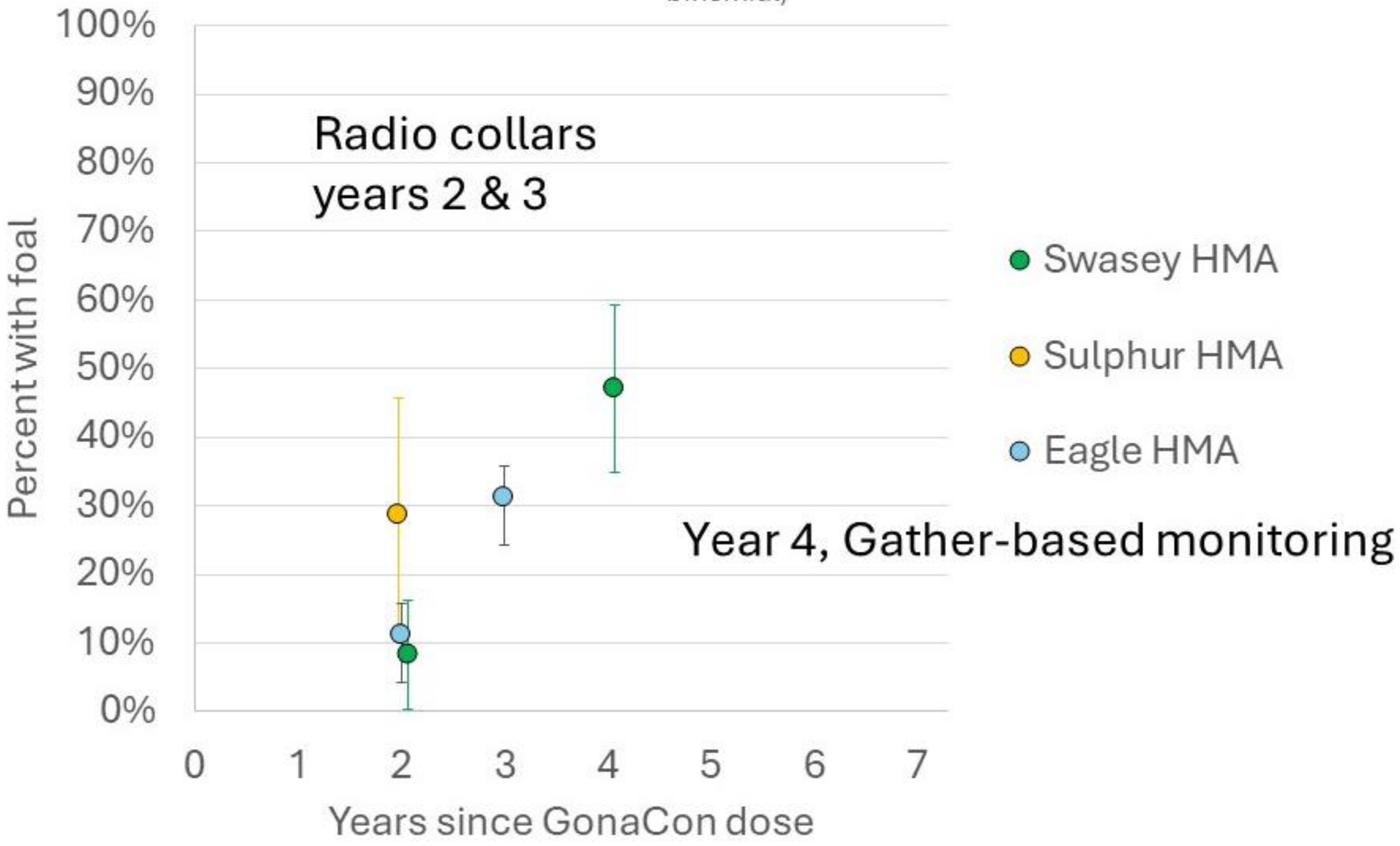

Published foaling rates, GonaCon-treated (+/- 1 S.E.; binomial)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent with foal
0
1
2
3
4
5
6
7
Years since GonaCon dose
Control (12-year avg.)
One dose
2 doses, 0.5, 1- or 2-year booster

PopEquus foaling rate, GonaCon-treated (+/- 1 S.E.; binomial)



