How does adding adding energy and lifecycle constraints effect the population dynamics compared to the baseline?

H0: introducing energy and lifecycle constraints into the baseline model does not significantly effect the population dynamics compared to the baseline model.

H1: Introducing energy and lifecycle constraints significantly changes population dynamics compared to the the baseline model.

Metrics for comparison:
steps_survived: how long the population persisted
final_rabbits, final_foxes: population sizes at termination
max_rabbits, max_foxes: peak population
min_rabbits, min_foxes: minimum recorded value (excl. 0 possibly)

Parameters:
Baseline model:
movement_speed=2.0,
radius=50,
fox_death_prob=0.01,
fox_hunt_radius=40,
rabbit_reproduction_prob=0.005,
duration=15000,
fox_start_energy=0,
fox_energy_gain_on_eat=0

Lifecycle and energy model:
movement_speed=2.0,
fox_death_prob=0.0005,
fox_hunt_radius=50,
rabbit_reproduction_prob=0.001,
fox_reproduction_prob=0.05,
mating_radius=40.0,
fox_start_energy=1000,
fox_energy_gain_on_eat=500,
rabbit_start_energy=800,
rabbit_energy_gain_on_eat=400,
rabbit_feed_radius=15,
grass_reproduction_prob=0.005,
max_age=200, enable_logging=False,
enable_recording=False,
duration=1000

Results:
Statistical analysis

steps_survived
BASELINE: mean = 248.70, SD = 124.07, 95% con inter = [199.62, 297.78]
ENERGY AND LIFECYCLE: mean = 201.00, SD = 0.00, 95% con inter = [201.00, 201.00]
T-test p-value = 0.0563
Mann-Whitney p-value = 0.6165

final_rabbits
BASELINE: mean = 12.59, SD = 23.83, 95% con inter = [3.17, 22.02]
ENERGY AND LIFECYCLE: mean = 1.70, SD = 1.25, 95% con inter = [0.80, 2.60]
T-test p-value = 0.0256
Mann-Whitney p-value = 0.3039

final_foxes
BASELINE: mean = 13.07, SD = 27.29, 95% con inter = [2.28, 23.87]
ENERGY AND LIFECYCLE: mean = 7.60, SD = 6.65, 95% con inter = [2.84, 12.36]
T-test p-value = 0.3404
Mann-Whitney p-value = 0.1164

max_rabbits
BASELINE: mean = 87.33, SD = 33.45, 95% con inter = [74.10, 100.57]
ENERGY AND LIFECYCLE: mean = 100.00, SD = 0.00, 95% con inter = [100.00, 100.00]
T-test p-value = 0.0599
Mann-Whitney p-value = 0.1242

max_foxes
BASELINE: mean = 110.67, SD = 69.69, 95% con inter = [83.10, 138.23]
ENERGY AND LIFECYCLE: mean = 26.10, SD = 9.04, 95% con inter = [19.64, 32.56]
T-test p-value = 0.0000
Mann-Whitney p-value = 0.0000

min_rabbits
BASELINE: mean = 2.93, SD = 4.38, 95% con inter = [1.19, 4.66]
ENERGY AND LIFECYCLE: mean = 1.70, SD = 1.25, 95% con inter = [0.80, 2.60]
T-test p-value = 0.1972
Mann-Whitney p-value = 0.8472

min_foxes
BASELINE: mean = 2.41, SD = 3.47, 95% con inter = [1.04, 3.78]
ENERGY AND LIFECYCLE: mean = 6.70, SD = 4.64, 95% con inter = [3.38, 10.02]
T-test p-value = 0.0197
Mann-Whitney p-value = 0.0043

About the stats:
The analysis show that there is overall no significant differences between the baseline model and the combined energy and lifecycle model.

steps_survived:
The baseline model had a slightly higher mean (248.7) than the energy+lifecycle model (201.0). However, the p-values (t-test: 0.0563, Mann-Whitney: 0.6165) are not low enough to suggest a significant difference. This means survival time was not significantly affected by the energy and lifecycle constraints.

final_rabbits and final_foxes:
Final population sizes were highly variable in the baseline model. The energy+lifecycle model had more stable, but smaller final rabbit and fox populations.
For rabbits, the t-test was significant ($p = 0.0256$), but Mann-Whitney was not ($p = 0.3039$), so results are inconclusive. For foxes, neither test showed significance, meaning no strong evidence for a difference in final predator populations.

min and max populations:
The maximum fox population was dramatically lower in the energy+lifecycle model (mean = 26.1 vs 110.7), with strong statistical support ($p = 0.0000$ for both tests). Minimum fox population was also higher in the energy model, with p-values below 0.05 in both tests. This suggests that energy and lifecycle constraints limited fox overgrowth and prevented total collapse. Max and min rabbit populations, however, did not differ significantly between the models.

confidence intervals:
Many confidence intervals overlap substantially, especially for final and minimum rabbit populations and for steps survived. This overlap means that in most metrics, observed differences may not be consistent across repeated trials.

non-parametric test (Mann-Whitney):
This test confirmed the t-test results in most cases. For max_foxes and min_foxes, both tests found strong evidence of a difference. In other metrics, Mann-Whitney p-values were high, supporting the null hypothesis.

final:
Adding energy and lifecycle constraints did not have a significant effect on most aspects of the predator-prey dynamics, except for the fox population. The constraints significantly reduced fox population peaks and increased their minimum population levels. Other metric such as steps survived, final populations, and rabbit dynamic remained statistically unchanged. This suggests that while the overall population dynamics did not significantly get effected by the energy concept and lifecycle implementation.