Chair Edwards, Committee members,

My name is Stephanie Taylor, and I'm a wildlife advocate from Portland, Oregon.

I have been involved in this issue all of last year. I testified at almost every ODFW Commission meeting in 2015 and was one of many who requested an independent scientific review of the Commission's biological status review, as required by law. I also testified against a similar Bill introduced by Representative Baretto last session (HB 3515) which sought to legislatively delist wolves, weeks before the ODFW had the opportunity to carry out its own process.

First, I want to thank Senator Dembrow and Senator Prozanski for asking critical questions about the delisting process and reasons behind the litigation, all which were ignored in the House last week. I have tried to provide you with all the information you requested at Tuesday's hearing. Senator Whitsett. I would like to go on record saying that I also like wolves, and all of Oregon's native wildlife.

We've heard from the Cattlemen time and again that we need to honor the promises ODFW made in the Wolf Plan. If you read the Plan text, nowhere does it call for automatic delisting in Phase 2. In the information presented to you on Tuesday on the screen, the text read simply that the Plan calls for a "consideration" to delist.

Speaking for a moment of honoring promises and truth, I have been to all the legislative hearings about this issue and watched the proceedings. Time and again, I heard proponents of the Bill misrepresent their intent and the affect of the bill. Then on Tuesday, your Committee put the bill under appropriate scrutiny and exposed the misrepresentation that allowed the bill to make it through the House. Confronted with those facts, an amendment that would hold the proponents of the bill to what they said, they seemed to not just own up to the real facts and intent, but to embrace them. Oregonians are sensitive to ethical concerns, and it doesn't seem like the legislature should be rewarding this kind of behavior. If, in fact, HB 4040 simply affirms the decision by the Oregon Fish and Wildlife Commission to de-list gray wolves, then I agree with Senator Prozanski that this Bill is needless, and is a waste of the short session limited time.

I was very disappointed when the Commission made the 4-2 decision to delist wolves. It was very disturbing that the ODFW and Commission staff confused the public by issuing conflicting statements about the comment deadline date. Here's a bit of a timeline for you:
Nov. 9th- during the first hour of the Commission meeting, the Commission submits their peer review to the record, breaking their own deadline.
October 30th- date ODFW set for all comments. However, the day prior:
October 29th – ODFW issued a news release (which you each have a copy of) stating they would be accepting public comments until November 6th. This press release reiterates their recommendation to delist. I want to reiterate that this was before their own comment deadline had arrived.
On October 29th , they were still receiving public comments, which include letters from 25 scientists who had taken an interest in the issue and who were submitting extensive comments highly critical of ODFW's wolf status review and delisting decision. (I have provided you each with a copy.)

In this submission, dated October 29th, you will find an extensive science review from 25 scientists – many of them local Oregonian researchers- who challenged the ODFW's science. You will find a legal analysis which shows the delisting wolves at that time would run counter to established state laws and administrative rules. You will find a one page public comment analysis demonstrating that 96% of those who commented were in support of wolf recovery and continued protections for wolves in Oregon. You will also find Conservation groups comments, addressing their concerns on public record. I am appalled that the Commission ignored all of this which was submitted on time, but accepted the comments from their reviewers past their deadline, and into their public meeting.

It appears only 4 of 29 independent scientists who commented on the plan actually supported de-listing. However, even they raised concerns that ODFW acknowledge were not addressed. It's notable that 2/4 were from the Idaho Department of Fish and Game, an agency renowned for poor wildlife science and management, and only one is a local researcher.

Something that did give me hope was the Commission asking the legislature to address the very real and serious problem of wolf poaching. To help address this issue, HB 4046 was introduced and eventually amended to include increased penalties for wolf poaching. It was disappointing on Tuesday to hear Rep. Baretto say that the purpose of his bill was to support ODFW when he himself opposed the poaching bill, the very bill that would have addressed that request from the Commission. It appears that the poaching bill has not yet made it to the Senate. ODFW Commission did not ask for this bill, and the Wolf Plan does not call for this.

As a concerned Oregonian, I find HB4040 very controversial. Voting to ratify the ODFW Commission decision is not simply saying the Commission followed the process correctly, it's also saying that 25 scientists who weighed in with their critiques of the ODFW decision are wrong. I agree with Senator Dembrow that – however well intentioned - legislators may not have all the necessary information, expertise, or the time in a short session, to make such a decision.

HB 4040 restricts the rights of Oregonians to challenge a controversial agency decision, undermines the Oregon Endangered Species Act, and sets a dangerous precedent for questionable science review processes leading the way on wildlife conservation in our state. Please oppose HB 4040. The Legislature should not influence judicial review, or undermine the Oregon Endangered Species Act.

Thank you.

ODFW recommends delisting gray wolf from state ESA throughout Oregon

Commission to consider at Nov. 9 meeting in Salem

October 29, 2015

SALEM, Ore.—ODFW staff believe gray wolves have met the criteria to be delisted from the state Endangered Species Act (ESA) and will recommend this action to the Fish and Wildlife Commission at their Nov. 9 meeting in Salem.

The meeting begins at 8 a.m. at ODFW Headquarters, 4034 Fairview Industrial Drive SE, Salem. It is open to the public and public testimony will be accepted during the meeting. Consideration of wolf delisting is the only item on the agenda. Written comments will also be accepted until Friday Nov. 6 at 5 p.m. and can be sent to odfw.commission@state.or.us More information about the meeting is available at http://www.dfw.state.or.us/agency/commission/minutes/15/11_november/index.asp

Wolf management in Oregon is guided by the Wolf Plan, which was originally crafted in 2005 by a broad group of stakeholders balancing competing interests. The Plan called for initiating a process to consider delisting wolves from the state ESA when eastern Oregon had a population of four breeding pairs of wolves for three consecutive years, an objective met in January 2015.

State ESA law gives the Fish and Wildlife Commission authority to list and remove species from the Endangered Species List. It requires them to look at five factors when considering delisting:

- Species not now in danger of extinction in any significant portion of its range.
- Natural reproductive potential not in danger of failure.
- Populations are not undergoing imminent or active deterioration of range or habitat.
- Over-utilization of the species is not occurring.
- Adequate protection programs exist to protect the species and its habitat in the future.

ODFW's looks at these five factors in depth and finds sufficient biological information to justify a delisting.

- Wolves are represented over a large geographic area of Oregon, are connected to other populations, and nothing is preventing them from occupying additional portions of Oregon.
- The wolf population is projected to continue to increase. The overall probability of extinction is very low and genetic variation is high.
- Wolf habitat in Oregon is stable and wolf range is expanding.
- Over-utilization of wolves is unlikely as the Wolf Plan continues to provide protections for wolves and any commercial, recreational or scientific take in the future is regulated by the Commission.
- The Wolf Plan ensures protection of wolves in the future, regardless of ESA status.

"The state's Wolf Plan adopted in 2005 was an agreement between stakeholders reached after one of ODFW's largest public processes," said Russ Morgan, ODFW wolf coordinator. "The Plan called for delisting consideration after wolves reached a minimum conservation threshold and envisions wolves being delisted as Oregon moves into future phases of management."

"Delisting would result in no immediate changes to wolf management in Oregon. Wolf management is guided by the Wolf Plan and its associated technical rules, not the species' ESA listing status," added Morgan. "But delisting allows the Plan to continue to work into the future."

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<u>EXHIBIT B</u>

November 9, 2015

Biological status review for the Gray Wolf (*Canis lupus*) in Oregon and evaluation of criteria to remove the Gray Wolf from the List of Endangered Species under the Oregon Endangered Species Act

SCIENCE REVIEW

Oregon Department of Fish and Wildlife
11/6/2015

Summary of responses received by ODFW as part of an internal solicitation for scientific review of the technical document contained within Appendix B, titled *Assessment of Population Viability of Wolves in Oregon*

The Oregon Department of Fish and Wildlife requested a courtesy review of the "Assessment of Population Viability of Wolves in Oregon" that will be presented at the November 9th, 2015 Commission meeting. We sent the document to 8 scientists and received responses back from 4 individuals. When soliciting a review, we explicitly expressed the individuals should focus on the validity of our population viability analysis (PVA) and not provide input on the process of delisting wolves. All reviewers provided their comments electronically on the Word document we provided with our analysis. Reviewers had until November 5th, 2015 to return comments. Our summary and response to reviews received by this date follows. We did not respond to each individual comments made by each reviewer.

Dr. Joe Bull – University of Copenhagen, Co-author of published model modified by ODFW to conduct PVA of wolves in Oregon

Dr. Bull's review of our model was positive and did not identify any major issues with our approach or conclusions. He stated, *"Overall I think the application of the model makes sense, as do the conclusions drawn, although I had some questions which I think need addressing. Also, I think the language around the way the results are presented needs modifying in some cases to reflect the degree to which conclusions can be drawn from a modelling exercise like this."*

Dr. Bull included 37 unique comments in the document and 6 technical edits to improve wording. Of 37 comments, 11 were general statements, 3 provided suggestions for rewording, and 21 areas where additional details might improve the document.

Dr. Jon Horne – Idaho Department of Fish and Game, Research Biologist

Dr. Horne stated, *"All in all a very well-done and thorough analysis. But there were a couple of very big issues. I didn't take much time to say all the good stuff I was thinking or really read the Discussion so in the interest of time, here you go".*

While his review had the most suggestions regarding our modeling approach, he never indicated our model was fundamentally flawed nor were our conclusions inappropriate. His primary concern centered around our use of uniform distributions to randomly draw vital rates. He had some confusion about how we were implementing this based on our description in the text. We agree that our writing was a bit confusing and could be improved, but Dr. Horne was able to determine that we used a uniform distribution. Dr. Horne did not explicitly say our approach was wrong, rather he identified alternative statistical distributions that might have been more appropriate statistically. We agree, there are alternative distributions available. However, we contend our use of the uniform distribution is appropriate and allowed us to implement a more conservative population model for the following reasons:

- Other distributions will have a central mean vital rate that is most commonly chosen through random sampling. This reduces overall variation in randomly drawn vital rates. Using a uniform distribution, we increase variation (i.e., all outcomes are equally likely) in randomly drawn vital rates.
- Increased variation in vital rates will cause a population to perform worse on average – this caused our approach to be conservative.
- Modeling with reduced variation in vital rates would cause a more optimistic view of population viability. We used a conservative approach to follow the precautionary principle.

In total, Dr. Horne provided 16 comments on our analysis. Of 14 comments not related to our use of uniform distributions, 6 were general statements and 8 were suggestions to increase clarity in the document. Dr. Horne, did not review the discussion section of our document.

Dr. Katie Dugger – U.S. Geological Survey, Oregon Cooperative Wildlife Research Unit, Assistant Unit Leader

Dr. Dugger had an overall favorable impression of our analysis and stated *"This was a substantial effort to predict wolf population growth in Oregon relative to conservation and management objectives. You used a rigorous modeling approach and what appears to be the best data available. Most of my attached comments suggest that you increase transparency of the modeling process by including more information regarding 1) the source(s) of the data you used in your model (i.e., full citations should be provided somewhere for vital rates in Table 1), and 2) when data was not available, how/why you decided to use the specific vital rates or values you chose (i.e., based on info for another species, "expert opinion" or just a "best guess"??). In some cases a better explanation of assumptions (and why you made them) would be helpful too"*.

Dr. Dugger's greatest concern in our modeling approach was related to our application of density-dependence because the numbers used to estimate this value had the most uncertainty. We don't necessarily disagree with Dr. Dugger on this point. However, we contend that this had little influence on our conclusion that wolves have a low risk of extinction in near term. Our model was designed to assess risk of extinction for a small population. Density-dependent factors would not occur until we had a large population and a large population would indicate an extremely secure and recovered wolf population.

In total, Dr. Dugger provided 22 comments on our analysis. Of these comments, 8 were suggestions to provide additional details in the text, 10 were general statements, and 4 provided suggested wording changes or changes to organization of the document.

Dr. Ryan Long – University of Idaho, Assistant Professor

Dr. Long provided the most positive review of our PVA. He stated, *"This was obviously a hell of a modeling effort, and I enjoyed reading it, so thanks for the opportunity. I have a handful of comments and/or questions scattered throughout, but certainly nothing major. As with any model like this, it would be easy to spend a bunch of time trying to pick apart your choices for parameterizing various components of the model, and ask a bunch of detailed questions about why you did one thing or another. There really doesn't seem to be much point in that here though. This is a rigorous, well thought-out modeling effort that appears to take full advantage* *of every bit of relevant data you could get your hands on. As you explain multiple times in the report, your results are likely conservative, and frankly, I find them very convincing".* We fully agree with this statement by Dr. Long. There are many options available when developing a model, but our approach was valid and rigorous.

In total, Dr. Long made 15 comments addressing our PVA. Of these comments, 9 were general statements and 6 were suggestions to provide additional details in the text.

Summary

Overall, we received 4 positive reviews from scientists that did not identify fatal flaws in our analysis approach. Most reviewers explicitly indicated our modeling approach was sound. Based on our review of comments received, there was only one major comment related to the technical application of our PVA. We provide a response to this comment and contend that our approach is sound and is a more conservative modeling approach than that suggested. For the most part, reviewers made suggestions to improve the clarity of our report and in general, we agree with these suggestions.

DR. JOE BULL

Assessment of Population Viability of Wolves in Oregon

This technical report to the Oregon Fish and Wildlife Commission presents results from an updated individual-based population model used to assess population viability of wolves in Oregon. The model uses wolf data collected in Oregon through July 2015.

Presented: November 9th, 2015

Suggested citation:

Oregon Department of Fish and Wildlife. 2015. An updated assessment of population viability of wolves in Oregon using data collected through July 2015. Oregon Department of Fish and Wildlife, 4034 Fairview Industrial Drive SE. Salem, OR 97302.

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Executive Summary

We present results from an individual-based population model (IBM) based on a peer-reviewed published[1] model (Bull et al. 2009) used to assess the viability of the gray wolf (*Canis lupus*; hereafter, wolf) population in Oregon. When parameterizing our model, we relied on peer-reviewed published estimates of wolf vital rates. Our population model, the assumptions made in the model, and vital rates used in the model were obtained or supported by peer-reviewed published literature. We compared estimates of parameters used in our model to those observed in Oregon from 2009-2014 and concluded our model used to project future population growth was conservative compared to growth rates currently observed in Oregon. We used a starting population size of 85 wolves which was based on wolf population counts conducted by the Oregon Department of Fish and Wildlife (ODFW) through July 2015. This value is higher than reported end of year counts (ODFW 2015) because additional wolves that were present in Oregon at the start of the biological year (i.e., April) were documented after January 31, 2015. Consequently, results presented in this report differ slightly from those presented to the Oregon Fish and Wildlife Commission on April 24, 2015. We used linear regression models to determine the relative effect of model parameters on intrinsic population growth rates of wolves. We assessed population viability using two metrics: 1) the cumulative proportion of simulations that had fewer than 4 breeding pairs (defined as conservation-failure) and 2) the cumulative proportion of simulations that had fewer than 5 wolves (defined as biological-extinction).

Increased pup ($\beta = 0.045$), yearling ($\beta = 0.024$), and adult ($\beta = 0.019$) survival resulted in increased population growth rates. Population growth rates of wolves were most sensitive to environmental stochasticity, which we modeled through the use of a prey multiplier ($\beta = 0.088$). The increased environmental stochasticity incorporated in the model by the prey multiplier increased variation in survival rates of wolves by up to 20% annually, which caused this parameter to have a large effect on population growth rates. Increased levels of illegal ($\beta = -0.027$) and legal ($\beta = -0.028$) anthropogenic mortality had negative effects on population growth rates. Increased mean litter size had a positive effect on population growth ($\beta = 0.049$). Increased mortality rates for dispersing wolves had a negative effect on population growth ($\beta = -0.026$) while increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on population growth ($\beta = 0.034$). Combined, these results highlight the importance of survival, reproduction, and human-caused mortality on population growth rates of wolves. Other parameters considered in our model had minimal effects on population growth rates or viability of wolves. Maintenance of high natural survival and reproductive rates of wolves while minimizing human-caused mortality will help ensure the long-term persistence of the species in Oregon.

Our baseline model indicated there was a 0.05 (95% CI = 0.01 – 0.09) probability of wolves falling below the conservation-failure threshold and a 0.01 (95% CI = 0.00 – 0.03) probability of falling below the biological-extinction threshold in the next 50 years. When we parameterized our model with vital rates required to match population growth rates observed in Oregon from 2009-2014, we did not observe any situations where the simulated wolf population fell below the conservation-failure or biological-extinction thresholds. Consequently, we contend future risk of conservation-failure falls between estimates from our baseline model (0.05 probability of conservation-failure) and our model parameterized with vital rates required to

Commented [JB1]: Perhaps clarify that the model in Bull et al was designed for use in Scotland and Norway, not Oregon (that is how the sentence could be read)

Commented [JB2]: This doesn't sound technically quite right: i.e. (1) model parameters do not actually affect intrinsic population rates (2) linear regression models to do not determine relative effect, rather they are used to roughly capture this effect (where it can be approximated using a linear model). Rephrase

Commented [JB3]: Why?

Commented [JB4]: Why?

Commented [JB5]: These rates seem very low…are these correct?

Commented [JB6]: I don't think you can 'contend' this – there are many things not accounted for in these models (e.g. disease, genetics).

Rather, say that the models you have used (using reasonable assumptions and best available knowledge on parameters) give you a risk falling in the range between model predictions.

[1] Peer-reviewed published literature is papers published in scientific journals or books that have been reviewed and deemed acceptable from a study design, analysis, and interpretation standpoint by one or more peers prior to being published.

match observed population growth rates of Oregon's wolves from 2009-2014 (0.00 probability of conservation-failure). Regardless of model parameterization, our results suggested it is extremely unlikely wolves in Oregon will be at risk of extirpation over the next 50 years.

Commented [JB7]: Even if that is what the model results suggest, I would be hesitant to conclude that there is a 0.00 probability of conservation failure (i.e. there is no such thing as a zero percent chance of extinction over 50 years…for any species).

Perhaps better to say that, since no simulations resulted in failure, the model suggests the probability of failure is negligible

Introduction

The Oregon Wolf Conservation and Management Plan (hereafter, Oregon Wolf Plan; Oregon Department of Fish and Wildlife [ODFW] 2010) outlines phases of wolf (*Canis lupus*) recovery and criteria for delisting wolves as required by Oregon's Endangered Species Act (ESA). In January 2015, Oregon's wolf population successfully reached population objectives for Phase I to allow ODFW to propose that the Oregon Fish and Wildlife Commission consider delisting of wolves from Oregon's ESA (ODFW 2010). Quantitative models are commonly used to assess population dynamics and extinction risk of threatened and endangered species (Boyce 1992, Morris and Doak 2002) and can provide insight into the first and second delisting criteria outlined in the Oregon ESA:

1. "The species is not now (and is not likely in the foreseeable future to be) in danger of extinction in any significant portion of its range in Oregon or in danger of becoming endangered"; and
2. "The species natural reproductive potential is not in danger of failure due to limited population numbers, disease, predation, or other natural or human related factors affecting its continued existence".

To address these delisting criteria, we modified a peer-reviewed quantitative model (Bull et al. 2009) to provide insight into dynamics of Oregon's wolf population to help inform any future decisions regarding wolves and Oregon's ESA.

To make accurate predictions of future population growth, quantitative population models should accurately reflect biological processes of the species being modeled. Individual-based models (IBM) were previously used to model wolf population dynamics (Vucetich et al. 1997, Haight et al. 1998, Nilsen et al. 2007, Bull et al. 2009) because they can most accurately represent the unique social and breeding structure of wolf populations. We modified an IBM developed to assess effects of management on wolf populations in Norway (Bull et al. 2009) to meet our needs to assess population viability of wolves in Oregon. Our modeling approach focused on determining effects of key biological processes, uncertainty in model parameters, and management actions on wolf population dynamics and viability.

Methods

We used an IBM modified from Bull et al. (2009) to assess future population dynamics of wolves in Oregon. The primary modifications to the Bull et al. (2009) were to change the vital rate values of wolves in North America based on our literature review. The biggest modification we implemented in our model was to alter the way reproduction was handled in the model. Bull et al. (2009) assigned pairs of wolves a probability of producing a large or small litter and assumed all dominant females would produce pups each year. In our modified model, we assumed not all dominant females would produce pups in a given year, but litter sizes would be determined from a single distribution each year. We modified the Bull et al. (2009) to include two types of catastrophes (see description below) and allowed dispersing wolves to leave Oregon and have increased risk of mortality during dispersal (see description below). All of these additional modifications provided increased reality to the model and would provide a more

Commented [JB8]: Reasonable

Commented [JB9]: Good inclusions

conservative view of wolf population growth. Other than these minor changes, our code used to implement the model was identical to the peer-reviewed model developed by Bull et al. (2009).

Commented [JB10]: One big finding from our model was that the Norwegian population was supported by immigration from Sweden (i.e. a neighbouring region in which, at the time, the wolf population was allowed to flourish).

Do you have a similar situation in Oregon – or is it different (e.g. once the wolves leave Oregon they experience similar or worse persecution)?

If the latter, then this is a key difference between our models that you haven't mentioned here.

Our model incorporated 6 demographic processes that affected wolf populations that were modeled in the following order (Fig. 1): 1) survival and transition between age classes, 2) dispersal and emigration out of Oregon, 3) territory establishment by dispersing wolves, 4) immigration from outside Oregon, 5) anthropogenic mortality, and 6) reproduction. Our IBM included 5 distinct social classifications of wolves (Fig. 2) and transitions between social classifications were governed by distinct model parameters (Table 1).

Our IBM was coded and implemented in R (R Development Core Team 2012). To generate our results, we conducted 100 realizations of population growth over 50 years. We utilized 100 realizations of population growth because this allowed the confidence intervals to be acceptably narrow, but not excessively narrow to indicate a false sense of precision in our estimates of population viability Bull et al. (2009). We incorporated environmental stochasticity in our model by randomly drawing vital rate values from a uniform distribution with a predefined mean and standard deviation at each time step of the simulation (Table 1). Unless otherwise noted, vital rates were applied at an individual level, which inherently incorporated demographic stochasticity into our model. For each simulated population we tracked parameter values, population size and growth rates, and number of breeding pairs (i.e., pairs of wolves with ≥ 2 pups surviving the biological year) at each time step.

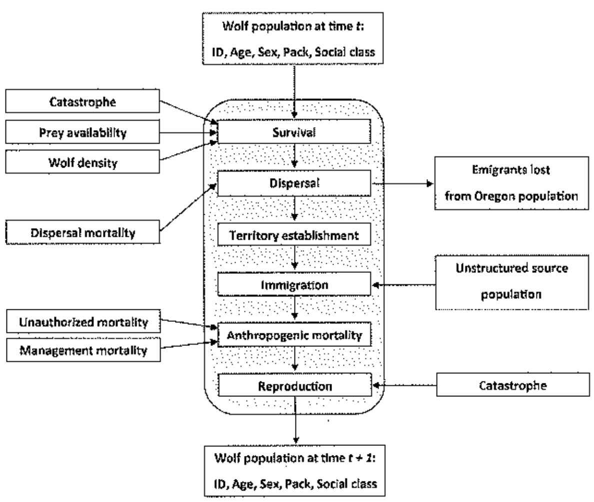

Figure 1. The order in which 6 key demographic processes are implemented in an individual-based population model to assess population viability of wolves in Oregon.

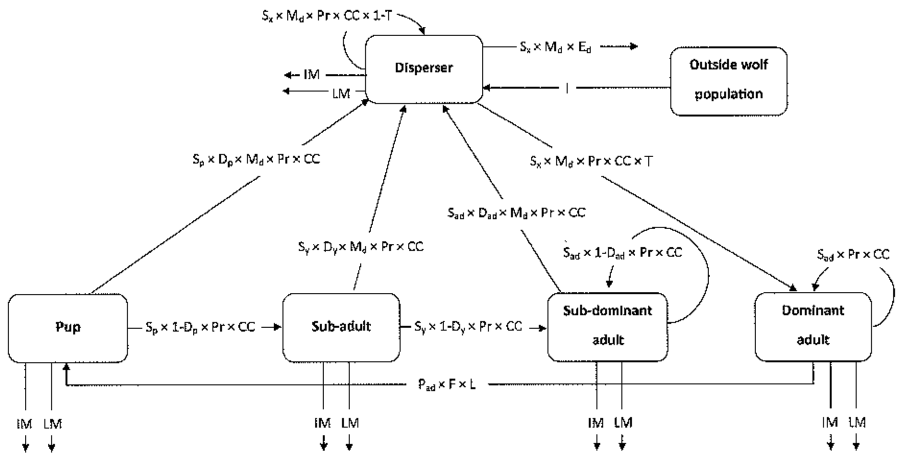

Figure 2. Visual representation of the life cycle of wolves implemented in an individual-based population model to assess population viability of wolves in Oregon. The diagram represents probabilities of transitions between age- and social-classes of wolves. Parameters used in transition calculations are defined in Table 1.

Table 1. Parameter values used to predict future population growth of wolves in Oregon compared to values required to match observed growth rates of Oregon's wolf population from 2010-2014. Values used at each time step of the analysis were randomly drawn from a uniform distribution within the specified standard deviation (SD). Mean values are probabilities unless otherwise stated. All estimates used in our baseline model were obtained or supported by peer-reviewed literature.

		Baseline model values		Values required to match growth rates observed in Oregon (2009-2014)	
Parameter	Notation	Mean	SD	Mean	SD
Pup survival rate	S_p	0.68	0.15	0.75	0.05
Yearling survival rate	S_y	0.81	0.06	0.91	0.04
Adult (2 to 7-yrs old) survival rate	S_{ad}	0.88	0.04	0.91	0.04
Old adult (8 to 9-yrs old) survival rate	S_{old}	0.63	0.11	0.85	0.05
Pup dispersal rate	D_p	0.15	0.05	0.15	0.05
Yearling dispersal rate	D_y	0.65	0.05	0.65	0.05
Non-breeding adult dispersal rate	D_{ad}	0.65	0.05	0.65	0.05
Proportion of dispersing wolves that survive	M_d	0.90	0.05	0.97	0.02
Proportion of dispersing wolves that leave Oregon	E_d	0.115	0.03	0.115	0.03
Probability of dispersing wolf establishing a territory	T	0.75	0.10	0.75	0.10
No. of immigrants arriving annually from outside Oregon	I	3	2	3	2
Pregnancy rate for dominant females	P_{ad}	0.95	0.02	0.95	0.02
Litter size	L	5	3	5	3
Proportion of wolves removed by illegal mortality	IM	0.05	0.03	0.02	0.01
Proportion of wolves removed by legal mortality	LM	0.05	0.03	NA	NA
Prey index multiplier (adjustment to survival rates)	Pr	1.00	0.10	1.00	0.10
Density dependent threshold (no. of wolves)	CC	1,500	NA	1,500	NA
Probability of population wide reduction in survival	S_{cas}	0.01	NA	NA	NA
Probability of pack-specific reproductive failure	R_{cas}	0.05	NA	0.05	NA

Commented [JB11]: It's not clear to the reader at this point what scenario the 'baseline model' captures

Commented [JB12]: Explain how these rates match up with this quoted in the Executive Summary

Model Parameters

Currently, Oregon has minimal vital rate information to parameterize a population model, and the potential for sampling bias or error from small sample sizes (i.e., observed data does not match the expected outcome) could cause inappropriate conclusions to be reached by using this information. Furthermore, estimated vital rates from protected wolf populations that are colonizing or recovering are unlikely to match those of established wolf populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Oregon's wolf population is transitioning from a recovering to established population. Vital rates used in our IBM were obtained from peer-reviewed published literature that presented results from studies conducted primarily in established wolf populations. Consequently, whenever possible, we compared vital rates observed in Oregon to those reported in peer-reviewed published literature to determine the degree to which vital rates used in our model were representative of those observed in Oregon since 2009. In general, most vital rates used in our baseline model were conservative compared to those observed in Oregon from 2009-2014. Using conservative vital rate estimates allowed us to err on the side of caution (e.g., the precautionary principle; Myers 1993, Meffe et al. 2006) and prevent overly optimistic conclusions of wolf population viability.

Starting Population Size.–We utilized minimum count data collected by ODFW to determine our starting population size and structure prior to wolves producing pups in April 2015. These counts were higher than final survey numbers reported at the end of 2014 (ODFW 2015) because ODFW identified additional wolves after the report was submitted. Based on wolf survey information collected through July 2015, a minimum of 85 wolves were present in Oregon at the start of April. We acknowledge additional, undocumented wolves may be present in Oregon, but we relied on known individuals when developing our model. Counts identified 16 pairs or packs of wolves in addition to 3 individual wolves present in Oregon. Whenever possible, we used known data to assign pack, age, social class, and sex of wolves and randomly assigned these attributes when unknown. Newly documented pairs of wolves were assumed to consist of a male and female and both individuals were assigned dominant-adult status.

Survival.–Baseline survival rates of wolves used in our model represented survival in the absence of anthropogenic mortality (e.g., poaching, management removals). We adjusted survival rates reported in peer-reviewed literature to account for anthropogenic mortality using the following approach: 1) determine the overall mortality rate (1 – survival rate), 2) estimate the anthropogenic mortality rate as the product of proportion of total mortalities caused by humans and the overall mortality rate, and 3) sum the estimated anthropogenic mortality rate and the reported survival rate. As an example, Smith et al. (2010) reported an annual survival rate of 0.750 with 54% of mortality attributable to legal or illegal actions by humans. The anthropogenic mortality rate was 0.135 ($1-0.750 \times 0.540$), which resulted in a 'natural' survival rate of 0.885 ($0.750 + 0.135$). In instances where authors directly reported cause-specific mortality rates (e.g., Wydeven et al. 1995), we summed reported survival and anthropogenic mortality rates to obtain an adjusted estimate of survival. After adjusting survival rates reported in peer-reviewed literature (Table 2) to account for human-caused mortality we arrived at a survival rate of 0.88 (± 0.04 SD) of adult wolves (2-7 years old; S_{ad}) for use in our model.

Commented [JB13]: Define location of wolf population analysed by Smith et al., and justify use of rates from this study

Using the largest sample size of radio-collared wolves reported in peer-reviewed published literature, Smith et al. (2010) reported that yearling wolves had a 54.9% higher risk ($1.0012^{365} = 1.549$) of mortality than adult wolves over 365 days. We adjusted the mean survival rate of 0.88 for adult (2-7 years) wolves by the increased hazard rate reported by Smith et al. (2010) to calculate a survival rate of 0.81 for yearling wolves (S_y; $1-[(1-0.88) \times 1.549]$; Table 1).

This may present an overly pessimistic view of resident yearling wolf survival, because yearlings have high dispersal rates (Gese and Mech 1991) and dispersing wolves were found to have higher risk of mortality (Smith et al. 2010). In our model, we utilized a separate mechanism to account for increased mortality of dispersing wolves (see below) and we recognize our estimates of yearling survival may be negatively biased. Senescence, observed through decreased survival at older ages is common for large mammals (Loison et al. 1999, Gaillard et al. 2000, Clark et al. 2014), but this phenomenon is not well documented in peer-reviewed published literature on wolves. To account for the potential of senescence, we used an annual survival rate for wolves > 7 years old of 0.63 as reported by Cubaynes et al. (2014), which we adjusted to 0.67 for use in our model (S_{old}) to account for anthropogenic mortality. Wolves ≥ 10 years of age had a survival rate of 0.00 in our model. While free-ranging wolves can live longer than 10 years, most wolves are typically no longer reproductively active after this age (Fuller et al. 2003, Kreeger 2003) and will contribute little to population growth and viability.

Estimates of non-pup survival used in our model were lower than observed to date in Oregon. Using known-fate survival analysis (White and Burnham 1999) on a sample 23 of wolves radio-collared in Oregon from 2009-2014, we estimated an annual survival rate of wolves > 6 months old of 0.91. Three collared wolves died during this timeframe, one of which was removed by ODFW and an additional wolf was illegally shot resulting in 66% of mortality being attributable to humans. Adjusting survival rates to account for anthropogenic mortality results in a survival rate of 0.97, which is substantially greater than the adult (0.88) and yearling (0.81) survival rates used in our model.

Table 2. Annual survival rates and human-caused mortality rates of non-pup wolves reported in peer-reviewed literature. Survival rates were estimated from known fates of radio-collared wolves unless otherwise noted. Adjusted survival rates represent survival rates on non-pups in the absence of human-caused mortality.

Source	Reported survival	Human-caused mortality rate	Adjusted survival rate[a]
Adams et al. (2008)	0.79	0.09[b]	0.89
Cubaynes et al. (2014)	0.80	0.04[c]	0.84
Fuller (1989)	0.62	0.26[c]	0.88
Hayes and Harestead (2000)	0.84	0.02[b]	0.86
Peterson et al. (1984)	0.67	0.26[b]	0.93
Smith et al. (2010)	0.75	0.14[b]	0.89
Webb et al. (2011)[d]	0.62	0.34[b]	0.96
Wydeven et al. (1995)	0.61	0.28[b]	0.89
Wydeven et al. (1995)	0.82	0.04[b]	0.86
Mean	0.72	0.16	0.88

[a] Sum of reported survival and human-caused mortality rate.
[b] Mortality rate calculated as the product of overall mortality rate (1-survival) and proportion of mortalities caused by humans.
[c] Human-caused mortality rate directly reported by authors.
[d] Apparent survival rates estimated from mark-recapture data.

Estimates of survival of wolf pups from birth to 6 months are highly variable and are usually estimated by comparing pup counts at den or rendezvous sites to *in utero* fetal counts of harvested females. Based on a review of peer-reviewed published literature (Table 3), we determined mean survival rates of wolf pups from birth to 6 months, determined from pup counts, were 0.73. Estimation of survival using pup count data assumes that pups are counted with a detection probability of 1.0, which is unrealistic and this method will likely produce negatively biased estimates of survival over the first 6 months of life. In general, radio-telemetry studies have indicated pup survival is similar to adult survival during months 7-12 after birth (Peterson et al. 1984, Fuller 1989, Adams et al. 2008). Consequently, we used 6 month survival rate of adults (~0.94), calculated as the square root of annual survival, to approximate survival of pups from ages 7-12 months. We used the product of summer survival rates times the 6 month survival rate of adult wolves as the annual estimate of pup survival (S_p) in our baseline model ($0.73 \times 0.94 = 0.68$; Table 1).

Table 3. Survival rates of wolf pups from birth to six months reported in peer-reviewed literature. Unless otherwise noted, survival was estimated by comparing pup counts six months after birth to *in utero* litter sizes. Annual survival rates calculated as the product of 6 month survival rates of pups and 6 month survival rates of adult wolves used in our model (0.88).

Source	Survival from birth to 6 months	Annual survival[a]
Fuller (1989)[b]	0.58	0.55
Mills et al. (2008)[c]	0.83	0.78
Fritts and Mech	0.57	0.53
Fuller and Keith (1980)	0.69	0.65
Adams et al. (2008)	0.81	0.76
Hayes and Harestead (2000)[d]	0.80	0.75
Petersen et al. (1984)	0.80	0.75
Ballard et al. (1987)	0.82	0.77
Mech et al. (1998)[e]	0.91	0.85
Hayes et al. (1991)[f]	0.48	0.45
Mean survival	0.73	0.68

[a] Annual survival is the product of survival from birth to 6 months and the 6 month survival rate of adult wolves used in our model.
[b] Survival rate reported was estimated over 8 month period using pup counts. Monthly survival rate was 0.9135 and survival over six months was 0.58.
[c] Survival was estimated with implant transmitters from Jun-Nov. Used monthly survival rates from this period to estimate 6 month survival rate.
[d] Survival estimated on an annual interval. Used the square root of reported survival rates to estimate survival from birth to 6 months.
[e] Survival estimate over first 4 months of life. Extrapolated to 6 months.
[f] Heavily exploited wolf population.

We compared the pup survival rates used in our model to pup count data collected in Oregon during winter surveys conducted from 2009-2014. During this time frame, 30 potential reproductive opportunities were documented. Of these 30 potential reproductive opportunities, 3 were censored because final pup counts were not completed. Assuming wolves give birth to an average of 5 pups per litter (Fuller et al. 2003), we calculated a total of 135 pups born from these 27 reproductive opportunities. Minimum pup counts conducted in December of 2009-2014 indicated a minimum of 82 pups across all years. Using this information we arrived at a minimum observed survival rate of 0.61 (95% CI = 0.53 – 0.69), which is lower but within ~~in~~ the range of the pup survival rate used in our model (0.68 ± 0.15; Table 1).

When implementing our model, annual survival rates were independently calculated for each age class by randomly drawing a survival rate from a uniform distribution with a predefined mean and standard deviation (Table 1). Survival rates of wolves were age-specific and were not influenced by social status of the individual (e.g., survival rates for a 4-year old sub-dominant adult were identical to survival rates for a 4-year old dominant adult). Survival rates were modeled at an individual level, with each individual having an independent probability of survival at each time step.

Commented [JB14]: Does this assumption need justification?

Density-dependence.– When populations surpassed a predefined population threshold, annual survival rates, regardless of age, were multiplied by the ratio of the threshold population size and current wolf population size. The specified threshold was implemented to account for the importance of density-dependence on population dynamics (Morris and Doak 2002), but does not represent an expected number of wolves in Oregon in future years. When implemented in our model, the density-threshold represents an arbitrary biological threshold where wolves begin to self-regulate through intraspecific strife or are limited by available prey.

Commented [JB15]: Worth noting that the model in Bull et al was developed for wolves far below the carrying capacity in a region…so whilst the model is useful in establishing whether the wolf population has a likelihood of going extinct due to demographic structure, it is NOT useful in estimating population dynamics close to carrying capacity.

Larsen and Ripple (2006) created a habitat suitability map for wolves in Oregon and found that a maximum of 1,450 wolves could occupy Oregon. This value increased to 2,200 wolves if industrial timberland in western Oregon was classified as suitable wolf habitat. Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000 \text{ km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 128,000 elk distributed across 151,500 km^2 of summer range habitat (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 2.53 (128,000 × 3/151,500). Based on this value maximum wolf densities were estimated to be 11.79 wolves/1,000 km^2 of summer range elk habitat. This would result in a total population of 1,780 wolves within 151,500 km^2 of elk summer range habitat in Oregon. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, Oregon's elk population is approximately 128,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 2,777.6 × 10,000 kg of primary prey biomass available to wolves across Oregon and a maximum population estimate of approximately 1,722 wolves.

Both the Fuller et al. (2003) and Carbone and Gittleman (2002) equations produce similar estimates of wolf population size and fall within the range reported by Larsen and Ripple (2006). However, these estimates were calculated under the assumption wolves will not cause reductions in prey populations. To account for this possibility, we used a conservative density-threshold (CC) of 1,500 wolves in our model. Again, it should be noted, the density-threshold represents

an estimate of maximum potential wolf population size, not a management objective for wolves in Oregon.

Prey multiplier.–Wolf-prey interactions can influence wolf densities and population dynamics (Fuller et al. 2003). We lacked sufficient data to explicitly model wolf-prey interactions and instead used a simplified approach described in the peer-reviewed published paper by Bull et al. (2009) where a stochastically generated a prey multiplier value (Pr) was used to represent changes in either prey abundance or vulnerability (e.g., increased vulnerability during severe winters). The prey multiplier represented environmental stochasticity in our model. At a value of 1.0, the prey multiplier represented baseline prey availability or vulnerability. Each year of the simulation, the prey multiplier had a 1 out of 3 chance of increasing, decreasing, or remaining the same, respectively. In years the prey multiplier increased or decreased, the maximum change was restricted to 0.10. The prey multiplier was bounded between 0.90 and 1.10 values generated outside this range were truncated to the maximum or minimum value. Survival rates used in the model were calculated as the product of randomly drawn survival rates and the prey multiplier after accounting for any density-dependent effects.

Commented [JB16]: It seems as though you are accounting for the availability of prey through this multiplier and also through the density dependence factor above…needs clarification as to why this isn't double counting

Dispersal and Emigration.–We assumed dominant wolves would maintain their territory and breeding positions until their death. In the event that both dominant animals in a pack died, all remaining pack members would disperse. This approach was partially used for simplicity of model implementation, but was also supported in peer-reviewed literature (Fuller et al. 2003). For example, Brainerd et al. (2008) found that in instances where both breeding wolves were lost, 85% of packs dissolved, and only 9% of packs reproduced the following year.

Sub-dominant wolves that survived the year had a probability of dispersing from their existing territory, which was dependent on age and breeding status (Table 1). Age-specific dispersal rates used in our model (D_p, D_y, D_{ad}) were obtained from literature (Potvin 1988, Fuller 1989, Gese and Mech 1991). We assumed non-breeding adults had similar dispersal rates as yearlings (Fuller et al. 2003). Survival rates of dispersing individuals were reduced (M_d) to account for increased mortality risk of wolves during dispersal (Table 1; Peterson et al. 1984, Fuller 1989, Smith et al. 2010). Smith et al. (2010) found dispersing wolves had a 38.9% higher risk of mortality over 365 days than resident wolves. After accounting for this increased risk, survival rates of dispersing adult wolves would be 0.83 with the ratio of dispersing versus resident adult survival rates of 0.94 (0.83/0.88). To be conservative, we lowered this value to 0.90 (± 0.05 SD) for use in our model, which is interpreted at 10% of dispersing wolves die during the dispersal process.

We used a spatial simulation to estimate emigration rates using peer-reviewed published estimates of dispersal distances of wolves (Fritts and Mech 1981, Fuller 1989, Gese and Mech 1991, Wydeven et al. 1995). We generated 10,000 random dispersal paths that started at a random location within summer range elk habitat (i.e., potential wolf habitat). We simulated dispersal paths using correlated random walks with the movement.simplecrw function in the Geospatial Modeling Environment (Beyer 2012) by selecting a random bearing from a uniform distribution (0 - 359°) and a random dispersal distance from normal distribution with a mean of 75 km (± 30 SD). We calculated emigration rates (E_d) as the proportion of simulated dispersal paths that terminated outside Oregon. Mean emigration rates were estimated to be 0.115 (Table 1). We estimated a standard deviation of the mean values calculated from 100 bootstrap samples that each contained 100 random dispersal paths. The estimated standard deviation of the mean of

these 100 samples was 0.03. Emigration was effectively treated as additional mortality in our model (i.e., these individuals were removed from the simulated population).

Territory Establishment.–Dispersing wolves ≥ 2 years old were assigned a probability of establishing a territory. Boyd and Pletscher (1999) found that 57% of dispersing wolves successfully found a mate the next breeding season after they dispersed. This value equates to the joint probability of two wolves establishing a territory. Independently, the probability of a dispersing wolf establishing a territory (T) would be 0.75 ($\sqrt{0.57}$), which we used in our model. Wolves that did not successfully establish a territory remained in the pool of dispersers until the following year. Those individuals that successfully established territories would first fill vacant alpha positions of the correct sex in established packs. If no alpha positions were available at established packs, dispersing wolves would then establish a new territory and maintain that position until they died or a mate joined them at the territory.

Commented [JB17]: So there are no barriers to creating new territories? I seem to remember Bull et al making it more difficult for dispersers to establish territory if all available territories were occupied.

Immigration.–We assumed wolves from the extant Rocky Mountain wolf population would be available to immigrate into Oregon. For model simplification, we assumed the wolf population outside Oregon was unstructured and would produce a steady, but limited, stream of immigrants. We assumed 3 wolves (± 2 SD) would immigrate (I) annually into Oregon from surrounding populations. We assumed all immigrating wolves were sub-adults because a review of peer-reviewed literature indicated this age class is most likely to engage in dispersal behavior (Fuller 1989, Gese and Mech 1991, Fuller et al. 2003). Individuals arriving in the Oregon population were randomly assigned a sex assuming parity among dispersers (Gese and Mech 1991).

