**Addendum to Appendix N. POPULATION VIABILITY ANALYSIS OF WESTERN GULLS ON THE FARALLON ISLANDS IN RELATION TO POTENTIAL MORTALITY DUE TO PROPOSED HOUSE MOUSE ERADICATION**

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**Summary**

This addendum to Appendix N of the draft EIS for proposed Farallon house mouse eradication was completed by the same authors of the original 2013 report. It serves to update the original report in two ways. Firstly, the addendum provides a more detailed introduction to the overview of the population modelling approach presented, and provides an explanatory figure to describe the approach. Secondly, the addendum provides Methods, Results and Discussion on the calculation of *C*, the mortality level where there would be 95% overlap in modelled population size after 20 years comparing all three examined Environmental Scenario (Optimistic, Realistic, or Pessimistic) with no mortality models. The original report only assessed this for the “Realistic” environmental scenario.

**Overview of Approach**

Our approach was to first develop a population dynamic model for the South Farallon population of Western gulls using the best available information (published and unpublished) that captures current population trend and incorporates stochasticity in the demographic parameters (Figure 1). To develop the model we analyzed demographic data from the study population of Western Gulls as necessary to estimate demographic parameters. These analyses either used the full time series (1986-2009) or the more recent years (1999-2009), whichever was more appropriate as explained in the Methods. These analyses were used to determine age-specific variation in the parameters needed for the Leslie matrix. The analyses also quantified annual variation in demographic parameters and established the degree of stochasticity in those parameters for the model. We then simulated three different environmental scenarios, in which the frequency of years with high reproductive failure in the future did not re-occur (“Optimistic”), occurred at low, historic frequency (“Realistic”), or occurred at the more recent, elevated frequency (“Pessimistic”). We projected future population change under these three scenarios over 20 years. We then compared those simulation results, with no additional mortality, to a comparable set of simulations in which a one-time mortality event occurred in Year 0 in which *C* Western gulls died. We define the threshold “*C*” as the number of gulls killed at year 0 at which there is no ecologically distinguishable impact in modelled population size results with and without mortality after 20 years. We determined the magnitude of *C* such that there would be 95% overlap in population size in Year 20 comparing an Environmental Scenario (Optimistic, Realistic, or Pessimistic) with additional mortality to the same scenario without additional mortality. We compared the frequency distribution of outcomes, varying *C* in order to obtain 95% overlap. Our assumption was that if overlap was 95% or greater between two scenarios (with and without mortality of C gulls) then the two were ecologically indistinguishable. The following describes our approach in detail.

**Methods: Starting Population Size, Mortality Scenarios, and Simulations**

The Leslie matrix population model was implemented using a post-breeding census (Caswell 2001, Akçakaya 2005). Hence, the youngest age class in the simulations refers to juvenile individuals who have just fledged. The simulations were of the entire population, juveniles, sub-adults, and adults. There was no evidence that survival or reproductive rates vary in relation to population size or density for this population (Point Blue unpublished). Therefore we assumed population parameters to be independent of density (Nur & Sydeman 1999a).

The starting total population size for the simulations was 32,200 individuals, including all age classes, in the absence of any additional mortality. To obtain this value we started with the best estimate for initial breeding population size most relevant to the time series examined here, 17,400 observed in 2011 (P. Warzybok, R. Bradley unpublished); this value was similar to the 2009-2011 three-year average of 17,100. Assuming average breeding probability and the long-term age structure implied by the elements of the Leslie matrix (Caswell 2001), given 17,400 breeding individuals, we expect an additional 14,800 juveniles, sub-adults, and non-breeding adults in the population.

In scenarios with mortality, the starting population size in year 0 was 32,200 – *C*, where *C* represents the number of gulls removed from the population as a result of a mortality event. For these scenarios, we assumed that *C* gulls were removed in proportion to the age distribution of the total population, as there are no data to suggest the risk of mortality differs between age classes.

This value of *C* was determined from an assessment of whether the set of outcomes under a “no-additional-mortality” scenario (henceforth “no mortality”) was different from the set of outcomes under an “additional mortality” scenario. We did this for each of the three Environmental Scenarios (“Optimistic”, “Realistic” and “Pessimistic”) by assessing overlap of the modeled distributions of simulated total population size after 20 years. We defined two probability distributions to be different if the overlap of one with the other was less than 95%. Thus, if the no-mortality distribution overlapped the additional mortality distribution by 95% or more, we considered the two distributions to be effectively indistinguishable even though their medians may be statistically different. Evaluating the null hypothesis of no difference in median (or mean) was not very relevant, since we know that we removed *C* gulls from one scenario (“mortality”) compared to the other (“no mortality”). Instead, we are assessing whether the population change “signal” resulting from removal of *C* gulls is still evident after 20 years of stochastic variability.

