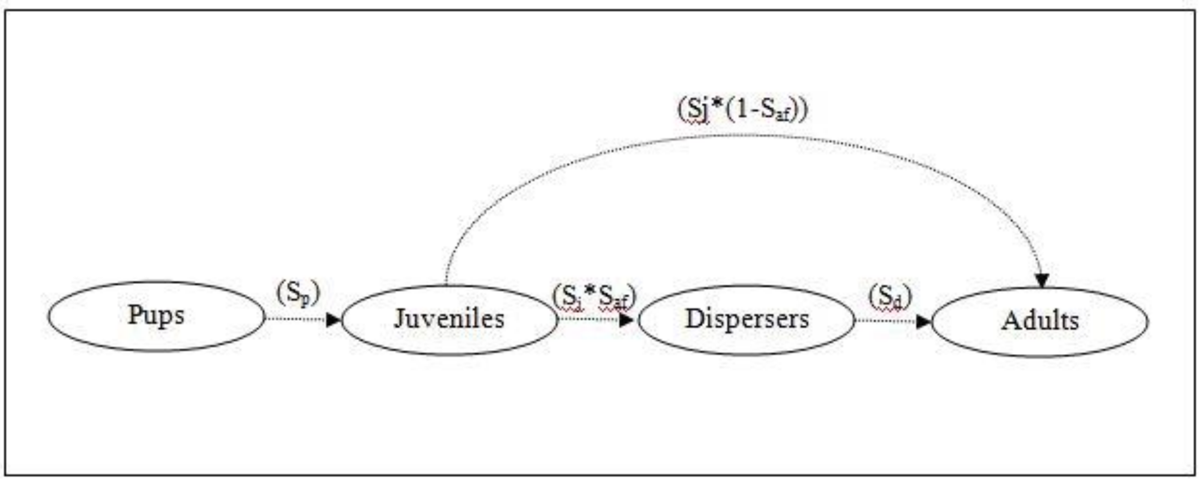
Population Viability Analysis for Conservation and Management

The Wolf Conservation and Management Plan for Washington (WDFW 2011) was approved in January 2012. The plan was not informed by a population viability analysis (PVA). A set of independent scientific reviewers of the draft plan (WDFW 2009) urged WDFW to conduct a PVA because (1) the plan contained low delisting thresholds that raised conservation concern, and (2) PVA is an essential tool to evaluate any population recovery plan (Perez *et al.* 2012). WDFW then contracted researchers at Washington State University to develop a wolf population model and to evaluate nine wolf population and management scenarios using model simulations (Maletzke and Wielgus 2011). These simulations resemble PVA in many respects, but differ from PVA in several important ways. The simulation results did not appear to inform the final wolf plan substantively, which does not differ from the draft plan in wolf downlisting and delisting criteria.

This project will lead you through a simplified version of such an analysis, using population parameter estimates from other wolf populations as recommended by the reviewers and used by (Maletzke and Wielgus 2011). You will use PVA to evaluate sensitivity of wolf population abundance and persistence on anthropogenic mortality, including hunting, poaching, and lethal control. Several caveats and simplifying assumptions limit practical application of analyses outlined below, including the following. Several caveats and simplifying assumptions limit practical application of analyses outlined below, including the following. (1) Wolf population processes will be affected by changes in human population size and distribution and changes in land use, which are not considered here. (2) Effects of climate change, wolf prey population changes, and other factors that may affect wolves are not included. (3) Habitat distribution and other spatial processes may constrain wolf population growth; these constraints are largely ignored here. (4) Dispersal of wolves to Washington from other regions may increase probability of wolf persistence, which we will not consider but could with simple code modifications.

The wolf life cycle can be summarized in four developmental stages: pups, juveniles, dispersing adults, and breeding adults. These stages and transitions among them are depicted in the figure below, from Maletzke and Wielgus (2011). The model is expressed as a set of inter-stage transition probabilities, *S*, which are estimated from wolf population data.



Wolf life cycle diagram, from Maletzke and Wielgus (2011). S_p, S_j, S_d, S_{af} are annual survival rates of pups, juveniles, dispersers, and adult females, respectively.

Wolf populations in the northern Rocky Mountains of the U.S. are most similar to what can be expected to expand into Washington. Maletzke and Wielgus (2011) provided demographic parameter estimates for wolf populations in central Idaho and northwest Montana. Human access and land designation in Washington are most similar to conditions in northwest Montana. These estimates and their uncertainties are summarized below as transition probabilities in a stage-structured population matrix developed from the wolf life cycle diagram above.

Stage matrix transition probabilities (and standard deviations) for the northwest Montana wolf population. Parameter estimates and standard deviations are from tables 1 and 2 in Maletzke and Wielgus (WDFW 2011), except as noted.

	Pups	Juveniles	Dispersers	Adults
Pups	0.00	0.35(0.13*)	1.04(0.38†)	1.04(0.38†)
Juveniles	0.81(0.16)	0.00	0.00	0.00
Dispersers	0.00	0.52(0.12)	0.00	0.00
Adults	0.00	0.20(0.04)	0.72(0.16)	0.72(0.16)

* Standard deviation in juvenile fecundity is 1/3 the adult value.