Commented [JB18]: Okay, so this is similar to the case in Norway/Sweden then. But need to justify this assumption of a steady stream of immigrants, as it is crucial to simulation outcomes.

Anthropogenic Mortality.–Anthropogenic mortality was incorporated in the model under two forms: legal and unauthorized mortality. Unauthorized mortality represented all sources of anthropogenic mortality (e.g., poaching, vehicle-killed individuals) excluding mortalities authorized by ODFW under current laws. Legal removals included any administrative removals authorized by ODFW (e.g., livestock damage, human safety, incidental take). Anthropogenic mortality was modeled using a two-step process where unauthorized mortality was modeled first and followed by legal mortality. A proportion of the total population that remained after accounting for natural mortality events would be removed each year by each anthropogenic mortality source (Table 1). Anthropogenic mortality was applied independent of age, social status, or pack membership. Effectively, this approach treats anthropogenic mortality as a reduction in survival. For example, using an annual adult survival rate of 0.88, survival rates would be reduced to 0.79 ($0.88 \times 0.95 \times 0.95$) if 5% of the population was removed for both legal and unauthorized mortality, respectively.

Commented [JB19]: Again, I would say this assumption needs some justification

From April 2009 to March 2015, ODFW has collected 54 wolf-years of data from radio-collared individuals. During this time, 1 radio-collared wolf was illegally killed and 1 radio-collared wolf was removed by ODFW, for a removal rate of 0.02 for each mortality source (ODFW, unpublished data). Due to the potential bias of radio-collared wolves being avoided by poachers, we increased the illegal mortality (IM) value to 0.05 (± 0.03 SD). To be conservative and allow for the potential of increased levels of lethal control actions, we used a value of 0.05 (± 0.03 SD) for legal mortality (LM) of wolves in our model (i.e., between 2-8% of wolves would be randomly removed from the population each year for management related actions).

Reproduction.–Only established wolf packs with a dominant pair of adults were allowed to reproduce. We were unable to find peer-reviewed estimates of pregnancy rates of dominant females in published literature; however, it is biologically unrealistic to assume all pairs of wolves successfully give birth to pups each year (i.e., female do not always become pregnant).

We assumed pregnancy rates of dominant females (P_{ad}) would be 0.95 (± 0.02 SD; Table 1). While evidence exists of multiple females producing pups within a pack, this is a rare occurrence and usually only occurs in extremely large packs (Mech 1999), and we assumed only one litter of pups would be born in packs with a dominant pair. The number of pups produced by pregnant females (L) was drawn from a uniform distribution ranging from 2-8 (Table 1) based on a review of literature (see summary in Fuller et al. 2003).

Catastrophes.–We included two catastrophes in our model. The first was modeled at the pack level as the probability of a pack having complete reproductive failure within a year (R_{cas}). Probability of reproductive failure was independent among packs and years. This approach was used to simulate the potential effects of diseases (e.g., canine parvovirus), which are known to negatively affect pup survival and recruitment (Mech and Goyal 1993, Almberg et al. 2009), where most or all pups die when exposed to the virus (Mech et al. 2008). We assumed complete reproductive failure had a probability of occurrence of 0.05 within each pack during each year of the simulation (i.e., one out of 20 litters will be subjected to complete reproductive failure). Packs that had complete reproductive failure were assigned a litter size of 0 (i.e., even if pups were produced they would all die before 1 year of age).

Our second catastrophe was modeled at the population level, where each year of the simulation there was a probability of a population wide reduction in survival (S_{cas}). This approach was used to represent extremely rare, range wide events that may affect wolf populations (e.g., disease, abiotic conditions, prey population crashes). We used a mean interval of 100 years between disturbance events, with each year having an independent probability of a disturbance event occurring. During years where a catastrophe event occurred, survival rates of all wolves in the population were reduced by 25%.

Assessment of Population Viability

We assessed population viability using two measures. The Oregon Wolf Plan defined a threshold of 4 breeding pairs for 3 consecutive years as a guideline to consider delisting wolves from the Oregon ESA (ODFW 2010). Consequently, we defined "conservation-failure" as a simulated population that fell below 4 breeding pairs. For each simulated population, we determined which time-step, if any, that the population dropped below the conservation-failure threshold. Simulated populations that dropped below the conservation-failure threshold were considered failures in all remaining time steps. We calculated risk of conservation-failure as the cumulative proportion of simulated populations that had < 4 breeding pairs.

We used a threshold of < 5 wolves as our metric of "biological-extinction". In simulations with < 5 wolves, the extant population would effectively be extirpated and immigrants from outside sources would be maintaining the Oregon population. For each simulated population, we determined the time-step, if any, that the population dropped below the biological-extinction threshold. Once the population dropped below this threshold it was determined to be biologically-extinct for all remaining time steps. We calculated biological-extinction rates as the cumulative proportion of simulated populations that < 5 wolves.

Model Validation

To validate our baseline model, we conducted a set of 100 realizations of population growth over 5 years, where the starting population size was the number of wolves present in Oregon at the end of 2009 (N = 14 wolves). We calculated the mean number of wolves and breeding pairs from simulations and compared these values to population counts conducted by ODFW from 2010-2014. Survival rates used in our baseline model were more conservative than observed in Oregon from 2010-2014. Consequently, we conducted a second set of simulations

Commented [JB20]: What biological phenomena does the previous section on Reproduction capture, then (i.e. not all packs breeding in a given year)? Need to explain how the previous section differs from Rcas.

Commented [JB21]: I think excellent to include this in here, as catastrophes are probably important.

But it would be good if there was some way of justifying the parameters. 1 in 100 years doesn't sound that often for the average catastrophe (if using all catastrophes mentioned, as well as others), and a reduction in survival rate of 25% (e.g. reducing the survival rate for non-pups from 0.88 to 0.66 doesn't sound all that catastrophic.

Another danger is that if this is included, it implies the model has adequately accounted for e.g. disease, which it hasn't. So need to be careful with the way the results are presented.

Commented [JB22]: Actually, conservation failure should arguably then be the number of **3 year intervals** in which 4 breeding packs were not achieved...not the number of years. The former will be higher, giving you a higher estimate of risk for conservation failure

Commented [JB23]: What if the population then rose dramatically by the end of the simulation? Still a conservation failure? Or did this not happen in any simulations?

Commented [JB24]: Why?

where we parameterized our model with vital rates required to match observed population growth rates in Oregon from 2009-2014 (see Table 1 for differences between vital rates in the two scenarios). Using observed vital rate values in our model would allow us to determine if our overall model structure allowed accurate estimation of population growth under known conditions.

Sensitivity Analysis

Effects of Stochastic Parameters.– We used *r* (i.e., intrinsic rate of increase) as the dependent variable in a linear regression model where stochastically varying parameters and relevant interactions were used as independent variables. We conducted 200 realizations of population growth over a 5-yr period which resulted in 1,000 random combinations of parameter values and associated intrinsic growth rates (*r*). The sensitivity analysis was limited to a 5-yr span because allowing population simulations to last longer than 5-yrs could cause some simulations to reach the density-threshold of 1,500 wolves and confound the effect of parameter variation and density-dependence on *r*. For each simulation, the starting population was assumed to be 120 wolves equally distributed among 20 packs. We used this starting population size because at extremely small population sizes (e.g., $N < 10$) immigration of wolves could produce biologically unreasonable population growth rates (e.g., $\lambda > 2.0$) and confound our ability to detect an effect of parameters on *r*. Prior to running our regression model, all independent variables were standardized (standardized value = [observed value - mean value]/standard deviation) to allow direct comparisons between results. We used an alpha level of 0.05 to determine significance of parameters and the sign and slope of beta coefficients to determine the strength and relative effect of the parameter on *r*.

Commented [JB25]: I don't understand why you were using r to test the sensitivity of model outputs to parameter values, when the model output of interest is the risk of conservation failure or biological extinction. Surely the latter should be your dependent variables in the sensitivity analysis?

If not, explain why not.

*Effects of Static Parameters.–*Starting population size, density-threshold, and frequency of survival and reproductive catastrophes were static parameters in our model and the effects of these were not included in our regression analysis used to determine the relative effects of parameters on *r*. Consequently, we conducted additional simulations where values of static parameters differed among simulations. Each simulation used 100 realizations of population growth over 50 years and was parameterized with baseline values except for changes in the static parameter of interest. We conducted 4 simulations to determine the effect of starting population sizes of 50 wolves, the known existing Oregon wolf population (N = 85; baseline value), 100 wolves and, 150 wolves. Simulations with starting populations of 50, 100, and 150 wolves were structured as follows: 1) each wolf belonged to a pack and each pack had 5 members with 2 of those members being dominant adults and 2) sex, age, and social class of remaining wolves were randomly assigned. To determine the relative influence of the density-threshold on population viability of wolves, we conducted a set of simulations where used a density-threshold of 100, 250, 500, 1000, and 1500 (baseline value) wolves. We conducted a set of 3 simulations where we investigated probabilities of individual pack reproductive failure of 0.05 (baseline value; once every 20 litters), 0.10 (once every 10 litters), and 0.20 (once every 5 litters). We investigated the effects catastrophic reductions in survival at year-specific probabilities of 0.01 (baseline value; once every 100 years), 0.02 (once every 50 years), 0.05 (once every 20 years), and 0.10 (once every 10 years).

Commented [JB26]: I do not think you need to include these as parameters in a separate sensitivity analysis.

My understanding is that the SA should show the effect of specified parameters on model outcomes, especially those that you have estimated without an empirical basis. If the model is highly sensitive to certain parameters, especially those estimated, the outcomes needed to be understood in that context. So it doesn't matter whether the parameters are static or stochastic.

Unless you have a different understanding, I would do all of this as one single SA with all parameters

Effects of lethal control of wolves

Legal, anthropogenic mortality is the parameter included in our model over which ODFW has the most control. To address the effects of varying rates of legal wolf removal on wolf population viability we conducted a set of 4 simulations where mean legal mortality rates and associated standard deviations varied among simulations while all other model parameters

were left at baseline values (Table 1). The following values were used as mean values (± SD) to represent legal anthropogenic mortality rates in the 4 simulations: 0.00 (± 0.00), 0.05 (± 0.03), 0.10 (± 0.06), and 0.20 (± 0.12). These levels of legal mortality rates were in addition to illegal mortality rates which were set at a mean value of 0.05 (± 0.03) during all simulations.

Our baseline model assumes legal removals will be implemented through random removal of individual wolves. However, the potential exists that lethal control actions could take place across entire wolf packs, rather than individuals. Consequently, we also conducted a simulation where legal removal of wolves would occur at a pack rather than individual level. We assumed the proportion of packs removed per year would be the same as the proportion of individuals removed in our baseline simulation (0.05 ± 0.03). After completion of simulations, we compared the results to the baseline simulation to determine what effect, if any, pack removal would have on population dynamics compared to individual removal.

RESULTS

Model Validation

Our baseline model resulted in underestimates of population size (Fig. 3a) and number of breeding pairs (Fig. 3b) compared to population count data collected in Oregon from 2010-2104. When our model was parameterized with survival rates of wolves observed from 2009-2014 (Table 1) the simulation results closely approximated observed population size and number of breeding pairs. Consequently, survival rates used in our baseline model are cautious compared to past survival rates in Oregon; however, the ability of the model to correctly predict past population dynamics when parameterized with observed survival rates suggests other parameters included in the model accurately portray wolf population dynamics in Oregon. Our baseline model predicted lower population growth compared to the model parameterized with survival rates observed from 2009-2014. This suggests our baseline model will underestimate wolf population growth and viability if survival rates from 2009-2014 are observed into the future.

Assessment of Population Viability

Using our baseline model, simulated wolf populations increased an average of 7% (i.e., $\lambda = 1.07 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.05 (95% CI = 0.01 – 0.09) probability of the population dropping below the conservation-failure threshold (Fig. 4). Most conservation-failures (3 out of 5) occurred within the first 10 years and by year 20, no additional populations passed the threshold. Of the five simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 7, 20, 39, 84 and 194 breeding pairs in year 50 of the simulation, respectively. There was a 0.01 (95% CI = 0.00 – 0.03) probability the simulated population dropped below the biological-extinction threshold over the next 50 years. The single simulated population that dropped below 5 individuals recovered to 360 individuals by year 50.

Commented [JB27]: Interesting... but does this not seriously challenge your assumption that <5 individuals should be considered "biologically extinct"?!

Using observed survival rates of wolves from 2009-2014 in our population model resulted in no scenarios where wolf populations dropped below the conservation-failure or biological-extinction thresholds. Our baseline model may be more likely to represent future population dynamics of wolves, but may be overly pessimistic, especially in the near future, given recently observed survival rates of wolves in Oregon. Consequently, we contend future risk of conservation-failure likely falls somewhere between our baseline model (0.05) and our model parameterized with vital rates required to match observed population growth rates from 2009-2014 (0.00). Our model results suggest it is extremely unlikely (≤ 0.01 probability) wolves in Oregon will be at risk of extirpation over the next 50 years.

Commented [JB28]: NB this statement is only true **in the context of the assumptions you have made** here

Many things have not been included in the model... e.g. what is the economic development rate in Oregon, and will this result in increasing human-wolf conflict? What will the influence of climate change be over 50 years? Need to make this clear.

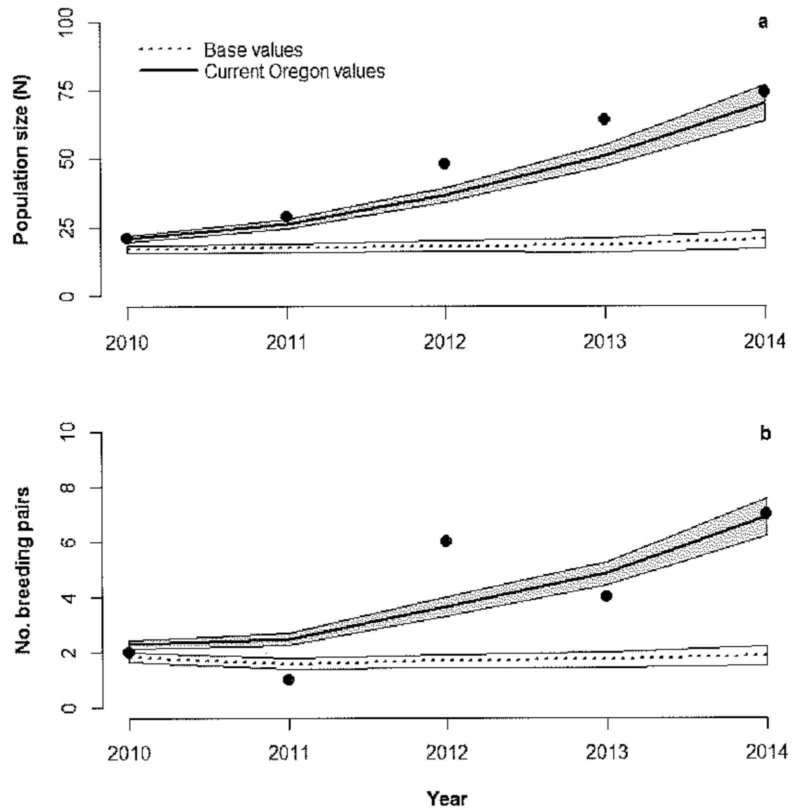

Figure 3. Comparison of (a) simulated mean population sizes compared to minimum population sizes observed in Oregon from 2009-2014 and (b) simulated number of breeding pairs to minimum number of known breeding pairs in Oregon from 2009-2014 using baseline simulation parameters (dashed line) or observed model parameters (solid line). Black dots represent observed wolf population size and number of breeding pairs determined from annual surveys of wolf populations conducted by ODFW. Polygons around simulated mean population sizes and number of breeding pairs represent 95% confidence intervals.

Figure 4. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

Sensitivity Analysis

Effects of Stochastic Parameters.–Nine out of 17 stochastic parameters included in our baseline model had a significant effect on intrinsic growth rates as measured by *r*, and no significant interactions between parameters were documented (Table 4). Most significant effects (Fig. 5) were directly or indirectly related to survival rates. Survival rates of pups (S_p; β = 0.045), yearlings (S_y; β = 0.024), and adults (S_{ad}; β = 0.019) were positively associated with *r*. The prey multiplier (Pr) increased variation in survival rates of all age classes of wolves by up to 20% and resulted in the prey multiplier, which represented increased environmental stochasticity, having the greatest effect on *r* (β = 0.088). Illegal (IM; β = -0.027) and legal (LM; β = -0.028) anthropogenic mortality were negatively associated with *r*.

Table 4. Results of linear regression model used to estimate sensitivity of intrinsic growth rates of wolf populations in Oregon using an individual-based population model. Standardized regression coefficients with associated standard errors estimated from the full model are provided. Significance is determined as follows: *** = P < 0.001, ** = P < 0.01, * = P < 0.05, and NS = P > 0.05.

Commented [JB29]: Might be useful to explain the model actually used for this analysis

Parameter	Standardized β_i	SE	P-value	Significance
Pup survival	0.045	0.007	0.000	***
Yearling survival	0.024	0.007	0.000	***
Adult (2 to 7-yrs old) survival	0.019	0.007	0.006	**
8-yr old adult survival	-0.006	0.007	0.411	NS
9-yr old adult survival	-0.002	0.007	0.789	NS
Pup dispersal	0.007	0.007	0.295	NS
Yearling dispersal	0.010	0.007	0.155	NS
Adult dispersal	-0.001	0.007	0.833	NS
Proportion of dispersing wolves that die	-0.026	0.007	0.000	***
No. of immigrants arriving annually	0.009	0.005	0.109	NS
Proportion of dispersing wolves that emigrate	-0.005	0.007	0.443	NS
Proportion of dispersing wolves that successfully establish a territory	0.034	0.006	0.000	***
Pregnancy rate for dominant females	0.001	0.007	0.912	NS
Mean litter size	0.049	0.004	0.000	***
Prey index multiplier	0.088	0.005	0.000	***
Illegal mortality	-0.027	0.007	0.000	***
Legal mortality	-0.028	0.007	0.000	***
Pup survival × Prey multiplier index	-0.011	0.009	0.198	NS
Yearling survival × Prey multiplier index	0.000	0.009	0.958	NS
Adult survival × Prey multiplier index	-0.003	0.009	0.737	NS
Pup survival × Illegal mortality	-0.004	0.012	0.720	NS
Yearling survival × Illegal mortality	0.012	0.012	0.293	NS
Adult survival × Illegal mortality	0.016	0.011	0.146	NS
Pup survival × Legal mortality	-0.003	0.012	0.797	NS
Yearling survival × Legal mortality	0.001	0.012	0.912	NS
Adult survival × Legal mortality	0.011	0.012	0.342	NS
Pup survival × Dispersal mortality	-0.013	0.011	0.248	NS
Yearling survival × Dispersal mortality	0.003	0.012	0.824	NS
Adult survival × Dispersal mortality	0.003	0.011	0.785	NS

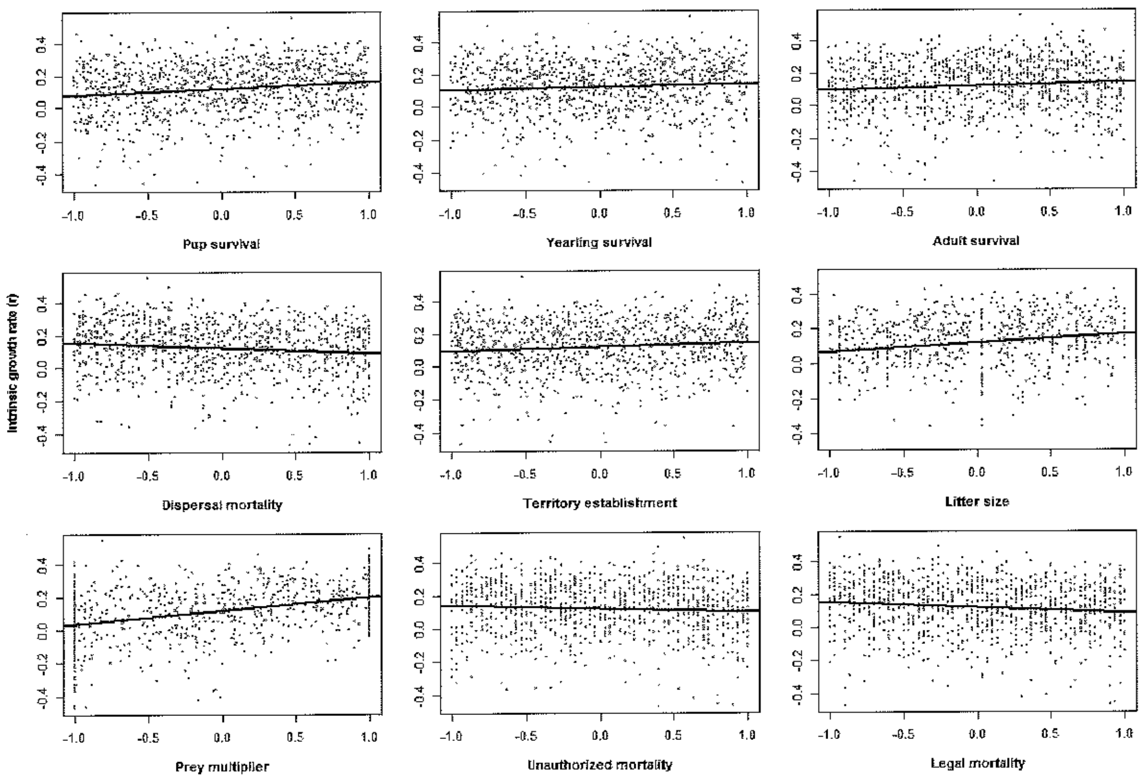

Figure 5. Estimated effects of significant ($p < 0.05$) model parameters on intrinsic growth rates of wolf populations. Estimates were generated using baseline model parameterization. Results generated from 1,000 unique combinations of model parameters and associated intrinsic growth rates. Model parameters are standardized to allow direct comparison among parameters. Black line represents estimated regression line. Gray dots represent individual parameter estimates and associated population growth rate.

Increased mortality rates of dispersing wolves (M_d; $\beta = -0.026$) had a negative effect on *r*. This parameter negatively affected *r* in two ways: 1) wolves were directly removed from the population and 2) fewer wolves were available to establish territories and contribute to population level reproduction. Increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on *r* (T; $\beta = 0.034$). Mean litter size (L; $\beta = 0.049$) was positively correlated with *r*. Pregnancy rates of dominant females (P_{ad}) were not significantly associated with *r*. We likely did not find a significant effect of pregnancy rates because of the high mean value (0.95) and low variation (SD = 0.02) used in our model.

Dispersal rates, regardless of age class (D_p, D_y, and D_{ad}) had minimal effects of on *r* (Table 4). Both immigration (I) and emigration (E_d) did not have a significant effect on *r*. At most, our model limited the number of immigrating wolves to 5 per year (range = 1 – 5) and contributions to population growth from immigrants will be limited except for extremely small extant populations. We modeled emigration rates as a proportion of the dispersing wolves that survived and left the population each year. Consequently, emigration could contribute to reduced population growth rates when the number of emigrants is greater than the number of immigrants. This scenario is more likely to occur for large extant populations.

Commented [JB30]: Interesting, when this was a key factor in Bull et al. Why is this?

Effects of Static Parameters.–As expected, simulations with larger starting populations reached the density-threshold faster than those with smaller starting size (Fig. 6a). The risk of conservation-failure declined with increased starting population size (Fig. 6b). Using our baseline model, simulations that started with 150 and 100 individuals had no risk and a 0.01 (95% CI = 0.00 – 0.03) probability of conservation-failure over the next 50 years, respectively. At the current minimum known wolf population in Oregon, risk of conservation-failure (0.05; 95% CI = 0.01 – 0.09) was slightly higher than if 100 animals were in the population but substantially lower than if only 50 wolves (0.14; 95% CI = 0.07 – 0.21) occurred in Oregon. We did not observe a relationship between starting population size and biological-extinction risk as biological-extinction risk was ≤ 0.01 over 50 years regardless of starting population size.

Unsurprisingly, mean maximum population sizes of wolves were larger for simulations with higher density-thresholds (Fig. 7a). The effects of varying density-thresholds on risk of conservation-failure over 50 years were similar for density thresholds between 250 – 1500 (range 0.03 – 0.05; Fig. 7b). In contrast, at a density-threshold of 100 wolves, risk of conservation-failure was much greater (0.64; 95% CI = 0.55 – 0.73), steadily increased over time, and never plateaued as observed in other simulations. This suggests that a population threshold of 100 wolves is insufficient to allow long-term persistence of ≥ 4 breeding pairs. Regardless of the density-threshold used, maximum observed biological-extinction risk was ≤ 0.01.

Increased frequency at which catastrophic reductions in survival rates occurred caused reduced population growth rates and reduced mean, maximum population size of wolves (Fig. 8a). Populations that were subjected to catastrophic reductions in survival at intervals of once every 100 or 50 years had a relatively low risk of conservation-failure (range = 0.05 – 0.06; Fig. 8b). Catastrophic reductions in survival at intervals of once every 20 (0.09; 95% CI = 0.03-0.15) and 10 (0.16; 95% CI = 0.09-0.23) years had moderate risk of conservation-failure compared to less or more frequent intervals. For all scenarios, biological extinction risk was ≤ 0.01 over 50 years.

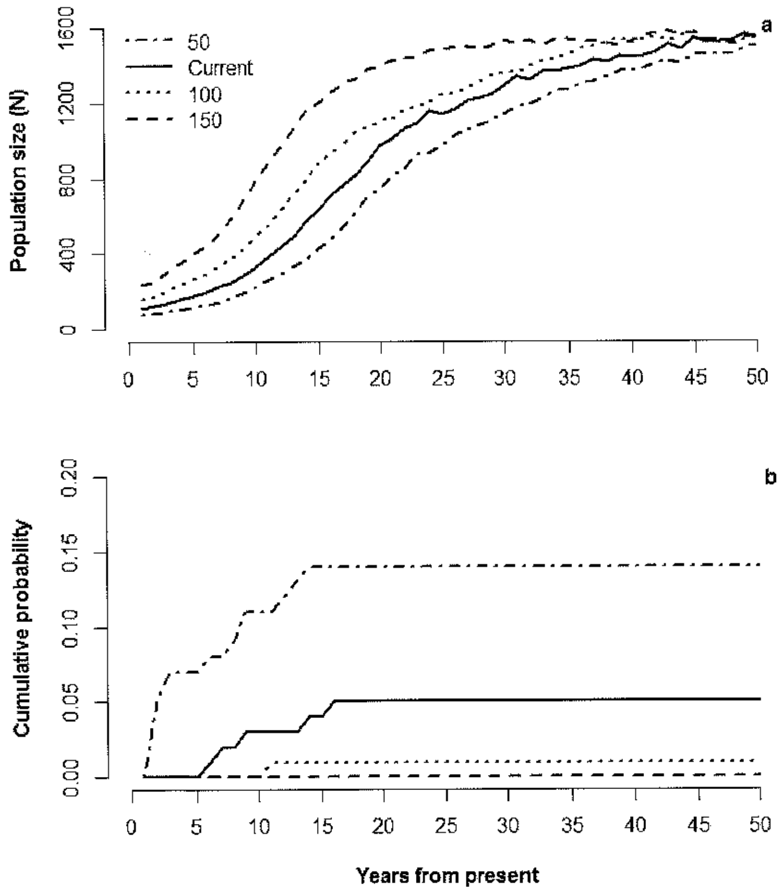

Figure 6. Estimated effect of variation in starting population size on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Current population size (N = 85) was the minimum wolf population size in Oregon as of April 1, 2015. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using the baseline model parameterization.

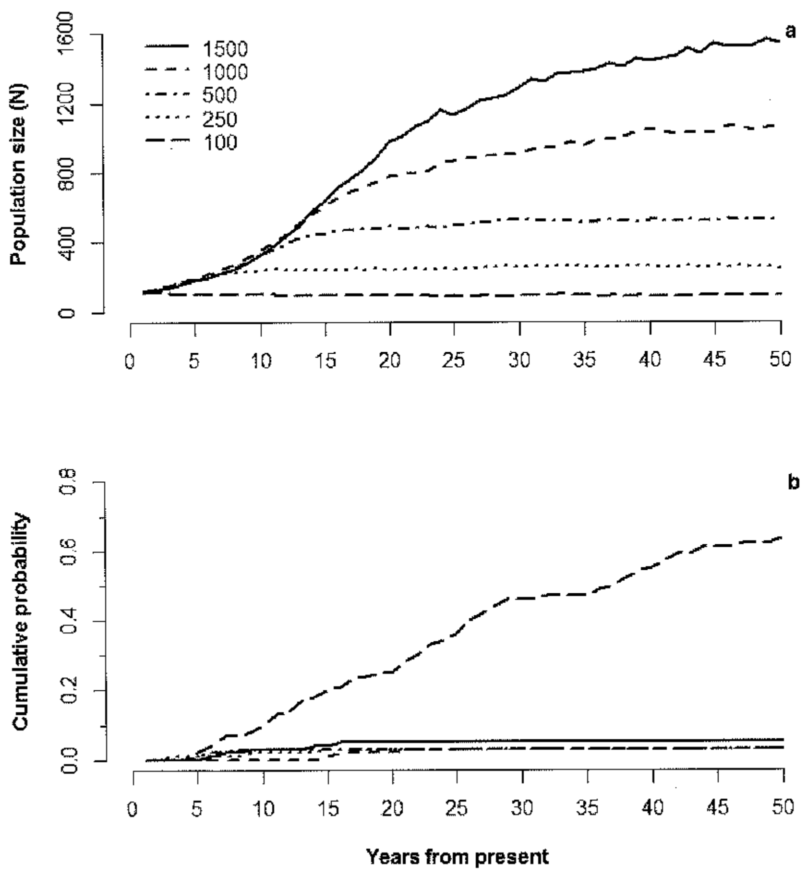

Figure 7. Estimated effect of variation in density-threshold on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

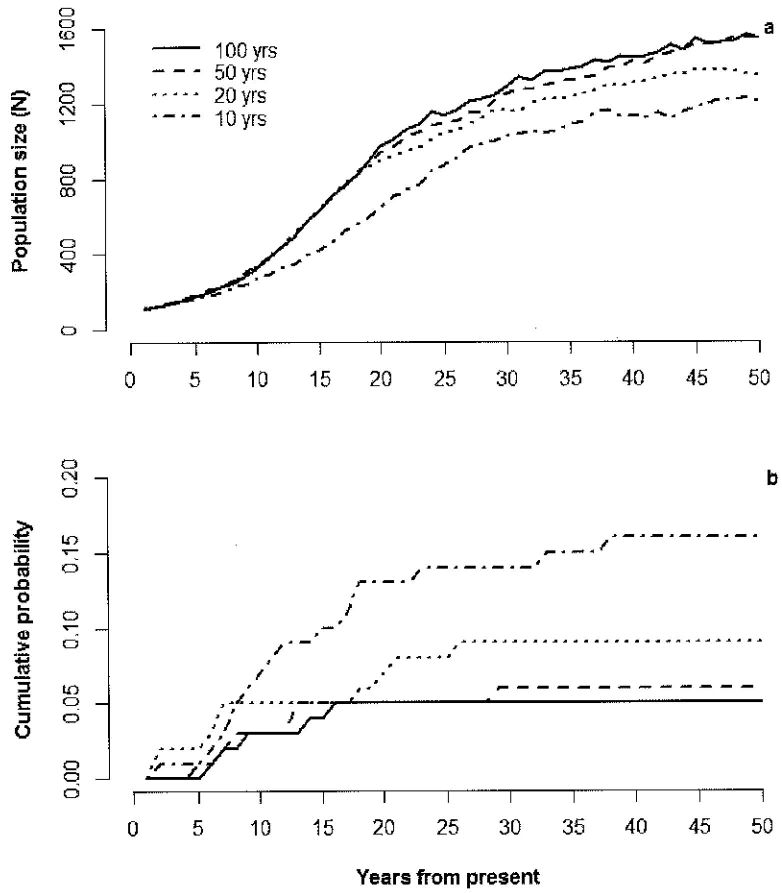

Figure 8. Estimated effect of variation in interval between catastrophic reductions in survival of wolves on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs). Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Increased frequency of pack-specific reproductive failure reduced population growth rates and mean, maximum population size of wolves (Fig. 9a). Scenarios with reproductive failure once every 20 (0.05; 95% CI = 0.01 – 0.09) and 10 litters (0.05; 95% CI = 0.01 – 0.09) had similar risk of conservation-failure in the next 50 years (Fig. 9b). Risk of conservation-failure was almost 6 times greater at intervals of once every 5 litters (0.29; 95% CI = 0.20 – 0.38). These results highlight the importance of pup production on ensure population viability of wolves. Risk of biological-extinction was not strongly affected by interval of reproductive failure as all scenarios had a risk of biological-extinction ≤ 0.02.

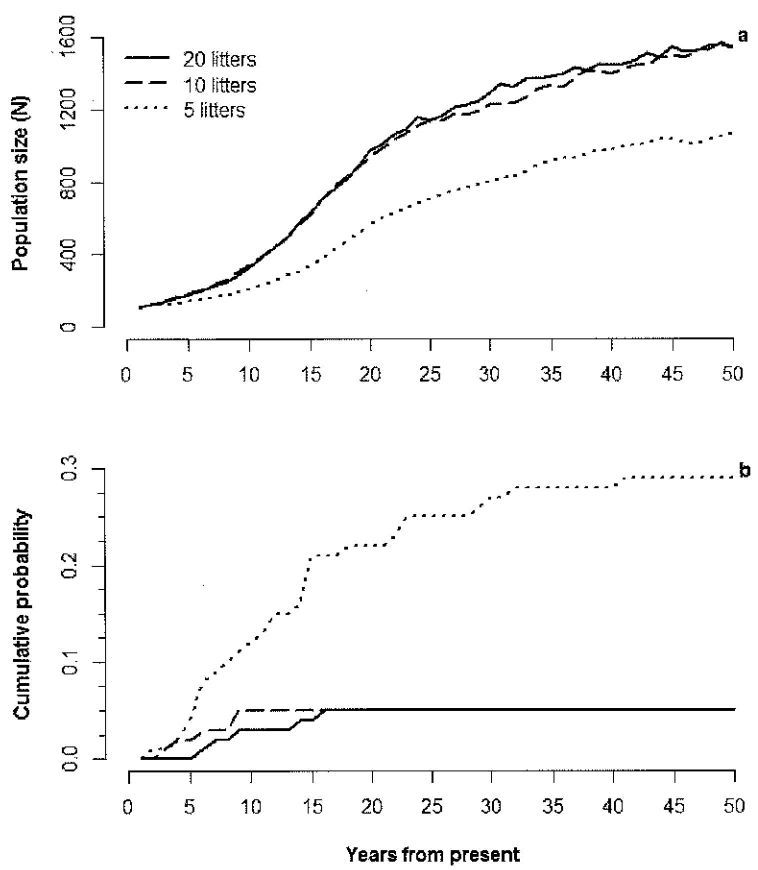

Figure 9. Estimated effect of variation in intervals between reproductive failure on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Effects of lethal control of wolves

Increased rates of legal mortality, while holding illegal mortality at baseline values, had a negative effect on population growth rates and mean, maximum population size of wolves (Fig. 10a). With a starting population of 85 wolves and at a legal mortality rate of 0.20, wolf populations declined. This suggested this rate of legal morality was not sustainable over the long-term at least at a starting population of 85 wolves and additional illegal mortality of 0.05. At a mean legal mortality rate of 0.05, which was used in our baseline model, probability of conservation-failure was 0.05 (95% CI = 0.01 – 0.09; Fig. 10b) over the next 50 years. At a reduced mean legal mortality rate of 0.00, no simulated populations dropped below the conservation-failure threshold. Probability of conservation-failure increased to 0.40 (95% CI = 0.30 – 0.50) and 1.00, for mean legal mortality rates of 0.10 and 0.20, respectively, when combined with illegal mortality rates of 0.05. Combined, these results highlight the importance of minimizing anthropogenic mortality to benefit population viability of wolves. Probability of biological-extinction was relatively low for all simulations with mean legal mortality rates ≤ 0.10 (range = 0.00 – 0.07; Fig. 10c). In contrast, mean legal mortality rates of 0.20 resulted in an extremely high probability of biological extinction (0.90; 95% CI = 0.84 – 0.96), at least when combined with an illegal mortality rate of 0.05 and a starting population of 85 individuals. Larger populations will be able to sustain higher mortality rates because they will have a greater buffer between extant population size and thresholds of biological extinction.

It should also be noted, the levels of anthropogenic mortality used in our model are not directly comparable to mortality rates commonly reported in literature (i.e., 1 – survival rate). Anthropogenic mortality rates as implemented in our model represent the proportion of wolves that would be removed from the population after accounting for natural mortality. For example, using a legal mortality rate of 0.10, an illegal mortality rate of 0.05, and a survival rate in the absence of anthropogenic mortality of 0.88, would result in an observed survival rate of 0.75 ($0.88 \times 1\text{-}0.10 \times 1\text{-}0.05$).

The effects of legal removals on wolves reported above are predicated on a starting population of 85 wolves. At larger population sizes, wolves will have an increased buffer between extant population size and conservation-failure or biological-extinction thresholds and fewer simulations would be expected to cross these thresholds. This is particularly true for moderate levels of legal mortality (0.05-0.15) where populations are likely to increase on average, but without a sufficient buffer and under stochastically varying conditions, 2-3 consecutive years of negative population growth could push the population below a predefined threshold. This phenomenon is evident in our simulations because most conservation-failures occurred shortly after simulations started. By later years, population sizes had sufficiently increased that they were able to withstand several consecutive years of negative population growth without falling below the conservation-failure threshold.

Comparison of individual vs. pack removal.–Lethal control actions conducted through random removal of individuals or entire packs had little influence on mean population size over 50 years (Fig. 11a). Mean populations for both removal scenarios reached the density-threshold (N = 1,500) by the 50th year of the simulation. Conservation-failure rates over 50 years were similar if individual wolves (0.05; 95% CI = 0.01 – 0.09) or packs (0.08; 95% CI = 0.03 – 0.13) were removed (Fig. 11b). Entire pack removal (0.01; 95% CI = 0.00 – 0.03) and removal of individuals (0.01; 95% CI = 0.00 – 0.03) resulted in similar estimates of biological-extinction risk over 50 years.

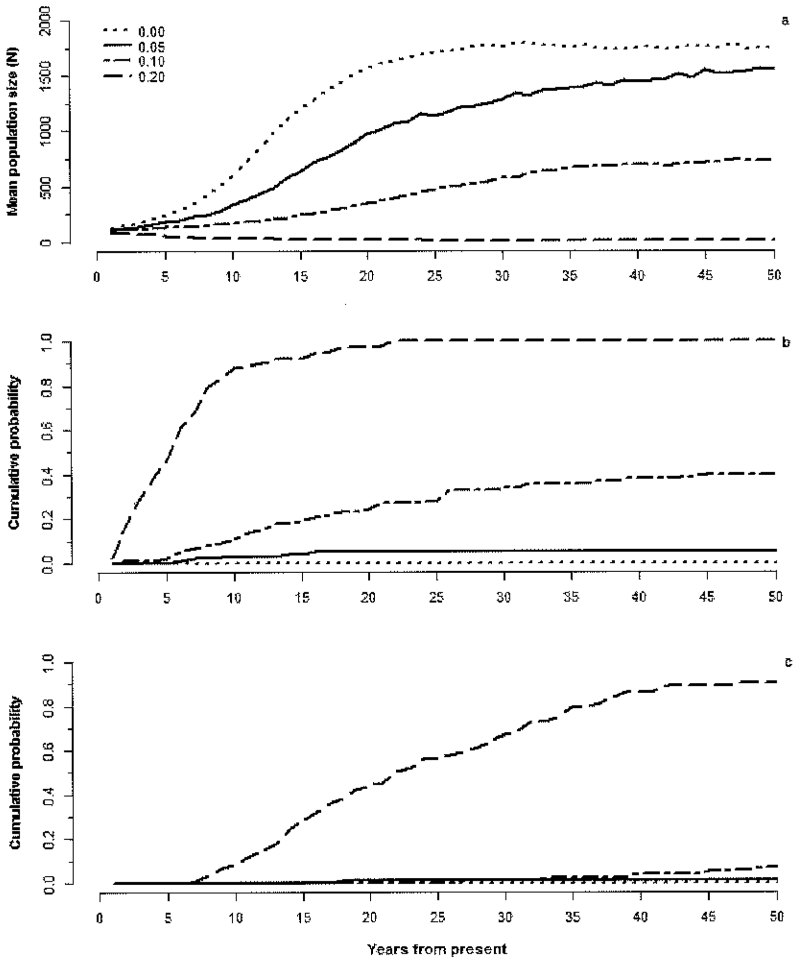

Figure 10. Estimated effect of variation in legal removal rates (proportion of wolves that would have survived the year otherwise) of wolves on (a) mean population size, (b) cumulative probability of conservation-failure (< 4 breeding pairs), and (c) cumulative probability of biological-extinction (< 5 wolves) over the next 50 years in Oregon when the starting population size was 85 wolves. Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. For all simulations, unauthorized morality rates of 0.05 (± 0.03 SD) occurred in addition to varying levels of legal removal.

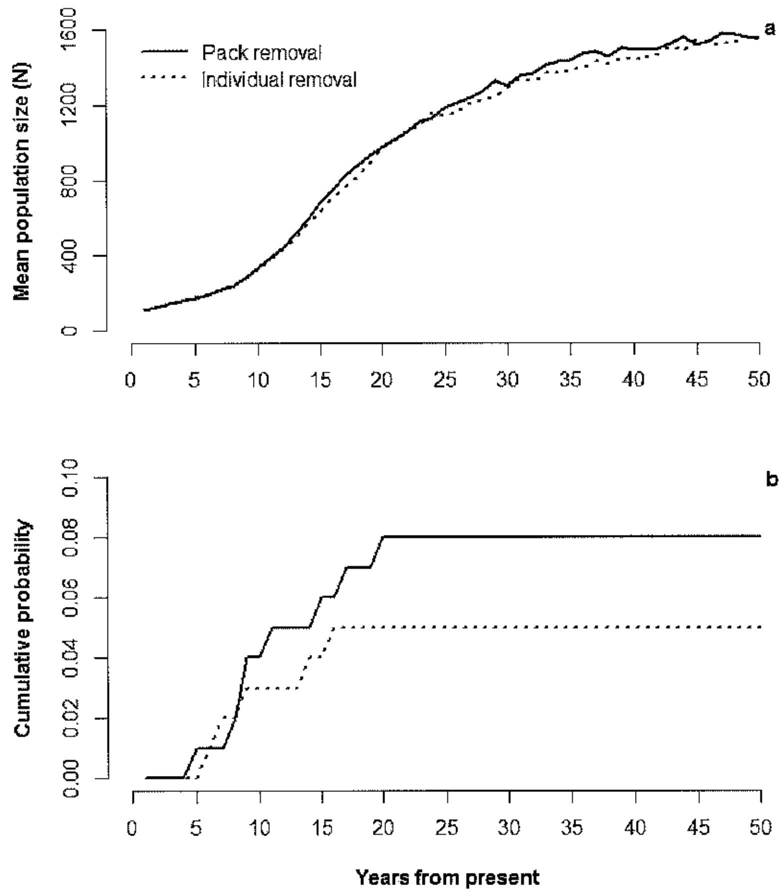

Figure 11. Estimated effect of individual versus pack level legal removal on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. Pack level and individual removal rates were identical for each simulation (0.05 ± 0.03).