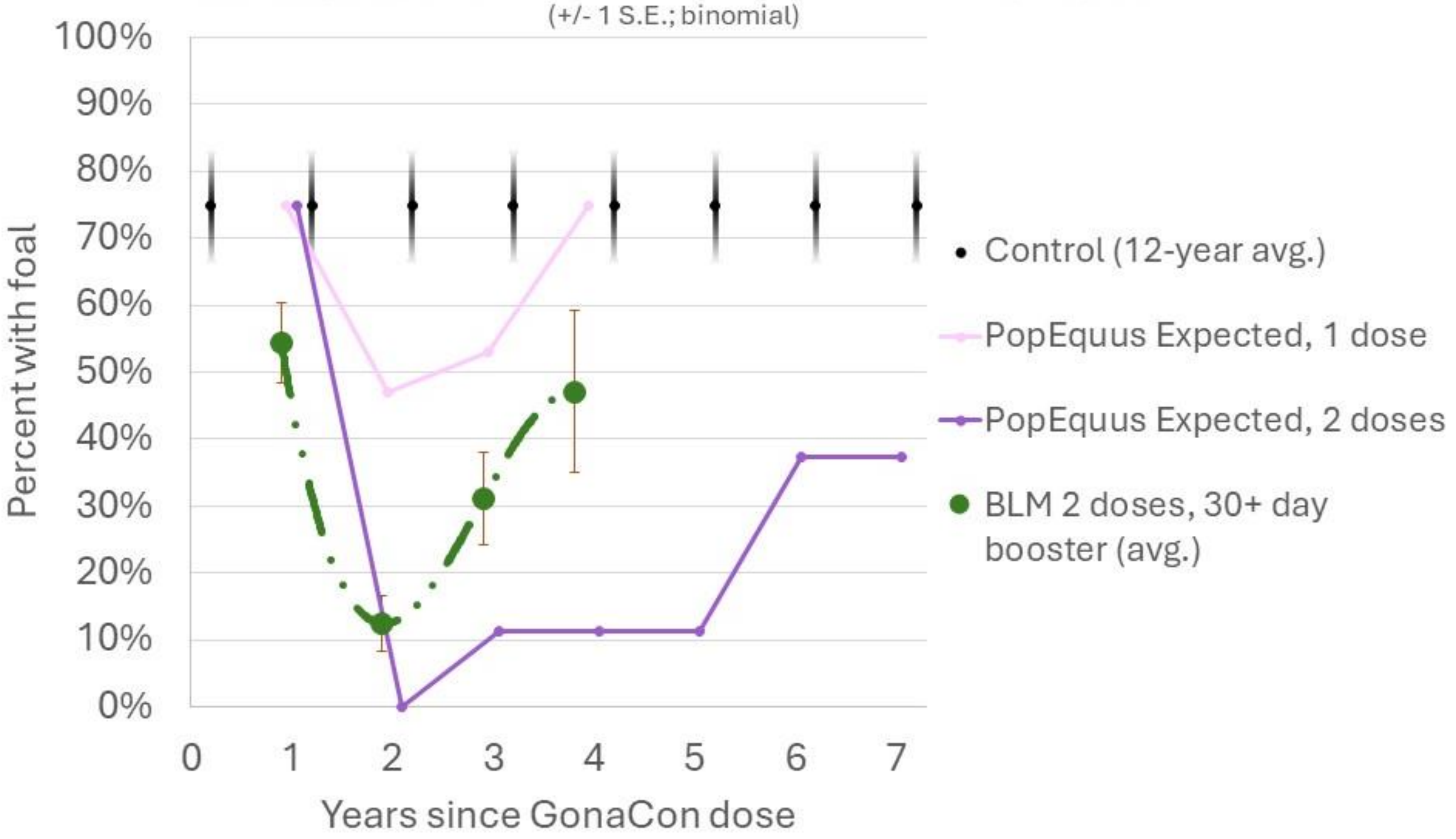
Expect an increasing return to fertility over time