† Maletzke and Wielgus(2011) did not report uncertainty in wolf fecundity, and neither did the publications they cited. Instead, above standard deviation in fecundity of adults and dispersers was calculated from Carroll *et al*. 2006, with a binomial adjustment for the 30% probability of each pack not reproducing in a given year.

The 2015 estimate of wolf abundance in Washington is 90 animals in 18 packs (WDFW 2015), with an additional pack located in 2016 (WDFW 2016). Wolf "carrying capacity" in Washington is estimated to be 76 packs, which, assuming a mean of 6 wolves/pack, would correspond to 456 wolves (Wiles et al. 2011).

Part 1: Recovery Criteria Assessment

1 Apply these survival and fecundity estimates to calculate an annual population growth rate and the standard deviation of that rate.

2 If all wolf demographic parameters were to remain constant at the mean rates listed above, how much time would pass before the WA wolf population grows from the current abundance of 27 to 456, the maximum number that could be supported in suitable habitat in the state (76 packs containing a mean of 6 wolves/pack; WDFW 2011)?

3 Of course, survival and fecundity rates will not remain constant. Determine whether the wolf plan's delisting criteria represents a low risk of population decline to extinction or "quasi-extinction." Assess risk by determining the probability the population would decline to the delisting threshold, or 15 packs (90 wolves) state-wide. Conduct your assessment using at least 1000 simulations for 100 years each. Let wolf demographic rates vary stochastically on an annual basis: assume all rates are normally distributed with means and standard deviations as given in the table above. Begin each simulation with the state-wide value used WDFW (2011) Appendix H: 23 packs (138 wolves). The wolf population in your simulations should not exceed 76 packs (456 individuals), the maximum number of pack territories suitable habitat in the state would support (WDFW 2011).

4 Simulations conducted to inform the wolf conservation and management plan were run for 50 years (Appendix H, WDFW 2011). This assessment window is unusually brief, particularly for a large mammal (Traill et al. 2007). Compare quasi-extinction risk over 50 years vs. the usual 100 year assessment window. Conduct at least 1000 simulations, using the same parameter values, initial

population size, and population ceiling as in part (3). How much does a 50 year assessment window underestimate quasi-extinction risk relative to a 100 year assessment window?

5 The wolf plan delineates three recovery regions. Delisting criteria require that each region contain at least four breeding pairs. Wolf sub-populations in each region may be isolated from each other due to dispersal barriers, as described in WDFW (2011) and illustrated in WHCWG (2010). This isolation implies that wolf population viability should be assessed on a regional basis. Repeat your analysis from part (3) for an individual region using the following simulation values: initial population size = 5 packs (30 wolves), quasi-extinction threshold = 4 packs (24 wolves), and population ceiling = 130 wolves (approximate number that the North Cascades region could support). You should run at least 1000 simulations for 100 years each. What is the probability that wolves in an isolated recovery region would decline to or below the quasi-extinction threshold, requiring relisting?

6 For the plan to be successful, wolves in all three regions must remain above the listing threshold. Apply your result from part (5) to determine the probability of this outcome for 100 years, assuming no wolf dispersal or translocation between regions.

7 Based on results of your analyses in parts (3 – 6), are the wolf plan delisting criteria appropriate (i.e., re-established population has a low risk of extinction)? Why or why not?

Part 2: Wolf Management after "Recovery"

Analysis of human-caused mortality impacts on Washington wolf population viability.

Wolf population persistence in Washington will depend most sensitively on human activities, including hunting, poaching, and lethal control. Before the Northern Rockies wolf population was delisted and wolf hunting commenced, approximately 10% wolves in the population were killed annually during lethal control actions, ~10% were killed illegally, and ~3% were killed in human-related accidents (WDFW 2011). These mortality rates are included in demographic parameter estimates listed in problem 2. After delisting, wolves in Washington likely would be managed as game animals subject to public hunting (WDFW 2011). If not managed appropriately, hunting could increase risk of wolf population declines toward extinction or quasi-extinction. Analyses in this part will lead you through analyses that could inform wolf conservation and management decisions. Of course, these analyses precede wolf delisting in Washington or collection of many wolf population data in Washington, so any results should be considered heuristic.

1 Determine the maximum harvest rate of wolves (non-pups) that could be sustained without reducing the 100-year persistence probability below 80%. Support your answer using at least 1000 stochastic simulations, using demographic rates and standard deviations listed above. Represent harvest rate as a proportional reduction in survival rates of juveniles, dispersers, and adults. Assume hunting does not affect fecundity. Conduct your analysis at a state-wide level, with a starting population of 300 wolves, a population ceiling of 76 packs (456 wolves), and a quasi-extinction threshold of 15 packs (90 wolves).

2 Repeat analysis for (1) at the level of a single recovery region, without wolf immigration from other regions. Use a starting population of 100 wolves, a population ceiling of 130 wolves, and a quasi-extinction threshold of 4 packs (24 wolves).

3 What do results of parts (1) and (2) suggest about management of various sources of human-caused mortality for wolf conservation and management in Washington?

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