DISCUSSION

Our baseline model underestimated population growth rates of wolves compared to observed population counts conducted in Oregon from 2010-2014. This was a consequence of two factors: 1) our baseline model used lower survival rates than were observed from 2010-2014 and 2) at small population sizes demographic stochasticity can have a dramatic effect on population growth rates (Lande 1998, Fox and Kendall 2002). However, our model parameterized with survival rates of wolves radio-collared in Oregon from 2009-2014 allowed our model to track observed population growth rates during this timeframe. We contend these findings suggest our model structure is capable of accurately portraying population dynamics of wolves when survival rates used in the model are representative of current conditions. We used conservative survival estimates in our baseline model to ensure our PVA erred on the side of caution (i.e., precautionary principle; Myers 1993, Meffe et al. 2006). Consequently, our results represent a conservative view of population viability of wolves in Oregon.

Commented [JB31]: Yes – over a short timeframe. But it is not clear whether the components of the model designed to deal with catastrophes can accurately capture them, as this was not tested between 2009-2014

If wolf populations in Oregon continue to follow vital rates observed from 2009-2014, our results indicated there would be no risk of conservation-failure or biological-extinction within the next 50 years. It is unlikely wolf populations in Oregon would continue to increase at observed population growth rates because established or exploited wolf populations do not increase as rapidly as protected or recovering populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Therefore, we contend results from our model parameterized with currently observed vital rates may present an overly optimistic view of wolf population dynamics moving forward in Oregon. Using our baseline model parameterized with vital rates obtained from a literature review, we documented a 0%, 3%, and 5% chance of conservation-failure over the next 5,10, and 50 years, respectively (Fig. 4). Most risk of conservation-failure occurs in the short-term (e.g., 15 years) because Oregon's extant wolf population is close to the conservation-failure threshold and a few years of poor population growth could cause the population to decline below the threshold. Furthermore, during the first few years of our simulations, population sizes are small, which allows demographic stochasticity to have a greater effect on population persistence (Vucetich et al. 1997).

Our baseline model suggested risk of conservation-failure was lower for populations that started with 100 or 150 wolves compared to the current population size observed in Oregon (N = 85; Fig. 6). This is not an unexpected finding because larger populations, regardless of species, have a reduced risk of extinction and can withstand longer periods of reduced population growth. These results highlight the importance of creating a buffer between extant population size and conservation-failure thresholds to allow for potential years of negative population growth. Furthermore, increased modeled starting population size will minimize effects of demographic stochasticity and increase population viability. Based on observed population growth rates from 2009-2014 (mean $\lambda = 1.43$) and known reproduction in 13 groups of wolves in 2015, Oregon's wolf population is expected to surpass 100 wolves by the end of the biological year. At this population size, risk of conservation-failure will effectively be eliminated (≤ 0.01).

In general, factors that influenced wolf survival had the greatest effect on intrinsic growth rates of wolves (r) in our simulation models. In our model, pup, yearling, and adult survival all had significant effects on intrinsic growth rates of wolf populations (Fig. 5). However, variation in pup survival had a greater effect on intrinsic growth rates than yearling or adult survival. While population growth rates of most large mammals are usually most sensitive to changes in adult survival, variability in adult survival, in the absence of high levels of anthropogenic mortality, is usually minimal compared to juveniles (Promislow and Harvey 1990, Gaillard et al.

1998, Robinson et al. 2014). The inherent variability in survival of juveniles causes this age class to have a disproportionate effect on population growth rates despite population growth rates being relatively insensitive to variation in this parameter. This does not discount the importance of adult and yearling survival on population growth and viability; rather it highlights the importance of minimizing annual variation and maintaining high survival rates of yearlings and adults.

Commented [JB32]: I'm not sure I understand – this sounds like a contradiction

Prey abundance and vulnerability are thought to influence wolf populations (Fuller and Keith 1980, Hayes and Harestad 2000, Vucetich and Peterson 2004). In our model, we did not explicitly model predator-prey relationships; rather, we used a prey multiplier value that increased stochastic variation in survival rates of wolves to simulate the effects of variation in prey abundance or changes in environmental conditions (e.g., snow depth) that influence vulnerability of prey over time. Effectively, the prey multiplier represented environmental stochasticity that allowed up to a 20% increase in variation in survival rates. Increased variability in survival (i.e., environmental stochasticity) will have negative effects on population growth rates and viability, regardless of the species of interest (Morris and Doak 2002). Consequently, it was expected that increased environmental stochasticity, modeled through our prey multiplier, had a negative effect on simulated wolf populations.

Anthropogenic mortality is the primary factor that influences dynamics of most wolf populations (Creel and Rotella 2010). Our model supported this conclusion because increased levels of anthropogenic mortality had a negative effect on intrinsic growth rates of wolves (Fig. 5). Furthermore, our simulation results indicated that increased rates of anthropogenic mortality resulted in increased risk of conservation-failure and biological-extinction when the initial population was 85 wolves (Fig. 10). Anthropogenic mortality is the parameter in our model over which ODFW has the most control and our results highlight that Oregon's wolf population will continue to increase and become self-sustaining if anthropogenic mortality is limited.

Commented [JB33]: This doesn't quite support the statement in the previous sentence (i.e. that it is the "primary factor" rather than just a factor).

Our baseline model used inputs of 0.05 for both illegal and legal anthropogenic mortality rates (i.e., 5% of wolves that do not die of natural causes will be removed by both illegal and legal mortality sources) and at this rate, risk of conservation-failure was low. If ODFW maintains mortality rates at or below this level, the wolf population is predicted to be at a low risk of conservation-failure (0.05) and biological-extinction (0.01). Sustained, high levels of anthropogenic mortality (e.g., 0.20) in a stochastically varying environment contributed to increased risk of conservation-failure in our simulations; however, this finding is predicated on our starting population size of 85 wolves. Larger populations would be able to sustain this level of anthropogenic mortality without reaching the conservation-failure threshold because there is an increased buffer between extant population size and the conservation-failure threshold. Our model suggested that total anthropogenic mortality rates (i.e., combined illegal and legal mortality) of 0.15 would result in an increasing population on average ($\lambda = 1.03$) but total anthropogenic mortality rates of 0.20 caused wolf populations to decline on average ($\lambda = 0.98$). Previous studies have indicated wolf populations can be sustained with mortality rates up to 0.25 - 0.30 (Adams et al. 2008, Creel and Rotella 2010, Sparkman et al. 2011). As implemented in our model, anthropogenic mortality rates of 0.20 would cause survival rates of adult wolves to be 0.70 (i.e., a mortality rate of 0.30) and the wolf population would decline slightly on average ($\lambda = 0.98$). Consequently, our model matches well with the results of previous studies.

Catastrophic reductions in survival of 25% had little effect on population growth rates and viability of wolves if the interval between occurrences was ≥ 50 years (Fig. 8). Widespread, catastrophic events are impossible to predict and little can be done to directly mitigate their

effect. However, general tenants of population ecology provide insight into actions that can minimize their effects on population viability. The primary way to reduce effects of catastrophes on population viability is to maintain larger extant populations. Larger populations are more viable because they have a sufficient number of individuals to withstand population declines. In our model, catastrophic events occurred at the population level. This is likely a biologically unrealistic expectation because catastrophic events are likely to occur in geographic regions (e.g., Blue Mountains or Cascade Range) due to localized differences in environmental conditions. This geographic separation should reduce population level effects of catastrophic events because not all wolves would be subjected to the event in a single year. However, these smaller sub-populations would have a greater risk of localized extinction compared to the larger extant population. This highlights the importance of risk spreading through spatial distribution of wolves in ensuring the long-term viability of wolf populations.

Commented [JB34]: It depends what the catastrophe is though, surely. If it is disease, and that is passed between individuals easily, then surely a better way would be to make sure isolated sub-populations exist somewhere. If it is due to prey availability, then having a larger predator population might not help.

Recruitment of pups into the adult population was a critical factor influencing population dynamics of wolves. While we did not directly include a recruitment parameter in our model, several factors that jointly influence pup recruitment had separate effects on wolf population growth and viability. Variation in mean litter size had a strong effect on intrinsic growth rates of wolves. Increased frequency of reproductive failure had a negative effect on population growth rates and viability. Finally, reductions in survival rates of pups had a negative effect on population growth rates of wolves. Pup production and recruitment affects wolf population growth and viability in two ways. At the end of the biological year, wolf pups typically represent a large fraction of the total wolf population (Fuller et al. 2003). Consequently, any reductions in pup recruitment will slow population growth rates of wolves in the short-term. In the long-term, reduced pup recruitment will affect the number of potential dispersing wolves in the population. Yearling wolves (i.e., recently recruited pups) are most likely to disperse and establish new territories (Gese and Mech 1991, Boyd and Pletscher 1999). Reduced pup recruitment will limit the number of potential dispersers in subsequent years, which should slow the rate of population growth because fewer dispersers will be available to establish territories and contribute to population level reproduction.

In our baseline model, we used a density-threshold value of 1,500 wolves. This value represented the biological phenomenon where population growth of wolves would be limited by availability of vulnerable prey (Fuller 1989, Mech et al. 1998, Fuller et al. 2003) or intraspecific mechanisms (Cariappa et al. 2011); however the ability of wolves to self-regulate through intrinsic mechanisms is thought to be limited (Keith 1983, McRoberts and Mech 2014). Varying the density-threshold value in our model had little effect on risk of conservation-failure at values ≥ 250 wolves. Consequently, we contend our choice of a density-threshold value had minimal effects on our results.

The Oregon Wolf Plan (ODFW 2010) provides guidelines as to when lethal control of wolves can occur. Our results indicated increased levels of anthropogenic mortality negatively affect wolf population growth and viability. However, whether anthropogenic mortality was implemented at an individual or pack-level had little effect on our results. Caution should be used when implementing lethal control to address management concerns. For example, breeder loss can have a significant, negative effect on wolf population dynamics (Brainerd et al. 2008, Borg et al. 2015). Consequently, decisions regarding lethal removal of breeding wolves should be carefully considered.

Commented [JB35]: Why do you think this did not show in the results (cf. two sentences previously "whether anthropogenic mortality was implemented at an individual or pack-level had little effect on our results")

Our analysis of wolf-population viability did not explicitly incorporate genetic effects. Genetic viability is a critical concern for any threatened or endangered population (Frankham et

al. 2002, Scribner et al. 2006) especially for extremely small, isolated populations (Frankham 1996). Inbreeding is a potentially serious threat to the long-term viability for small, isolated populations of wolves (Liberg 2005, Fredrickson et al. 2007) but can be minimized through connectivity to adjacent populations. As few as 1-2 immigrants per generation (~5 years) can be sufficient to minimize effects of inbreeding on wolf populations (Vila et al. 2003, Liberg 2005). High levels of genetic diversity in Oregon's wolf population are likely to be maintained through connectivity to the larger northern Rocky Mountain wolf population. Wolves are capable of long-distance dispersal (Fritts 1983, Boyd and Pletscher 1999, Wabakken et al. 2007) which should allow a sufficient number of immigrants to arrive in Oregon so long as sufficient connectivity is maintained between populations in adjacent states (Hebblewhite et al. 2010). While our model did not account for genetic effects, we acknowledge the importance of genetics for isolated populations of mammals and recognize that genetic effects could become important if the Oregon wolf population becomes isolated from the remainder of the northern Rocky Mountain wolf population.

Commented [JB36]: Is there a study showing that the Rocky Mountain wolves are likely to persist in the long term? Useful to cite it if so

The IBM we used to assess wolf population viability in Oregon should provide a realistic biological representation of wolf population dynamics. However, our IBM does not have a spatial component and does not rely on habitat or other landscape features. Spatially-explicit models could provide a more biologically realistic representation of wolf population dynamics; however, spatially-explicit models require substantial amounts of data that is currently not available in Oregon to effectively parameterize the model. Habitat suitability maps have been developed for Oregon (e.g., Larsen and Ripple 2006), but these maps have not been validated and use of these maps would introduce another unknown source of error in population models. Furthermore, the effects of habitat on survival, reproduction, and dispersal of wolves in Oregon are unknown and it would be impossible to accurately model these effects without unwarranted speculation. For these reasons, we contend our non-spatial analysis of wolf population dynamics is currently the most appropriate approach to model wolf population dynamics and viability because it does not rely on unfounded assumptions that could lead to inappropriate conclusions.

Commented [JB37]: Although Sandom et al combined this model with a spatial model in 2012 (http://link.springer.com/chapter/10.1007%2F978-1-4614-0902-1_14). Worth pointing to that to show that it can be done...also, Sandom et al. develop a simple prey model too. The results are relevant

Supplement 1: Population Viability of Wolves in the Eastern Wolf Management Zone.

We used our existing IBM to assess viability of wolves in the eastern Wolf Management Zone (WMZ) of Oregon (see ODFW 2010 for description of eastern WMZ). In this analysis, we restricted our starting population size to those wolves known to occur in the eastern WMZ as of April 1, 2015 ($N = 76$) and set the density threshold to 600 wolves compared to 1,500 wolves used in the statewide analysis. We selected the density-threshold for eastern WMZ using the equations following: Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000\ \text{km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 66,000 elk distributed across 53,320 km^2 of summer range habitat in the eastern WMZ (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 3.71 (66,000 × 3/53,320). Based on this value maximum wolf densities were estimated to be 15.64 wolves/1,000 km^2 of summer range elk habitat in the eastern WMZ. This would result in a total population of 834 wolves within 53,320 km^2 of elk summer range habitat in the eastern WMZ. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, the elk population in the eastern WMZ is approximately 66,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 1,432.2 × 10,000 kg of primary prey biomass available to wolves across the eastern WMZ and a maximum population estimate of approximately 888 wolves. To be conservative, we used a density-threshold of 600 wolves in the eastern WMZ.

Remaining methods and parameter inputs for this analysis were identical to those used in the statewide assessment of wolf population viability (Table 1). As with the statewide analysis, we used two metrics to assess population viability: 1) conservation-failure, defined as the population dropping below 4 breeding pairs and 2) biological-extinction, defined as the population having fewer than 5 individuals.

Using our baseline model, simulated wolf populations increased an average of 6% (i.e., $\lambda = 1.06 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.06 (95% CI = 0.01 – 0.11) probability of the population dropping below the conservation-failure threshold (Fig. S1). Half of the conservation-failures occurred within the first 10 years and by year 20 no additional populations passed the threshold. Of the six simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 22, 37, 61, 67, 72, and 88 breeding pairs by year 50, respectively. No simulated populations dropped below the biological-extinction threshold over the next 50 years. Risk of conservation-failure in the eastern WMZ was slightly higher, but not significantly different, than risk at a statewide level (0.06 vs. 0.05; Fig. S2). Our simulation results suggested risk of conservation-failure declined with increasing starting population size (Fig. 6), so it was not surprising that the slightly smaller starting population in the eastern WMZ ($N = 76$) had a slightly higher risk of conservation-failure compared to the statewide population ($N = 85$).

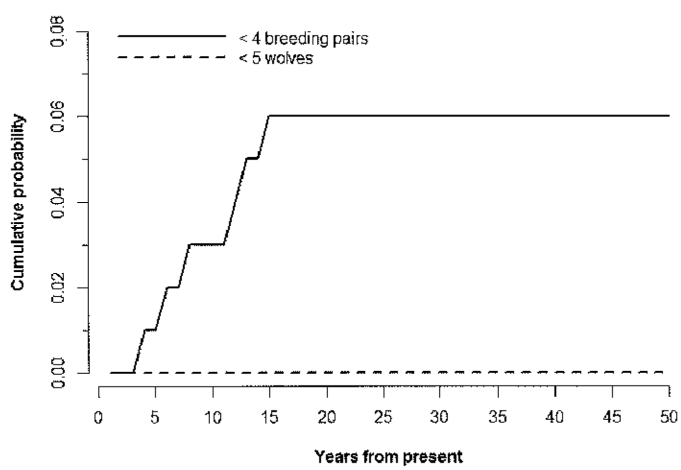

Figure S1. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

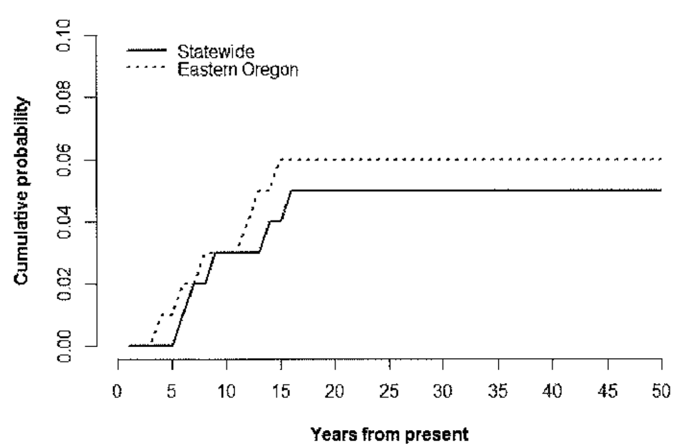

Figure S2. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) over the next 50 years across the entire state or in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

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DR. JOHN HORNE

Assessment of Population Viability of Wolves in Oregon

This technical report to the Oregon Fish and Wildlife Commission presents results from an updated individual-based population model used to assess population viability of wolves in Oregon. The model uses wolf data collected in Oregon through July 2015.

Presented: November 9th, 2015

Suggested citation:

Oregon Department of Fish and Wildlife. 2015. An updated assessment of population viability of wolves in Oregon using data collected through July 2015. Oregon Department of Fish and Wildlife, 4034 Fairview Industrial Drive SE. Salem, OR 97302.

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Executive Summary

We present results from an individual-based population model (IBM) based on a peer-reviewed published[1] model (Bull et al. 2009) used to assess the viability of the gray wolf (*Canis lupus*; hereafter, wolf) population in Oregon. When parameterizing our model, we relied on peer-reviewed published estimates of wolf vital rates. Our population model, the assumptions made in the model, and vital rates used in the model were obtained or supported by peer-reviewed published literature. We compared estimates of parameters used in our model to those observed in Oregon from 2009-2014 and concluded our model used to project future population growth was conservative compared to growth rates currently observed in Oregon. We used a starting population size of 85 wolves which was based on wolf population counts conducted by the Oregon Department of Fish and Wildlife (ODFW) through July 2015. This value is higher than reported end of year counts (ODFW 2015) because additional wolves that were present in Oregon at the start of the biological year (i.e., April) were documented after January 31, 2015. Consequently, results presented in this report differ slightly from those presented to the Oregon Fish and Wildlife Commission on April 24, 2015. We used linear regression models to determine the relative effect of model parameters on intrinsic population growth rates of wolves. We assessed population viability using two metrics: 1) the cumulative proportion of simulations that had fewer than 4 breeding pairs (defined as conservation-failure) and 2) the cumulative proportion of simulations that had fewer than 5 wolves (defined as biological-extinction).

Increased pup ($\beta = 0.045$), yearling ($\beta = 0.024$), and adult ($\beta = 0.019$) survival resulted in increased population growth rates. Population growth rates of wolves were most sensitive to environmental stochasticity, which we modeled through the use of a prey multiplier ($\beta = 0.088$). The increased environmental stochasticity incorporated in the model by the prey multiplier increased variation in survival rates of wolves by up to 20% annually, which caused this parameter to have a large effect on population growth rates. Increased levels of illegal ($\beta = -0.027$) and legal ($\beta = -0.028$) anthropogenic mortality had negative effects on population growth rates. Increased mean litter size had a positive effect on population growth ($\beta = 0.049$). Increased mortality rates for dispersing wolves had a negative effect on population growth ($\beta = -0.026$) while increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on population growth ($\beta = 0.034$). Combined, these results highlight the importance of survival, reproduction, and human-caused mortality on population growth rates of wolves. Other parameters considered in our model had minimal effects on population growth rates or viability of wolves. Maintenance of high natural survival and reproductive rates of wolves while minimizing human-caused mortality will help ensure the long-term persistence of the species in Oregon.

Our baseline model indicated there was a 0.05 (95% CI = 0.01 – 0.09) probability of wolves falling below the conservation-failure threshold and a 0.01 (95% CI = 0.00 – 0.03) probability of falling below the biological-extinction threshold in the next 50 years. When we parameterized our model with vital rates required to match population growth rates observed in Oregon from 2009-2014, we did not observe any situations where the simulated wolf population fell below the conservation-failure or biological-extinction thresholds. Consequently, we contend future risk of conservation-failure falls between estimates from our baseline model (0.05 probability of conservation-failure) and our model parameterized with vital rates required to

[1] Peer-reviewed published literature is papers published in scientific journals or books that have been reviewed and deemed acceptable from a study design, analysis, and interpretation standpoint by one or more peers prior to being published.

match observed population growth rates of Oregon's wolves from 2009-2014 (0.00 probability of conservation-failure). Regardless of model parameterization, our results suggested it is extremely unlikely wolves in Oregon will be at risk of extirpation over the next 50 years.

INTRODUCTION

The Oregon Wolf Conservation and Management Plan (hereafter, Oregon Wolf Plan; Oregon Department of Fish and Wildlife [ODFW] 2010) outlines phases of wolf (*Canis lupus*) recovery and criteria for delisting wolves as required by Oregon's Endangered Species Act (ESA). In January 2015, Oregon's wolf population successfully reached population objectives for Phase I to allow ODFW to propose that the Oregon Fish and Wildlife Commission consider delisting of wolves from Oregon's ESA (ODFW 2010). Quantitative models are commonly used to assess population dynamics and extinction risk of threatened and endangered species (Boyce 1992, Morris and Doak 2002) and can provide insight into the first and second delisting criteria outlined in the Oregon ESA:

1. "The species is not now (and is not likely in the foreseeable future to be) in danger of extinction in any significant portion of its range in Oregon or in danger of becoming endangered"; and
2. "The species natural reproductive potential is not in danger of failure due to limited population numbers, disease, predation, or other natural or human related factors affecting its continued existence".

To address these delisting criteria, we modified a peer-reviewed quantitative model (Bull et al. 2009) to provide insight into dynamics of Oregon's wolf population to help inform any future decisions regarding wolves and Oregon's ESA.

To make accurate predictions of future population growth, quantitative population models should accurately reflect biological processes of the species being modeled. Individual-based models (IBM) were previously used to model wolf population dynamics (Vucetich et al. 1997, Haight et al. 1998, Nilsen et al. 2007, Bull et al. 2009) because they can most accurately represent the unique social and breeding structure of wolf populations. We modified an IBM developed to assess effects of management on wolf populations in Norway (Bull et al. 2009) to meet our needs to assess population viability of wolves in Oregon. Our modeling approach focused on determining effects of key biological processes, uncertainty in model parameters, and management actions on wolf population dynamics and viability.

METHODS

We used an IBM modified from Bull et al. (2009) to assess future population dynamics of wolves in Oregon. The primary modifications to the Bull et al. (2009) were to change the vital rate values of wolves in North America based on our literature review. The biggest modification we implemented in our model was to alter the way reproduction was handled in the model. Bull et al. (2009) assigned pairs of wolves a probability of producing a large or small litter and assumed all dominant females would produce pups each year. In our modified model, we assumed not all dominant females would produce pups in a given year, but litter sizes would be determined from a single distribution each year. We modified the Bull et al. (2009) to include two types of catastrophes (see description below) and allowed dispersing wolves to leave Oregon and have increased risk of mortality during dispersal (see description below). All of these additional modifications provided increased reality to the model and would provide a more

conservative view of wolf population growth. Other than these minor changes, our code used to implement the model was identical to the peer-reviewed model developed by Bull et al. (2009).

Our model incorporated 6 demographic processes that affected wolf populations that were modeled in the following order (Fig. 1): 1) survival and transition between age classes, 2) dispersal and emigration out of Oregon, 3) territory establishment by dispersing wolves, 4) immigration from outside Oregon, 5) anthropogenic mortality, and 6) reproduction. Our IBM included 5 distinct social classifications of wolves (Fig. 2) and transitions between social classifications were governed by distinct model parameters (Table 1).

Our IBM was coded and implemented in R (R Development Core Team 2012). To generate our results, we conducted 100 realizations of population growth over 50 years. We utilized 100 realizations of population growth because this allowed the confidence intervals to be acceptably narrow, but not excessively narrow to indicate a false sense of precision in our estimates of population viability Bull et al. (2009). We incorporated environmental stochasticity in our model by randomly drawing vital rate values from a uniform distribution with a predefined mean and standard deviation at each time step of the simulation (Table 1). Unless otherwise noted, vital rates were applied at an individual level, which inherently incorporated demographic stochasticity into our model. For each simulated population we tracked parameter values, population size and growth rates, and number of breeding pairs (i.e., pairs of wolves with ≥ 2 pups surviving the biological year) at each time step.

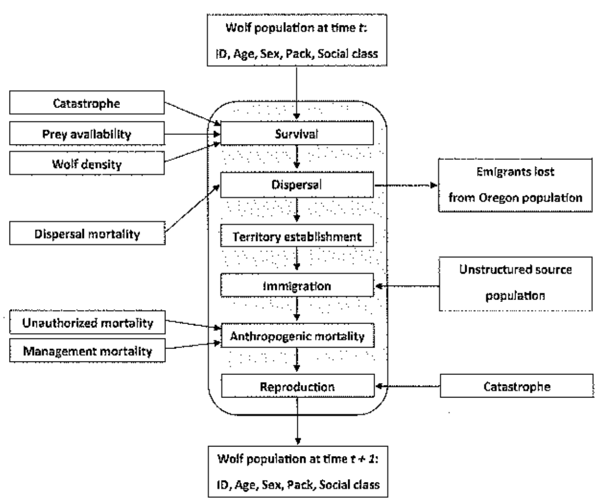

Figure 1. The order in which 6 key demographic processes are implemented in an individual-based population model to assess population viability of wolves in Oregon.

Commented [j1]: Completely arbitrary and incorrect use of Confidence Interval. Bull et al. utilized 100 reps such that estimates of viability were acceptably precise. There is no reason to suggest doing more would allow for a "false sense of precision"... there is no false. The CIs refer to how confident you are in characterizing the results of the simulations, not reality. The only reason (as Bull did) to not use more reps is because of computation time.

Commented [j2]: Why and how?
1st, how did you specify drawing a random deviate in R from a uniform with a specified std dev? R function "runif" asks for a min and max bound of the uniform dist.. There is a way to get the bounds of a uniform distribution from the sample mean and variance but... is this what you did?

2nd, Variation in # offspring produced is probably better modeled with a Poisson
Variation in "rate" or "prob" parameters (e.g., survival, dispersal, etc.) is usually modeled with a truncated log-normal or more commonly a Beta distribution that is bounded by 0 and 1.

Commented [j3]: What type of variation does the standard deviation used here reflect? For example, the 0.15 SD used for pup survival rate... how was 0.15 calculated? It should be the variation among *annual* estimates of pup survival. And if that is what was used, did you remove the effect of estimation error?

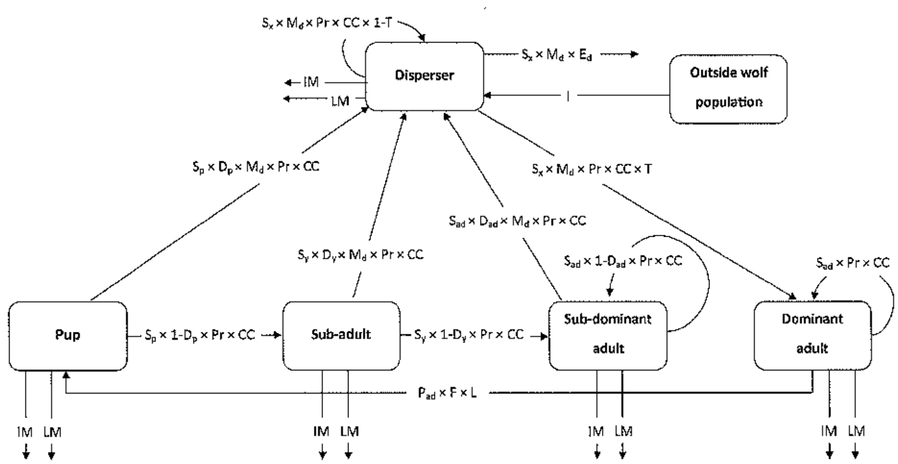

Figure 2. Visual representation of the life cycle of wolves implemented in an individual-based population model to assess population viability of wolves in Oregon. The diagram represents probabilities of transitions between age- and social-classes of wolves. Parameters used in transition calculations are defined in Table 1.

Table 1. Parameter values used to predict future population growth of wolves in Oregon compared to values required to match observed growth rates of Oregon's wolf population from 2010-2014. Values used at each time step of the analysis were randomly drawn from a uniform distribution within the specified standard deviation (SD). Mean values are probabilities unless otherwise stated. All estimates used in our baseline model were obtained or supported by peer-reviewed literature.

		Baseline model values		Values required to match growth rates observed in Oregon (2009-2014)	
Parameter	Notation	Mean	SD	Mean	SD
Pup survival rate	S_p	0.68	0.15	0.75	0.05
Yearling survival rate	S_y	0.81	0.06	0.91	0.04
Adult (2 to 7-yrs old) survival rate	S_{ad}	0.88	0.04	0.91	0.04
Old adult (8 to 9-yrs old) survival rate	S_{old}	0.63	0.11	0.85	0.05
Pup dispersal rate	D_p	0.15	0.05	0.15	0.05
Yearling dispersal rate	D_y	0.65	0.05	0.65	0.05
Non-breeding adult dispersal rate	D_{ad}	0.65	0.05	0.65	0.05
Proportion of dispersing wolves that survive	M_d	0.90	0.05	0.97	0.02
Proportion of dispersing wolves that leave Oregon	E_d	0.115	0.03	0.115	0.03
Probability of dispersing wolf establishing a territory	T	0.75	0.10	0.75	0.10
No. of immigrants arriving annually from outside Oregon	I	3	2	3	2
Pregnancy rate for dominant females	P_{ad}	0.95	0.02	0.95	0.02
Litter size	L	5	3	5	3
Proportion of wolves removed by illegal mortality	IM	0.05	0.03	0.02	0.01
Proportion of wolves removed by legal mortality	LM	0.05	0.03	NA	NA
Prey index multiplier (adjustment to survival rates)	Pr	1.00	0.10	1.00	0.10
Density dependent threshold (no. of wolves)	CC	1,500	NA	1,500	NA
Probability of population wide reduction in survival	S_{cas}	0.01	NA	NA	NA
Probability of pack-specific reproductive failure	R_{cas}	0.05	NA	0.05	NA

Model Parameters

Commented [j4]: You did a VERY good job of describing how the mean values were obtained but the SD used has way more influence on viability metrics and sensitivity analyses… thus, an equally complete description of how the SDs were obtained is needed.

Currently, Oregon has minimal vital rate information to parameterize a population model, and the potential for sampling bias or error from small sample sizes (i.e., observed data does not match the expected outcome) could cause inappropriate conclusions to be reached by using this information. Furthermore, estimated vital rates from protected wolf populations that are colonizing or recovering are unlikely to match those of established wolf populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Oregon's wolf population is transitioning from a recovering to established population. Vital rates used in our IBM were obtained from peer-reviewed published literature that presented results from studies conducted primarily in established wolf populations. Consequently, whenever possible, we compared vital rates observed in Oregon to those reported in peer-reviewed published literature to determine the degree to which vital rates used in our model were representative of those observed in Oregon since 2009. In general, most vital rates used in our baseline model were conservative compared to those observed in Oregon from 2009-2014. Using conservative vital rate estimates allowed us to err on the side of caution (e.g., the precautionary principle; Myers 1993, Meffe et al. 2006) and prevent overly optimistic conclusions of wolf population viability.

Starting Population Size.–We utilized minimum count data collected by ODFW to determine our starting population size and structure prior to wolves producing pups in April 2015. These counts were higher than final survey numbers reported at the end of 2014 (ODFW 2015) because ODFW identified additional wolves after the report was submitted. Based on wolf survey information collected through July 2015, a minimum of 85 wolves were present in Oregon at the start of April. We acknowledge additional, undocumented wolves may be present in Oregon, but we relied on known individuals when developing our model. Counts identified 16 pairs or packs of wolves in addition to 3 individual wolves present in Oregon. Whenever possible, we used known data to assign pack, age, social class, and sex of wolves and randomly assigned these attributes when unknown. Newly documented pairs of wolves were assumed to consist of a male and female and both individuals were assigned dominant-adult status.

Survival.–Baseline survival rates of wolves used in our model represented survival in the absence of anthropogenic mortality (e.g., poaching, management removals). We adjusted survival rates reported in peer-reviewed literature to account for anthropogenic mortality using the following approach: 1) determine the overall mortality rate (1 – survival rate), 2) estimate the anthropogenic mortality rate as the product of proportion of total mortalities caused by humans and the overall mortality rate, and 3) sum the estimated anthropogenic mortality rate and the reported survival rate. As an example, Smith et al. (2010) reported an annual survival rate of 0.750 with 54% of mortality attributable to legal or illegal actions by humans. The anthropogenic mortality rate was 0.135 (1-0.750 × 0.540), which resulted in a 'natural' survival rate of 0.885 (0.750 + 0.135). In instances where authors directly reported cause-specific mortality rates (e.g., Wydeven et al. 1995), we summed reported survival and anthropogenic mortality rates to obtain an adjusted estimate of survival. After adjusting survival rates reported in peer-reviewed literature (Table 2) to account for human-caused mortality we arrived at a survival rate of 0.88 (± 0.04 SD) of adult wolves (2-7 years old; S_{ad}) for use in our model.

Using the largest sample size of radio-collared wolves reported in peer-reviewed published literature, Smith et al. (2010) reported that yearling wolves had a 54.9% higher risk ($1.0012^{365} = 1.549$) of mortality than adult wolves over 365 days. We adjusted the mean survival rate of 0.88 for adult (2-7 years) wolves by the increased hazard rate reported by Smith et al. (2010) to calculate a survival rate of 0.81 for yearling wolves (S_y; 1-[(1-0.88) × 1.549]; Table 1).

This may present an overly pessimistic view of resident yearling wolf survival, because yearlings have high dispersal rates (Gese and Mech 1991) and dispersing wolves were found to have higher risk of mortality (Smith et al. 2010). In our model, we utilized a separate mechanism to account for increased mortality of dispersing wolves (see below) and we recognize our estimates of yearling survival may be negatively biased. Senescence, observed through decreased survival at older ages is common for large mammals (Loison et al. 1999, Gaillard et al. 2000, Clark et al. 2014), but this phenomenon is not well documented in peer-reviewed published literature on wolves. To account for the potential of senescence, we used an annual survival rate for wolves > 7 years old of 0.63 as reported by Cubaynes et al. (2014), which we adjusted to 0.67 for use in our model (S_{old}) to account for anthropogenic mortality. Wolves ≥ 10 years of age had a survival rate of 0.00 in our model. While free-ranging wolves can live longer than 10 years, most wolves are typically no longer reproductively active after this age (Fuller et al. 2003, Kreeger 2003) and will contribute little to population growth and viability.

Estimates of non-pup survival used in our model were lower than observed to date in Oregon. Using known-fate survival analysis (White and Burnham 1999) on a sample 23 of wolves radio-collared in Oregon from 2009-2014, we estimated an annual survival rate of wolves > 6 months old of 0.91. Three collared wolves died during this timeframe, one of which was removed by ODFW and an additional wolf was illegally shot resulting in 66% of mortality being attributable to humans. Adjusting survival rates to account for anthropogenic mortality results in a survival rate of 0.97, which is substantially greater than the adult (0.88) and yearling (0.81) survival rates used in our model.

Commented [j5]: Might mention that you would expect more mortality as the population becomes more established.

Table 2. Annual survival rates and human-caused mortality rates of non-pup wolves reported in peer-reviewed literature. Survival rates were estimated from known fates of radio-collared wolves unless otherwise noted. Adjusted survival rates represent survival rates on non-pups in the absence of human-caused mortality.

Source	Reported survival	Human-caused mortality rate	Adjusted survival rate[a]
Adams et al. (2008)	0.79	0.09[b]	0.89
Cubaynes et al. (2014)	0.80	0.04[c]	0.84
Fuller (1989)	0.62	0.26[c]	0.88
Hayes and Harestead (2000)	0.84	0.02[b]	0.86
Peterson et al. (1984)	0.67	0.26[b]	0.93
Smith et al. (2010)	0.75	0.14[b]	0.89
Webb et al. (2011)[d]	0.62	0.34[b]	0.96
Wydeven et al. (1995)	0.61	0.28[b]	0.89
Wydeven et al. (1995)	0.82	0.04[b]	0.86
Mean	0.72	0.16	0.88

[a] Sum of reported survival and human-caused mortality rate.
[b] Mortality rate calculated as the product of overall mortality rate (1-survival) and proportion of mortalities caused by humans.
[c] Human-caused mortality rate directly reported by authors.
[d] Apparent survival rates estimated from mark-recapture data.

Estimates of survival of wolf pups from birth to 6 months are highly variable and are usually estimated by comparing pup counts at den or rendezvous sites to *in utero* fetal counts of harvested females. Based on a review of peer-reviewed published literature (Table 3), we determined mean survival rates of wolf pups from birth to 6 months, determined from pup counts, were 0.73. Estimation of survival using pup count data assumes that pups are counted with a detection probability of 1.0, which is unrealistic and this method will likely produce negatively biased estimates of survival over the first 6 months of life. In general, radio-telemetry studies have indicated pup survival is similar to adult survival during months 7-12 after birth (Peterson et al. 1984, Fuller 1989, Adams et al. 2008). Consequently, we used 6 month survival rate of adults (~0.94), calculated as the square root of annual survival, to approximate survival of pups from ages 7-12 months. We used the product of summer survival rates times the 6 month survival rate of adult wolves as the annual estimate of pup survival (S_p) in our baseline model ($0.73 \times 0.94 = 0.68$; Table 1).

Table 3. Survival rates of wolf pups from birth to six months reported in peer-reviewed literature. Unless otherwise noted, survival was estimated by comparing pup counts six months after birth to *in utero* litter sizes. Annual survival rates calculated as the product of 6 month survival rates of pups and 6 month survival rates of adult wolves used in our model (0.88).

Commented [j6]: Are these survival rates (for each study) across multiple years of study?

Source	Survival from birth to 6 months	Annual survival[a]
Fuller (1989)[b]	0.58	0.55
Mills et al. (2008)[c]	0.83	0.78
Fritts and Mech	0.57	0.53
Fuller and Keith (1980)	0.69	0.65
Adams et al. (2008)	0.81	0.76
Hayes and Harestead (2000)[d]	0.80	0.75
Petersen et al. (1984)	0.80	0.75
Ballard et al. (1987)	0.82	0.77
Mech et al. (1998)[e]	0.91	0.85
Hayes et al. (1991)[f]	0.48	0.45
Mean survival	0.73	0.68

[a] Annual survival is the product of survival from birth to 6 months and the 6 month survival rate of adult wolves used in our model.

[b] Survival rate reported was estimated over 8 month period using pup counts. Monthly survival rate was 0.9135 and survival over six months was 0.58.

[c] Survival was estimated with implant transmitters from Jun-Nov. Used monthly survival rates from this period to estimate 6 month survival rate.

[d] Survival estimated on an annual interval. Used the square root of reported survival rates to estimate survival from birth to 6 months.

[e] Survival estimate over first 4 months of life. Extrapolated to 6 months.

[f] Heavily exploited wolf population.

We compared the pup survival rates used in our model to pup count data collected in Oregon during winter surveys conducted from 2009-2014. During this time frame, 30 potential reproductive opportunities were documented. Of these 30 potential reproductive opportunities, 3 were censored because final pup counts were not completed. Assuming wolves give birth to an average of 5 pups per litter (Fuller et al. 2003), we calculated a total of 135 pups born from these 27 reproductive opportunities. Minimum pup counts conducted in December of 2009-2014 indicated a minimum of 82 pups across all years. Using this information we arrived at a minimum observed survival rate of 0.61 (95% CI = 0.53 – 0.69), which is lower but within in the range of the pup survival rate used in our model (0.68 ± 0.15; Table 1).

When implementing our model, annual survival rates were independently calculated for each age class by randomly drawing a survival rate from a uniform distribution with a predefined mean and standard deviation (Table 1). Survival rates of wolves were age-specific and were not influenced by social status of the individual (e.g., survival rates for a 4-year old sub-dominant adult were identical to survival rates for a 4-year old dominant adult). Survival rates were modeled at an individual level, with each individual having an independent probability of survival at each time step.

Commented [j7]: Again, this is not common... In fact, I've never seen it. Now, I have seen researchers draw from a uniform when they want to do a sensitivity analysis of model parameters (e.g., vary all model parameters... including the SD parameters... by 10%).

Density-dependence.– When populations surpassed a predefined population threshold, annual survival rates, regardless of age, were multiplied by the ratio of the threshold population size and current wolf population size. The specified threshold was implemented to account for the importance of density-dependence on population dynamics (Morris and Doak 2002), but does not represent an expected number of wolves in Oregon in future years. When implemented in our model, the density-threshold represents an arbitrary biological threshold where wolves begin to self-regulate through intraspecific strife or are limited by available prey.

Larsen and Ripple (2006) created a habitat suitability map for wolves in Oregon and found that a maximum of 1,450 wolves could occupy Oregon. This value increased to 2,200 wolves if industrial timberland in western Oregon was classified as suitable wolf habitat. Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000\ \text{km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 128,000 elk distributed across 151,500 km^2 of summer range habitat (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 2.53 (128,000 × 3/151,500). Based on this value maximum wolf densities were estimated to be 11.79 wolves/1,000 km^2 of summer range elk habitat. This would result in a total population of 1,780 wolves within 151,500 km^2 of elk summer range habitat in Oregon. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, Oregon's elk population is approximately 128,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 2,777.6 × 10,000 kg of primary prey biomass available to wolves across Oregon and a maximum population estimate of approximately 1,722 wolves.

Both the Fuller et al. (2003) and Carbone and Gittleman (2002) equations produce similar estimates of wolf population size and fall within the range reported by Larsen and Ripple (2006). However, these estimates were calculated under the assumption wolves will not cause reductions in prey populations. To account for this possibility, we used a conservative density-threshold (CC) of 1,500 wolves in our model. Again, it should be noted, the density-threshold represents

an estimate of maximum potential wolf population size, not a management objective for wolves in Oregon.

Prey multiplier.–Wolf-prey interactions can influence wolf densities and population dynamics (Fuller et al. 2003). We lacked sufficient data to explicitly model wolf-prey interactions and instead used a simplified approach described in the peer-reviewed published paper by Bull et al. (2009) where a stochastically generated a prey multiplier value (Pr) was used to represent changes in either prey abundance or vulnerability (e.g., increased vulnerability during severe winters). The prey multiplier represented environmental stochasticity in our model. At a value of 1.0, the prey multiplier represented baseline prey availability or vulnerability. Each year of the simulation, the prey multiplier had a 1 out of 3 chance of increasing, decreasing, or remaining the same, respectively. In years the prey multiplier increased or decreased, the maximum change was restricted to 0.10. The prey multiplier was bounded between 0.90 and 1.10 values generated outside this range were truncated to the maximum or minimum value. Survival rates used in the model were calculated as the product of randomly drawn survival rates and the prey multiplier after accounting for any density-dependent effects.

Commented [j8]: I understand this as including an additional source of stochasticity in the model beyond the variation in observed values... But, shouldn't the observed values already reflect this additional stochasticity? It seems to me like this is adding stochasticity to the system that shouldn't be added.

Dispersal and Emigration.–We assumed dominant wolves would maintain their territory and breeding positions until their death. In the event that both dominant animals in a pack died, all remaining pack members would disperse. This approach was partially used for simplicity of model implementation, but was also supported in peer-reviewed literature (Fuller et al. 2003). For example, Brainerd et al. (2008) found that in instances where both breeding wolves were lost, 85% of packs dissolved, and only 9% of packs reproduced the following year.