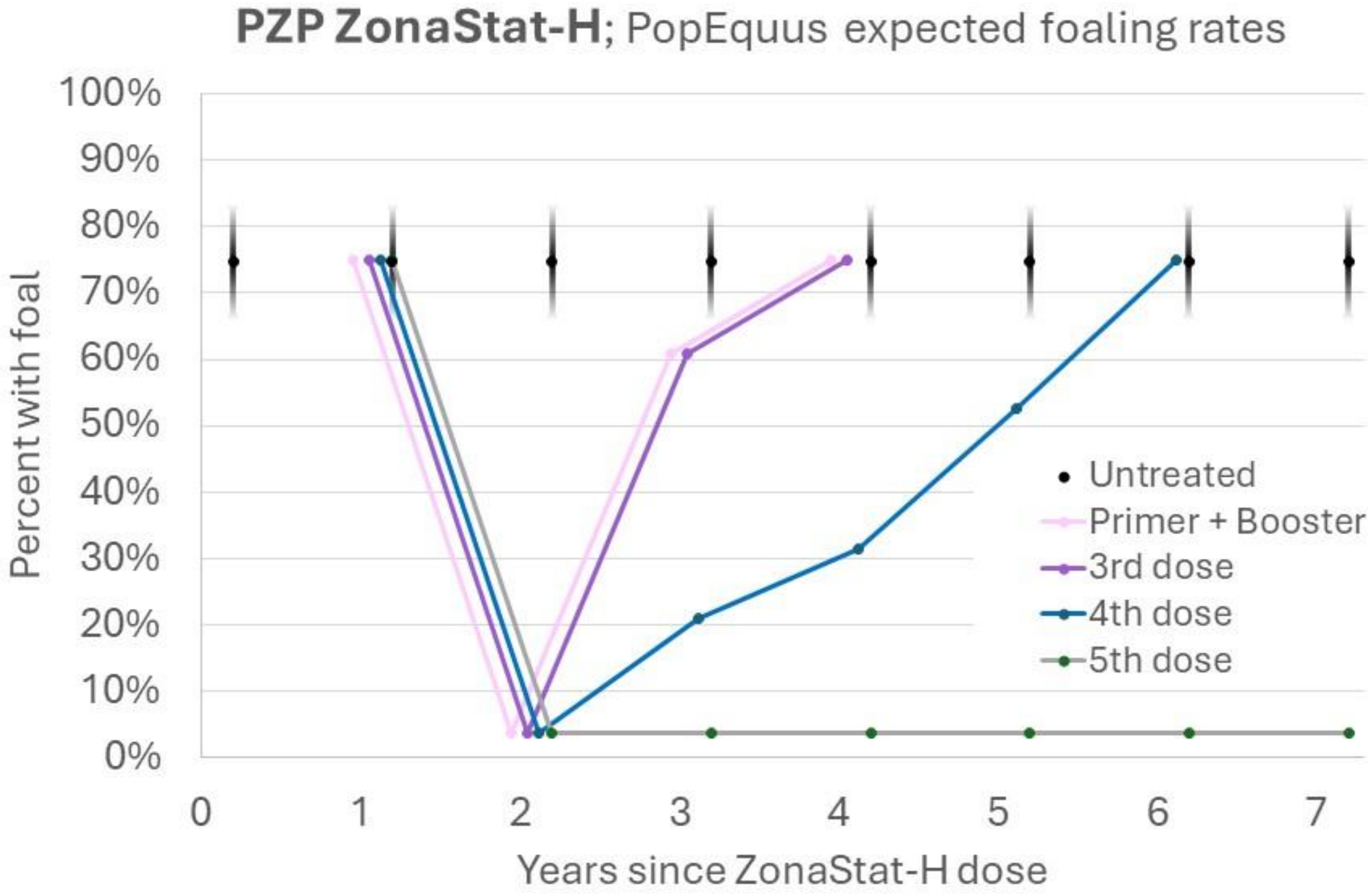
Monitoring, GonaCon booster after ~30 days (+/- 1 S.E.; binomial)