To operationalize this definition we first identified the median of the no mortality distribution, which we call mno. We then analyzed the distribution of outcomes under the same conditions except that *C* gulls were removed at the outset. We determined *C* by varying it in increments of 100 and identifying the value at which, with *C* gulls removed, the distribution of outcomes had been shifted by 5% (i.e., 55% of outcomes were now below the original median) when compared with the “no mortality” scenario. A displacement in the distribution by 5%, specifically from 50% below mno to 55% of outcomes below mno, is equivalent to an overlap of 95% between two distributions, assuming the two distributions differ only in their location and have the same shape and spread, and acknowledging that the tails of these distributions are subject to random error. Note that a displacement of 0% implies an overlap of 100%, whereas a displacement of 50% necessarily entails an overlap of 50%. In the latter case, 50% of the original distribution lies above the maximum value observed for the new distribution.

We repeated this exercise for each of the three Environmental Scenarios, “Optimistic”, “Realistic”, and “Pessimistic.” All scenarios depict results based on 10,000 simulations, the maximum for the RAMAS program. For the calculations of overlap of distributions, however, we used 30,000 simulations, combining results of three different runs of 10,000 simulations each in order to more precisely characterize the degree of overlap.

In summary, the value of *C* obtained in these modeling exercises represents the maximum level of mortality that produced ecologically indistinguishable differences in the probability distributions of Western gull population size 20 years into the future when compared to the no-additional-mortality distribution.

**Results: Determination of Mortality Threshold, *C***

By simulating results with different mortality levels, we determined that, for the “Realistic” Scenario, removal of 1700 gulls results in a shifting of the probability distribution of population size after 20 years by 5% and thus represents 95% overlap between the “mortality” and “no additional mortality” scenarios. What had been the 50th percentile under “No additional mortality” (8.7% decline) becomes the 55th percentile under assumption of “Mortality of 1700 gulls” at year 0 of the simulation. Using the same methods, we determined that *C* for the “Optimistic” Scenario was 1100, and for the “Pessimistic” Scenario was 1900. The 95% CI for the calculations of *C* in all scenarios was approximately ± 300 individuals. Thus, *C* increased as the proportion of “bad” breeding years increased in the simulations.

**Discussion of Long-term Mortality Impacts and the Mortality Threshold, *C***

We determined the level of mortality, *C*, that produced 95% overlap in the probability distributions of Western gull population size 20 years in the future, for scenarios with and without mortality, under “Realistic” productivity conditions. Given our estimates of the total Farallon population of 32,200 birds in 2011, the value of *C* was 1700 gulls. These results are independent of any assessment of actual risk to this Western gull population from rodenticide exposure in a proposed eradication effort; instead, results obtained apply to any mortality event of relatively short duration.

This value is substantial, and reflects the high degree of stochasticity associated with the three demographic parameters, especially for reproductive success. We also found that *C* varied with environmental scenario; *C* was 1100 under the “Optimistic” scenario and was 1900 under the “Pessimistic” scenario. While it might seem counterintuitive that a lower level of mortality is sufficient to shift the outcome distribution by 5% under “Optimistic” conditions, compared to the “Realistic” and “Pessimistic” scenarios, these results are consistent with our finding that the coefficient of variation (CV) of population outcome was greatest for the “Pessimistic” scenario (0.41) and lowest for the “Optimistic” scenario (0.36). In other words, the greater the variability in population outcome, the greater *C* must be to result in a long-term effect of the mortality event that can be discriminated against the backdrop of environmental variability. The relative similarity of *C* values between the “Realistic” and “Pessimistic” scenarios (1700 vs 1900) is notable; the two mortality thresholds were not statistically distinguishable. This results suggests that it is occurrence of near breeding failure events, or absence of such events, that is most important to future population numbers in 20 years, rather than the precise frequency of near breeding failure events.

**Figure 1.** Overview of model development and application. Two sets of input parameters were used: those for age-specific values needed for the Leslie matrix (upper left) and those for determining annual variation in demographic parameters to capture stochasticity (upper right). The population model was used to consider three environmental scenarios (“Optimistic”, “Realistic”, and “Pessimistic”), which differed with respect to frequency of “bad years” for gull reproduction. These same scenarios were also used to compare results with and without the additional mortality event, i.e., death of *C* gulls in year 0. The magnitude of *C* was determined for each environmental scenario separately.