Sub-dominant wolves that survived the year had a probability of dispersing from their existing territory, which was dependent on age and breeding status (Table 1). Age-specific dispersal rates used in our model (D_p, D_y, D_{ad}) were obtained from literature (Potvin 1988, Fuller 1989, Gese and Mech 1991). We assumed non-breeding adults had similar dispersal rates as yearlings (Fuller et al. 2003). Survival rates of dispersing individuals were reduced (M_d) to account for increased mortality risk of wolves during dispersal (Table 1; Peterson et al. 1984, Fuller 1989, Smith et al. 2010). Smith et al. (2010) found dispersing wolves had a 38.9% higher risk of mortality over 365 days than resident wolves. After accounting for this increased risk, survival rates of dispersing adult wolves would be 0.83 with the ratio of dispersing versus resident adult survival rates of 0.94 (0.83/0.88). To be conservative, we lowered this value to 0.90 (± 0.05 SD) for use in our model, which is interpreted at 10% of dispersing wolves die during the dispersal process.

We used a spatial simulation to estimate emigration rates using peer-reviewed published estimates of dispersal distances of wolves (Fritts and Mech 1981, Fuller 1989, Gese and Mech 1991, Wydeven et al. 1995). We generated 10,000 random dispersal paths that started at a random location within summer range elk habitat (i.e., potential wolf habitat). We simulated dispersal paths using correlated random walks with the movement.simplecrw function in the Geospatial Modeling Environment (Beyer 2012) by selecting a random bearing from a uniform distribution (0 - 359°) and a random dispersal distance from normal distribution with a mean of 75 km (± 30 SD). We calculated emigration rates (E_d) as the proportion of simulated dispersal paths that terminated outside Oregon. Mean emigration rates were estimated to be 0.115 (Table 1). We estimated a standard deviation of the mean values calculated from 100 bootstrap samples that each contained 100 random dispersal paths. The estimated standard deviation of the mean of

these 100 samples was 0.03. Emigration was effectively treated as additional mortality in our model (i.e., these individuals were removed from the simulated population).

Territory Establishment.–Dispersing wolves ≥ 2 years old were assigned a probability of establishing a territory. Boyd and Pletscher (1999) found that 57% of dispersing wolves successfully found a mate the next breeding season after they dispersed. This value equates to the joint probability of two wolves establishing a territory. Independently, the probability of a dispersing wolf establishing a territory (T) would be 0.75 ($\sqrt{0.57}$), which we used in our model. Wolves that did not successfully establish a territory remained in the pool of dispersers until the following year. Those individuals that successfully established territories would first fill vacant alpha positions of the correct sex in established packs. If no alpha positions were available at established packs, dispersing wolves would then establish a new territory and maintain that position until they died or a mate joined them at the territory.

Immigration.–We assumed wolves from the extant Rocky Mountain wolf population would be available to immigrate into Oregon. For model simplification, we assumed the wolf population outside Oregon was unstructured and would produce a steady, but limited, stream of immigrants. We assumed 3 wolves (± 2 SD) would immigrate (I) annually into Oregon from surrounding populations. We assumed all immigrating wolves were sub-adults because a review of peer-reviewed literature indicated this age class is most likely to engage in dispersal behavior (Fuller 1989, Gese and Mech 1991, Fuller et al. 2003). Individuals arriving in the Oregon population were randomly assigned a sex assuming parity among dispersers (Gese and Mech 1991).

Anthropogenic Mortality.–Anthropogenic mortality was incorporated in the model under two forms: legal and unauthorized mortality. Unauthorized mortality represented all sources of anthropogenic mortality (e.g., poaching, vehicle-killed individuals) excluding mortalities authorized by ODFW under current laws. Legal removals included any administrative removals authorized by ODFW (e.g., livestock damage, human safety, incidental take). Anthropogenic mortality was modeled using a two-step process where unauthorized mortality was modeled first and followed by legal mortality. A proportion of the total population that remained after accounting for natural mortality events would be removed each year by each anthropogenic mortality source (Table 1). Anthropogenic mortality was applied independent of age, social status, or pack membership. Effectively, this approach treats anthropogenic mortality as a reduction in survival. For example, using an annual adult survival rate of 0.88, survival rates would be reduced to 0.79 ($0.88 \times 0.95 \times 0.95$) if 5% of the population was removed for both legal and unauthorized mortality, respectively.

From April 2009 to March 2015, ODFW has collected 54 wolf-years of data from radio-collared individuals. During this time, 1 radio-collared wolf was illegally killed and 1 radio-collared wolf was removed by ODFW, for a removal rate of 0.02 for each mortality source (ODFW, unpublished data). Due to the potential bias of radio-collared wolves being avoided by poachers, we increased the illegal mortality (IM) value to 0.05 (± 0.03 SD). To be conservative and allow for the potential of increased levels of lethal control actions, we used a value of 0.05 (± 0.03 SD) for legal mortality (LM) of wolves in our model (i.e., between 2-8% of wolves would be randomly removed from the population each year for management related actions).

Reproduction.–Only established wolf packs with a dominant pair of adults were allowed to reproduce. We were unable to find peer-reviewed estimates of pregnancy rates of dominant females in published literature; however, it is biologically unrealistic to assume all pairs of wolves successfully give birth to pups each year (i.e., female do not always become pregnant).

We assumed pregnancy rates of dominant females (P_{ad}) would be 0.95 (± 0.02 SD; Table 1). While evidence exists of multiple females producing pups within a pack, this is a rare occurrence and usually only occurs in extremely large packs (Mech 1999), and we assumed only one litter of pups would be born in packs with a dominant pair. The number of pups produced by pregnant females (L) was drawn from a uniform distribution ranging from 2-8 (Table 1) based on a review of literature (see summary in Fuller et al. 2003).

Catastrophes.–We included two catastrophes in our model. The first was modeled at the pack level as the probability of a pack having complete reproductive failure within a year (R_{cas}). Probability of reproductive failure was independent among packs and years. This approach was used to simulate the potential effects of diseases (e.g., canine parvovirus), which are known to negatively affect pup survival and recruitment (Mech and Goyal 1993, Almberg et al. 2009), where most or all pups die when exposed to the virus (Mech et al. 2008). We assumed complete reproductive failure had a probability of occurrence of 0.05 within each pack during each year of the simulation (i.e., one out of 20 litters will be subjected to complete reproductive failure). Packs that had complete reproductive failure were assigned a litter size of 0 (i.e., even if pups were produced they would all die before 1 year of age).

Our second catastrophe was modeled at the population level, where each year of the simulation there was a probability of a population wide reduction in survival (S_{cas}). This approach was used to represent extremely rare, range wide events that may affect wolf populations (e.g., disease, abiotic conditions, prey population crashes). We used a mean interval of 100 years between disturbance events, with each year having an independent probability of a disturbance event occurring. During years where a catastrophe event occurred, survival rates of all wolves in the population were reduced by 25%.

Assessment of Population Viability

We assessed population viability using two measures. The Oregon Wolf Plan defined a threshold of 4 breeding pairs for 3 consecutive years as a guideline to consider delisting wolves from the Oregon ESA (ODFW 2010). Consequently, we defined "conservation-failure" as a simulated population that fell below 4 breeding pairs. For each simulated population, we determined which time-step, if any, that the population dropped below the conservation-failure threshold. Simulated populations that dropped below the conservation-failure threshold were considered failures in all remaining time steps. We calculated risk of conservation-failure as the cumulative proportion of simulated populations that had < 4 breeding pairs.

We used a threshold of < 5 wolves as our metric of "biological-extinction". In simulations with < 5 wolves, the extant population would effectively be extirpated and immigrants from outside sources would be maintaining the Oregon population. For each simulated population, we determined the time-step, if any, that the population dropped below the biological-extinction threshold. Once the population dropped below this threshold it was determined to be biologically-extinct for all remaining time steps. We calculated biological-extinction rates as the cumulative proportion of simulated populations that < 5 wolves.

Model Validation

To validate our baseline model, we conducted a set of 100 realizations of population growth over 5 years, where the starting population size was the number of wolves present in Oregon at the end of 2009 (N = 14 wolves). We calculated the mean number of wolves and breeding pairs from simulations and compared these values to population counts conducted by ODFW from 2010-2014. Survival rates used in our baseline model were more conservative than observed in Oregon from 2010-2014. Consequently, we conducted a second set of simulations

where we parameterized our model with vital rates required to match observed population growth rates in Oregon from 2009-2014 (see Table 1 for differences between vital rates in the two scenarios). Using observed vital rate values in our model would allow us to determine if our overall model structure allowed accurate estimation of population growth under known conditions.

Sensitivity Analysis

Effects of Stochastic Parameters.– We used r (i.e., intrinsic rate of increase) as the dependent variable in a linear regression model where stochastically varying parameters and relevant interactions were used as independent variables. We conducted 200 realizations of population growth over a 5-yr period which resulted in 1,000 random combinations of parameter values and associated intrinsic growth rates (r). The sensitivity analysis was limited to a 5-yr span because allowing population simulations to last longer than 5-yrs could cause some simulations to reach the density-threshold of 1,500 wolves and confound the effect of parameter variation and density-dependence on r. For each simulation, the starting population was assumed to be 120 wolves equally distributed among 20 packs. We used this starting population size because at extremely small population sizes (e.g., $N < 10$) immigration of wolves could produce biologically unreasonable population growth rates (e.g., $\lambda > 2.0$) and confound our ability to detect an effect of parameters on r. Prior to running our regression model, all independent variables were standardized (standardized value = [observed value - mean value]/standard deviation) to allow direct comparisons between results. We used an alpha level of 0.05 to determine significance of parameters and the sign and slope of beta coefficients to determine the strength and relative effect of the parameter on r.

Effects of Static Parameters.–Starting population size, density-threshold, and frequency of survival and reproductive catastrophes were static parameters in our model and the effects of these were not included in our regression analysis used to determine the relative effects of parameters on r. Consequently, we conducted additional simulations where values of static parameters differed among simulations. Each simulation used 100 realizations of population growth over 50 years and was parameterized with baseline values except for changes in the static parameter of interest. We conducted 4 simulations to determine the effect of starting population sizes of 50 wolves, the known existing Oregon wolf population (N = 85; baseline value), 100 wolves and, 150 wolves. Simulations with starting populations of 50, 100, and 150 wolves were structured as follows: 1) each wolf belonged to a pack and each pack had 5 members with 2 of those members being dominant adults and 2) sex, age, and social class of remaining wolves were randomly assigned. To determine the relative influence of the density-threshold on population viability of wolves, we conducted a set of simulations where used a density-threshold of 100, 250, 500, 1000, and 1500 (baseline value) wolves. We conducted a set of 3 simulations where we investigated probabilities of individual pack reproductive failure of 0.05 (baseline value; once every 20 litters), 0.10 (once every 10 litters), and 0.20 (once every 5 litters). We investigated the effects catastrophic reductions in survival at year-specific probabilities of 0.01 (baseline value; once every 100 years), 0.02 (once every 50 years), 0.05 (once every 20 years), and 0.10 (once every 10 years).

Effects of lethal control of wolves

Legal, anthropogenic mortality is the parameter included in our model over which ODFW has the most control. To address the effects of varying rates of legal wolf removal on wolf population viability we conducted a set of 4 simulations where mean legal mortality rates and associated standard deviations varied among simulations while all other model parameters

Commented [j9]: This is essentially a "Life Stage Simulation Analysis", right? If so, might go ahead and cite Wisdom et al.

Commented [j10]: This is a completely different kind of "sensitivity analysis" and does not provide the same information as a LSA. This evaluates sensitivity of the model results to the values of the specified parameters… a classical "Sensitivity Analysis" that I talked about earlier when discussion the use of a uniform distribution. It's o.k. to do one, but if you do, you should do it with all model parameters including stochastic ones.

were left at baseline values (Table 1). The following values were used as mean values (± SD) to represent legal anthropogenic mortality rates in the 4 simulations: 0.00 (± 0.00), 0.05 (± 0.03), 0.10 (± 0.06), and 0.20 (± 0.12). These levels of legal mortality rates were in addition to illegal mortality rates which were set at a mean value of 0.05 (± 0.03) during all simulations.

Our baseline model assumes legal removals will be implemented through random removal of individual wolves. However, the potential exists that lethal control actions could take place across entire wolf packs, rather than individuals. Consequently, we also conducted a simulation where legal removal of wolves would occur at a pack rather than individual level. We assumed the proportion of packs removed per year would be the same as the proportion of individuals removed in our baseline simulation (0.05 ± 0.03). After completion of simulations, we compared the results to the baseline simulation to determine what effect, if any, pack removal would have on population dynamics compared to individual removal.

RESULTS

Model Validation

Our baseline model resulted in underestimates of population size (Fig. 3a) and number of breeding pairs (Fig. 3b) compared to population count data collected in Oregon from 2010-2104. When our model was parameterized with survival rates of wolves observed from 2009-2014 (Table 1) the simulation results closely approximated observed population size and number of breeding pairs. Consequently, survival rates used in our baseline model are cautious compared to past survival rates in Oregon; however, the ability of the model to correctly predict past population dynamics when parameterized with observed survival rates suggests other parameters included in the model accurately portray wolf population dynamics in Oregon. Our baseline model predicted lower population growth compared to the model parameterized with survival rates observed from 2009-2014. This suggests our baseline model will underestimate wolf population growth and viability if survival rates from 2009-2014 are observed into the future.

Commented [j11]: I know you say this in a few places, but I guess I would mention it here as well… that it might not underestimate *future* pop. growth if survival rates decrease a bit with a more established wolf population

Assessment of Population Viability

Using our baseline model, simulated wolf populations increased an average of 7% (i.e., $\lambda = 1.07 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.05 (95% CI = 0.01 – 0.09) probability of the population dropping below the conservation-failure threshold (Fig. 4). Most conservation-failures (3 out of 5) occurred within the first 10 years and by year 20, no additional populations passed the threshold. Of the five simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 7, 20, 39, 84 and 194 breeding pairs in year 50 of the simulation, respectively. There was a 0.01 (95% CI = 0.00 – 0.03) probability the simulated population dropped below the biological-extinction threshold over the next 50 years. The single simulated population that dropped below 5 individuals recovered to 360 individuals by year 50.

Using observed survival rates of wolves from 2009-2014 in our population model resulted in no scenarios where wolf populations dropped below the conservation-failure or biological-extinction thresholds. Our baseline model may be more likely to represent future population dynamics of wolves, but may be overly pessimistic, especially in the near future, given recently observed survival rates of wolves in Oregon. Consequently, we contend future risk of conservation-failure likely falls somewhere between our baseline model (0.05) and our model parameterized with vital rates required to match observed population growth rates from 2009-2014 (0.00). Our model results suggest it is extremely unlikely (≤ 0.01 probability) wolves in Oregon will be at risk of extirpation over the next 50 years.

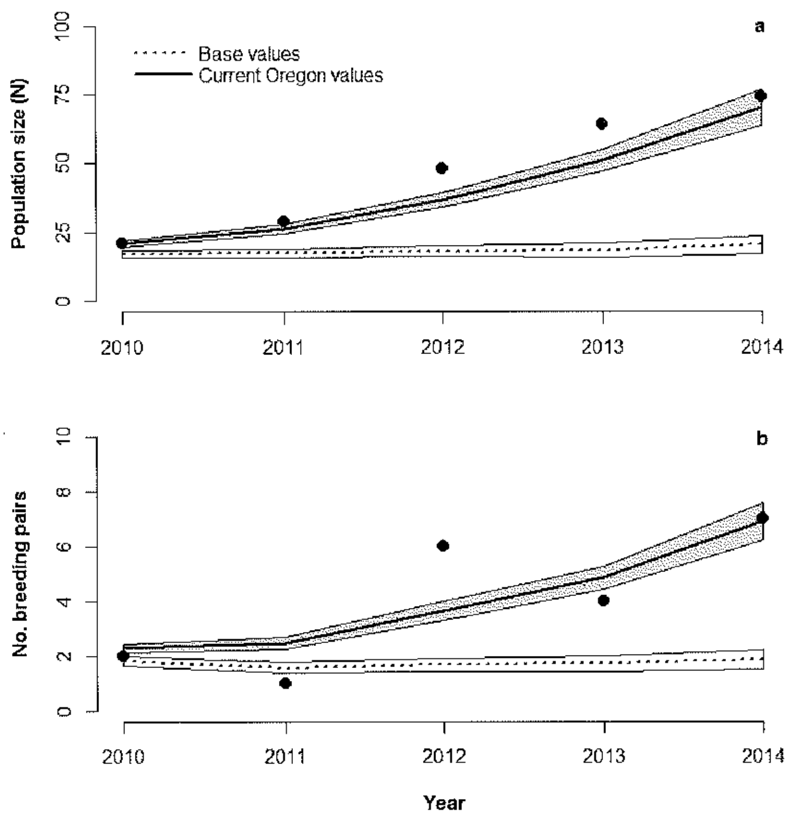

Figure 3. Comparison of (a) simulated mean population sizes compared to minimum population sizes observed in Oregon from 2009-2014 and (b) simulated number of breeding pairs to minimum number of known breeding pairs in Oregon from 2009-2014 using baseline simulation parameters (dashed line) or observed model parameters (solid line). Black dots represent observed wolf population size and number of breeding pairs determined from annual surveys of wolf populations conducted by ODFW. Polygons around simulated mean population sizes and number of breeding pairs represent 95% confidence intervals.

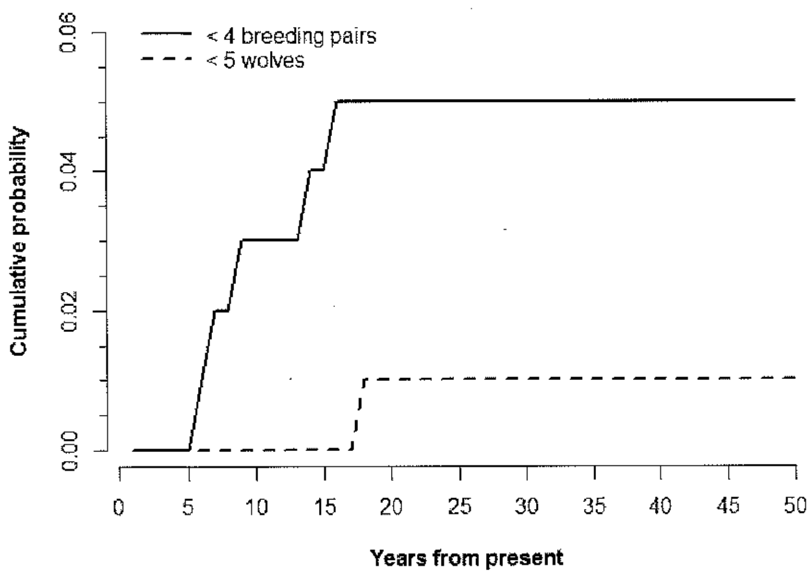

Figure 4. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

Sensitivity Analysis

Effects of Stochastic Parameters.–Nine out of 17 stochastic parameters included in our baseline model had a significant effect on intrinsic growth rates as measured by *r*, and no significant interactions between parameters were documented (Table 4). Most significant effects (Fig. 5) were directly or indirectly related to survival rates. Survival rates of pups (S_p; β = 0.045), yearlings (S_y; β = 0.024), and adults (S_{ad}; β = 0.019) were positively associated with *r*. The prey multiplier (Pr) increased variation in survival rates of all age classes of wolves by up to 20% and resulted in the prey multiplier, which represented increased environmental stochasticity, having the greatest effect on *r* (β = 0.088). Illegal (IM; β = -0.027) and legal (LM; β = -0.028) anthropogenic mortality were negatively associate with *r*.

Commented [j12]: Significance tests are completely irrelevant and should be removed. They are solely dependent on the number of replications used.

What is relevant is the slope and the r-squared of the regression. I would replace p-values and significance tests with r-squared values.

Table 4. Results of linear regression model used to estimate sensitivity of intrinsic growth rates of wolf populations in Oregon using an individual-based population model. Standardized regression coefficients with associated standard errors estimated from the full model are provided. Significance is determined as follows: *** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, and NS = $P > 0.05$.

Parameter	Standardized β_i	SE	P-value	Significance
Pup survival	0.045	0.007	0.000	***
Yearling survival	0.024	0.007	0.000	***
Adult (2 to 7-yrs old) survival	0.019	0.007	0.006	**
8-yr old adult survival	-0.006	0.007	0.411	NS
9-yr old adult survival	-0.002	0.007	0.789	NS
Pup dispersal	0.007	0.007	0.295	NS
Yearling dispersal	0.010	0.007	0.155	NS
Adult dispersal	-0.001	0.007	0.833	NS
Proportion of dispersing wolves that die	-0.026	0.007	0.000	***
No. of immigrants arriving annually	0.009	0.005	0.109	NS
Proportion of dispersing wolves that emigrate	-0.005	0.007	0.443	NS
Proportion of dispersing wolves that successfully establish a territory	0.034	0.006	0.000	***
Pregnancy rate for dominant females	0.001	0.007	0.912	NS
Mean litter size	0.049	0.004	0.000	***
Prey index multiplier	0.088	0.005	0.000	***
Illegal mortality	-0.027	0.007	0.000	***
Legal mortality	-0.028	0.007	0.000	***
Pup survival × Prey multiplier index	-0.011	0.009	0.198	NS
Yearling survival × Prey multiplier index	0.000	0.009	0.958	NS
Adult survival × Prey multiplier index	-0.003	0.009	0.737	NS
Pup survival × Illegal mortality	-0.004	0.012	0.720	NS
Yearling survival × Illegal mortality	0.012	0.012	0.293	NS
Adult survival × Illegal mortality	0.016	0.011	0.146	NS
Pup survival × Legal mortality	-0.003	0.012	0.797	NS
Yearling survival × Legal mortality	0.001	0.012	0.912	NS
Adult survival × Legal mortality	0.011	0.012	0.342	NS
Pup survival × Dispersal mortality	-0.013	0.011	0.248	NS
Yearling survival × Dispersal mortality	0.003	0.012	0.824	NS
Adult survival × Dispersal mortality	0.003	0.011	0.785	NS

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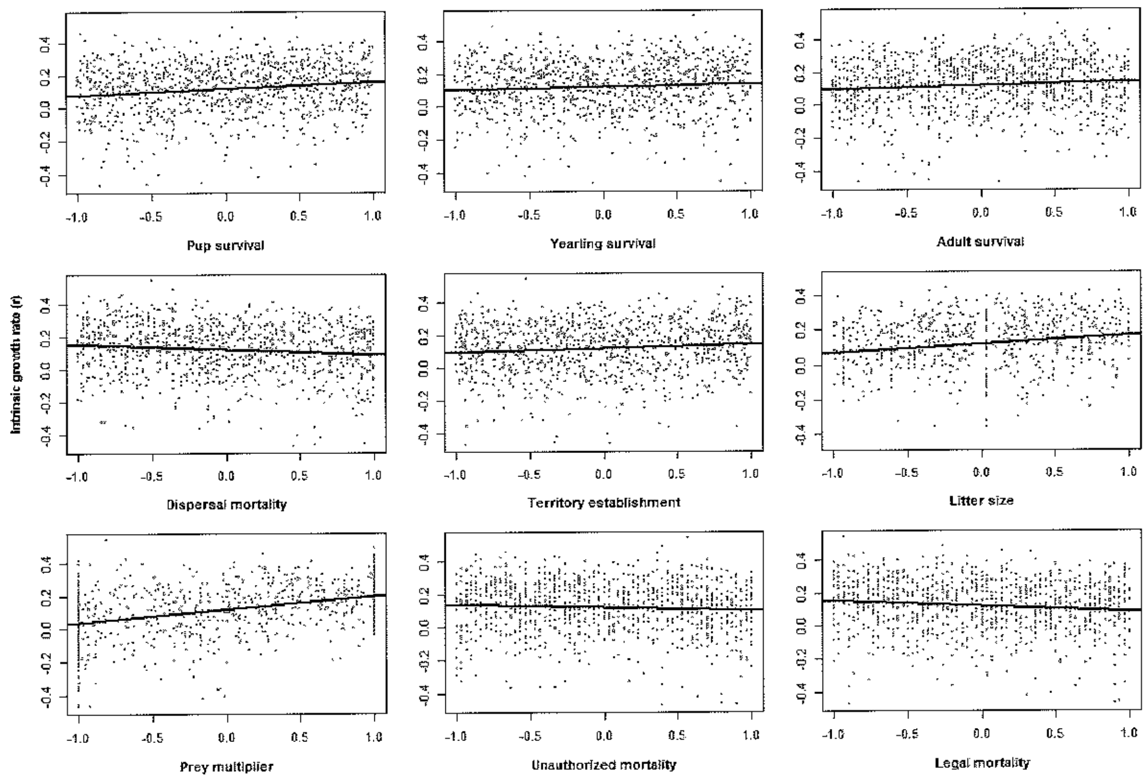

Figure 5. Estimated effects of significant ($p < 0.05$) model parameters on intrinsic growth rates of wolf populations. Estimates were generated using baseline model parameterization. Results generated from 1,000 unique combinations of model parameters and associated intrinsic growth rates. Model parameters are standardized to allow direct comparison among parameters. Black line represents estimated regression line. Gray dots represent individual parameter estimates and associated population growth rate.

Increased mortality rates of dispersing wolves (M_d; β = -0.026) had a negative effect on *r*. This parameter negatively affected *r* in two ways: 1) wolves were directly removed from the population and 2) fewer wolves were available to establish territories and contribute to population level reproduction. Increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on *r* (T; β = 0.034). Mean litter size (L; β = 0.049) was positively correlated with *r*. Pregnancy rates of dominant females (P_{ad}) were not significantly associated with *r*. We likely did not find a significant effect of pregnancy rates because of the high mean value (0.95) and low variation (SD = 0.02) used in our model.

Dispersal rates, regardless of age class (D_p, D_y, and D_{ad}) had minimal effects of on *r* (Table 4). Both immigration (I) and emigration (E_d) did not have a significant effect on *r*. At most, our model limited the number of immigrating wolves to 5 per year (range = 1 – 5) and contributions to population growth from immigrants will be limited except for extremely small extant populations. We modeled emigration rates as a proportion of the dispersing wolves that survived and left the population each year. Consequently, emigration could contribute to reduced population growth rates when the number of emigrants is greater than the number of immigrants. This scenario is more likely to occur for large extant populations.

Commented [j14]: Rankings of both amount of variation in growth explained by each parameter (given by r-squared) as well as the amount of change in r for a unit change in parameter (given by slope or Beta) is way more informative than obvious directions of influence… i.e., that increasing survival increases growth rate.

Effects of Static Parameters.–As expected, simulations with larger starting populations reached the density-threshold faster than those with smaller starting size (Fig. 6a). The risk of conservation-failure declined with increased starting population size (Fig. 6b). Using our baseline model, simulations that started with 150 and 100 individuals had no risk and a 0.01 (95% CI = 0.00 – 0.03) probability of conservation-failure over the next 50 years, respectively. At the current minimum known wolf population in Oregon, risk of conservation-failure (0.05; 95% CI = 0.01 – 0.09) was slightly higher than if 100 animals were in the population but substantially lower than if only 50 wolves (0.14; 95% CI = 0.07 – 0.21) occurred in Oregon. We did not observe a relationship between starting population size and biological-extinction risk as biological-extinction risk was ≤ 0.01 over 50 years regardless of starting population size.

Commented [j15]: Again, this type of sensitivity analysis gives you very different information than the previous 2 paragraphs.

Unsurprisingly, mean maximum population sizes of wolves were larger for simulations with higher density-thresholds (Fig. 7a). The effects of varying density-thresholds on risk of conservation-failure over 50 years were similar for density thresholds between 250 – 1500 (range 0.03 – 0.05; Fig. 7b). In contrast, at a density-threshold of 100 wolves, risk of conservation-failure was much greater (0.64; 95% CI = 0.55 – 0.73), steadily increased over time, and never plateaued as observed in other simulations. This suggests that a population threshold of 100 wolves is insufficient to allow long-term persistence of ≥ 4 breeding pairs. Regardless of the density-threshold used, maximum observed biological-extinction risk was ≤ 0.01.

Increased frequency at which catastrophic reductions in survival rates occurred caused reduced population growth rates and reduced mean, maximum population size of wolves (Fig. 8a). Populations that were subjected to catastrophic reductions in survival at intervals of once every 100 or 50 years had a relatively low risk of conservation-failure (range = 0.05 – 0.06; Fig. 8b). Catastrophic reductions in survival at intervals of once every 20 (0.09; 95% CI = 0.03-0.15) and 10 (0.16; 95% CI = 0.09-0.23) years had moderate risk of conservation-failure compared to less or more frequent intervals. For all scenarios, biological extinction risk was ≤ 0.01 over 50 years.

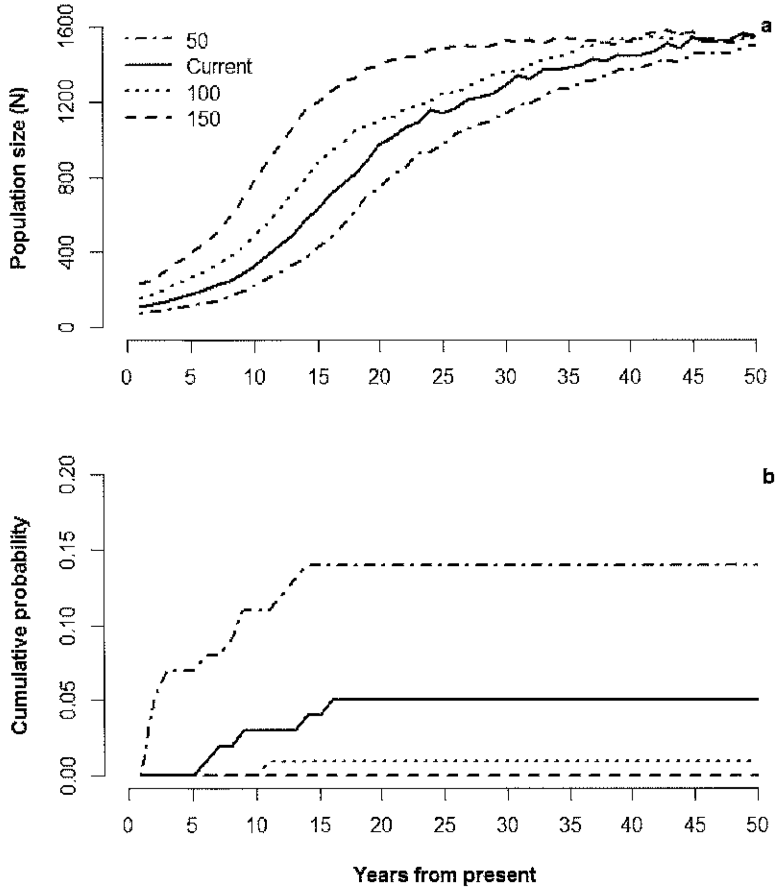

Figure 6. Estimated effect of variation in starting population size on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Current population size (N = 85) was the minimum wolf population size in Oregon as of April 1, 2015. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using the baseline model parameterization.

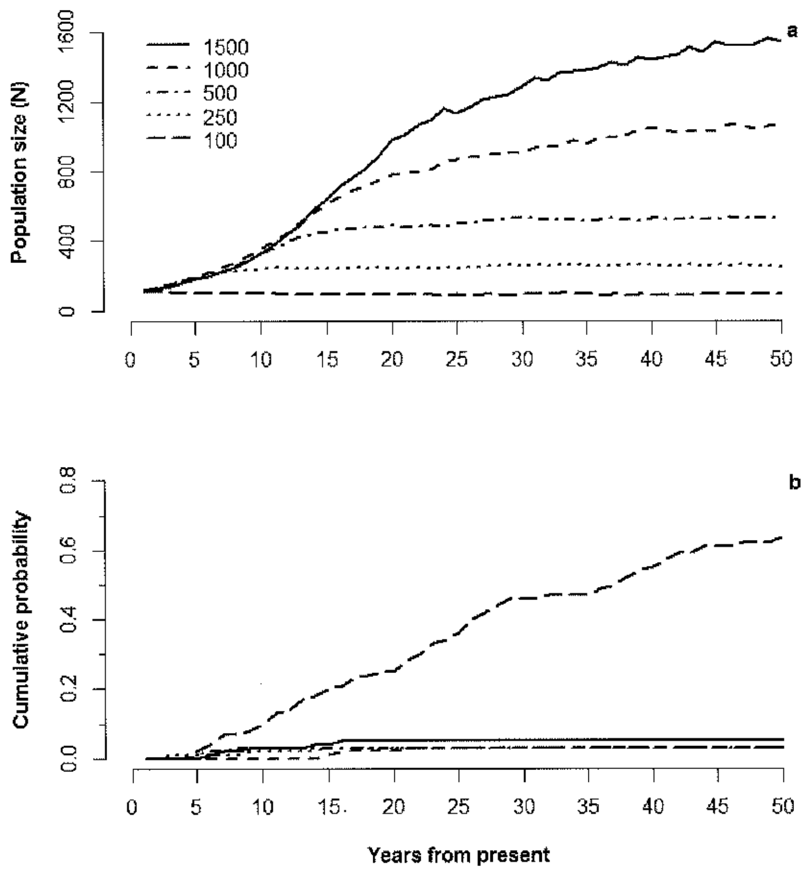

Figure 7. Estimated effect of variation in density-threshold on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

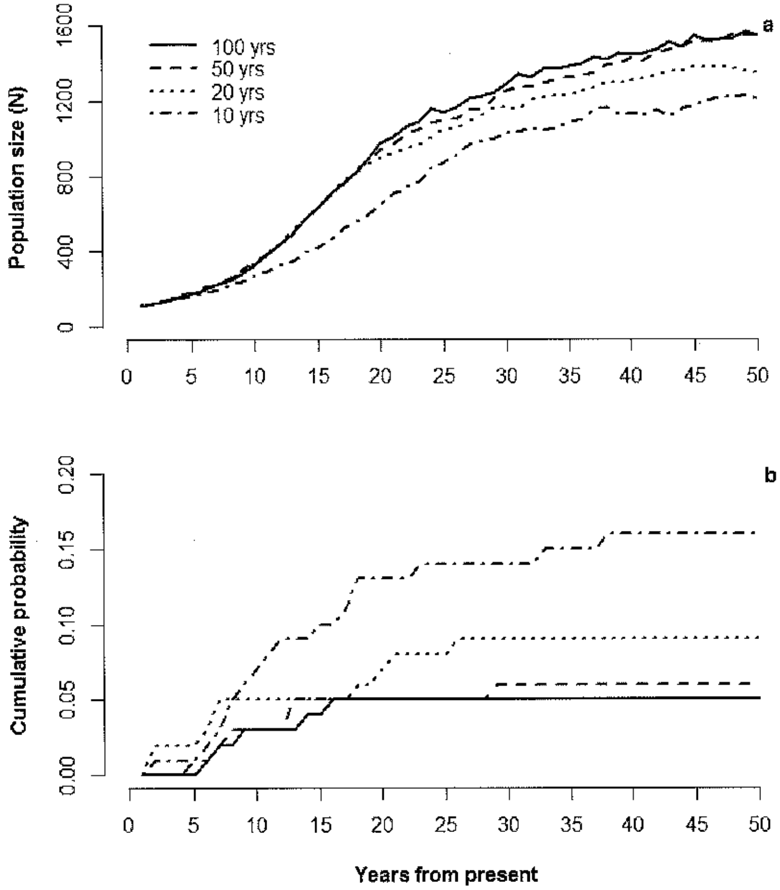

Figure 8. Estimated effect of variation in interval between catastrophic reductions in survival of wolves on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs). Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Increased frequency of pack-specific reproductive failure reduced population growth rates and mean, maximum population size of wolves (Fig. 9a). Scenarios with reproductive failure once every 20 (0.05; 95% CI = 0.01 – 0.09) and 10 litters (0.05; 95% CI = 0.01 – 0.09) had similar risk of conservation-failure in the next 50 years (Fig. 9b). Risk of conservation-failure was almost 6 times greater at intervals of once every 5 litters (0.29; 95% CI = 0.20 – 0.38). These results highlight the importance of pup production on ensure population viability of wolves. Risk of biological-extinction was not strongly affected by interval of reproductive failure as all scenarios had a risk of biological-extinction ≤ 0.02.

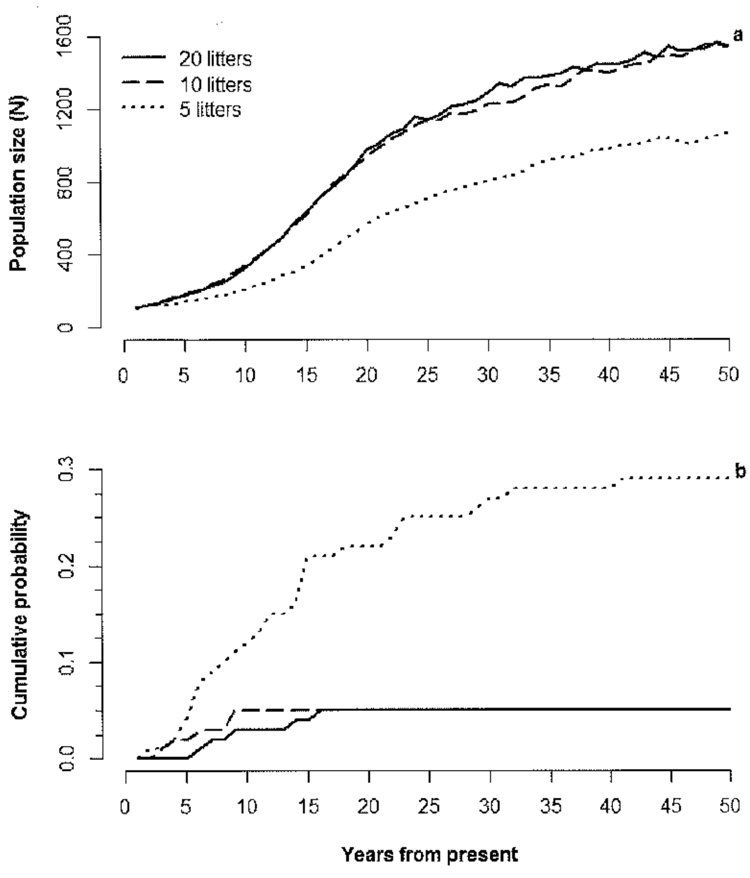

Figure 9. Estimated effect of variation in intervals between reproductive failure on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Effects of lethal control of wolves

Increased rates of legal mortality, while holding illegal mortality at baseline values, had a negative effect on population growth rates and mean, maximum population size of wolves (Fig. 10a). With a starting population of 85 wolves and at a legal mortality rate of 0.20, wolf populations declined. This suggested this rate of legal morality was not sustainable over the long-term at least at a starting population of 85 wolves and additional illegal mortality of 0.05. At a mean legal mortality rate of 0.05, which was used in our baseline model, probability of conservation-failure was 0.05 (95% CI = 0.01 – 0.09; Fig. 10b) over the next 50 years. At a reduced mean legal mortality rate of 0.00, no simulated populations dropped below the conservation-failure threshold. Probability of conservation-failure increased to 0.40 (95% CI = 0.30 – 0.50) and 1.00, for mean legal mortality rates of 0.10 and 0.20, respectively, when combined with illegal mortality rates of 0.05. Combined, these results highlight the importance of minimizing anthropogenic mortality to benefit population viability of wolves. Probability of biological-extinction was relatively low for all simulations with mean legal mortality rates ≤ 0.10 (range = 0.00 – 0.07; Fig. 10c). In contrast, mean legal mortality rates of 0.20 resulted in an extremely high probability of biological extinction (0.90; 95% CI = 0.84 – 0.96), at least when combined with an illegal mortality rate of 0.05 and a starting population of 85 individuals. Larger populations will be able to sustain higher mortality rates because they will have a greater buffer between extant population size and thresholds of biological extinction.

Commented [j16]: This seems to contradict observed wolf dynamics in Alaska under significant harvest… why?

It should also be noted, the levels of anthropogenic mortality used in our model are not directly comparable to mortality rates commonly reported in literature (i.e., 1 – survival rate). Anthropogenic mortality rates as implemented in our model represent the proportion of wolves that would be removed from the population after accounting for natural mortality. For example, using a legal mortality rate of 0.10, an illegal mortality rate of 0.05, and a survival rate in the absence of anthropogenic mortality of 0.88, would result in an observed survival rate of 0.75 ($0.88 \times 1\text{-}0.10 \times 1\text{-}0.05$).

The effects of legal removals on wolves reported above are predicated on a starting population of 85 wolves. At larger population sizes, wolves will have an increased buffer between extant population size and conservation-failure or biological-extinction thresholds and fewer simulations would be expected to cross these thresholds. This is particularly true for moderate levels of legal mortality (0.05-0.15) where populations are likely to increase on average, but without a sufficient buffer and under stochastically varying conditions, 2-3 consecutive years of negative population growth could push the population below a predefined threshold. This phenomenon is evident in our simulations because most conservation-failures occurred shortly after simulations started. By later years, population sizes had sufficiently increased that they were able to withstand several consecutive years of negative population growth without falling below the conservation-failure threshold.

Comparison of individual vs. pack removal.--Lethal control actions conducted through random removal of individuals or entire packs had little influence on mean population size over 50 years (Fig. 11a). Mean populations for both removal scenarios reached the density-threshold (N = 1,500) by the 50th year of the simulation. Conservation-failure rates over 50 years were similar if individual wolves (0.05; 95% CI = 0.01 – 0.09) or packs (0.08; 95% CI = 0.03 – 0.13) were removed (Fig. 11b). Entire pack removal (0.01; 95% CI = 0.00 – 0.03) and removal of individuals (0.01; 95% CI = 0.00 – 0.03) resulted in similar estimates of biological-extinction risk over 50 years.

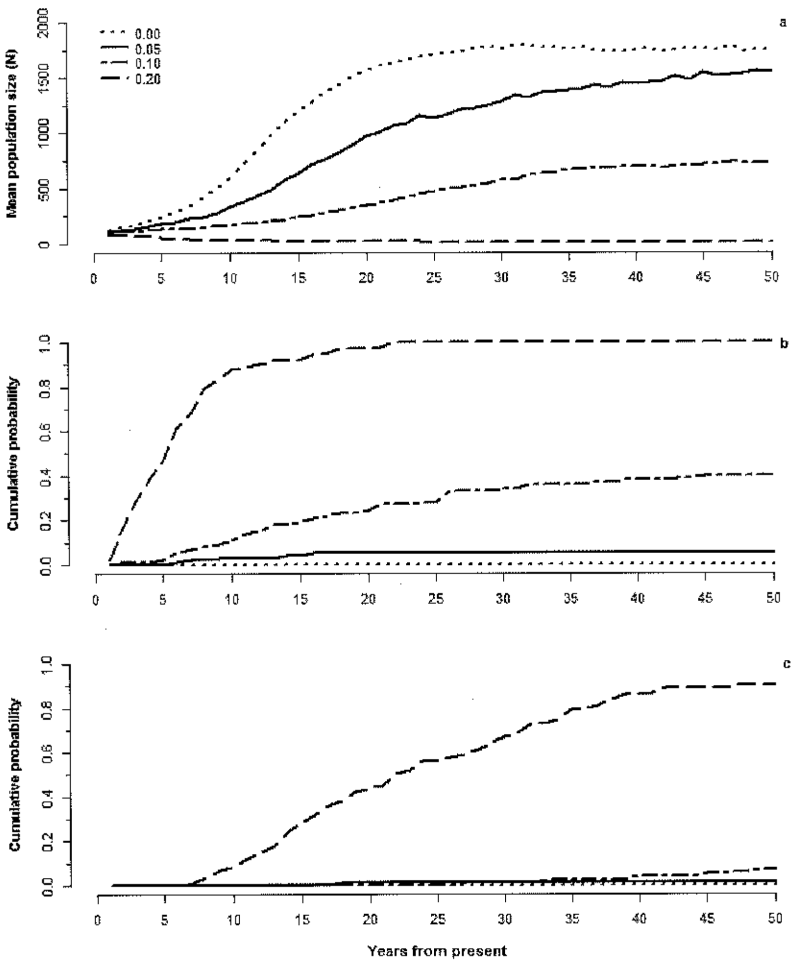

Figure 10. Estimated effect of variation in legal removal rates (proportion of wolves that would have survived the year otherwise) of wolves on (a) mean population size, (b) cumulative probability of conservation-failure (< 4 breeding pairs), and (c) cumulative probability of biological-extinction (< 5 wolves) over the next 50 years in Oregon when the starting population size was 85 wolves. Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. For all simulations, unauthorized morality rates of 0.05 (± 0.03 SD) occurred in addition to varying levels of legal removal.