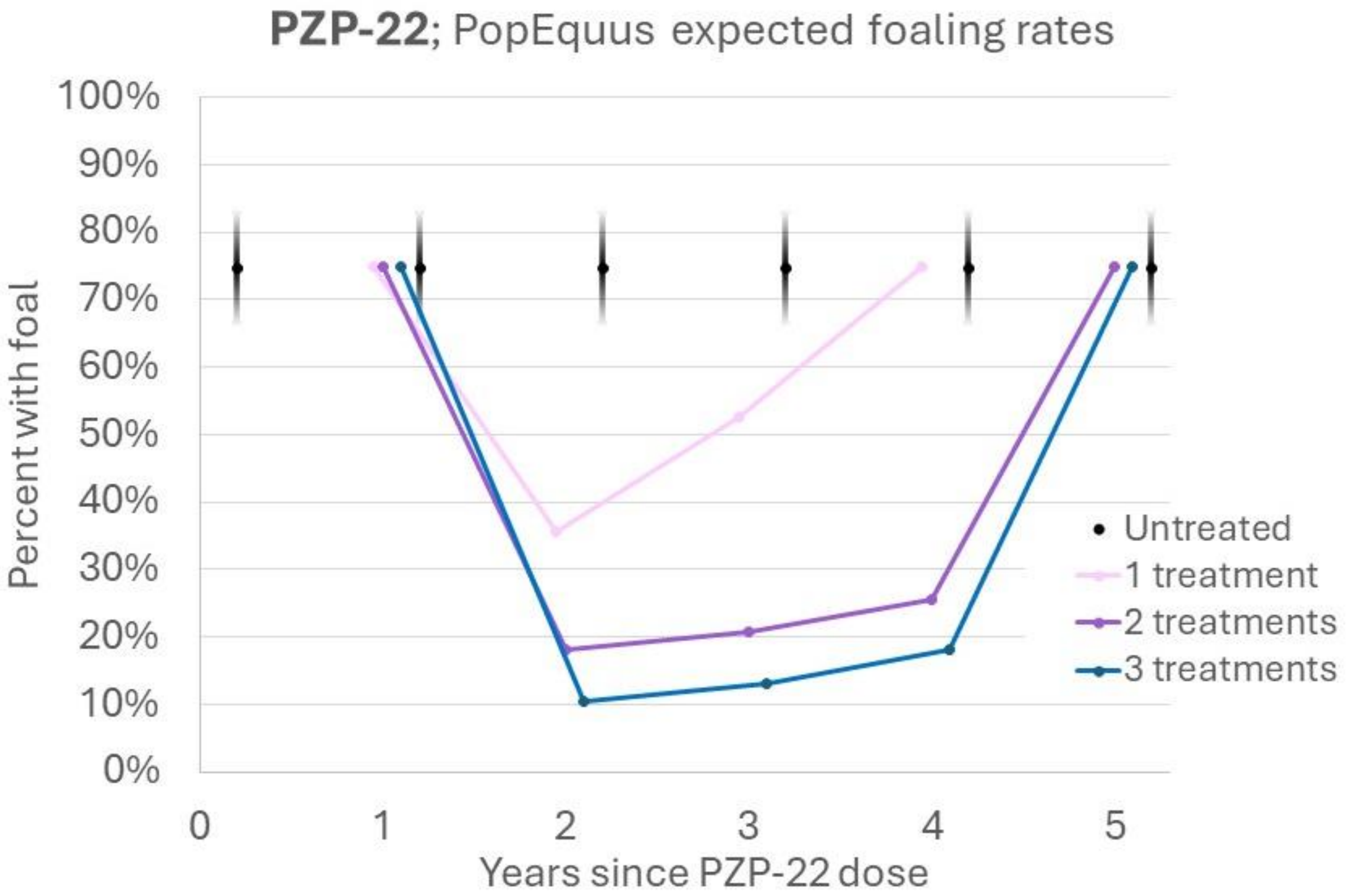
Preliminary, unpublished BLM monitoring data; generally an increasing return to fertility over time