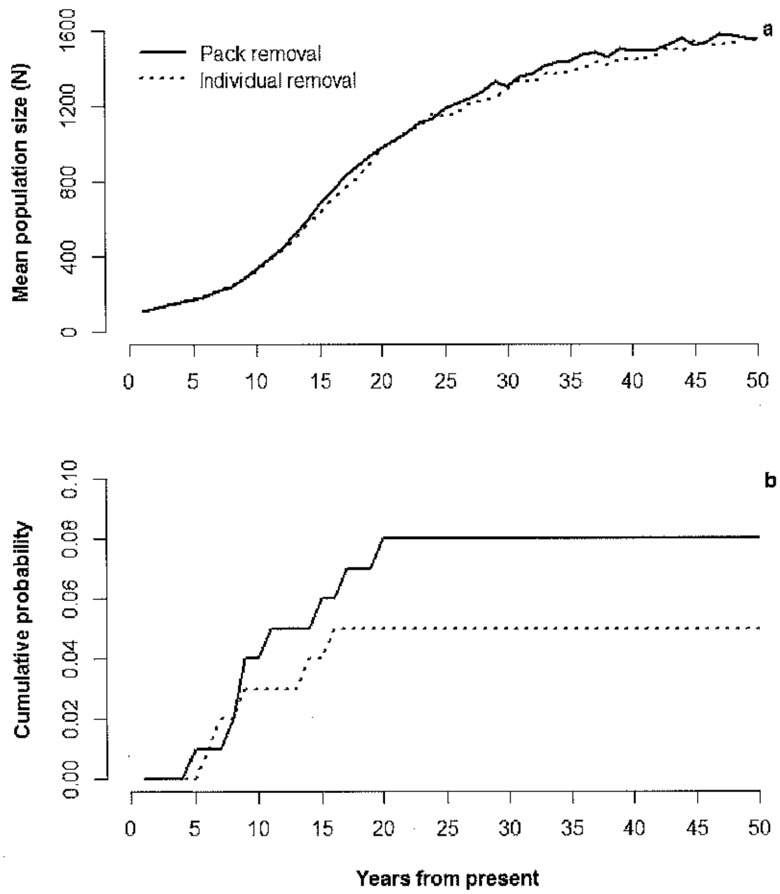

Figure 11. Estimated effect of individual versus pack level legal removal on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. Pack level and individual removal rates were identical for each simulation (0.05 ± 0.03).

Discussion

Our baseline model underestimated population growth rates of wolves compared to observed population counts conducted in Oregon from 2010-2014. This was a consequence of two factors: 1) our baseline model used lower survival rates than were observed from 2010-2014 and 2) at small population sizes demographic stochasticity can have a dramatic effect on population growth rates (Lande 1998, Fox and Kendall 2002). However, our model parameterized with survival rates of wolves radio-collared in Oregon from 2009-2014 allowed our model to track observed population growth rates during this timeframe. We contend these findings suggest our model structure is capable of accurately portraying population dynamics of wolves when survival rates used in the model are representative of current conditions. We used conservative survival estimates in our baseline model to ensure our PVA erred on the side of caution (i.e., precautionary principle; Myers 1993, Meffe et al. 2006). Consequently, our results represent a conservative view of population viability of wolves in Oregon.

If wolf populations in Oregon continue to follow vital rates observed from 2009-2014, our results indicated there would be no risk of conservation-failure or biological-extinction within the next 50 years. It is unlikely wolf populations in Oregon would continue to increase at observed population growth rates because established or exploited wolf populations do not increase as rapidly as protected or recovering populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Therefore, we contend results from our model parameterized with currently observed vital rates may present an overly optimistic view of wolf population dynamics moving forward in Oregon. Using our baseline model parameterized with vital rates obtained from a literature review, we documented a 0%, 3%, and 5% chance of conservation-failure over the next 5,10, and 50 years, respectively (Fig. 4). Most risk of conservation-failure occurs in the short-term (e.g., 15 years) because Oregon's extant wolf population is close to the conservation-failure threshold and a few years of poor population growth could cause the population to decline below the threshold. Furthermore, during the first few years of our simulations, population sizes are small, which allows demographic stochasticity to have a greater effect on population persistence (Vucetich et al. 1997).

Our baseline model suggested risk of conservation-failure was lower for populations that started with 100 or 150 wolves compared to the current population size observed in Oregon (N = 85; Fig. 6). This is not an unexpected finding because larger populations, regardless of species, have a reduced risk of extinction and can withstand longer periods of reduced population growth. These results highlight the importance of creating a buffer between extant population size and conservation-failure thresholds to allow for potential years of negative population growth. Furthermore, increased modeled starting population size will minimize effects of demographic stochasticity and increase population viability. Based on observed population growth rates from 2009-2014 (mean $\lambda = 1.43$) and known reproduction in 13 groups of wolves in 2015, Oregon's wolf population is expected to surpass 100 wolves by the end of the biological year. At this population size, risk of conservation-failure will effectively be eliminated (≤ 0.01).

In general, factors that influenced wolf survival had the greatest effect on intrinsic growth rates of wolves (r) in our simulation models. In our model, pup, yearling, and adult survival all had significant effects on intrinsic growth rates of wolf populations (Fig. 5). However, variation in pup survival had a greater effect on intrinsic growth rates than yearling or adult survival. While population growth rates of most large mammals are usually most sensitive to changes in adult survival, variability in adult survival, in the absence of high levels of anthropogenic mortality, is usually minimal compared to juveniles (Promislow and Harvey 1990, Gaillard et al.

1998, Robinson et al. 2014). The inherent variability in survival of juveniles causes this age class to have a disproportionate effect on population growth rates despite population growth rates being relatively insensitive to variation in this parameter. This does not discount the importance of adult and yearling survival on population growth and viability; rather it highlights the importance of minimizing annual variation and maintaining high survival rates of yearlings and adults.

Prey abundance and vulnerability are thought to influence wolf populations (Fuller and Keith 1980, Hayes and Harestad 2000, Vucetich and Peterson 2004). In our model, we did not explicitly model predator-prey relationships; rather, we used a prey multiplier value that increased stochastic variation in survival rates of wolves to simulate the effects of variation in prey abundance or changes in environmental conditions (e.g., snow depth) that influence vulnerability of prey over time. Effectively, the prey multiplier represented environmental stochasticity that allowed up to a 20% increase in variation in survival rates. Increased variability in survival (i.e., environmental stochasticity) will have negative effects on population growth rates and viability, regardless of the species of interest (Morris and Doak 2002). Consequently, it was expected that increased environmental stochasticity, modeled through our prey multiplier, had a negative effect on simulated wolf populations.

Anthropogenic mortality is the primary factor that influences dynamics of most wolf populations (Creel and Rotella 2010). Our model supported this conclusion because increased levels of anthropogenic mortality had a negative effect on intrinsic growth rates of wolves (Fig. 5). Furthermore, our simulation results indicated that increased rates of anthropogenic mortality resulted in increased risk of conservation-failure and biological-extinction when the initial population was 85 wolves (Fig. 10). Anthropogenic mortality is the parameter in our model over which ODFW has the most control and our results highlight that Oregon's wolf population will continue to increase and become self-sustaining if anthropogenic mortality is limited.

Our baseline model used inputs of 0.05 for both illegal and legal anthropogenic mortality rates (i.e., 5% of wolves that do not die of natural causes will be removed by both illegal and legal mortality sources) and at this rate, risk of conservation-failure was low. If ODFW maintains mortality rates at or below this level, the wolf population is predicted to be at a low risk of conservation-failure (0.05) and biological-extinction (0.01). Sustained, high levels of anthropogenic mortality (e.g., 0.20) in a stochastically varying environment contributed to increased risk of conservation-failure in our simulations; however, this finding is predicated on our staring population size of 85 wolves. Larger populations would be able to sustain this level of anthropogenic mortality without reaching the conservation-failure threshold because there is an increased buffer between extant population size and the conservation-failure threshold. Our model suggested that total anthropogenic mortality rates (i.e., combined illegal and legal mortality) of 0.15 would result in an increasing population on average ($\lambda = 1.03$) but total anthropogenic mortality rates of 0.20 caused wolf populations to decline on average ($\lambda = 0.98$). Previous studies have indicated wolf populations can be sustained with mortality rates up to 0.25 - 0.30 (Adams et al. 2008, Creel and Rotella 2010, Sparkman et al. 2011). As implemented in our model, anthropogenic mortality rates of 0.20 would cause survival rates of adult wolves to be 0.70 (i.e., a mortality rate of 0.30) and the wolf population would decline slightly on average ($\lambda = 0.98$). Consequently, our model matches well with the results previous studies.

Catastrophic reductions in survival of 25% had little effect on population growth rates and viability of wolves if the interval between occurrences was ≥ 50 years (Fig. 8). Widespread, catastrophic events are impossible to predict and little can be done to directly mitigate their

effect. However, general tenants of population ecology provide insight into actions that can minimize their effects on population viability. The primary way to reduce effects of catastrophes on population viability is to maintain larger extant populations. Larger populations are more viable because they have a sufficient number of individuals to withstand population declines. In our model, catastrophic events occurred at the population level. This is likely a biologically unrealistic expectation because catastrophic events are likely to occur in geographic regions (e.g., Blue Mountains or Cascade Range) due to localized differences in environmental conditions. This geographic separation should reduce population level effects of catastrophic events because not all wolves would be subjected to the event in a single year. However, these smaller sub-populations would have a greater risk of localized extinction compared to the larger extant population. This highlights the importance of risk spreading through spatial distribution of wolves in ensuring the long-term viability of wolf populations.

Recruitment of pups into the adult population was a critical factor influencing population dynamics of wolves. While we did not directly include a recruitment parameter in our model, several factors that jointly influence pup recruitment had separate effects on wolf population growth and viability. Variation in mean litter size had a strong effect on intrinsic growth rates of wolves. Increased frequency of reproductive failure had a negative effect on population growth rates and viability. Finally, reductions in survival rates of pups had a negative effect on population growth rates of wolves. Pup production and recruitment affects wolf population growth and viability in two ways. At the end of the biological year, wolf pups typically represent a large fraction of the total wolf population (Fuller et al. 2003). Consequently, any reductions in pup recruitment will slow population growth rates of wolves in the short-term. In the long-term, reduced pup recruitment will affect the number of potential dispersing wolves in the population. Yearling wolves (i.e., recently recruited pups) are most likely to disperse and establish new territories (Gese and Mech 1991, Boyd and Pletscher 1999). Reduced pup recruitment will limit the number of potential dispersers in subsequent years, which should slow the rate of population growth because fewer dispersers will be available to establish territories and contribute to population level reproduction.

In our baseline model, we used a density-threshold value of 1,500 wolves. This value represented the biological phenomenon where population growth of wolves would be limited by availability of vulnerable prey (Fuller 1989, Mech et al. 1998, Fuller et al. 2003) or intraspecific mechanisms (Cariappa et al. 2011); however the ability of wolves to self-regulate through intrinsic mechanisms is thought to be limited (Keith 1983, McRoberts and Mech 2014). Varying the density-threshold value in our model had little effect on risk of conservation-failure at values ≥ 250 wolves. Consequently, we contend our choice of a density-threshold value had minimal effects on our results.

The Oregon Wolf Plan (ODFW 2010) provides guidelines as to when lethal control of wolves can occur. Our results indicated increased levels of anthropogenic mortality negatively affect wolf population growth and viability. However, whether anthropogenic mortality was implemented at an individual or pack-level had little effect on our results. Caution should be used when implementing lethal control to address management concerns. For example, breeder loss can have a significant, negative effect on wolf population dynamics (Brainerd et al. 2008, Borg et al. 2015). Consequently, decisions regarding lethal removal of breeding wolves should be carefully considered.

Our analysis of wolf-population viability did not explicitly incorporate genetic effects. Genetic viability is a critical concern for any threatened or endangered population (Frankham et

al. 2002, Scribner et al. 2006) especially for extremely small, isolated populations (Frankham 1996). Inbreeding is a potentially serious threat to the long-term viability for small, isolated populations of wolves (Liberg 2005, Fredrickson et al. 2007) but can be minimized through connectivity to adjacent populations. As few as 1-2 immigrants per generation (~5 years) can be sufficient to minimize effects of inbreeding on wolf populations (Vila et al. 2003, Liberg 2005). High levels of genetic diversity in Oregon's wolf population are likely to be maintained through connectivity to the larger northern Rocky Mountain wolf population. Wolves are capable of long-distance dispersal (Fritts 1983, Boyd and Pletscher 1999, Wabakken et al. 2007) which should allow a sufficient number of immigrants to arrive in Oregon so long as sufficient connectivity is maintained between populations in adjacent states (Hebblewhite et al. 2010). While our model did not account for genetic effects, we acknowledge the importance of genetics for isolated populations of mammals and recognize that genetic effects could become important if the Oregon wolf population becomes isolated from the remainder of the northern Rocky Mountain wolf population.

The IBM we used to assess wolf population viability in Oregon should provide a realistic biological representation of wolf population dynamics. However, our IBM does not have a spatial component and does not rely on habitat or other landscape features. Spatially-explicit models could provide a more biologically realistic representation of wolf population dynamics; however, spatially-explicit models require substantial amounts of data that is currently not available in Oregon to effectively parameterize the model. Habitat suitability maps have been developed for Oregon (e.g., Larsen and Ripple 2006), but these maps have not been validated and use of these maps would introduce another unknown source of error in population models. Furthermore, the effects of habitat on survival, reproduction, and dispersal of wolves in Oregon are unknown and it would be impossible to accurately model these effects without unwarranted speculation. For these reasons, we contend our non-spatial analysis of wolf population dynamics is currently the most appropriate approach to model wolf population dynamics and viability because it does not rely on unfounded assumptions that could lead to inappropriate conclusions.

Supplement 1: Population Viability of Wolves in the Eastern Wolf Management Zone.

We used our existing IBM to assess viability of wolves in the eastern Wolf Management Zone (WMZ) of Oregon (see ODFW 2010 for description of eastern WMZ). In this analysis, we restricted our starting population size to those wolves known to occur in the eastern WMZ as of April 1, 2015 ($N = 76$) and set the density threshold to 600 wolves compared to 1,500 wolves used in the statewide analysis. We selected the density-threshold for eastern WMZ using the equations following: Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves/1,000 km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 66,000 elk distributed across 53,320 km^2 of summer range habitat in the eastern WMZ (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 3.71 (66,000 × 3/53,320). Based on this value maximum wolf densities were estimated to be 15.64 wolves/1,000 km^2 of summer range elk habitat in the eastern WMZ. This would result in a total population of 834 wolves within 53,320 km^2 of elk summer range habitat in the eastern WMZ. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, the elk population in the eastern WMZ is approximately 66,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 1,432.2 × 10,000 kg of primary prey biomass available to wolves across the eastern WMZ and a maximum population estimate of approximately 888 wolves. To be conservative, we used a density-threshold of 600 wolves in the eastern WMZ.

Remaining methods and parameter inputs for this analysis were identical to those used in the statewide assessment of wolf population viability (Table 1). As with the statewide analysis, we used two metrics to assess population viability: 1) conservation-failure, defined as the population dropping below 4 breeding pairs and 2) biological-extinction, defined as the population having fewer than 5 individuals.

Using our baseline model, simulated wolf populations increased an average of 6% (i.e., $\lambda = 1.06 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.06 (95% CI = 0.01 – 0.11) probability of the population dropping below the conservation-failure threshold (Fig. S1). Half of the conservation-failures occurred within the first 10 years and by year 20 no additional populations passed the threshold. Of the six simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 22, 37, 61, 67, 72, and 88 breeding pairs by year 50, respectively. No simulated populations dropped below the biological-extinction threshold over the next 50 years. Risk of conservation-failure in the eastern WMZ was slightly higher, but not significantly different, than risk at a statewide level (0.06 vs. 0.05; Fig. S2). Our simulation results suggested risk of conservation-failure declined with increasing starting population size (Fig. 6), so it was not surprising that the slightly smaller starting population in the eastern WMZ ($N = 76$) had a slightly higher risk of conservation-failure compared to the statewide population ($N = 85$).

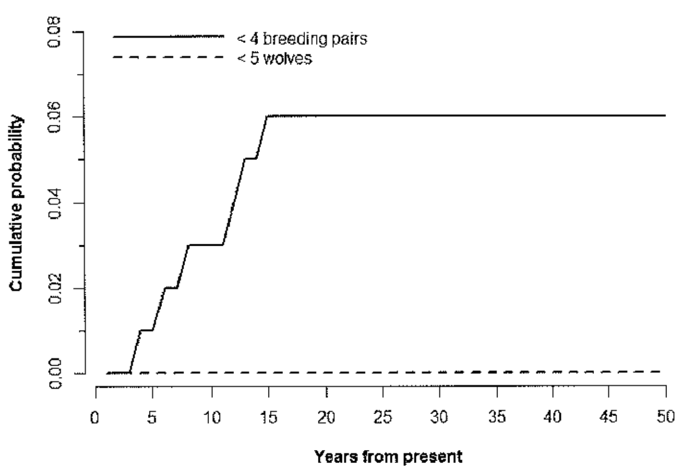

Figure S1. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

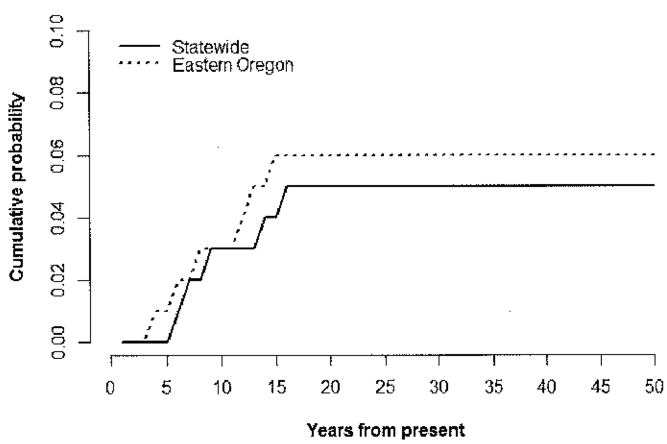

Figure S2. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) over the next 50 years across the entire state or in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

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DR. KATIE DUGGER

Assessment of Population Viability of Wolves in Oregon

This technical report to the Oregon Fish and Wildlife Commission presents results from an updated individual-based population model used to assess population viability of wolves in Oregon. The model uses wolf data collected in Oregon through July 2015.

Presented: November 9th, 2015

Suggested citation:

Oregon Department of Fish and Wildlife. 2015. An updated assessment of population viability of wolves in Oregon using data collected through July 2015. Oregon Department of Fish and Wildlife, 4034 Fairview Industrial Drive SE. Salem, OR 97302.

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Executive Summary

We present results from an individual-based population model (IBM) based on a peer-reviewed published[1] model (Bull et al. 2009) used to assess the viability of the gray wolf (*Canis lupus*; hereafter, wolf) population in Oregon. When parameterizing our model, we relied on peer-reviewed published estimates of wolf vital rates. Our population model, the assumptions made in the model, and vital rates used in the model were obtained or supported by peer-reviewed published literature. We compared estimates of parameters used in our model to those observed in Oregon from 2009-2014 and concluded our model used to project future population growth was conservative compared to growth rates currently observed in Oregon. We used a starting population size of 85 wolves which was based on wolf population counts conducted by the Oregon Department of Fish and Wildlife (ODFW) through July 2015. This value is higher than reported end of year counts (ODFW 2015) because additional wolves that were present in Oregon at the start of the biological year (i.e., April) were documented after January 31, 2015. Consequently, results presented in this report differ slightly from those presented to the Oregon Fish and Wildlife Commission on April 24, 2015. We used linear regression models to determine the relative effect of model parameters on intrinsic population growth rates of wolves. We assessed population viability using two metrics: 1) the cumulative proportion of simulations that had fewer than 4 breeding pairs (defined as conservation-failure) and 2) the cumulative proportion of simulations that had fewer than 5 wolves (defined as biological-extinction).

Increased pup ($\beta = 0.045$), yearling ($\beta = 0.024$), and adult ($\beta = 0.019$) survival resulted in increased population growth rates. Population growth rates of wolves were most sensitive to environmental stochasticity, which we modeled through the use of a prey multiplier ($\beta = 0.088$). The increased environmental stochasticity incorporated in the model by the prey multiplier increased variation in survival rates of wolves by up to 20% annually, which caused this parameter to have a large effect on population growth rates. Increased levels of illegal ($\beta = -0.027$) and legal ($\beta = -0.028$) anthropogenic mortality had negative effects on population growth rates. Increased mean litter size had a positive effect on population growth ($\beta = 0.049$). Increased mortality rates for dispersing wolves had a negative effect on population growth ($\beta = -0.026$) while increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on population growth ($\beta = 0.034$). Combined, these results highlight the importance of survival, reproduction, and human-caused mortality on population growth rates of wolves. Other parameters considered in our model had minimal effects on population growth rates or viability of wolves. Maintenance of high natural survival and reproductive rates of wolves while minimizing human-caused mortality will help ensure the long-term persistence of the species in Oregon.

Our baseline model indicated there was a 0.05 (95% CI = 0.01 – 0.09) probability of wolves falling below the conservation-failure threshold and a 0.01 (95% CI = 0.00 – 0.03) probability of falling below the biological-extinction threshold in the next 50 years. When we parameterized our model with vital rates required to match population growth rates observed in Oregon from 2009-2014, we did not observe any situations where the simulated wolf population fell below the conservation-failure or biological-extinction thresholds. Consequently, we contend future risk of conservation-failure falls between estimates from our baseline model (0.05 probability of conservation-failure) and our model parameterized with vital rates required to

[1] Peer-reviewed published literature is papers published in scientific journals or books that have been reviewed and deemed acceptable from a study design, analysis, and interpretation standpoint by one or more peers prior to being published.

match observed population growth rates of Oregon's wolves from 2009-2014 (0.00 probability of conservation-failure). Regardless of model parameterization, our results suggested it is extremely unlikely wolves in Oregon will be at risk of extirpation over the next 50 years.

INTRODUCTION

The Oregon Wolf Conservation and Management Plan (hereafter, Oregon Wolf Plan; Oregon Department of Fish and Wildlife [ODFW] 2010) outlines phases of wolf (*Canis lupus*) recovery and criteria for delisting wolves as required by Oregon's Endangered Species Act (ESA). In January 2015, Oregon's wolf population successfully reached population objectives for Phase I to allow ODFW to propose that the Oregon Fish and Wildlife Commission consider delisting of wolves from Oregon's ESA (ODFW 2010). Quantitative models are commonly used to assess population dynamics and extinction risk of threatened and endangered species (Boyce 1992, Morris and Doak 2002) and can provide insight into the first and second delisting criteria outlined in the Oregon ESA:

1. "The species is not now (and is not likely in the foreseeable future to be) in danger of extinction in any significant portion of its range in Oregon or in danger of becoming endangered"; and
2. "The species natural reproductive potential is not in danger of failure due to limited population numbers, disease, predation, or other natural or human related factors affecting its continued existence".

To address these delisting criteria, we modified a peer-reviewed quantitative model (Bull et al. 2009) to provide insight into dynamics of Oregon's wolf population to help inform any future decisions regarding wolves and Oregon's ESA.

To make accurate predictions of future population growth, quantitative population models should accurately reflect biological processes of the species being modeled. Individual-based models (IBM) were previously used to model wolf population dynamics (Vucetich et al. 1997, Haight et al. 1998, Nilsen et al. 2007, Bull et al. 2009) because they can most accurately represent the unique social and breeding structure of wolf populations. We modified an IBM developed to assess effects of management on wolf populations in Norway (Bull et al. 2009) to meet our needs to assess population viability of wolves in Oregon. Our modeling approach focused on determining effects of key biological processes, uncertainty in model parameters, and management actions on wolf population dynamics and viability.

METHODS

We used an IBM modified from Bull et al. (2009) to assess future population dynamics of wolves in Oregon. The primary modifications to the Bull et al. (2009) were to change the vital rate values of wolves in North America based on our literature review. The biggest modification we implemented in our model was to alter the way reproduction was handled in the model. Bull et al. (2009) assigned pairs of wolves a probability of producing a large or small litter and assumed all dominant females would produce pups each year. In our modified model, we assumed not all dominant females would produce pups in a given year, but litter sizes would be determined from a single distribution each year. We modified the Bull et al. (2009) to include two types of catastrophes (see description below) and allowed dispersing wolves to leave Oregon and have increased risk of mortality during dispersal (see description below). All of these additional modifications provided increased reality to the model and would provide a more

Commented [DK1]: Why did you make this modification? What information did you have to support this change?

conservative view of wolf population growth. Other than these minor changes, our code used to implement the model was identical to the peer-reviewed model developed by Bull et al. (2009).

Our model incorporated 6 demographic processes that affected wolf populations that were modeled in the following order (Fig. 1): 1) survival and transition between age classes, 2) dispersal and emigration out of Oregon, 3) territory establishment by dispersing wolves, 4) immigration from outside Oregon, 5) anthropogenic mortality, and 6) reproduction. Our IBM included 5 distinct social classifications of wolves (Fig. 2) and transitions between social classifications were governed by distinct model parameters (Table 1).

Our IBM was coded and implemented in R (R Development Core Team 2012). To generate our results, we conducted 100 realizations of population growth over 50 years. We utilized 100 realizations of population growth because this allowed the confidence intervals to be acceptably narrow, but not excessively narrow to indicate a false sense of precision in our estimates of population viability Bull et al. (2009). We incorporated environmental stochasticity in our model by randomly drawing vital rate values from a uniform distribution with a predefined mean and standard deviation at each time step of the simulation (Table 1). Unless otherwise noted, vital rates were applied at an individual level, which inherently incorporated demographic stochasticity into our model. For each simulated population we tracked parameter values, population size and growth rates, and number of breeding pairs (i.e., pairs of wolves with ≥ 2 pups surviving the biological year) at each time step.

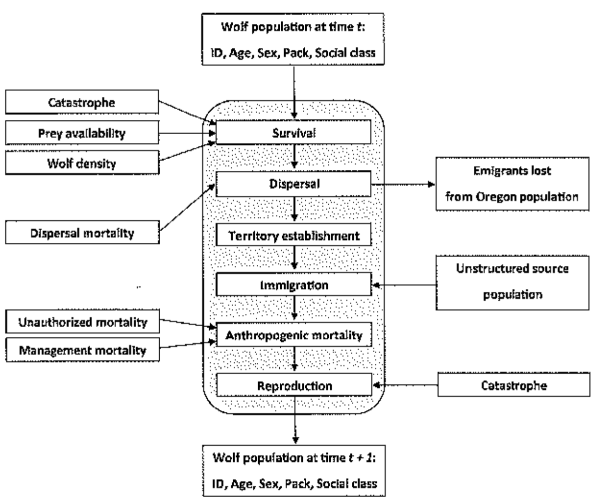

Figure 1. The order in which 6 key demographic processes are implemented in an individual-based population model to assess population viability of wolves in Oregon.

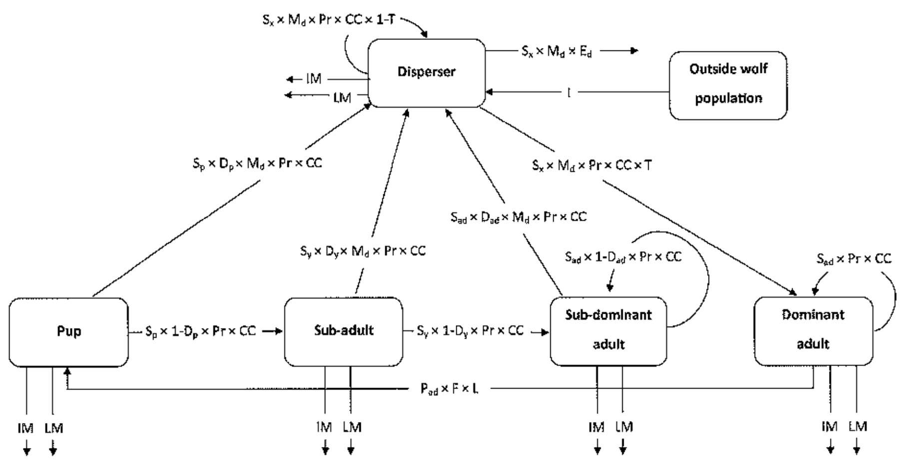

Figure 2. Visual representation of the life cycle of wolves implemented in an individual-based population model to assess population viability of wolves in Oregon. The diagram represents probabilities of transitions between age- and social-classes of wolves. Parameters used in transition calculations are defined in Table 1.

Table 1. Parameter values used to predict future population growth of wolves in Oregon compared to values required to match observed growth rates of Oregon's wolf population from 2010-2014. Values used at each time step of the analysis were randomly drawn from a uniform distribution within the specified standard deviation (SD). Mean values are probabilities unless otherwise stated. All estimates used in our baseline model were obtained or supported by peer-reviewed literature.

Parameter	Notation	Baseline model values		Values required to match growth rates observed in Oregon (2009-2014)	
		Mean	SD	Mean	SD
Pup survival rate	S_p	0.68	0.15	0.75	0.05
Yearling survival rate	S_y	0.81	0.06	0.91	0.04
Adult (2 to 7-yrs old) survival rate	S_{ad}	0.88	0.04	0.91	0.04
Old adult (8 to 9-yrs old) survival rate	S_{old}	0.63	0.11	0.85	0.05
Pup dispersal rate	D_p	0.15	0.05	0.15	0.05
Yearling dispersal rate	D_y	0.65	0.05	0.65	0.05
Non-breeding adult dispersal rate	D_{ad}	0.65	0.05	0.65	0.05
Proportion of dispersing wolves that survive	M_d	0.90	0.05	0.97	0.02
Proportion of dispersing wolves that leave Oregon	E_d	0.115	0.03	0.115	0.03
Probability of dispersing wolf establishing a territory	T	0.75	0.10	0.75	0.10
No. of immigrants arriving annually from outside Oregon	I	3	2	3	2
Pregnancy rate for dominant females	P_{ad}	0.95	0.02	0.95	0.02
Litter size	L	5	3	5	3
Proportion of wolves removed by illegal mortality	IM	0.05	0.03	0.02	0.01
Proportion of wolves removed by legal mortality	LM	0.05	0.03	NA	NA
Prey index multiplier (adjustment to survival rates)	Pr	1.00	0.10	1.00	0.10
Density dependent threshold (no. of wolves)	CC	1,500	NA	1,500	NA
Probability of population wide reduction in survival	S_{cas}	0.01	NA	NA	NA
Probability of pack-specific reproductive failure	R_{cas}	0.05	NA	0.05	NA

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Model Parameters

Currently, Oregon has minimal vital rate information to parameterize a population model, and the potential for sampling bias or error from small sample sizes (i.e., observed data does not match the expected outcome) could cause inappropriate conclusions to be reached by using this information. Furthermore, estimated vital rates from protected wolf populations that are colonizing or recovering are unlikely to match those of established wolf populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Oregon's wolf population is transitioning from a recovering to established population. Vital rates used in our IBM were obtained from peer-reviewed published literature that presented results from studies conducted primarily in established wolf populations. Consequently, whenever possible, we compared vital rates observed in Oregon to those reported in peer-reviewed published literature to determine the degree to which vital rates used in our model were representative of those observed in Oregon since 2009. In general, most vital rates used in our baseline model were conservative compared to those observed in Oregon from 2009-2014 (Table 1). Using conservative vital rate estimates allowed us to err on the side of caution (e.g., the precautionary principle; Myers 1993, Meffe et al. 2006) and prevent overly optimistic conclusions of wolf population viability.

Commented [DK3]: How? Higher survival and repro in "protected" populations compared to unprotected? Clarify the direction of the difference in vital rates between protected and unprotected populations.

Starting Population Size.–We utilized minimum count data collected by ODFW to determine our starting population size and structure prior to wolves producing pups in April 2015. These counts were higher than final survey numbers reported at the end of 2014 (ODFW 2015) because ODFW identified additional wolves after the report was submitted. Based on wolf survey information collected through July 2015, a minimum of 85 wolves were present in Oregon at the start of April. We acknowledge additional, undocumented wolves may be present in Oregon, but we relied on known individuals when developing our model. Counts identified 16 pairs or packs of wolves in addition to 3 individual wolves present in Oregon. Whenever possible, we used known data to assign pack, age, social class, and sex of wolves and randomly assigned these attributes when unknown. Newly documented pairs of wolves were assumed to consist of a male and female and both individuals were assigned dominant-adult status.

Survival.–Baseline survival rates of wolves used in our model represented survival in the absence of anthropogenic mortality (e.g., poaching, management removals). We adjusted survival rates reported in peer-reviewed literature to account for anthropogenic mortality using the following approach: 1) determine the overall mortality rate (1 – survival rate), 2) estimate the anthropogenic mortality rate as the product of proportion of total mortalities caused by humans and the overall mortality rate, and 3) sum the estimated anthropogenic mortality rate and the reported survival rate. As an example, Smith et al. (2010) reported an annual survival rate of 0.750 with 54% of mortality attributable to legal or illegal actions by humans. The anthropogenic mortality rate was 0.135 (1-0.750 × 0.540), which resulted in a 'natural' survival rate of 0.885 (0.750 + 0.135). In instances where authors directly reported cause-specific mortality rates (e.g., Wydeven et al. 1995), we summed reported survival and anthropogenic mortality rates to obtain an adjusted estimate of survival. After adjusting survival rates reported in peer-reviewed literature (Table 2) to account for human-caused mortality we arrived at a survival rate of 0.88 (± 0.04 SD) of adult wolves (2-7 years old; S_{ad}) for use in our model.

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Using the largest sample size of radio-collared wolves reported in peer-reviewed published literature, Smith et al. (2010) reported that yearling wolves had a 54.9% higher risk ($1.0012^{365} = 1.549$) of mortality than adult wolves over 365 days. We adjusted the mean survival rate of 0.88 for adult (2-7 years) wolves by the increased hazard rate reported by Smith et al. (2010) to calculate a survival rate of 0.81 for yearling wolves (S_y; 1-[(1-0.88) × 1.549]; Table 1).

This may present an overly pessimistic view of resident yearling wolf survival, because yearlings have high dispersal rates (Gese and Mech 1991) and dispersing wolves were found to have higher risk of mortality (Smith et al. 2010). In our model, we utilized a separate mechanism to account for increased mortality of dispersing wolves (see below) and we recognize our estimates of yearling survival may be negatively biased. Senescence, observed through decreased survival at older ages is common for large mammals (Loison et al. 1999, Gaillard et al. 2000, Clark et al. 2014), but this phenomenon is not well documented in peer-reviewed published literature on wolves. To account for the potential of senescence, we used an annual survival rate for wolves > 7 years old of 0.63 as reported by Cubaynes et al. (2014), which we adjusted to 0.67 for use in our model (S_{old}) to account for anthropogenic mortality. Wolves ≥ 10 years of age had a survival rate of 0.00 in our model. While free-ranging wolves can live longer than 10 years, most wolves are typically no longer reproductively active after this age (Fuller et al. 2003, Kreeger 2003) and will contribute little to population growth and viability.

Commented [DK5]: What about reproduction? At the end of this paragraph you suggest reproductive senescence occurs in old wolves (so they may survive, but not reproduce).

Estimates of non-pup survival used in our model were lower than observed to date in Oregon. Using known-fate survival analysis (White and Burnham 1999) on a sample 23 of wolves radio-collared in Oregon from 2009-2014, we estimated an annual survival rate of wolves > 6 months old of 0.91. Three collared wolves died during this timeframe, one of which was removed by ODFW and an additional wolf was illegally shot resulting in 66% of mortality being attributable to humans. Adjusting survival rates to account for anthropogenic mortality results in a survival rate of 0.97, which is substantially greater than the adult (0.88) and yearling (0.81) survival rates used in our model.

Table 2. Annual survival rates and human-caused mortality rates of non-pup wolves reported in peer-reviewed literature. Survival rates were estimated from known fates of radio-collared wolves unless otherwise noted. Adjusted survival rates represent survival rates on non-pups in the absence of human-caused mortality.

Source	Reported survival	Human-caused mortality rate	Adjusted survival rate[a]
Adams et al. (2008)	0.79	0.09[b]	0.89
Cubaynes et al. (2014)	0.80	0.04[c]	0.84
Fuller (1989)	0.62	0.26[c]	0.88
Hayes and Harestead (2000)	0.84	0.02[b]	0.86
Peterson et al. (1984)	0.67	0.26[b]	0.93
Smith et al. (2010)	0.75	0.14[b]	0.89
Webb et al. (2011)[d]	0.62	0.34[b]	0.96
Wydeven et al. (1995)	0.61	0.28[b]	0.89
Wydeven et al. (1995)	0.82	0.04[b]	0.86
Mean	0.72	0.16	0.88

[a] Sum of reported survival and human-caused mortality rate.
[b] Mortality rate calculated as the product of overall mortality rate (1-survival) and proportion of mortalities caused by humans.
[c] Human-caused mortality rate directly reported by authors.
[d] Apparent survival rates estimated from mark-recapture data.

Estimates of survival of wolf pups from birth to 6 months are highly variable and are usually estimated by comparing pup counts at den or rendezvous sites to *in utero* fetal counts of harvested females. Based on pup counts from ~~a review of~~ peer-reviewed published literature (Table 3), we determined mean survival rates of wolf pups from birth to 6 months~~, determined from pup counts,~~ were 0.73. Estimation of survival using pup count data assumes that all pups alive and presented are counted each year (i.e., ~~with~~ a detection probability = ~~of~~ 1.0), which is unrealistic, so ~~and this method will~~ it's likely ~~produce negatively biased~~ that estimates of survival over the first 6 months of life based on this method are negatively biased. In general, radio-telemetry studies have indicated pup survival is similar to adult survival during months 7-12 after birth (Peterson et al. 1984, Fuller 1989, Adams et al. 2008). Consequently, we used 6 month survival rate of adults (~0.94), calculated as the square root of annual survival, to approximate survival of pups from ages 7-12 months. We used the product of summer survival rates times the 6 month survival rate of adult wolves as the annual estimate of pup survival (S_p) in our baseline model ($0.73 \times 0.94 = 0.68$; Table 1).

Commented [DK6]: But you used them anyway right? Might need to state that explicitly……

Table 3. Survival rates of wolf pups from birth to six months reported in peer-reviewed literature. Unless otherwise noted, survival was estimated by comparing pup counts six months after birth to *in utero* litter sizes. Annual survival rates calculated as the product of 6 month survival rates of pups and 6 month survival rates of adult wolves used in our model (0.88).

Source	Survival from birth to 6 months	Annual survival[a]
Fuller (1989)[b]	0.58	0.55
Mills et al. (2008)[c]	0.83	0.78
Fritts and Mech	0.57	0.53
Fuller and Keith (1980)	0.69	0.65
Adams et al. (2008)	0.81	0.76
Hayes and Harestead (2000)[d]	0.80	0.75
Petersen et al. (1984)	0.80	0.75
Ballard et al. (1987)	0.82	0.77
Mech et al. (1998)[e]	0.91	0.85
Hayes et al. (1991)[f]	0.48	0.45
Mean survival	0.73	0.68

[a] Annual survival is the product of survival from birth to 6 months and the 6 month survival rate of adult wolves used in our model.
[b] Survival rate reported was estimated over 8 month period using pup counts. Monthly survival rate was 0.9135 and survival over six months was 0.58.
[c] Survival was estimated with implant transmitters from Jun-Nov. Used monthly survival rates from this period to estimate 6 month survival rate.
[d] Survival estimated on an annual interval. Used the square root of reported survival rates to estimate survival from birth to 6 months.
[e] Survival estimate over first 4 months of life. Extrapolated to 6 months.
[f] Heavily exploited wolf population.

We compared the pup survival rates used in our model to pup count data collected in Oregon during winter surveys conducted from 2009-2014. During this time frame, 30 potential reproductive opportunities were documented. Of these 30 potential reproductive opportunities, 3 were censored because final pup counts were not completed. Assuming wolves give birth to an average of 5 pups per litter (Fuller et al. 2003), we calculated a total of 135 pups born from these 27 reproductive opportunities. Minimum pup counts conducted in December of 2009-2014 indicated a minimum of 82 pups across all years. Using this information we arrived at a minimum observed survival rate of 0.61 (95% CI = 0.53 – 0.69), which is lower but within in the range of the pup survival rate used in our model (0.68 ± 0.15; Table 1).

When implementing our model, annual survival rates were independently calculated for each age class by randomly drawing a survival rate from a uniform distribution with a predefined mean and standard deviation (Table 1). Survival rates of wolves were age-specific and were not influenced by social status of the individual (e.g., survival rates for a 4-year old sub-dominant adult were identical to survival rates for a 4-year old dominant adult). Survival rates were modeled at an individual level, with each individual having an independent probability of survival at each time step.

Density-dependence.– When populations surpassed a predefined population threshold, annual survival rates, regardless of age, were multiplied by the ratio of the threshold population size and current wolf population size. The specified threshold was implemented to account for the importance of density-dependence on population dynamics (Morris and Doak 2002), but does not represent an expected number of wolves in Oregon in future years. When implemented in our model, the density-threshold represents an ~~arbitrary~~ biological threshold where wolves begin to self-regulate through intraspecific strife or are limited by available prey.

Commented [DK7]: This stuff gives me the most heartburn, as I think it's probably the numbers that are fraught with the most uncertainty. The question of carrying-capacity and when/where density dependence thresholds kick in are poorly understood for most species, including wolves in Oregon. I think the best you can do is be very clear about source of the numbers you're using and the assumptions you're making. I've noted places where I think you need to shore up justifications and/or provide more information.

Commented [DK8]: This isn't really "arbitrary" is it? It is based on some information and assumptions right (i.e., all the information that follows)?

Larsen and Ripple (2006) created a habitat suitability map for wolves in Oregon and found that a maximum of 1,450 wolves could occupy Oregon. This value increased to 2,200 wolves if industrial timberland in western Oregon was classified as suitable wolf habitat. Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000\ \text{km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 128,000 elk distributed across 151,500 km^2 of summer range habitat (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 2.53 (128,000 × 3/151,500). Based on this value maximum wolf densities were estimated to be 11.79 wolves/1,000 km^2 of summer range elk habitat. This would result in a total population of 1,780 wolves within 151,500 km^2 of elk summer range habitat in Oregon. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

Commented [DK9]: Huh? What does a value of "3" represent? What is the range and/or what values would you give to other ungulate species?

Commented [DK10]: So you're assuming wolves only eat elk? You should be clear that this is the assumption you're making and why (i.e., it's a primary prey source and you have the best population data for elk in Oregon compared to other prey species).