~30-day booster GonaCon foaling vs PopEquus





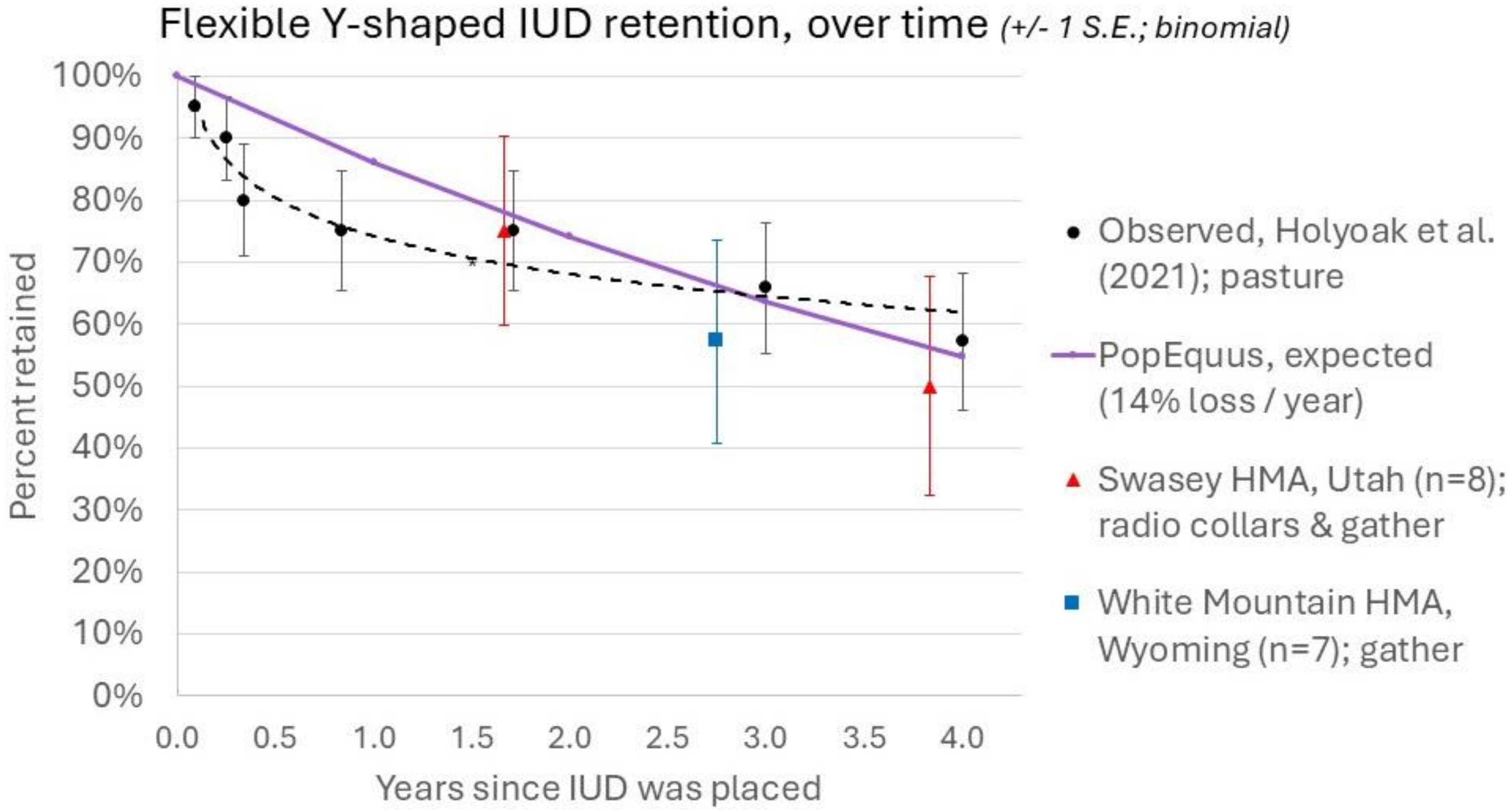
PopEquus expectations for 2-3 doses of PZP ZonaStat-H based on Turner et al. 1997 & Kirkpatrick and Turner 2008
PopEquus expectations for 4-5 doses of PZP ZonaStat-H based on Kirkpatrick and Turner 2008 & Nuñez et al. 2017



PopEquus expectations for 1-2 treatments of PZP-22 based on Rutberg et al. 2017

PopEquus expectations for 3 treatments are surmised: 10% more effective than 2nd dose

Fertility control efficacy: flexible IUDs



PopEquus expectation of 14% IUD loss per year is after Holyoak et al. 2021

Predation rates

Recent research studies:
Iacono et al. 2024. *Ecosphere*
Schulmann et al. 2024. *Vaccines*
Andreassen et al. 2021. *Journal of Wildlife Management*

- In many areas, predation on horses is not common
- Adults were rarely killed
- Even foal mortality levels of 50% allow for herd growth, but predation *can* reduce growth rates

PopEquus updates may include variable foal and yearling predation rates

Flanigan HMA, Nevada. BLM Photo: John Axtell, 2020