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, Oregon's elk population is approximately 128,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 2,777.6 × 10,000 kg of primary prey biomass available to wolves across Oregon and a maximum population estimate of approximately 1,722 wolves.

Both the Fuller et al. (2003) and Carbone and Gittleman (2002) equations produce similar estimates of wolf population size and fall within the range reported by Larsen and Ripple (2006). However, these estimates were calculated under the assumption wolves will not cause reductions in prey populations. To account for this possibility, we used a conservative density-threshold (CC) of 1,500 wolves in our model. Again, it should be noted, the density-threshold represents

Commented [DK11]: So what sort of bias can this assumption cause? An overestimate of carrying capacity for wolves in Oregon?

an estimate of maximum potential wolf population size, not a management objective for wolves in Oregon.

Prey multiplier.–Wolf-prey interactions can influence wolf densities and population dynamics (Fuller et al. 2003). We lacked sufficient data to explicitly model wolf-prey interactions and instead used a simplified approach described in the peer-reviewed published paper by Bull et al. (2009) where a stochastically generated a prey multiplier value (Pr) was used to represent changes in either prey abundance or vulnerability (e.g., increased vulnerability during severe winters). The prey multiplier represented environmental stochasticity in our model. At a value of 1.0, the prey multiplier represented baseline prey availability or vulnerability. Each year of the simulation, the prey multiplier had a 1 out of 3 chance of increasing, decreasing, or remaining the same, respectively. In years the prey multiplier increased or decreased, the maximum change was restricted to 0.10. The prey multiplier was bounded between 0.90 and 1.10 values generated outside this range were truncated to the maximum or minimum value. Survival rates used in the model were calculated as the product of randomly drawn survival rates and the prey multiplier after accounting for any density-dependent effects.

Commented [DK12]: Another big source of uncertainty……

Dispersal and Emigration.–We assumed dominant wolves would maintain their territory and breeding positions until their death. In the event that both dominant animals in a pack died, all remaining pack members would disperse. This approach was partially used for simplicity of model implementation, but was also supported in peer-reviewed literature (Fuller et al. 2003). For example, Brainerd et al. (2008) found that in instances where both breeding wolves were lost, 85% of packs dissolved, and only 9% of packs reproduced the following year.

Sub-dominant wolves that survived the year had a probability of dispersing from their existing territory, which was dependent on age and breeding status (Table 1). Age-specific dispersal rates used in our model (D_p, D_y, D_{ad}) were obtained from literature (Potvin 1988, Fuller 1989, Gese and Mech 1991). We assumed non-breeding adults had similar dispersal rates as yearlings (Fuller et al. 2003). Survival rates of dispersing individuals were reduced (M_d) to account for increased mortality risk of wolves during dispersal (Table 1; Peterson et al. 1984, Fuller 1989, Smith et al. 2010). Smith et al. (2010) found dispersing wolves had a 38.9% higher risk of mortality over 365 days than resident wolves. After accounting for this increased risk, survival rates of dispersing adult wolves would be 0.83 with the ratio of dispersing versus resident adult survival rates of 0.94 (0.83/0.88). To be conservative, we lowered this value to 0.90 (± 0.05 SD) for use in our model, which is interpreted at 10% of dispersing wolves die during the dispersal process.

We used a spatial simulation to estimate emigration rates using peer-reviewed published estimates of dispersal distances of wolves (Fritts and Mech 1981, Fuller 1989, Gese and Mech 1991, Wydeven et al. 1995). We generated 10,000 random dispersal paths that started at a random location within summer range elk habitat (i.e., potential wolf habitat). We simulated dispersal paths using correlated random walks with the movement.simplecrw function in the Geospatial Modeling Environment (Beyer 2012) by selecting a random bearing from a uniform distribution (0 - 359°) and a random dispersal distance from normal distribution with a mean of 75 km (± 30 SD). We calculated emigration rates (E_d) as the proportion of simulated dispersal paths that terminated outside Oregon. Mean emigration rates were estimated to be 0.115 (Table 1). We estimated a standard deviation of the mean values calculated from 100 bootstrap samples that each contained 100 random dispersal paths. The estimated standard deviation of the mean of

these 100 samples was 0.03. Emigration was effectively treated as additional mortality in our model (i.e., these individuals were removed from the simulated population).

Territory Establishment.–Dispersing wolves ≥ 2 years old were assigned a probability of establishing a territory. Boyd and Pletscher (1999) found that 57% of dispersing wolves successfully found a mate the next breeding season after they dispersed. This value equates to the joint probability of two wolves establishing a territory. Independently, the probability of a dispersing wolf establishing a territory (T) would be 0.75 ($\sqrt{0.57}$), which we used in our model. Wolves that did not successfully establish a territory remained in the pool of dispersers until the following year. Those individuals that successfully established territories would first fill vacant alpha positions of the correct sex in established packs. If no alpha positions were available at established packs, dispersing wolves would then establish a new territory and maintain that position until they died or a mate joined them at the territory.

Immigration.–We assumed wolves from the extant Rocky Mountain wolf population would be available to immigrate into Oregon. For model simplification, we assumed the wolf population outside Oregon was unstructured and would produce a steady, but limited, stream of immigrants. We assumed 3 wolves (± 2 SD) would immigrate (I) annually into Oregon from surrounding populations. We assumed all immigrating wolves were sub-adults because a review of peer-reviewed literature indicated this age class is most likely to engage in dispersal behavior (Fuller 1989, Gese and Mech 1991, Fuller et al. 2003). Individuals arriving in the Oregon population were randomly assigned a sex assuming parity among dispersers (Gese and Mech 1991).

Commented [DK13]: Where did this value come from?

Anthropogenic Mortality.–Anthropogenic mortality was incorporated in the model under two forms: legal and unauthorized mortality. Unauthorized mortality represented all sources of anthropogenic mortality (e.g., poaching, vehicle-killed individuals) excluding mortalities authorized by ODFW under current laws. Legal removals included any administrative removals authorized by ODFW (e.g., livestock damage, human safety, incidental take). Anthropogenic mortality was modeled using a two-step process where unauthorized mortality was modeled first and followed by legal mortality. A proportion of the total population that remained after accounting for natural mortality events would be removed each year by each anthropogenic mortality source (Table 1). Anthropogenic mortality was applied independent of age, social status, or pack membership. Effectively, this approach treats anthropogenic mortality as a reduction in survival. For example, using an annual adult survival rate of 0.88, survival rates would be reduced to 0.79 (0.88 × 0.95 × 0.95) if 5% of the population was removed for both legal and unauthorized mortality, respectively.

Commented [DK14]: Again, need to explain why you felt it was important to model this source of mortality separately from other sources. Maybe move this entire section up to follow the "survival" section, and include a justification that covers both the separation of anthropogenic mortality from all other sources, and the adjustment to survival.

From April 2009 to March 2015, ODFW has collected 54 wolf-years of data from radio-collared individuals. During this time, 1 radio-collared wolf was illegally killed and 1 radio-collared wolf was removed by ODFW, for a removal rate of 0.02 for each mortality source (ODFW, unpublished data). Due to the potential bias of radio-collared wolves being avoided by poachers, we increased the illegal mortality (IM) value to 0.05 (± 0.03 SD). To be conservative and allow for the potential of increased levels of lethal control actions, we used a value of 0.05 (± 0.03 SD) for legal mortality (LM) of wolves in our model (i.e., between 2-8% of wolves would be randomly removed from the population each year for management related actions).

Reproduction.–Only established wolf packs with a dominant pair of adults were allowed to reproduce. We were unable to find peer-reviewed estimates of pregnancy rates of dominant females in published literature; however, it is biologically unrealistic to assume all pairs of wolves successfully give birth to pups each year (i.e., female do not always become pregnant).

Commented [DK15]: Really? Plenty of animal systems where "breeder" breed every year, so this must be based on some information that suggests that might not be the case for wolves. Maybe pregnancy rates or breeding propensity in other canids (coyotes or foxes)?

We assumed pregnancy rates of dominant females (P_{ad}) would be 0.95 (± 0.02 SD; Table 1). While evidence exists of multiple females producing pups within a pack, this is a rare occurrence and usually only occurs in extremely large packs (Mech 1999), and we assumed only one litter of pups would be born in packs with a dominant pair. The number of pups produced by pregnant females (L) was drawn from a uniform distribution ranging from 2-8 (Table 1) based on a review of literature (see summary in Fuller et al. 2003).

Catastrophes.–We included two catastrophes in our model. The first was modeled at the pack level as the probability of a pack having complete reproductive failure within a year (R_{cas}). Probability of reproductive failure was independent among packs and years. This approach was used to simulate the potential effects of diseases (e.g., canine parvovirus), which are known to negatively affect pup survival and recruitment (Mech and Goyal 1993, Almberg et al. 2009), where most or all pups die when exposed to the virus (Mech et al. 2008). We assumed complete reproductive failure had a probability of occurrence of 0.05 within each pack during each year of the simulation (i.e., one out of 20 litters will be subjected to complete reproductive failure). Packs that had complete reproductive failure were assigned a litter size of 0 (i.e., even if pups were produced they would all die before 1 year of age).

Commented [DK16]: Based on what? There must be some information that that helped you decide on this failure rate.

Our second catastrophe was modeled at the population level, where each year of the simulation there was a probability of a population wide reduction in survival (S_{cas}). This approach was used to represent extremely rare, range wide events that may affect wolf populations (e.g., disease, abiotic conditions, prey population crashes). We used a mean interval of 100 years between disturbance events, with each year having an independent probability of a disturbance event occurring. During years where a catastrophe event occurred, survival rates of all wolves in the population were reduced by 25%.

Assessment of Population Viability

We assessed population viability using two measures. The Oregon Wolf Plan defined a threshold of 4 breeding pairs for 3 consecutive years as a guideline to consider delisting wolves from the Oregon ESA (ODFW 2010). Consequently, we defined "conservation-failure" as a simulated population that fell below 4 breeding pairs. For each simulated population, we determined which time-step, if any, that the population dropped below the conservation-failure threshold. Simulated populations that dropped below the conservation-failure threshold were considered failures in all remaining time steps. We calculated risk of conservation-failure as the cumulative proportion of simulated populations that had < 4 breeding pairs.

We used a threshold of < 5 wolves as our metric of "biological-extinction". In simulations with < 5 wolves, the extant population would effectively be extirpated and immigrants from outside sources would be maintaining the Oregon population. For each simulated population, we determined the time-step, if any, that the population dropped below the biological-extinction threshold. Once the population dropped below this threshold it was determined to be biologically-extinct for all remaining time steps. We calculated biological-extinction rates as the cumulative proportion of simulated populations that < 5 wolves.

Model Validation

To validate our baseline model, we conducted a set of 100 realizations of population growth over 5 years, where the starting population size was the number of wolves present in Oregon at the end of 2009 (N = 14 wolves). We calculated the mean number of wolves and breeding pairs from simulations and compared these values to population counts conducted by ODFW from 2010-2014. Survival rates used in our baseline model were more conservative than observed in Oregon from 2010-2014. Consequently, we conducted a second set of simulations

where we parameterized our model with vital rates required to match observed population growth rates in Oregon from 2009-2014 (see Table 1 for differences between vital rates in the two scenarios). Using observed vital rate values in our model would allow us to determine if our overall model structure allowed accurate estimation of population growth under known conditions.

Sensitivity Analysis

Effects of Stochastic Parameters.– We used *r* (i.e., intrinsic rate of increase) as the dependent variable in a linear regression model where stochastically varying parameters and relevant interactions were used as independent variables. We conducted 200 realizations of population growth over a 5-yr period which resulted in 1,000 random combinations of parameter values and associated intrinsic growth rates (*r*). The sensitivity analysis was limited to a 5-yr span because allowing population simulations to last longer than 5-yrs could cause some simulations to reach the density-threshold of 1,500 wolves and confound the effect of parameter variation and density-dependence on *r*. For each simulation, the starting population was assumed to be 120 wolves equally distributed among 20 packs. We used this starting population size because at extremely small population sizes (e.g., $N < 10$) immigration of wolves could produce biologically unreasonable population growth rates (e.g., $\lambda > 2.0$) and confound our ability to detect an effect of parameters on *r*. Prior to running our regression model, all independent variables were standardized (standardized value = [observed value - mean value]/standard deviation) to allow direct comparisons between results. We used an alpha level of 0.05 to determine significance of parameters and the sign and slope of beta coefficients to determine the strength and relative effect of the parameter on *r*.

Effects of Static Parameters.–Starting population size, density-threshold, and frequency of survival and reproductive catastrophes were static parameters in our model and the effects of these were not included in our regression analysis used to determine the relative effects of parameters on *r*. Consequently, we conducted additional simulations where values of static parameters differed among simulations. Each simulation used 100 realizations of population growth over 50 years and was parameterized with baseline values except for changes in the static parameter of interest. We conducted 4 simulations to determine the effect of starting population sizes of 50 wolves, the known existing Oregon wolf population (N = 85; baseline value), 100 wolves and, 150 wolves. Simulations with starting populations of 50, 100, and 150 wolves were structured as follows: 1) each wolf belonged to a pack and each pack had 5 members with 2 of those members being dominant adults and 2) sex, age, and social class of remaining wolves were randomly assigned. To determine the relative influence of the density-threshold on population viability of wolves, we conducted a set of simulations where used a density-threshold of 100, 250, 500, 1000, and 1500 (baseline value) wolves. We conducted a set of 3 simulations where we investigated probabilities of individual pack reproductive failure of 0.05 (baseline value; once every 20 litters), 0.10 (once every 10 litters), and 0.20 (once every 5 litters). We investigated the effects catastrophic reductions in survival at year-specific probabilities of 0.01 (baseline value; once every 100 years), 0.02 (once every 50 years), 0.05 (once every 20 years), and 0.10 (once every 10 years).

Effects of lethal control of wolves

Legal, anthropogenic mortality is the parameter included in our model over which ODFW has the most control. To address the effects of varying rates of legal wolf removal on wolf population viability we conducted a set of 4 simulations where mean legal mortality rates and associated standard deviations varied among simulations while all other model parameters

were left at baseline values (Table 1). The following values were used as mean values (± SD) to represent legal anthropogenic mortality rates in the 4 simulations: 0.00 (± 0.00), 0.05 (± 0.03), 0.10 (± 0.06), and 0.20 (± 0.12). These levels of legal mortality rates were in addition to illegal mortality rates which were set at a mean value of 0.05 (± 0.03) during all simulations.

Our baseline model assumes legal removals will be implemented through random removal of individual wolves. However, the potential exists that lethal control actions could take place across entire wolf packs, rather than individuals. Consequently, we also conducted a simulation where legal removal of wolves would occur at a pack rather than individual level. We assumed the proportion of packs removed per year would be the same as the proportion of individuals removed in our baseline simulation (0.05 ± 0.03). After completion of simulations, we compared the results to the baseline simulation to determine what effect, if any, pack removal would have on population dynamics compared to individual removal.

RESULTS

Model Validation

Our baseline model resulted in underestimates of population size (Fig. 3a) and number of breeding pairs (Fig. 3b) compared to population count data collected in Oregon from 2010-2104. When our model was parameterized with survival rates of wolves observed from 2009-2014 (Table 1) the simulation results closely approximated observed population size and number of breeding pairs. Consequently, survival rates used in our baseline model are cautious compared to past survival rates in Oregon; however, the ability of the model to correctly predict past population dynamics when parameterized with observed survival rates suggests other parameters included in the model accurately portray wolf population dynamics in Oregon. Our baseline model predicted lower population growth compared to the model parameterized with survival rates observed from 2009-2014. This suggests our baseline model will underestimate wolf population growth and viability if survival rates from 2009-2014 are observed into the future.

Assessment of Population Viability

Using our baseline model, simulated wolf populations increased an average of 7% (i.e., $\lambda = 1.07 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.05 (95% CI = 0.01 – 0.09) probability of the population dropping below the conservation-failure threshold (Fig. 4). Most conservation-failures (3 out of 5) occurred within the first 10 years and by year 20, no additional populations passed the threshold. Of the five simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 7, 20, 39, 84 and 194 breeding pairs in year 50 of the simulation, respectively. There was a 0.01 (95% CI = 0.00 – 0.03) probability the simulated population dropped below the biological-extinction threshold over the next 50 years. The single simulated population that dropped below 5 individuals recovered to 360 individuals by year 50.

Using observed survival rates of wolves from 2009-2014 in our population model resulted in no scenarios where wolf populations dropped below the conservation-failure or biological-extinction thresholds. Our baseline model may be more likely to represent future population dynamics of wolves, but may be overly pessimistic, especially in the near future, given recently observed survival rates of wolves in Oregon. Consequently, we contend future risk of conservation-failure likely falls somewhere between our baseline model (0.05) and our model parameterized with vital rates required to match observed population growth rates from 2009-2014 (0.00). Our model results suggest it is extremely unlikely (≤ 0.01 probability) wolves in Oregon will be at risk of extirpation over the next 50 years.

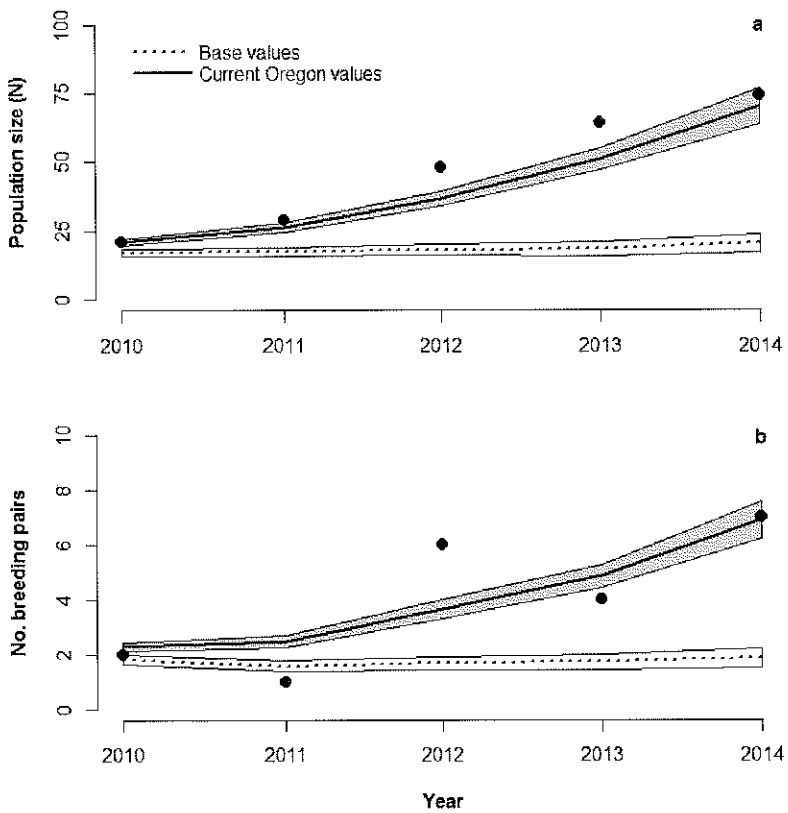

Figure 3. Comparison of (a) simulated mean population sizes compared to minimum population sizes observed in Oregon from 2009-2014 and (b) simulated number of breeding pairs to minimum number of known breeding pairs in Oregon from 2009-2014 using baseline simulation parameters (dashed line) or observed model parameters (solid line). Black dots represent observed wolf population size and number of breeding pairs determined from annual surveys of wolf populations conducted by ODFW. Polygons around simulated mean population sizes and number of breeding pairs represent 95% confidence intervals.

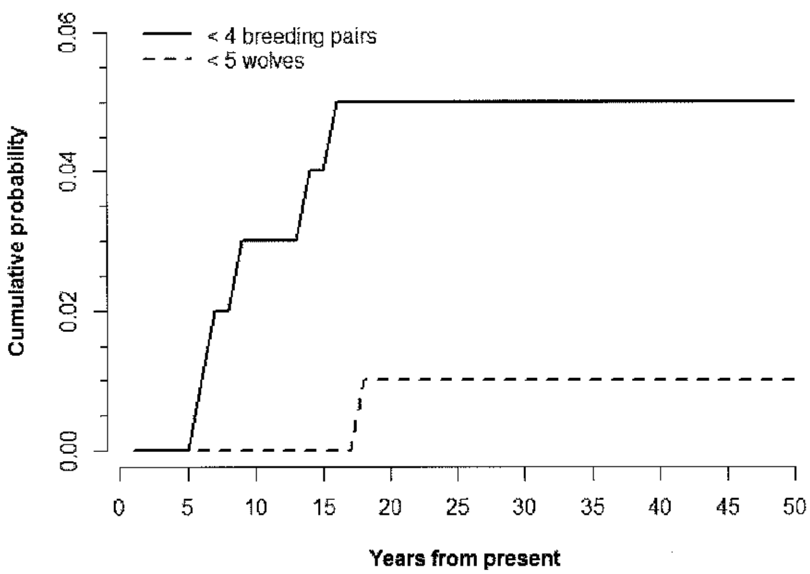

Figure 4. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

Sensitivity Analysis

Effects of Stochastic Parameters.–Nine out of 17 stochastic parameters included in our baseline model had a significant effect on intrinsic growth rates as measured by *r*, and no significant interactions between parameters were documented (Table 4). Most significant effects (Fig. 5) were directly or indirectly related to survival rates. Survival rates of pups (S_p; β = 0.045), yearlings (S_y; β = 0.024), and adults (S_{ad}; β = 0.019) were positively associated with *r*. The prey multiplier (Pr) increased variation in survival rates of all age classes of wolves by up to 20% and resulted in the prey multiplier, which represented increased environmental stochasticity, having the greatest effect on *r* (β = 0.088). Illegal (IM; β = -0.027) and legal (LM; β = -0.028) anthropogenic mortality were negatively associate with *r*.

Commented [DK17]: Wow, this is a huge effect (20% change in survival due to this "prey multiplier"). Are you comfortable with the strong effect this multiplier has on r given it's simplistic or "ad hoc" nature?

Table 4. Results of linear regression model used to estimate sensitivity of intrinsic growth rates of wolf populations in Oregon using an individual-based population model. Standardized regression coefficients with associated standard errors estimated from the full model are provided. Significance is determined as follows: *** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, and NS = $P > 0.05$.

Parameter	Standardized β_i	SE	P-value	Significance
Pup survival	0.045	0.007	0.000	***
Yearling survival	0.024	0.007	0.000	***
Adult (2 to 7-yrs old) survival	0.019	0.007	0.006	**
8-yr old adult survival	-0.006	0.007	0.411	NS
9-yr old adult survival	-0.002	0.007	0.789	NS
Pup dispersal	0.007	0.007	0.295	NS
Yearling dispersal	0.010	0.007	0.155	NS
Adult dispersal	-0.001	0.007	0.833	NS
Proportion of dispersing wolves that die	-0.026	0.007	0.000	***
No. of immigrants arriving annually	0.009	0.005	0.109	NS
Proportion of dispersing wolves that emigrate	-0.005	0.007	0.443	NS
Proportion of dispersing wolves that successfully establish a territory	0.034	0.006	0.000	***
Pregnancy rate for dominant females	0.001	0.007	0.912	NS
Mean litter size	0.049	0.004	0.000	***
Prey index multiplier	0.088	0.005	0.000	***
Illegal mortality	-0.027	0.007	0.000	***
Legal mortality	-0.028	0.007	0.000	***
Pup survival × Prey multiplier index	-0.011	0.009	0.198	NS
Yearling survival × Prey multiplier index	0.000	0.009	0.958	NS
Adult survival × Prey multiplier index	-0.003	0.009	0.737	NS
Pup survival × Illegal mortality	-0.004	0.012	0.720	NS
Yearling survival × Illegal mortality	0.012	0.012	0.293	NS
Adult survival × Illegal mortality	0.016	0.011	0.146	NS
Pup survival × Legal mortality	-0.003	0.012	0.797	NS
Yearling survival × Legal mortality	0.001	0.012	0.912	NS
Adult survival × Legal mortality	0.011	0.012	0.342	NS
Pup survival × Dispersal mortality	-0.013	0.011	0.248	NS
Yearling survival × Dispersal mortality	0.003	0.012	0.824	NS
Adult survival × Dispersal mortality	0.003	0.011	0.785	NS

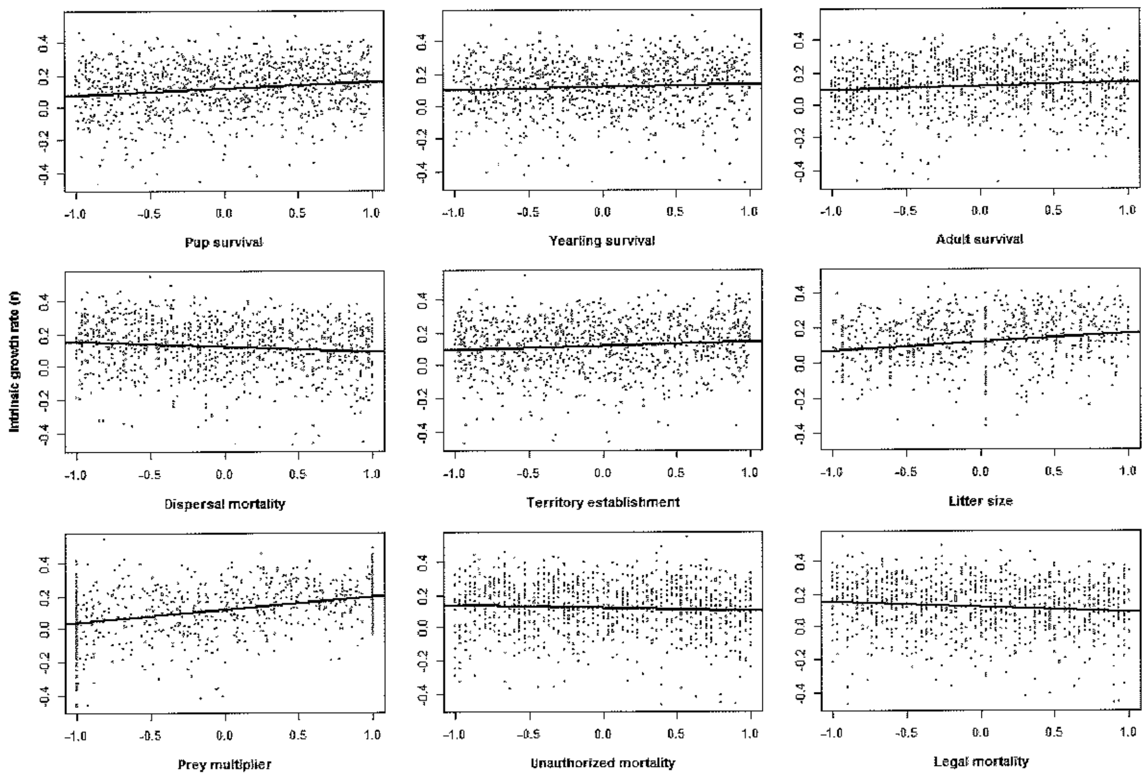

Figure 5. Estimated effects of significant ($p < 0.05$) model parameters on intrinsic growth rates of wolf populations. Estimates were generated using baseline model parameterization. Results generated from 1,000 unique combinations of model parameters and associated intrinsic growth rates. Model parameters are standardized to allow direct comparison among parameters. Black line represents estimated regression line. Gray dots represent individual parameter estimates and associated population growth rate.

Increased mortality rates of dispersing wolves (M_d; $\beta = -0.026$) had a negative effect on r. This parameter negatively affected r in two ways: 1) wolves were directly removed from the population and 2) fewer wolves were available to establish territories and contribute to population level reproduction. Increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on r (T; $\beta = 0.034$). Mean litter size (L; $\beta = 0.049$) was positively correlated with r. Pregnancy rates of dominant females (P_{ad}) were not significantly associated with r. We likely did not find a significant effect of pregnancy rates because of the high mean value (0.95) and low variation (SD = 0.02) used in our model.

Dispersal rates, regardless of age class (D_p, D_y, and D_{ad}) had minimal effects of on r (Table 4). Both immigration (I) and emigration (E_d) did not have a significant effect on r. At most, our model limited the number of immigrating wolves to 5 per year (range = 1 – 5) and contributions to population growth from immigrants will be limited except for extremely small extant populations. We modeled emigration rates as a proportion of the dispersing wolves that survived and left the population each year. Consequently, emigration could contribute to reduced population growth rates when the number of emigrants is greater than the number of immigrants. This scenario is more likely to occur for large extant populations that are near carrying capacity.

Effects of Static Parameters.–As expected, simulations with larger starting populations reached the density-threshold faster than those with smaller starting size (Fig. 6a). The risk of conservation-failure declined with increased starting population size (Fig. 6b). Using our baseline model, simulations that started with 150 and 100 individuals had no risk and a 0.01 (95% CI = 0.00 – 0.03) probability of conservation-failure over the next 50 years, respectively. At the current minimum known wolf population in Oregon, risk of conservation-failure (0.05; 95% CI = 0.01 – 0.09) was slightly higher than if 100 animals were in the population (value, 95% CI: ......) but substantially lower than if only 50 wolves (0.14; 95% CI = 0.07 – 0.21) occurred in Oregon. We did not observe a relationship between starting population size and biological-extinction risk as biological-extinction risk was ≤ 0.01 over 50 years regardless of starting population size used in this analysis.

Commented [DK18]: Put the numbers in for 100 animals.

Unsurprisingly, mean maximum population sizes of wolves were larger for simulations with higher density-thresholds (Fig. 7a). The effects of varying density-thresholds on risk of conservation-failure over 50 years were similar for density thresholds between 250 – 1500 (range 0.03 – 0.05; Fig. 7b). In contrast, at a density-threshold of 100 wolves, risk of conservation-failure was much greater (0.64; 95% CI = 0.55 – 0.73), steadily increased over time, and never plateaued as observed in other simulations. This suggests that a population density threshold of 100 wolves is insufficient to allow long-term persistence of ≥ 4 breeding pairs. Regardless of the density-threshold used, maximum observed biological-extinction risk was ≤ 0.01.

Commented [DK19]: So if carrying capacity for wolves in Oregon is <100, then long-term persistence of >=4 breeding pairs is not a reasonable conservation objective right?

Increased frequency at which catastrophic reductions in survival rates occurred caused reduced population growth rates and reduced mean, maximum population size of wolves (Fig. 8a). Populations that were subjected to catastrophic reductions in survival at intervals of once every 100 or 50 years had a relatively low risk of conservation-failure (range = 0.05 – 0.06; Fig. 8b). Catastrophic reductions in survival at intervals of once every 20 (0.09; 95% CI = 0.03-0.15) and 10 (0.16; 95% CI = 0.09-0.23) years had moderate risk of conservation-failure compared to less or more frequent intervals. For all scenarios, biological extinction risk was ≤ 0.01 over 50 years.

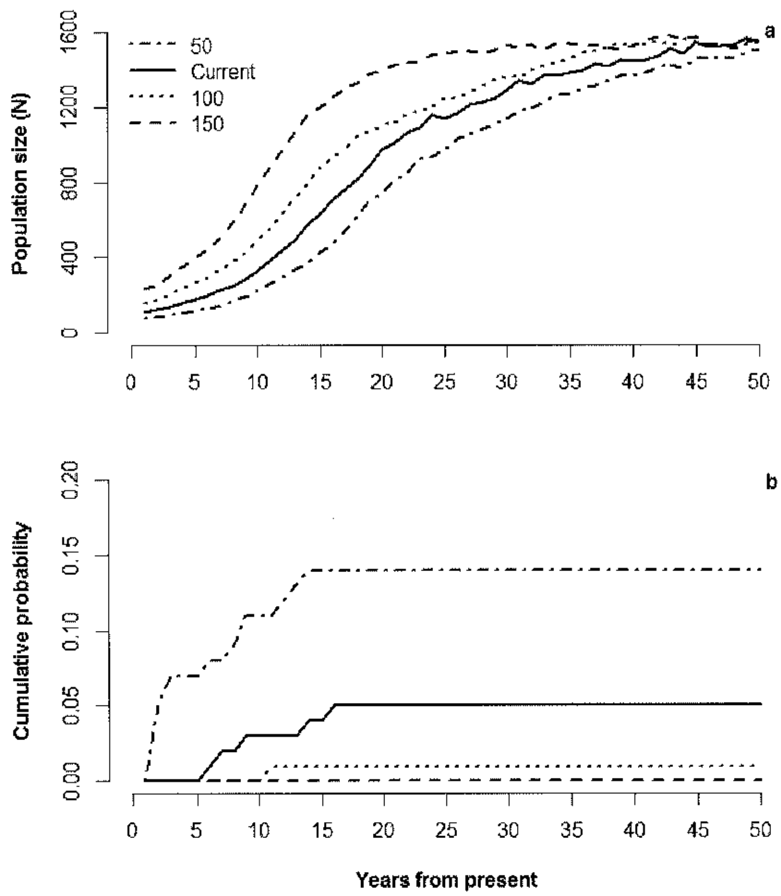

Figure 6. Estimated effect of variation in starting population size on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Current population size (N = 85) was the minimum wolf population size in Oregon as of April 1, 2015. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using the baseline model parameterization.

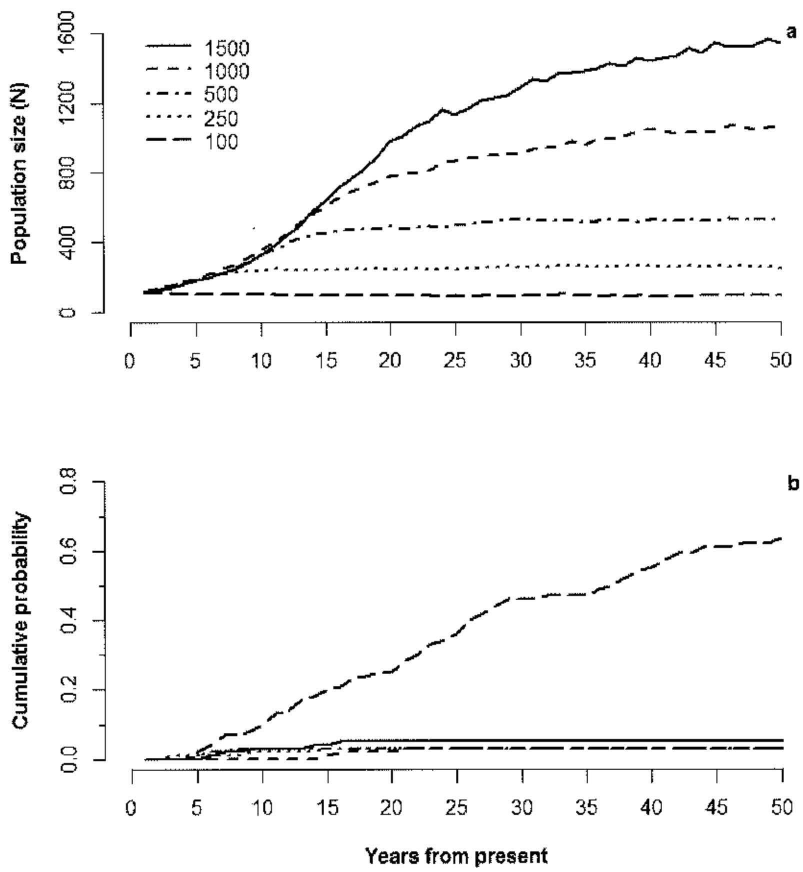

Figure 7. Estimated effect of variation in density-threshold on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

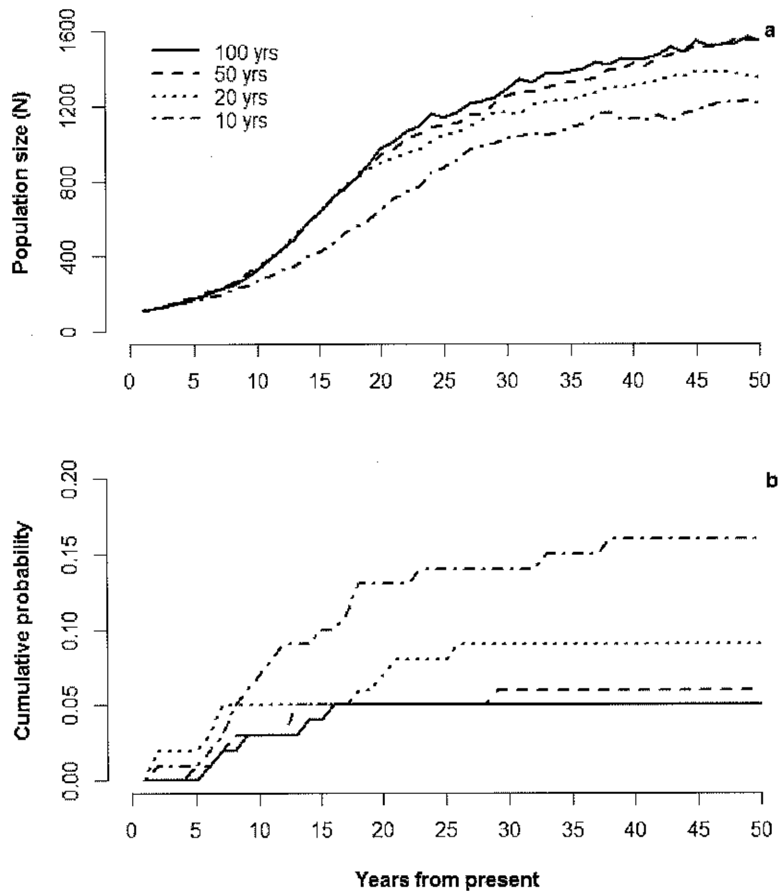

Figure 8. Estimated effect of variation in interval between catastrophic reductions in survival of wolves on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs). Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Increased frequency of pack-specific reproductive failure reduced population growth rates and mean, maximum population size of wolves (Fig. 9a). Scenarios with reproductive failure once every 20 (0.05; 95% CI = 0.01 – 0.09) and 10 litters (0.05; 95% CI = 0.01 – 0.09) had similar risk of conservation-failure in the next 50 years (Fig. 9b). Risk of conservation-failure was almost 6 times greater at intervals of once every 5 litters (0.29; 95% CI = 0.20 – 0.38). These results highlight the importance of pup production on ensure population viability of wolves. Risk of biological-extinction was not strongly affected by interval of reproductive failure as all scenarios had a risk of biological-extinction ≤ 0.02.

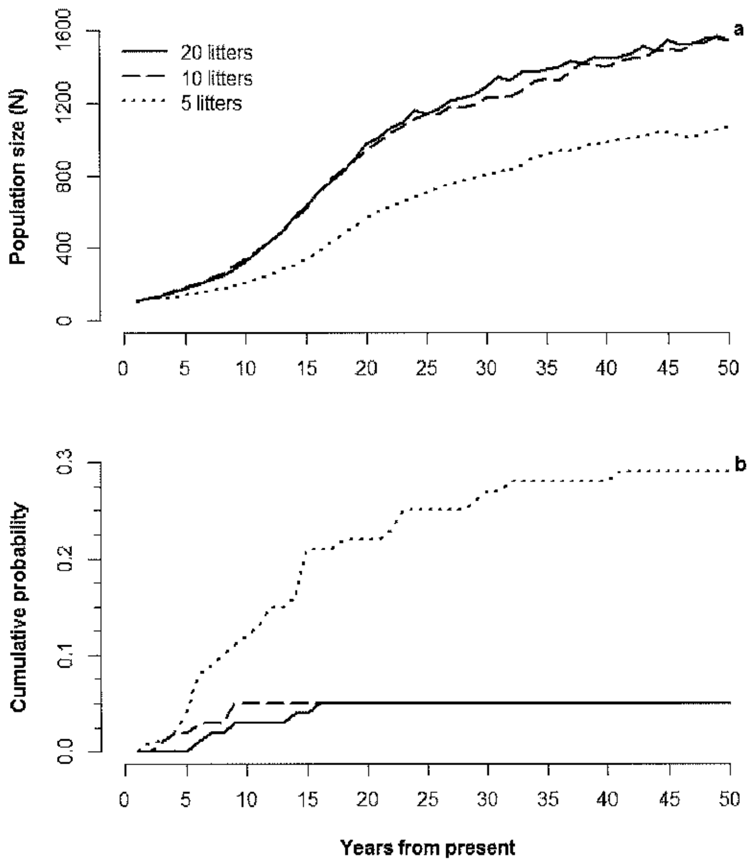

Figure 9. Estimated effect of variation in intervals between reproductive failure on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Effects of lethal control of wolves

Increased rates of legal mortality, while holding illegal mortality at baseline values, had a negative effect on population growth rates and mean, maximum population size of wolves (Fig. 10a). With a starting population of 85 wolves and at a legal mortality rate of 0.20, wolf populations declined. This suggested this rate of legal morality was not sustainable over the long-term at least at a starting population of 85 wolves and additional illegal mortality of 0.05. At a mean legal mortality rate of 0.05, which was used in our baseline model, probability of conservation-failure was 0.05 (95% CI = 0.01 – 0.09; Fig. 10b) over the next 50 years. At a reduced mean legal mortality rate of 0.00, no simulated populations dropped below the conservation-failure threshold. Probability of conservation-failure increased to 0.40 (95% CI = 0.30 – 0.50) and 1.00, for mean legal mortality rates of 0.10 and 0.20, respectively, when combined with illegal mortality rates of 0.05. Combined, these results highlight the importance of minimizing anthropogenic mortality to benefit population viability of wolves. Probability of biological-extinction was relatively low for all simulations with mean legal mortality rates ≤ 0.10 (range = 0.00 – 0.07; Fig. 10c). In contrast, mean legal mortality rates of 0.20 resulted in an extremely high probability of biological extinction (0.90; 95% CI = 0.84 – 0.96), at least when combined with an illegal mortality rate of 0.05 and a starting population of 85 individuals. Larger populations will be able to sustain higher mortality rates because they will have a greater buffer between extant population size and thresholds of biological extinction.

It should also be noted, the levels of anthropogenic mortality used in our model are not directly comparable to mortality rates commonly reported in literature (i.e., 1 – survival rate). Anthropogenic mortality rates as implemented in our model represent the proportion of wolves that would be removed from the population after accounting for natural mortality. For example, using a legal mortality rate of 0.10, an illegal mortality rate of 0.05, and a survival rate in the absence of anthropogenic mortality of 0.88, would result in an observed survival rate of 0.75 ($0.88 \times 1\text{-}0.10 \times 1\text{-}0.05$).

The effects of legal removals on wolves reported above are predicated on a starting population of 85 wolves. At larger population sizes, wolves will have an increased buffer between extant population size and conservation-failure or biological-extinction thresholds and fewer simulations would be expected to cross these thresholds. This is particularly true for moderate levels of legal mortality (0.05-0.15) where populations are likely to increase on average, but without a sufficient buffer and under stochastically varying conditions, 2-3 consecutive years of negative population growth could push the population below a predefined threshold. This phenomenon is evident in our simulations because most conservation-failures occurred shortly after simulations started. By later years, population sizes had sufficiently increased that they were able to withstand several consecutive years of negative population growth without falling below the conservation-failure threshold.

Comparison of individual vs. pack removal.–Lethal control actions conducted through random removal of individuals or entire packs had little influence on mean population size over 50 years (Fig. 11a). Mean populations for both removal scenarios reached the density-threshold (N = 1,500) by the 50th year of the simulation. Conservation-failure rates over 50 years were similar if individual wolves (0.05; 95% CI = 0.01 – 0.09) or packs (0.08; 95% CI = 0.03 – 0.13) were removed (Fig. 11b). Entire pack removal (0.01; 95% CI = 0.00 – 0.03) and removal of individuals (0.01; 95% CI = 0.00 – 0.03) resulted in similar estimates of biological-extinction risk over 50 years.

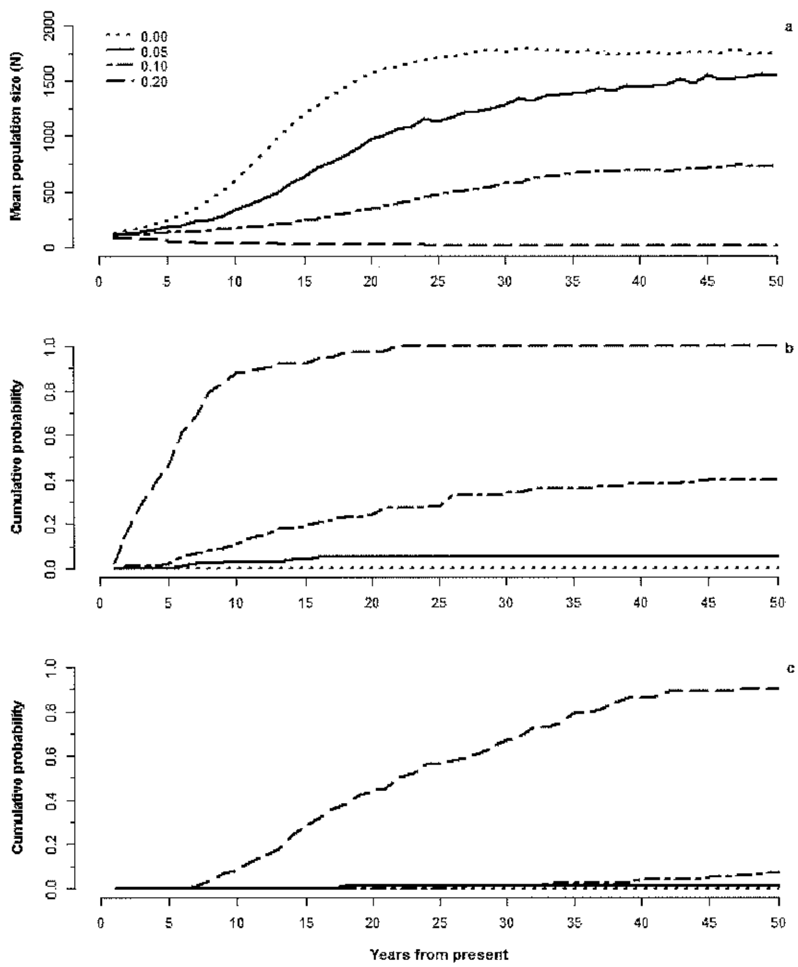

Figure 10. Estimated effect of variation in legal removal rates (proportion of wolves that would have survived the year otherwise) of wolves on (a) mean population size, (b) cumulative probability of conservation-failure (< 4 breeding pairs), and (c) cumulative probability of biological-extinction (< 5 wolves) over the next 50 years in Oregon when the starting population size was 85 wolves. Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. For all simulations, unauthorized morality rates of 0.05 (± 0.03 SD) occurred in addition to varying levels of legal removal.

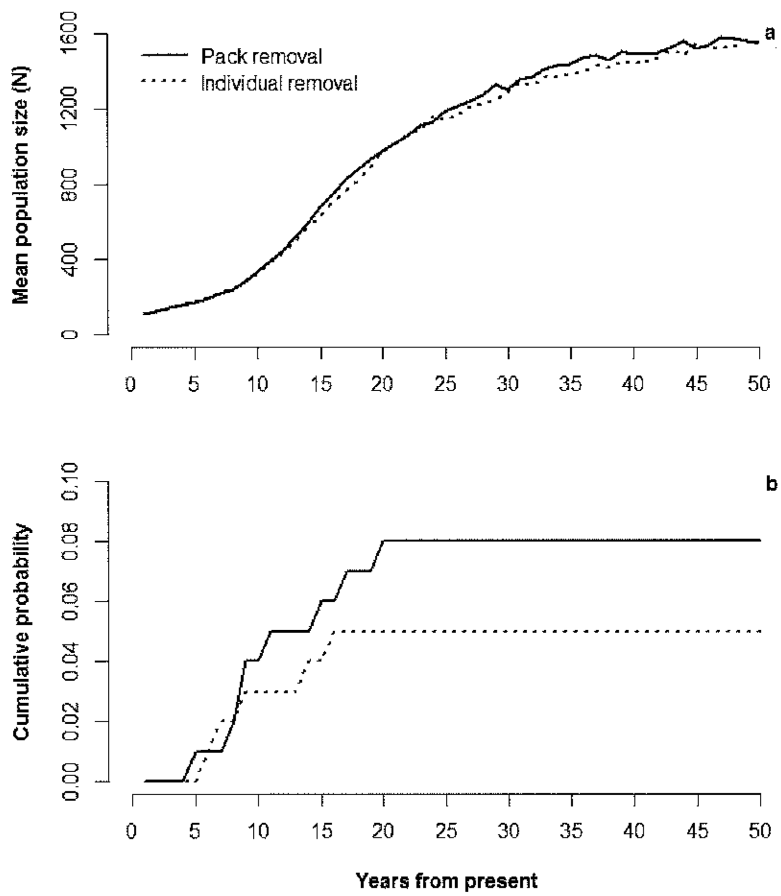

Figure 11. Estimated effect of individual versus pack level legal removal on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. Pack level and individual removal rates were identical for each simulation (0.05 ± 0.03).

DISCUSSION

Our baseline model underestimated population growth rates of wolves compared to observed population counts conducted in Oregon from 2010-2014. This was a consequence of two factors: 1) our baseline model used lower survival rates than were observed from 2010-2014 and 2) at small population sizes demographic stochasticity can have a dramatic effect on population growth rates (Lande 1998, Fox and Kendall 2002). However, our model parameterized with survival rates of wolves radio-collared in Oregon from 2009-2014 allowed our model to track observed population growth rates during this timeframe. We contend these findings suggest our model structure is capable of accurately portraying population dynamics of wolves when survival rates used in the model are representative of current conditions. We used conservative survival estimates in our baseline model to ensure our PVA erred on the side of caution (i.e., precautionary principle; Myers 1993, Meffe et al. 2006). Consequently, our results represent a conservative view of population viability of wolves in Oregon.

Commented [DK20]: OK, but didn't you say your population is still in the "recovery" or "expansion" phase and you wanted to model an "established" population?

Somewhere – probably in the Intro, it would be good to explain how vital rates might differ between "colonizing" or "expanding" populations vs. "established" populations. I think you mean populations that are far below carrying capacity relative to available resources, vs. those that are closer to those "density-thresholds", but it would probably be good to explain those differences, and associated vital rate differences explicitly in the beginning of the document.

If wolf populations in Oregon continue to follow vital rates observed from 2009-2014, our results indicated there would be no risk of conservation-failure or biological-extinction within the next 50 years. It is unlikely wolf populations in Oregon would continue to increase at observed population growth rates because established or exploited wolf populations do not increase as rapidly as protected or recovering populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Therefore, we contend results from our model parameterized with currently observed vital rates may present an overly optimistic view of wolf population dynamics moving forward in Oregon. Using our baseline model parameterized with vital rates obtained from a literature review, we documented a 0%, 3%, and 5% chance of conservation-failure over the next 5,10, and 50 years, respectively (Fig. 4). Most risk of conservation-failure occurs in the short-term (e.g., 15 years) because Oregon's extant wolf population is close to the conservation-failure threshold and a few years of poor population growth could cause the population to decline below the threshold. Furthermore, during the first few years of our simulations, population sizes are small, which allows demographic stochasticity to have a greater effect on population persistence (Vucetich et al. 1997).

Our baseline model suggested risk of conservation-failure was lower for populations that started with 100 or 150 wolves compared to the current population size observed in Oregon (N = 85; Fig. 6). This is not an unexpected finding because larger populations, regardless of species, have a reduced risk of extinction and can withstand longer periods of reduced population growth. These results highlight the importance of creating a buffer between extant population size and conservation-failure thresholds to allow for potential years of negative population growth. Furthermore, increased modeled starting population size will minimize effects of demographic stochasticity and increase population viability. Based on observed population growth rates from 2009-2014 (mean $\lambda = 1.43$) and known reproduction in 13 groups of wolves in 2015, Oregon's wolf population is expected to surpass 100 wolves by the end of the biological year. At this population size, risk of conservation-failure will effectively be eliminated (≤ 0.01).

In general, factors that influenced wolf survival had the greatest effect on intrinsic growth rates of wolves (r) in our simulation models. In our model, pup, yearling, and adult survival all had significant effects on intrinsic growth rates of wolf populations (Fig. 5). However, variation in pup survival had a greater effect on intrinsic growth rates than yearling or adult survival. While population growth rates of most large mammals are usually most sensitive to changes in adult survival, variability in adult survival, in the absence of high levels of anthropogenic mortality, is usually minimal compared to juveniles (Promislow and Harvey 1990, Gaillard et al.

1998, Robinson et al. 2014). The inherent variability in survival of juveniles causes this age class to have a disproportionate effect on population growth rates despite population growth rates being relatively insensitive to variation in this parameter. This does not discount the importance of adult and yearling survival on population growth and viability; rather it highlights the importance of minimizing annual variation and maintaining high survival rates of yearlings and adults.

Prey abundance and vulnerability are thought to influence wolf populations (Fuller and Keith 1980, Hayes and Harestad 2000, Vucetich and Peterson 2004). In our model, we did not explicitly model predator-prey relationships; rather, we used a prey multiplier value that increased stochastic variation in survival rates of wolves to simulate the effects of variation in prey abundance or changes in environmental conditions (e.g., snow depth) that influence vulnerability of prey over time. Effectively, the prey multiplier represented environmental stochasticity that allowed up to a 20% increase in variation in survival rates. Increased variability in survival (i.e., environmental stochasticity) will have negative effects on population growth rates and viability, regardless of the species of interest (Morris and Doak 2002). Consequently, it was expected that increased environmental stochasticity, modeled through our prey multiplier, had a negative effect on simulated wolf populations.

Anthropogenic mortality is the primary factor that influences dynamics of most wolf populations (Creel and Rotella 2010). Our model supported this conclusion because increased levels of anthropogenic mortality had a negative effect on intrinsic growth rates of wolves (Fig. 5). Furthermore, our simulation results indicated that increased rates of anthropogenic mortality resulted in increased risk of conservation-failure and biological-extinction when the initial population was 85 wolves (Fig. 10). Anthropogenic mortality is the parameter in our model over which ODFW has the most control and our results highlight that Oregon's wolf population will continue to increase and become self-sustaining if anthropogenic mortality is limited.

Our baseline model used inputs of 0.05 for both illegal and legal anthropogenic mortality rates (i.e., 5% of wolves that do not die of natural causes will be removed by both illegal and legal mortality sources) and at this rate, risk of conservation-failure was low. If ODFW maintains mortality rates at or below this level, the wolf population is predicted to be at a low risk of conservation-failure (0.05) and biological-extinction (0.01). Sustained, high levels of anthropogenic mortality (e.g., 0.20) in a stochastically varying environment contributed to increased risk of conservation-failure in our simulations; however, this finding is predicated on our staring population size of 85 wolves. Larger populations would be able to sustain this level of anthropogenic mortality without reaching the conservation-failure threshold because there is an increased buffer between extant population size and the conservation-failure threshold. Our model suggested that total anthropogenic mortality rates (i.e., combined illegal and legal mortality) of 0.15 would result in an increasing population on average ($\lambda = 1.03$) but total anthropogenic mortality rates of 0.20 caused wolf populations to decline on average ($\lambda = 0.98$). Previous studies have indicated wolf populations can be sustained with mortality rates up to 0.25 - 0.30 (Adams et al. 2008, Creel and Rotella 2010, Sparkman et al. 2011). As implemented in our model, anthropogenic mortality rates of 0.20 would cause survival rates of adult wolves to be 0.70 (i.e., a mortality rate of 0.30) and the wolf population would decline slightly on average ($\lambda = 0.98$). Consequently, our model matches well with the results previous studies.

Catastrophic reductions in survival of 25% had little effect on population growth rates and viability of wolves if the interval between occurrences was ≥ 50 years (Fig. 8). Widespread, catastrophic events are impossible to predict and little can be done to directly mitigate their

effect. However, general tenants of population ecology provide insight into actions that can minimize their effects on population viability. The primary way to reduce effects of catastrophes on population viability is to maintain larger extant populations. Larger populations are more viable because they have a sufficient number of individuals to withstand population declines. In our model, catastrophic events occurred at the population level. This is likely a biologically unrealistic expectation because catastrophic events are likely to occur in geographic regions (e.g., Blue Mountains or Cascade Range) due to localized differences in environmental conditions. This geographic separation should reduce population level effects of catastrophic events because not all wolves would be subjected to the event in a single year. However, these smaller sub-populations would have a greater risk of localized extinction compared to the larger extant population. This highlights the importance of risk spreading through spatial distribution of wolves in ensuring the long-term viability of wolf populations.

Recruitment of pups into the adult population was a critical factor influencing population dynamics of wolves. While we did not directly include a recruitment parameter in our model, several factors that jointly influence pup recruitment had separate effects on wolf population growth and viability. Variation in mean litter size had a strong effect on intrinsic growth rates of wolves. Increased frequency of reproductive failure had a negative effect on population growth rates and viability. Finally, reductions in survival rates of pups had a negative effect on population growth rates of wolves. Pup production and recruitment affects wolf population growth and viability in two ways. At the end of the biological year, wolf pups typically represent a large fraction of the total wolf population (Fuller et al. 2003). Consequently, any reductions in pup recruitment will slow population growth rates of wolves in the short-term. In the long-term, reduced pup recruitment will affect the number of potential dispersing wolves in the population. Yearling wolves (i.e., recently recruited pups) are most likely to disperse and establish new territories (Gese and Mech 1991, Boyd and Pletscher 1999). Reduced pup recruitment will limit the number of potential dispersers in subsequent years, which should slow the rate of population growth because fewer dispersers will be available to establish territories and contribute to population level reproduction.

In our baseline model, we used a density-threshold value of 1,500 wolves. This value represented the biological phenomenon where population growth of wolves would be limited by availability of vulnerable prey (Fuller 1989, Mech et al. 1998, Fuller et al. 2003) or intraspecific mechanisms (Cariappa et al. 2011); however the ability of wolves to self-regulate through intrinsic mechanisms is thought to be limited (Keith 1983, McRoberts and Mech 2014). Varying the density-threshold value in our model had little effect on risk of conservation-failure at values ≥ 250 wolves. Consequently, ~~we contend~~ our choice of a density-threshold value had minimal effects on our results, as all values were high enough to avoid conservation-failure.

Commented [DK21]: Right, but this is because the number of wolves needed to avoid "conservation-failure" (>100) is well below 250.....so you didn't investigate density-thresholds that were low enough to affect your conservation-failure threshold.

The Oregon Wolf Plan (ODFW 2010) provides guidelines as to when lethal control of wolves can occur. Our results indicated increased levels of anthropogenic mortality negatively affect wolf population growth and viability. However, whether anthropogenic mortality was implemented at an individual or pack-level had little effect on our results. Caution should be used when implementing lethal control to address management concerns. For example, breeder loss can have a significant, negative effect on wolf population dynamics (Brainerd et al. 2008, Borg et al. 2015). Consequently, decisions regarding lethal removal of breeding wolves should be carefully considered.

Our analysis of wolf-population viability did not explicitly incorporate genetic effects. Genetic viability is a critical concern for any threatened or endangered population (Frankham et

al. 2002, Scribner et al. 2006) especially for extremely small, isolated populations (Frankham 1996). Inbreeding is a potentially serious threat to the long-term viability for small, isolated populations of wolves (Liberg 2005, Fredrickson et al. 2007) but can be minimized through connectivity to adjacent populations. As few as 1-2 immigrants per generation (~5 years) can be sufficient to minimize effects of inbreeding on wolf populations (Vila et al. 2003, Liberg 2005). High levels of genetic diversity in Oregon's wolf population are likely to be maintained through connectivity to the larger northern Rocky Mountain wolf population. Wolves are capable of long-distance dispersal (Fritts 1983, Boyd and Pletscher 1999, Wabakken et al. 2007) which should allow a sufficient number of immigrants to arrive in Oregon so long as sufficient connectivity is maintained between populations in adjacent states (Hebblewhite et al. 2010). While our model did not account for genetic effects, we acknowledge the importance of genetics for isolated populations of mammals and recognize that genetic effects could become important if the Oregon wolf population becomes isolated from the remainder of the northern Rocky Mountain wolf population.

The IBM we used to assess wolf population viability in Oregon should provide a realistic biological representation of wolf population dynamics. However, our IBM does not have a spatial component and does not rely on habitat or other landscape features. Spatially-explicit models could provide a more biologically realistic representation of wolf population dynamics; however, spatially-explicit models require substantial amounts of data that is currently not available in Oregon to effectively parameterize the model. Habitat suitability maps have been developed for Oregon (e.g., Larsen and Ripple 2006), but these maps have not been validated and use of these maps would introduce another unknown source of error in population models. Furthermore, the effects of habitat on survival, reproduction, and dispersal of wolves in Oregon are unknown and it would be impossible to accurately model these effects without unwarranted speculation. For these reasons, we contend our non-spatial analysis of wolf population dynamics is currently the most appropriate approach to model wolf population dynamics and viability because it does not rely on unfounded assumptions that could lead to inappropriate conclusions.

Supplement 1: Population Viability of Wolves in the Eastern Wolf Management Zone.

We used our existing IBM to assess viability of wolves in the eastern Wolf Management Zone (WMZ) of Oregon (see ODFW 2010 for description of eastern WMZ). In this analysis, we restricted our starting population size to those wolves known to occur in the eastern WMZ as of April 1, 2015 ($N = 76$) and set the density threshold to 600 wolves compared to 1,500 wolves used in the statewide analysis. We selected the density-threshold for eastern WMZ using the equations following: Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000\ \text{km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km²). Using an estimated elk (*Cervus elaphus*) population of 66,000 elk distributed across 53,320 km² of summer range habitat in the eastern WMZ (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 3.71 (66,000 × 3/53,320). Based on this value maximum wolf densities were estimated to be 15.64 wolves/1,000 km² of summer range elk habitat in the eastern WMZ. This would result in a total population of 834 wolves within 53,320 km² of elk summer range habitat in the eastern WMZ. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, the elk population in the eastern WMZ is approximately 66,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 1,432.2 × 10,000 kg of primary prey biomass available to wolves across the eastern WMZ and a maximum population estimate of approximately 888 wolves. To be conservative, we used a density-threshold of 600 wolves in the eastern WMZ.

Commented [DK22]: See previous comment – need to support focus on elk only with some information (i.e., elk primary food source, only ungulate for which ODFW has good population numbers, yada, yada).

Remaining methods and parameter inputs for this analysis were identical to those used in the statewide assessment of wolf population viability (Table 1). As with the statewide analysis, we used two metrics to assess population viability: 1) conservation-failure, defined as the population dropping below 4 breeding pairs and 2) biological-extinction, defined as the population having fewer than 5 individuals.

Using our baseline model, simulated wolf populations increased an average of 6% (i.e., $\lambda = 1.06 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.06 (95% CI = 0.01 – 0.11) probability of the population dropping below the conservation-failure threshold (Fig. S1). Half of the conservation-failures occurred within the first 10 years and by year 20 no additional populations passed the threshold. Of the six simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 22, 37, 61, 67, 72, and 88 breeding pairs by year 50, respectively. No simulated populations dropped below the biological-extinction threshold over the next 50 years. Risk of conservation-failure in the eastern WMZ was slightly higher, but not significantly different, than risk at a statewide level (0.06 vs. 0.05; Fig. S2). Our simulation results suggested risk of conservation-failure declined with increasing starting population size (Fig. 6), so it was not surprising that the slightly smaller starting population in the eastern WMZ ($N = 76$) had a slightly higher risk of conservation-failure compared to the statewide population ($N = 85$).

Figure S1. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

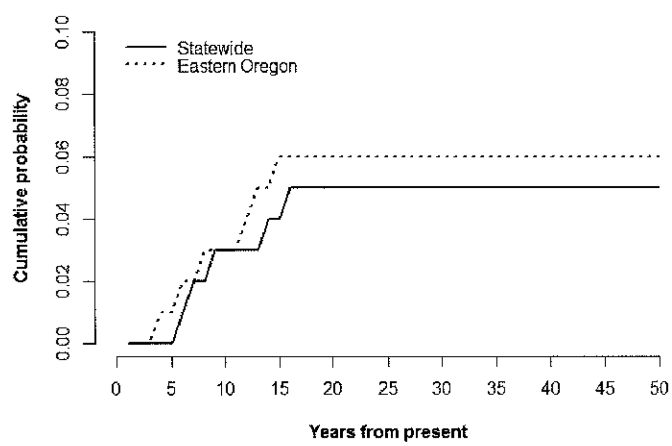

Figure S2. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) over the next 50 years across the entire state or in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

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DR. RYAN LONG

Assessment of Population Viability of Wolves in Oregon

This technical report to the Oregon Fish and Wildlife Commission presents results from an updated individual-based population model used to assess population viability of wolves in Oregon. The model uses wolf data collected in Oregon through July 2015.

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Suggested citation:

Oregon Department of Fish and Wildlife. 2015. An updated assessment of population viability of wolves in Oregon using data collected through July 2015. Oregon Department of Fish and Wildlife, 4034 Fairview Industrial Drive SE. Salem, OR 97302.

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Executive Summary

We present results from an individual-based population model (IBM) based on a peer-reviewed published[1] model (Bull et al. 2009) used to assess the viability of the gray wolf (*Canis lupus*; hereafter, wolf) population in Oregon. When parameterizing our model, we relied on peer-reviewed published estimates of wolf vital rates. Our population model, the assumptions made in the model, and vital rates used in the model were obtained or supported by peer-reviewed published literature. We compared estimates of parameters used in our model to those observed in Oregon from 2009-2014 and concluded our model used to project future population growth was conservative compared to growth rates currently observed in Oregon. We used a starting population size of 85 wolves which was based on wolf population counts conducted by the Oregon Department of Fish and Wildlife (ODFW) through July 2015. This value is higher than reported end of year counts (ODFW 2015) because additional wolves that were present in Oregon at the start of the biological year (i.e., April) were documented after January 31, 2015. Consequently, results presented in this report differ slightly from those presented to the Oregon Fish and Wildlife Commission on April 24, 2015. We used linear regression models to determine the relative effect of model parameters on intrinsic population growth rates of wolves. We assessed population viability using two metrics: 1) the cumulative proportion of simulations that had fewer than 4 breeding pairs (defined as conservation-failure) and 2) the cumulative proportion of simulations that had fewer than 5 wolves (defined as biological-extinction).

Increased pup ($\beta = 0.045$), yearling ($\beta = 0.024$), and adult ($\beta = 0.019$) survival resulted in increased population growth rates. Population growth rates of wolves were most sensitive to environmental stochasticity, which we modeled through the use of a prey multiplier ($\beta = 0.088$). The increased environmental stochasticity incorporated in the model by the prey multiplier increased variation in survival rates of wolves by up to 20% annually, which caused this parameter to have a large effect on population growth rates. Increased levels of illegal ($\beta = -0.027$) and legal ($\beta = -0.028$) anthropogenic mortality had negative effects on population growth rates. Increased mean litter size had a positive effect on population growth ($\beta = 0.049$). Increased mortality rates for dispersing wolves had a negative effect on population growth ($\beta = -0.026$) while increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on population growth ($\beta = 0.034$). Combined, these results highlight the importance of survival, reproduction, and human-caused mortality on population growth rates of wolves. Other parameters considered in our model had minimal effects on population growth rates or viability of wolves. Maintenance of high natural survival and reproductive rates of wolves while minimizing human-caused mortality will help ensure the long-term persistence of the species in Oregon.

Our baseline model indicated there was a 0.05 (95% CI = 0.01 – 0.09) probability of wolves falling below the conservation-failure threshold and a 0.01 (95% CI = 0.00 – 0.03) probability of falling below the biological-extinction threshold in the next 50 years. When we parameterized our model with vital rates required to match population growth rates observed in Oregon from 2009-2014, we did not observe any situations where the simulated wolf population fell below the conservation-failure or biological-extinction thresholds. Consequently, we contend future risk of conservation-failure falls between estimates from our baseline model (0.05 probability of conservation-failure) and our model parameterized with vital rates required to

[1] Peer-reviewed published literature is papers published in scientific journals or books that have been reviewed and deemed acceptable from a study design, analysis, and interpretation standpoint by one or more peers prior to being published.

match observed population growth rates of Oregon's wolves from 2009-2014 (0.00 probability of conservation-failure). Regardless of model parameterization, our results suggested it is extremely unlikely wolves in Oregon will be at risk of extirpation over the next 50 years.

INTRODUCTION

The Oregon Wolf Conservation and Management Plan (hereafter, Oregon Wolf Plan; Oregon Department of Fish and Wildlife [ODFW] 2010) outlines phases of wolf (*Canis lupus*) recovery and criteria for delisting wolves as required by Oregon's Endangered Species Act (ESA). In January 2015, Oregon's wolf population successfully reached population objectives for Phase I to allow ODFW to propose that the Oregon Fish and Wildlife Commission consider delisting of wolves from Oregon's ESA (ODFW 2010). Quantitative models are commonly used to assess population dynamics and extinction risk of threatened and endangered species (Boyce 1992, Morris and Doak 2002) and can provide insight into the first and second delisting criteria outlined in the Oregon ESA:

1. "The species is not now (and is not likely in the foreseeable future to be) in danger of extinction in any significant portion of its range in Oregon or in danger of becoming endangered"; and
2. "The species natural reproductive potential is not in danger of failure due to limited population numbers, disease, predation, or other natural or human related factors affecting its continued existence".

To address these delisting criteria, we modified a peer-reviewed quantitative model (Bull et al. 2009) to provide insight into dynamics of Oregon's wolf population to help inform any future decisions regarding wolves and Oregon's ESA.

To make accurate predictions of future population growth, quantitative population models should accurately reflect biological processes of the species being modeled. Individual-based models (IBM) were previously used to model wolf population dynamics (Vucetich et al. 1997, Haight et al. 1998, Nilsen et al. 2007, Bull et al. 2009) because they can most accurately represent the unique social and breeding structure of wolf populations. We modified an IBM developed to assess effects of management on wolf populations in Norway (Bull et al. 2009) to meet our needs to assess population viability of wolves in Oregon. Our modeling approach focused on determining effects of key biological processes, uncertainty in model parameters, and management actions on wolf population dynamics and viability.

METHODS

We used an IBM modified from Bull et al. (2009) to assess future population dynamics of wolves in Oregon. The primary modifications to the Bull et al. (2009) were to change the vital rate values of wolves in North America based on our literature review. The biggest modification we implemented in our model was to alter the way reproduction was handled in the model. Bull et al. (2009) assigned pairs of wolves a probability of producing a large or small litter and assumed all dominant females would produce pups each year. In our modified model, we assumed not all dominant females would produce pups in a given year, but litter sizes would be determined from a single distribution each year. We modified the Bull et al. (2009) to include two types of catastrophes (see description below) and allowed dispersing wolves to leave Oregon and have increased risk of mortality during dispersal (see description below). All of these additional modifications provided increased reality to the model and would provide a more

conservative view of wolf population growth. Other than these minor changes, our code used to implement the model was identical to the peer-reviewed model developed by Bull et al. (2009).

Our model incorporated 6 demographic processes that affected wolf populations that were modeled in the following order (Fig. 1): 1) survival and transition between age classes, 2) dispersal and emigration out of Oregon, 3) territory establishment by dispersing wolves, 4) immigration from outside Oregon, 5) anthropogenic mortality, and 6) reproduction. Our IBM included 5 distinct social classifications of wolves (Fig. 2) and transitions between social classifications were governed by distinct model parameters (Table 1).

Our IBM was coded and implemented in R (R Development Core Team 2012). To generate our results, we conducted 100 realizations of population growth over 50 years. We utilized 100 realizations of population growth because this allowed the confidence intervals to be acceptably narrow, but not excessively narrow to indicate a false sense of precision in our estimates of population viability Bull et al. (2009). We incorporated environmental stochasticity in our model by randomly drawing vital rate values from a uniform distribution with a predefined mean and standard deviation at each time step of the simulation (Table 1). Unless otherwise noted, vital rates were applied at an individual level, which inherently incorporated demographic stochasticity into our model. For each simulated population we tracked parameter values, population size and growth rates, and number of breeding pairs (i.e., pairs of wolves with ≥ 2 pups surviving the biological year) at each time step.

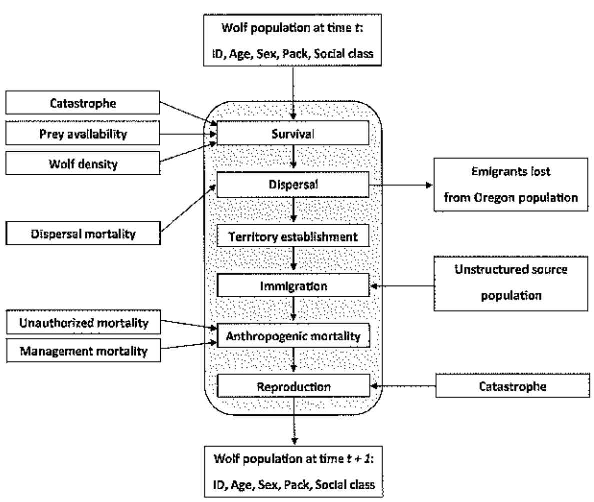

Figure 1. The order in which 6 key demographic processes are implemented in an individual-based population model to assess population viability of wolves in Oregon.

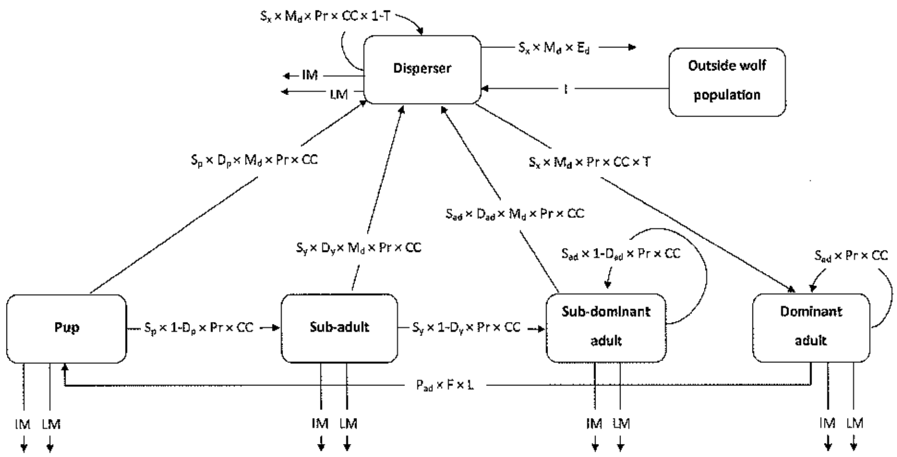

Figure 2. Visual representation of the life cycle of wolves implemented in an individual-based population model to assess population viability of wolves in Oregon. The diagram represents probabilities of transitions between age- and social-classes of wolves. Parameters used in transition calculations are defined in Table 1.

Table 1. Parameter values used to predict future population growth of wolves in Oregon compared to values required to match observed growth rates of Oregon's wolf population from 2010-2014. Values used at each time step of the analysis were randomly drawn from a uniform distribution within the specified standard deviation (SD). Mean values are probabilities unless otherwise stated. All estimates used in our baseline model were obtained or supported by peer-reviewed literature.

		Baseline model values		Values required to match growth rates observed in Oregon (2009-2014)	
Parameter	Notation	Mean	SD	Mean	SD
Pup survival rate	S_p	0.68	0.15	0.75	0.05
Yearling survival rate	S_y	0.81	0.06	0.91	0.04
Adult (2 to 7-yrs old) survival rate	S_{ad}	0.88	0.04	0.91	0.04
Old adult (8 to 9-yrs old) survival rate	S_{old}	0.63	0.11	0.85	0.05
Pup dispersal rate	D_p	0.15	0.05	0.15	0.05
Yearling dispersal rate	D_y	0.65	0.05	0.65	0.05
Non-breeding adult dispersal rate	D_{ad}	0.65	0.05	0.65	0.05
Proportion of dispersing wolves that survive	M_d	0.90	0.05	0.97	0.02
Proportion of dispersing wolves that leave Oregon	E_d	0.115	0.03	0.115	0.03
Probability of dispersing wolf establishing a territory	T	0.75	0.10	0.75	0.10
No. of immigrants arriving annually from outside Oregon	I	3	2	3	2
Pregnancy rate for dominant females	P_{ad}	0.95	0.02	0.95	0.02
Litter size	L	5	3	5	3
Proportion of wolves removed by illegal mortality	IM	0.05	0.03	0.02	0.01
Proportion of wolves removed by legal mortality	LM	0.05	0.03	NA	NA
Prey index multiplier (adjustment to survival rates)	Pr	1.00	0.10	1.00	0.10
Density dependent threshold (no. of wolves)	CC	1,500	NA	1,500	NA
Probability of population wide reduction in survival	S_{cas}	0.01	NA	NA	NA
Probability of pack-specific reproductive failure	R_{cas}	0.05	NA	0.05	NA

Commented [RL1]: This seems like a really nice approach. The baseline values for parameterizing the model are almost universally conservative, which means that estimates of population viability will also be conservative. However, this is still appropriate, because the wolf population in Oregon is currently small (i.e., no density-dependent effects likely) and largely unharvested. So, many of the vital rates in the two right-hand columns that apparently characterize the current wolf population in Oregon will likely decline over time, and will begin to approach the values used in the modeling, as the wolf population increases.

Commented [RL2]: Although the mean values of these parameters are certainly critical, the SD's are equally important for determining the influence that a stochastic parameter has on the results of a model like this. It's clear from the information below where the mean values came from, but it's not clear where the variances/SDs came from. Were they averaged across studies similar to the vital rates themselves (e.g., Table 2)?

Model Parameters

Currently, Oregon has minimal vital rate information to parameterize a population model, and the potential for sampling bias or error from small sample sizes (i.e., observed data does not match the expected outcome) could cause inappropriate conclusions to be reached by using this information. Furthermore, estimated vital rates from protected wolf populations that are colonizing or recovering are unlikely to match those of established wolf populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Oregon's wolf population is transitioning from a recovering to established population. Vital rates used in our IBM were obtained from peer-reviewed published literature that presented results from studies conducted primarily in established wolf populations. Consequently, whenever possible, we compared vital rates observed in Oregon to those reported in peer-reviewed published literature to determine the degree to which vital rates used in our model were representative of those observed in Oregon since 2009. In general, most vital rates used in our baseline model were conservative compared to those observed in Oregon from 2009-2014. Using conservative vital rate estimates allowed us to err on the side of caution (e.g., the precautionary principle; Myers 1993, Meffe et al. 2006) and prevent overly optimistic conclusions of wolf population viability.

Starting Population Size.–We utilized minimum count data collected by ODFW to determine our starting population size and structure prior to wolves producing pups in April 2015. These counts were higher than final survey numbers reported at the end of 2014 (ODFW 2015) because ODFW identified additional wolves after the report was submitted. Based on wolf survey information collected through July 2015, a minimum of 85 wolves were present in Oregon at the start of April. We acknowledge additional, undocumented wolves may be present in Oregon, but we relied on known individuals when developing our model. Counts identified 16 pairs or packs of wolves in addition to 3 individual wolves present in Oregon. Whenever possible, we used known data to assign pack, age, social class, and sex of wolves and randomly assigned these attributes when unknown. Newly documented pairs of wolves were assumed to consist of a male and female and both individuals were assigned dominant-adult status.

Commented [RL3]: Which makes your analysis even more conservative.

Survival.–Baseline survival rates of wolves used in our model represented survival in the absence of anthropogenic mortality (e.g., poaching, management removals). We adjusted survival rates reported in peer-reviewed literature to account for anthropogenic mortality using the following approach: 1) determine the overall mortality rate (1 – survival rate), 2) estimate the anthropogenic mortality rate as the product of proportion of total mortalities caused by humans and the overall mortality rate, and 3) sum the estimated anthropogenic mortality rate and the reported survival rate. As an example, Smith et al. (2010) reported an annual survival rate of 0.750 with 54% of mortality attributable to legal or illegal actions by humans. The anthropogenic mortality rate was 0.135 (1-0.750 × 0.540), which resulted in a 'natural' survival rate of 0.885 (0.750 + 0.135). In instances where authors directly reported cause-specific mortality rates (e.g., Wydeven et al. 1995), we summed reported survival and anthropogenic mortality rates to obtain an adjusted estimate of survival. After adjusting survival rates reported in peer-reviewed literature (Table 2) to account for human-caused mortality we arrived at a survival rate of 0.88 (± 0.04 SD) of adult wolves (2-7 years old; S_{ad}) for use in our model.

Using the largest sample size of radio-collared wolves reported in peer-reviewed published literature, Smith et al. (2010) reported that yearling wolves had a 54.9% higher risk ($1.0012^{365} = 1.549$) of mortality than adult wolves over 365 days. We adjusted the mean survival rate of 0.88 for adult (2-7 years) wolves by the increased hazard rate reported by Smith et al. (2010) to calculate a survival rate of 0.81 for yearling wolves (S_y; 1-[(1-0.88) × 1.549]; Table 1).

This may present an overly pessimistic view of resident yearling wolf survival, because yearlings have high dispersal rates (Gese and Mech 1991) and dispersing wolves were found to have higher risk of mortality (Smith et al. 2010). In our model, we utilized a separate mechanism to account for increased mortality of dispersing wolves (see below) and we recognize our estimates of yearling survival may be negatively biased. Senescence, observed through decreased survival at older ages is common for large mammals (Loison et al. 1999, Gaillard et al. 2000, Clark et al. 2014), but this phenomenon is not well documented in peer-reviewed published literature on wolves. To account for the potential of senescence, we used an annual survival rate for wolves > 7 years old of 0.63 as reported by Cubaynes et al. (2014), which we adjusted to 0.67 for use in our model (S_{old}) to account for anthropogenic mortality. Wolves ≥ 10 years of age had a survival rate of 0.00 in our model. While free-ranging wolves can live longer than 10 years, most wolves are typically no longer reproductively active after this age (Fuller et al. 2003, Kreeger 2003) and will contribute little to population growth and viability.

Estimates of non-pup survival used in our model were lower than observed to date in Oregon. Using known-fate survival analysis (White and Burnham 1999) on a sample 23 of wolves radio-collared in Oregon from 2009-2014, we estimated an annual survival rate of wolves > 6 months old of 0.91. Three collared wolves died during this timeframe, one of which was removed by ODFW and an additional wolf was illegally shot resulting in 66% of mortality being attributable to humans. Adjusting survival rates to account for anthropogenic mortality results in a survival rate of 0.97, which is substantially greater than the adult (0.88) and yearling (0.81) survival rates used in our model.

Table 2. Annual survival rates and human-caused mortality rates of non-pup wolves reported in peer-reviewed literature. Survival rates were estimated from known fates of radio-collared wolves unless otherwise noted. Adjusted survival rates represent survival rates on non-pups in the absence of human-caused mortality.

Source	Reported survival	Human-caused mortality rate	Adjusted survival rate[a]
Adams et al. (2008)	0.79	0.09[b]	0.89
Cubaynes et al. (2014)	0.80	0.04[c]	0.84
Fuller (1989)	0.62	0.26[c]	0.88
Hayes and Harestead (2000)	0.84	0.02[b]	0.86
Peterson et al. (1984)	0.67	0.26[b]	0.93
Smith et al. (2010)	0.75	0.14[b]	0.89
Webb et al. (2011)[d]	0.62	0.34[b]	0.96
Wydeven et al. (1995)	0.61	0.28[b]	0.89
Wydeven et al. (1995)	0.82	0.04[b]	0.86
Mean	0.72	0.16	0.88

[a] Sum of reported survival and human-caused mortality rate.
[b] Mortality rate calculated as the product of overall mortality rate (1-survival) and proportion of mortalities caused by humans.
[c] Human-caused mortality rate directly reported by authors.
[d] Apparent survival rates estimated from mark-recapture data.

Estimates of survival of wolf pups from birth to 6 months are highly variable and are usually estimated by comparing pup counts at den or rendezvous sites to *in utero* fetal counts of harvested females. Based on a review of peer-reviewed published literature (Table 3), we determined mean survival rates of wolf pups from birth to 6 months, determined from pup counts, were 0.73. Estimation of survival using pup count data assumes that pups are counted with a detection probability of 1.0, which is unrealistic and this method will likely produce negatively biased estimates of survival over the first 6 months of life. In general, radio-telemetry studies have indicated pup survival is similar to adult survival during months 7-12 after birth (Peterson et al. 1984, Fuller 1989, Adams et al. 2008). Consequently, we used 6 month survival rate of adults (~0.94), calculated as the square root of annual survival, to approximate survival of pups from ages 7-12 months. We used the product of summer survival rates times the 6 month survival rate of adult wolves as the annual estimate of pup survival (S_p) in our baseline model ($0.73 \times 0.94 = 0.68$; Table 1).

Table 3. Survival rates of wolf pups from birth to six months reported in peer-reviewed literature. Unless otherwise noted, survival was estimated by comparing pup counts six months after birth to *in utero* litter sizes. Annual survival rates calculated as the product of 6 month survival rates of pups and 6 month survival rates of adult wolves used in our model (0.88).

Source	Survival from birth to 6 months	Annual survival[a]
Fuller (1989)[b]	0.58	0.55
Mills et al. (2008)[c]	0.83	0.78
Fritts and Mech	0.57	0.53
Fuller and Keith (1980)	0.69	0.65
Adams et al. (2008)	0.81	0.76
Hayes and Harestead (2000)[d]	0.80	0.75
Petersen et al. (1984)	0.80	0.75
Ballard et al. (1987)	0.82	0.77
Mech et al. (1998)[e]	0.91	0.85
Hayes et al. (1991)[f]	0.48	0.45
Mean survival	0.73	0.68

[a] Annual survival is the product of survival from birth to 6 months and the 6 month survival rate of adult wolves used in our model.
[b] Survival rate reported was estimated over 8 month period using pup counts. Monthly survival rate was 0.9135 and survival over six months was 0.58.
[c] Survival was estimated with implant transmitters from Jun-Nov. Used monthly survival rates from this period to estimate 6 month survival rate.
[d] Survival estimated on an annual interval. Used the square root of reported survival rates to estimate survival from birth to 6 months.
[e] Survival estimate over first 4 months of life. Extrapolated to 6 months.
[f] Heavily exploited wolf population.

We compared the pup survival rates used in our model to pup count data collected in Oregon during winter surveys conducted from 2009-2014. During this time frame, 30 potential reproductive opportunities were documented. Of these 30 potential reproductive opportunities, 3 were censored because final pup counts were not completed. Assuming wolves give birth to an average of 5 pups per litter (Fuller et al. 2003), we calculated a total of 135 pups born from these 27 reproductive opportunities. Minimum pup counts conducted in December of 2009-2014 indicated a minimum of 82 pups across all years. Using this information we arrived at a minimum observed survival rate of 0.61 (95% CI = 0.53 – 0.69), which is lower but within in the range of the pup survival rate used in our model (0.68 ± 0.15; Table 1).

Commented [RL4]: It may be lower because you overestimated the number of pups born. How variable are the published data on litter size in wolves, and do you have any empirical data from Oregon on mean litter size?

When implementing our model, annual survival rates were independently calculated for each age class by randomly drawing a survival rate from a uniform distribution with a predefined mean and standard deviation (Table 1). Survival rates of wolves were age-specific and were not influenced by social status of the individual (e.g., survival rates for a 4-year old sub-dominant adult were identical to survival rates for a 4-year old dominant adult). Survival rates were modeled at an individual level, with each individual having an independent probability of survival at each time step.

Density-dependence.– When populations surpassed a predefined population threshold, annual survival rates, regardless of age, were multiplied by the ratio of the threshold population size and current wolf population size. The specified threshold was implemented to account for the importance of density-dependence on population dynamics (Morris and Doak 2002), but does not represent an expected number of wolves in Oregon in future years. When implemented in our model, the density-threshold represents an arbitrary biological threshold where wolves begin to self-regulate through intraspecific strife or are limited by available prey.

Larsen and Ripple (2006) created a habitat suitability map for wolves in Oregon and found that a maximum of 1,450 wolves could occupy Oregon. This value increased to 2,200 wolves if industrial timberland in western Oregon was classified as suitable wolf habitat. Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000\ \text{km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 128,000 elk distributed across 151,500 km^2 of summer range habitat (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 2.53 (128,000 × 3/151,500). Based on this value maximum wolf densities were estimated to be 11.79 wolves/1,000 km^2 of summer range elk habitat. This would result in a total population of 1,780 wolves within 151,500 km^2 of elk summer range habitat in Oregon. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, Oregon's elk population is approximately 128,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 2,777.6 × 10,000 kg of primary prey biomass available to wolves across Oregon and a maximum population estimate of approximately 1,722 wolves.

Commented [RL5]: What about prey species other than elk? Is there any reason to think that deer should be included as part of these equations?

Both the Fuller et al. (2003) and Carbone and Gittleman (2002) equations produce similar estimates of wolf population size and fall within the range reported by Larsen and Ripple (2006). However, these estimates were calculated under the assumption wolves will not cause reductions in prey populations. To account for this possibility, we used a conservative density-threshold (CC) of 1,500 wolves in our model. Again, it should be noted, the density-threshold represents

an estimate of maximum potential wolf population size, not a management objective for wolves in Oregon.

Prey multiplier.–Wolf-prey interactions can influence wolf densities and population dynamics (Fuller et al. 2003). We lacked sufficient data to explicitly model wolf-prey interactions and instead used a simplified approach described in the peer-reviewed published paper by Bull et al. (2009) where a stochastically generated a prey multiplier value (Pr) was used to represent changes in either prey abundance or vulnerability (e.g., increased vulnerability during severe winters). The prey multiplier represented environmental stochasticity in our model. At a value of 1.0, the prey multiplier represented baseline prey availability or vulnerability. Each year of the simulation, the prey multiplier had a 1 out of 3 chance of increasing, decreasing, or remaining the same, respectively. In years the prey multiplier increased or decreased, the maximum change was restricted to 0.10. The prey multiplier was bounded between 0.90 and 1.10 values generated outside this range were truncated to the maximum or minimum value. Survival rates used in the model were calculated as the product of randomly drawn survival rates and the prey multiplier after accounting for any density-dependent effects.

Commented [RL6]: So does this mean that temporal variation in prey abundance was modeled as an entirely stochastic process? I suppose that's probably fine if elk are the primary prey species, because elk in general are doing really well. However, if there's any reason to believe that mule deer might be an important prey item in some cases, then that might be a different story.

Dispersal and Emigration.–We assumed dominant wolves would maintain their territory and breeding positions until their death. In the event that both dominant animals in a pack died, all remaining pack members would disperse. This approach was partially used for simplicity of model implementation, but was also supported in peer-reviewed literature (Fuller et al. 2003). For example, Brainerd et al. (2008) found that in instances where both breeding wolves were lost, 85% of packs dissolved, and only 9% of packs reproduced the following year.

Sub-dominant wolves that survived the year had a probability of dispersing from their existing territory, which was dependent on age and breeding status (Table 1). Age-specific dispersal rates used in our model (D_p, D_y, D_{ad}) were obtained from literature (Potvin 1988, Fuller 1989, Gese and Mech 1991). We assumed non-breeding adults had similar dispersal rates as yearlings (Fuller et al. 2003). Survival rates of dispersing individuals were reduced (M_d) to account for increased mortality risk of wolves during dispersal (Table 1; Peterson et al. 1984, Fuller 1989, Smith et al. 2010). Smith et al. (2010) found dispersing wolves had a 38.9% higher risk of mortality over 365 days than resident wolves. After accounting for this increased risk, survival rates of dispersing adult wolves would be 0.83 with the ratio of dispersing versus resident adult survival rates of 0.94 (0.83/0.88). To be conservative, we lowered this value to 0.90 (± 0.05 SD) for use in our model, which is interpreted at 10% of dispersing wolves die during the dispersal process.

We used a spatial simulation to estimate emigration rates using peer-reviewed published estimates of dispersal distances of wolves (Fritts and Mech 1981, Fuller 1989, Gese and Mech 1991, Wydeven et al. 1995). We generated 10,000 random dispersal paths that started at a random location within summer range elk habitat (i.e., potential wolf habitat). We simulated dispersal paths using correlated random walks with the movement.simplecrw function in the Geospatial Modeling Environment (Beyer 2012) by selecting a random bearing from a uniform distribution (0 - 359°) and a random dispersal distance from normal distribution with a mean of 75 km (± 30 SD). We calculated emigration rates (E_d) as the proportion of simulated dispersal paths that terminated outside Oregon. Mean emigration rates were estimated to be 0.115 (Table 1). We estimated a standard deviation of the mean values calculated from 100 bootstrap samples that each contained 100 random dispersal paths. The estimated standard deviation of the mean of

Commented [RL7]: Where did this value come from?

these 100 samples was 0.03. Emigration was effectively treated as additional mortality in our model (i.e., these individuals were removed from the simulated population).

Territory Establishment.–Dispersing wolves ≥ 2 years old were assigned a probability of establishing a territory. Boyd and Pletscher (1999) found that 57% of dispersing wolves successfully found a mate the next breeding season after they dispersed. This value equates to the joint probability of two wolves establishing a territory. Independently, the probability of a dispersing wolf establishing a territory (T) would be 0.75 ($\sqrt{0.57}$), which we used in our model. Wolves that did not successfully establish a territory remained in the pool of dispersers until the following year. Those individuals that successfully established territories would first fill vacant alpha positions of the correct sex in established packs. If no alpha positions were available at established packs, dispersing wolves would then establish a new territory and maintain that position until they died or a mate joined them at the territory.

Commented [RL8]: I would imagine that this rate must be density dependent. I wonder exactly how variable this success rate actually is as a function of density? If the variation is substantial, then you could potentially model this parameter as an increasing function of density as the population grows.

Immigration.–We assumed wolves from the extant Rocky Mountain wolf population would be available to immigrate into Oregon. For model simplification, we assumed the wolf population outside Oregon was unstructured and would produce a steady, but limited, stream of immigrants. We assumed 3 wolves (± 2 SD) would immigrate (I) annually into Oregon from surrounding populations. We assumed all immigrating wolves were sub-adults because a review of peer-reviewed literature indicated this age class is most likely to engage in dispersal behavior (Fuller 1989, Gese and Mech 1991, Fuller et al. 2003). Individuals arriving in the Oregon population were randomly assigned a sex assuming parity among dispersers (Gese and Mech 1991).

Anthropogenic Mortality.–Anthropogenic mortality was incorporated in the model under two forms: legal and unauthorized mortality. Unauthorized mortality represented all sources of anthropogenic mortality (e.g., poaching, vehicle-killed individuals) excluding mortalities authorized by ODFW under current laws. Legal removals included any administrative removals authorized by ODFW (e.g., livestock damage, human safety, incidental take). Anthropogenic mortality was modeled using a two-step process where unauthorized mortality was modeled first and followed by legal mortality. A proportion of the total population that remained after accounting for natural mortality events would be removed each year by each anthropogenic mortality source (Table 1). Anthropogenic mortality was applied independent of age, social status, or pack membership. Effectively, this approach treats anthropogenic mortality as a reduction in survival. For example, using an annual adult survival rate of 0.88, survival rates would be reduced to 0.79 ($0.88 \times 0.95 \times 0.95$) if 5% of the population was removed for both legal and unauthorized mortality, respectively.

From April 2009 to March 2015, ODFW has collected 54 wolf-years of data from radio-collared individuals. During this time, 1 radio-collared wolf was illegally killed and 1 radio-collared wolf was removed by ODFW, for a removal rate of 0.02 for each mortality source (ODFW, unpublished data). Due to the potential bias of radio-collared wolves being avoided by poachers, we increased the illegal mortality (IM) value to 0.05 (± 0.03 SD). To be conservative and allow for the potential of increased levels of lethal control actions, we used a value of 0.05 (± 0.03 SD) for legal mortality (LM) of wolves in our model (i.e., between 2-8% of wolves would be randomly removed from the population each year for management related actions).

Reproduction.–Only established wolf packs with a dominant pair of adults were allowed to reproduce. We were unable to find peer-reviewed estimates of pregnancy rates of dominant females in published literature; however, it is biologically unrealistic to assume all pairs of wolves successfully give birth to pups each year (i.e., female do not always become pregnant).

We assumed pregnancy rates of dominant females (P_{ad}) would be 0.95 (± 0.02 SD; Table 1). While evidence exists of multiple females producing pups within a pack, this is a rare occurrence and usually only occurs in extremely large packs (Mech 1999), and we assumed only one litter of pups would be born in packs with a dominant pair. The number of pups produced by pregnant females (L) was drawn from a uniform distribution ranging from 2-8 (Table 1) based on a review of literature (see summary in Fuller et al. 2003).

Catastrophes.–We included two catastrophes in our model. The first was modeled at the pack level as the probability of a pack having complete reproductive failure within a year (R_{cas}). Probability of reproductive failure was independent among packs and years. This approach was used to simulate the potential effects of diseases (e.g., canine parvovirus), which are known to negatively affect pup survival and recruitment (Mech and Goyal 1993, Almberg et al. 2009), where most or all pups die when exposed to the virus (Mech et al. 2008). We assumed complete reproductive failure had a probability of occurrence of 0.05 within each pack during each year of the simulation (i.e., one out of 20 litters will be subjected to complete reproductive failure). Packs that had complete reproductive failure were assigned a litter size of 0 (i.e., even if pups were produced they would all die before 1 year of age).

Our second catastrophe was modeled at the population level, where each year of the simulation there was a probability of a population wide reduction in survival (S_{cas}). This approach was used to represent extremely rare, range wide events that may affect wolf populations (e.g., disease, abiotic conditions, prey population crashes). We used a mean interval of 100 years between disturbance events, with each year having an independent probability of a disturbance event occurring. During years where a catastrophe event occurred, survival rates of all wolves in the population were reduced by 25%.

Assessment of Population Viability

We assessed population viability using two measures. The Oregon Wolf Plan defined a threshold of 4 breeding pairs for 3 consecutive years as a guideline to consider delisting wolves from the Oregon ESA (ODFW 2010). Consequently, we defined "conservation-failure" as a simulated population that fell below 4 breeding pairs. For each simulated population, we determined which time-step, if any, that the population dropped below the conservation-failure threshold. Simulated populations that dropped below the conservation-failure threshold were considered failures in all remaining time steps. We calculated risk of conservation-failure as the cumulative proportion of simulated populations that had < 4 breeding pairs.

We used a threshold of < 5 wolves as our metric of "biological-extinction". In simulations with < 5 wolves, the extant population would effectively be extirpated and immigrants from outside sources would be maintaining the Oregon population. For each simulated population, we determined the time-step, if any, that the population dropped below the biological-extinction threshold. Once the population dropped below this threshold it was determined to be biologically-extinct for all remaining time steps. We calculated biological-extinction rates as the cumulative proportion of simulated populations that < 5 wolves.

Model Validation

To validate our baseline model, we conducted a set of 100 realizations of population growth over 5 years, where the starting population size was the number of wolves present in Oregon at the end of 2009 (N = 14 wolves). We calculated the mean number of wolves and breeding pairs from simulations and compared these values to population counts conducted by ODFW from 2010-2014. Survival rates used in our baseline model were more conservative than observed in Oregon from 2010-2014. Consequently, we conducted a second set of simulations

where we parameterized our model with vital rates required to match observed population growth rates in Oregon from 2009-2014 (see Table 1 for differences between vital rates in the two scenarios). Using observed vital rate values in our model would allow us to determine if our overall model structure allowed accurate estimation of population growth under known conditions.

Sensitivity Analysis

Effects of Stochastic Parameters.– We used r (i.e., intrinsic rate of increase) as the dependent variable in a linear regression model where stochastically varying parameters and relevant interactions were used as independent variables. We conducted 200 realizations of population growth over a 5-yr period which resulted in 1,000 random combinations of parameter values and associated intrinsic growth rates (r). The sensitivity analysis was limited to a 5-yr span because allowing population simulations to last longer than 5-yrs could cause some simulations to reach the density-threshold of 1,500 wolves and confound the effect of parameter variation and density-dependence on r. For each simulation, the starting population was assumed to be 120 wolves equally distributed among 20 packs. We used this starting population size because at extremely small population sizes (e.g., $N < 10$) immigration of wolves could produce biologically unreasonable population growth rates (e.g., $\lambda > 2.0$) and confound our ability to detect an effect of parameters on r. Prior to running our regression model, all independent variables were standardized (standardized value = [observed value - mean value]/standard deviation) to allow direct comparisons between results. We used an alpha level of 0.05 to determine significance of parameters and the sign and slope of beta coefficients to determine the strength and relative effect of the parameter on r.

Effects of Static Parameters.–Starting population size, density-threshold, and frequency of survival and reproductive catastrophes were static parameters in our model and the effects of these were not included in our regression analysis used to determine the relative effects of parameters on r. Consequently, we conducted additional simulations where values of static parameters differed among simulations. Each simulation used 100 realizations of population growth over 50 years and was parameterized with baseline values except for changes in the static parameter of interest. We conducted 4 simulations to determine the effect of starting population sizes of 50 wolves, the known existing Oregon wolf population ($N = 85$; baseline value), 100 wolves and, 150 wolves. Simulations with starting populations of 50, 100, and 150 wolves were structured as follows: 1) each wolf belonged to a pack and each pack had 5 members with 2 of those members being dominant adults and 2) sex, age, and social class of remaining wolves were randomly assigned. To determine the relative influence of the density-threshold on population viability of wolves, we conducted a set of simulations where used a density-threshold of 100, 250, 500, 1000, and 1500 (baseline value) wolves. We conducted a set of 3 simulations where we investigated probabilities of individual pack reproductive failure of 0.05 (baseline value; once every 20 litters), 0.10 (once every 10 litters), and 0.20 (once every 5 litters). We investigated the effects catastrophic reductions in survival at year-specific probabilities of 0.01 (baseline value; once every 100 years), 0.02 (once every 50 years), 0.05 (once every 20 years), and 0.10 (once every 10 years).

Effects of lethal control of wolves

Legal, anthropogenic mortality is the parameter included in our model over which ODFW has the most control. To address the effects of varying rates of legal wolf removal on wolf population viability we conducted a set of 4 simulations where mean legal mortality rates and associated standard deviations varied among simulations while all other model parameters

were left at baseline values (Table 1). The following values were used as mean values (± SD) to represent legal anthropogenic mortality rates in the 4 simulations: 0.00 (± 0.00), 0.05 (± 0.03), 0.10 (± 0.06), and 0.20 (± 0.12). These levels of legal mortality rates were in addition to illegal mortality rates which were set at a mean value of 0.05 (± 0.03) during all simulations.

Our baseline model assumes legal removals will be implemented through random removal of individual wolves. However, the potential exists that lethal control actions could take place across entire wolf packs, rather than individuals. Consequently, we also conducted a simulation where legal removal of wolves would occur at a pack rather than individual level. We assumed the proportion of packs removed per year would be the same as the proportion of individuals removed in our baseline simulation (0.05 ± 0.03). After completion of simulations, we compared the results to the baseline simulation to determine what effect, if any, pack removal would have on population dynamics compared to individual removal.

Results

Model Validation

Our baseline model resulted in underestimates of population size (Fig. 3a) and number of breeding pairs (Fig. 3b) compared to population count data collected in Oregon from 2010-2104. When our model was parameterized with survival rates of wolves observed from 2009-2014 (Table 1) the simulation results closely approximated observed population size and number of breeding pairs. Consequently, survival rates used in our baseline model are cautious compared to past survival rates in Oregon; however, the ability of the model to correctly predict past population dynamics when parameterized with observed survival rates suggests other parameters included in the model accurately portray wolf population dynamics in Oregon. Our baseline model predicted lower population growth compared to the model parameterized with survival rates observed from 2009-2014. This suggests our baseline model will underestimate wolf population growth and viability if survival rates from 2009-2014 are observed into the future.

Assessment of Population Viability

Using our baseline model, simulated wolf populations increased an average of 7% (i.e., $\lambda = 1.07 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.05 (95% CI = 0.01 – 0.09) probability of the population dropping below the conservation-failure threshold (Fig. 4). Most conservation-failures (3 out of 5) occurred within the first 10 years and by year 20, no additional populations passed the threshold. Of the five simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 7, 20, 39, 84 and 194 breeding pairs in year 50 of the simulation, respectively. There was a 0.01 (95% CI = 0.00 – 0.03) probability the simulated population dropped below the biological-extinction threshold over the next 50 years. The single simulated population that dropped below 5 individuals recovered to 360 individuals by year 50.

Using observed survival rates of wolves from 2009-2014 in our population model resulted in no scenarios where wolf populations dropped below the conservation-failure or biological-extinction thresholds. Our baseline model may be more likely to represent future population dynamics of wolves, but may be overly pessimistic, especially in the near future, given recently observed survival rates of wolves in Oregon. Consequently, we contend future risk of conservation-failure likely falls somewhere between our baseline model (0.05) and our model parameterized with vital rates required to match observed population growth rates from 2009-2014 (0.00). Our model results suggest it is extremely unlikely (≤ 0.01 probability) wolves in Oregon will be at risk of extirpation over the next 50 years.

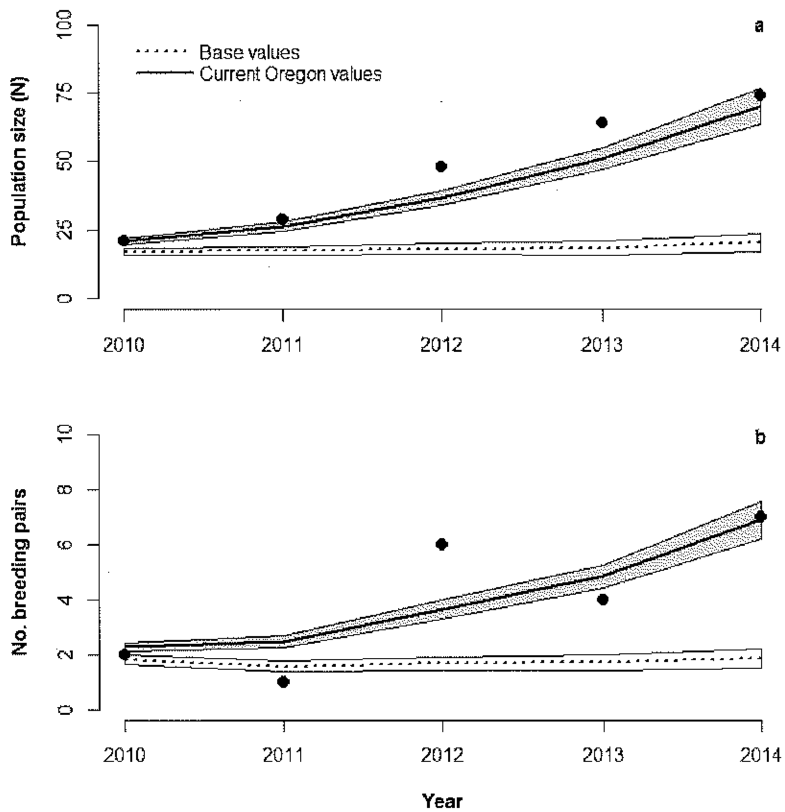

Figure 3. Comparison of (a) simulated mean population sizes compared to minimum population sizes observed in Oregon from 2009-2014 and (b) simulated number of breeding pairs to minimum number of known breeding pairs in Oregon from 2009-2014 using baseline simulation parameters (dashed line) or observed model parameters (solid line). Black dots represent observed wolf population size and number of breeding pairs determined from annual surveys of wolf populations conducted by ODFW. Polygons around simulated mean population sizes and number of breeding pairs represent 95% confidence intervals.

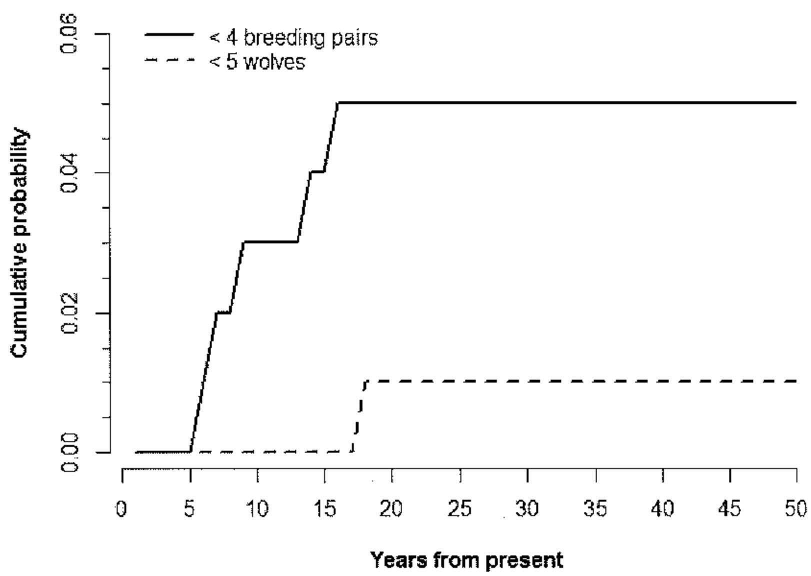

Figure 4. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

Sensitivity Analysis

Effects of Stochastic Parameters.--Nine out of 17 stochastic parameters included in our baseline model had a significant effect on intrinsic growth rates as measured by r, and no significant interactions between parameters were documented (Table 4). Most significant effects (Fig. 5) were directly or indirectly related to survival rates. Survival rates of pups (S_p; β = 0.045), yearlings (S_y; β = 0.024), and adults (S_{ad}; β = 0.019) were positively associated with r. The prey multiplier (Pr) increased variation in survival rates of all age classes of wolves by up to 20% and resulted in the prey multiplier, which represented increased environmental stochasticity, having the greatest effect on r (β = 0.088). Illegal (IM; β = -0.027) and legal (LM; β = -0.028) anthropogenic mortality were negatively associate with r.

Table 4. Results of linear regression model used to estimate sensitivity of intrinsic growth rates of wolf populations in Oregon using an individual-based population model. Standardized regression coefficients with associated standard errors estimated from the full model are provided. Significance is determined as follows: *** = P < 0.001, ** = P < 0.01, * = P < 0.05, and NS = P > 0.05.

Parameter	Standardized β_i	SE	P-value	Significance
Pup survival	0.045	0.007	0.000	***
Yearling survival	0.024	0.007	0.000	***
Adult (2 to 7-yrs old) survival	0.019	0.007	0.006	**
8-yr old adult survival	-0.006	0.007	0.411	NS
9-yr old adult survival	-0.002	0.007	0.789	NS
Pup dispersal	0.007	0.007	0.295	NS
Yearling dispersal	0.010	0.007	0.155	NS
Adult dispersal	-0.001	0.007	0.833	NS
Proportion of dispersing wolves that die	-0.026	0.007	0.000	***
No. of immigrants arriving annually	0.009	0.005	0.109	NS
Proportion of dispersing wolves that emigrate	-0.005	0.007	0.443	NS
Proportion of dispersing wolves that successfully establish a territory	0.034	0.006	0.000	***
Pregnancy rate for dominant females	0.001	0.007	0.912	NS
Mean litter size	0.049	0.004	0.000	***
Prey index multiplier	0.088	0.005	0.000	***
Illegal mortality	-0.027	0.007	0.000	***
Legal mortality	-0.028	0.007	0.000	***
Pup survival × Prey multiplier index	-0.011	0.009	0.198	NS
Yearling survival × Prey multiplier index	0.000	0.009	0.958	NS
Adult survival × Prey multiplier index	-0.003	0.009	0.737	NS
Pup survival × Illegal mortality	-0.004	0.012	0.720	NS
Yearling survival × Illegal mortality	0.012	0.012	0.293	NS
Adult survival × Illegal mortality	0.016	0.011	0.146	NS
Pup survival × Legal mortality	-0.003	0.012	0.797	NS
Yearling survival × Legal mortality	0.001	0.012	0.912	NS
Adult survival × Legal mortality	0.011	0.012	0.342	NS
Pup survival × Dispersal mortality	-0.013	0.011	0.248	NS
Yearling survival × Dispersal mortality	0.003	0.012	0.824	NS
Adult survival × Dispersal mortality	0.003	0.011	0.785	NS

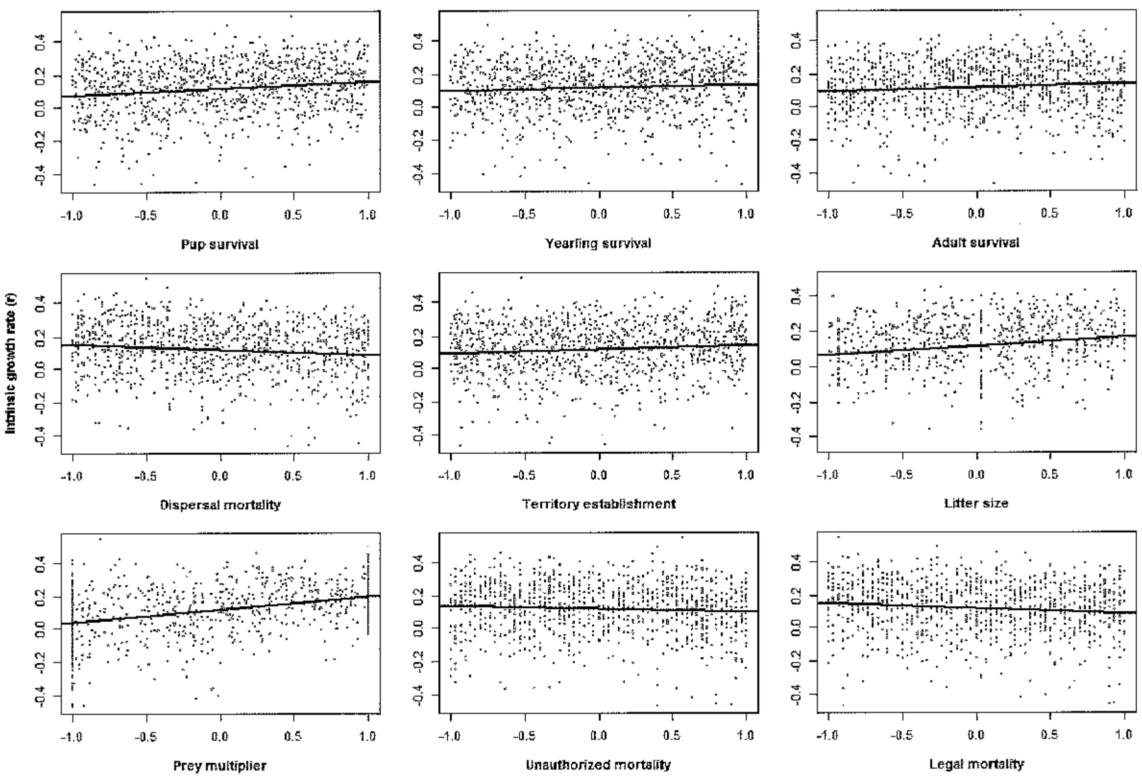

Figure 5. Estimated effects of significant ($p < 0.05$) model parameters on intrinsic growth rates of wolf populations. Estimates were generated using baseline model parameterization. Results generated from 1,000 unique combinations of model parameters and associated intrinsic growth rates. Model parameters are standardized to allow direct comparison among parameters. Black line represents estimated regression line. Gray dots represent individual parameter estimates and associated population growth rate.

Increased mortality rates of dispersing wolves (M_d; $\beta = -0.026$) had a negative effect on r. This parameter negatively affected r in two ways: 1) wolves were directly removed from the population and 2) fewer wolves were available to establish territories and contribute to population level reproduction. Increased probabilities of dispersing wolves successfully establishing a territory had a positive effect on r (T; $\beta = 0.034$). Mean litter size (L; $\beta = 0.049$) was positively correlated with r. Pregnancy rates of dominant females (P_{ad}) were not significantly associated with r. We likely did not find a significant effect of pregnancy rates because of the high mean value (0.95) and low variation (SD = 0.02) used in our model.

Dispersal rates, regardless of age class (D_p, D_y, and D_{ad}) had minimal effects of on r (Table 4). Both immigration (I) and emigration (E_d) did not have a significant effect on r. At most, our model limited the number of immigrating wolves to 5 per year (range = 1 – 5) and contributions to population growth from immigrants will be limited except for extremely small extant populations. We modeled emigration rates as a proportion of the dispersing wolves that survived and left the population each year. Consequently, emigration could contribute to reduced population growth rates when the number of emigrants is greater than the number of immigrants. This scenario is more likely to occur for large extant populations.

Effects of Static Parameters.–As expected, simulations with larger starting populations reached the density-threshold faster than those with smaller starting size (Fig. 6a). The risk of conservation-failure declined with increased starting population size (Fig. 6b). Using our baseline model, simulations that started with 150 and 100 individuals had no risk and a 0.01 (95% CI = 0.00 – 0.03) probability of conservation-failure over the next 50 years, respectively. At the current minimum known wolf population in Oregon, risk of conservation-failure (0.05; 95% CI = 0.01 – 0.09) was slightly higher than if 100 animals were in the population but substantially lower than if only 50 wolves (0.14; 95% CI = 0.07 – 0.21) occurred in Oregon. We did not observe a relationship between starting population size and biological-extinction risk as biological-extinction risk was ≤ 0.01 over 50 years regardless of starting population size.

Unsurprisingly, mean maximum population sizes of wolves were larger for simulations with higher density-thresholds (Fig. 7a). The effects of varying density-thresholds on risk of conservation-failure over 50 years were similar for density thresholds between 250 – 1500 (range 0.03 – 0.05; Fig. 7b). In contrast, at a density-threshold of 100 wolves, risk of conservation-failure was much greater (0.64; 95% CI = 0.55 – 0.73), steadily increased over time, and never plateaued as observed in other simulations. This suggests that a population threshold of 100 wolves is insufficient to allow long-term persistence of ≥ 4 breeding pairs. Regardless of the density-threshold used, maximum observed biological-extinction risk was ≤ 0.01.

Commented [RL9]: Functionally this means an environment with a carrying capacity of 100 wolves is insufficient to facilitate long-term persistence of at least four breeding pairs, correct?

Increased frequency at which catastrophic reductions in survival rates occurred caused reduced population growth rates and reduced mean, maximum population size of wolves (Fig. 8a). Populations that were subjected to catastrophic reductions in survival at intervals of once every 100 or 50 years had a relatively low risk of conservation-failure (range = 0.05 – 0.06; Fig. 8b). Catastrophic reductions in survival at intervals of once every 20 (0.09; 95% CI = 0.03-0.15) and 10 (0.16; 95% CI = 0.09-0.23) years had moderate risk of conservation-failure compared to less or more frequent intervals. For all scenarios, biological extinction risk was ≤ 0.01 over 50 years.

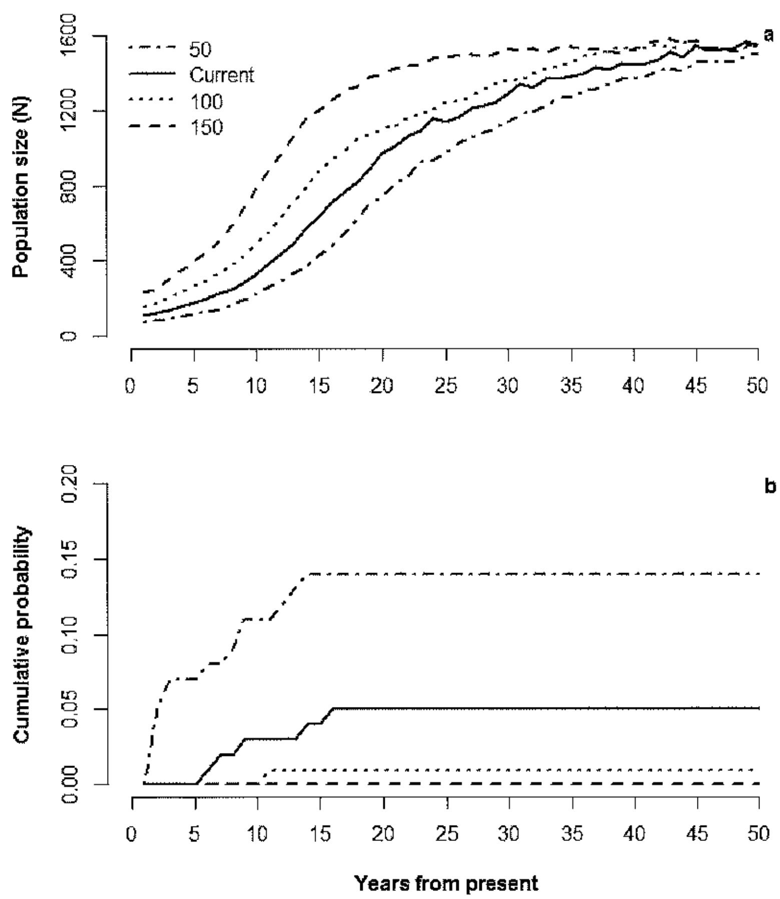

Figure 6. Estimated effect of variation in starting population size on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Current population size (N = 85) was the minimum wolf population size in Oregon as of April 1, 2015. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using the baseline model parameterization.

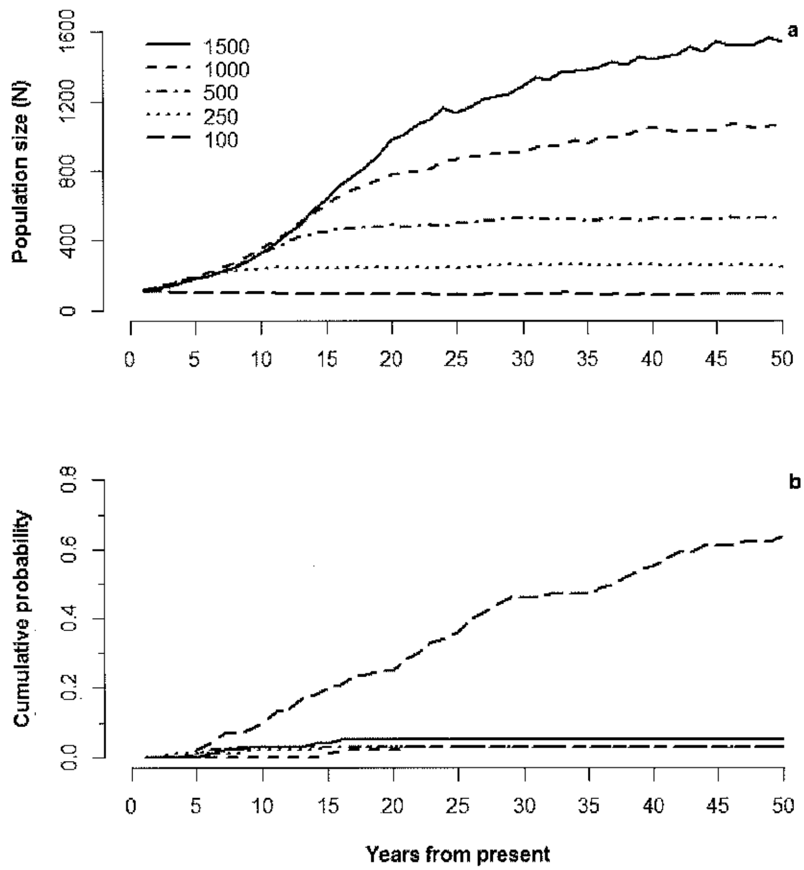

Figure 7. Estimated effect of variation in density-threshold on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

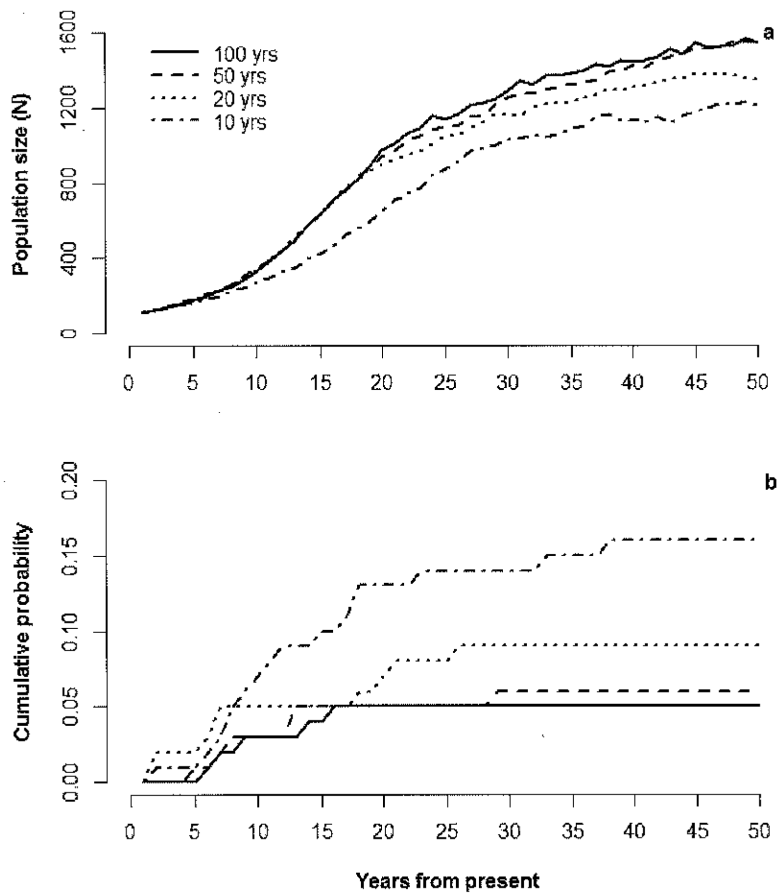

Figure 8. Estimated effect of variation in interval between catastrophic reductions in survival of wolves on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs). Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Increased frequency of pack-specific reproductive failure reduced population growth rates and mean, maximum population size of wolves (Fig. 9a). Scenarios with reproductive failure once every 20 (0.05; 95% CI = 0.01 – 0.09) and 10 litters (0.05; 95% CI = 0.01 – 0.09) had similar risk of conservation-failure in the next 50 years (Fig. 9b). Risk of conservation-failure was almost 6 times greater at intervals of once every 5 litters (0.29; 95% CI = 0.20 – 0.38). These results highlight the importance of pup production on ensure population viability of wolves. Risk of biological-extinction was not strongly affected by interval of reproductive failure as all scenarios had a risk of biological-extinction ≤ 0.02.

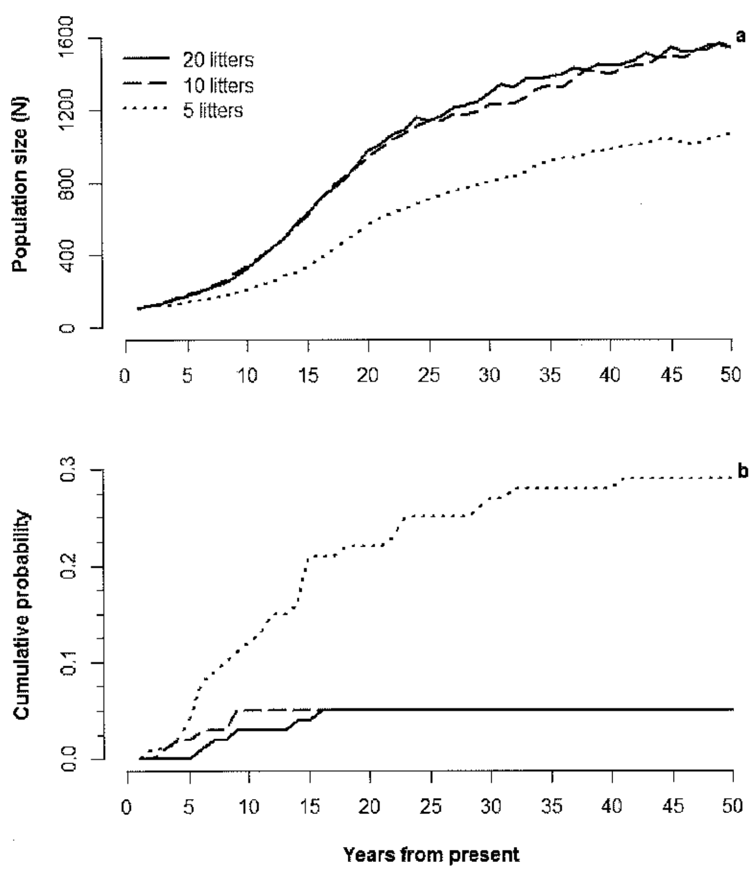

Figure 9. Estimated effect of variation in intervals between reproductive failure on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization.

Effects of lethal control of wolves

Increased rates of legal mortality, while holding illegal mortality at baseline values, had a negative effect on population growth rates and mean, maximum population size of wolves (Fig. 10a). With a starting population of 85 wolves and at a legal mortality rate of 0.20, wolf populations declined. This suggested this rate of legal morality was not sustainable over the long-term at least at a starting population of 85 wolves and additional illegal mortality of 0.05. At a mean legal mortality rate of 0.05, which was used in our baseline model, probability of conservation-failure was 0.05 (95% CI = 0.01 – 0.09; Fig. 10b) over the next 50 years. At a reduced mean legal mortality rate of 0.00, no simulated populations dropped below the conservation-failure threshold. Probability of conservation-failure increased to 0.40 (95% CI = 0.30 – 0.50) and 1.00, for mean legal mortality rates of 0.10 and 0.20, respectively, when combined with illegal mortality rates of 0.05. Combined, these results highlight the importance of minimizing anthropogenic mortality to benefit population viability of wolves. Probability of biological-extinction was relatively low for all simulations with mean legal mortality rates ≤ 0.10 (range = 0.00 – 0.07; Fig. 10c). In contrast, mean legal mortality rates of 0.20 resulted in an extremely high probability of biological extinction (0.90; 95% CI = 0.84 – 0.96), at least when combined with an illegal mortality rate of 0.05 and a starting population of 85 individuals. Larger populations will be able to sustain higher mortality rates because they will have a greater buffer between extant population size and thresholds of biological extinction.

It should also be noted, the levels of anthropogenic mortality used in our model are not directly comparable to mortality rates commonly reported in literature (i.e., 1 – survival rate). Anthropogenic mortality rates as implemented in our model represent the proportion of wolves that would be removed from the population after accounting for natural mortality. For example, using a legal mortality rate of 0.10, an illegal mortality rate of 0.05, and a survival rate in the absence of anthropogenic mortality of 0.88, would result in an observed survival rate of 0.75 (0.88 × 1-0.10 ×1-0.05).

The effects of legal removals on wolves reported above are predicated on a starting population of 85 wolves. At larger population sizes, wolves will have an increased buffer between extant population size and conservation-failure or biological-extinction thresholds and fewer simulations would be expected to cross these thresholds. This is particularly true for moderate levels of legal mortality (0.05-0.15) where populations are likely to increase on average, but without a sufficient buffer and under stochastically varying conditions, 2-3 consecutive years of negative population growth could push the population below a predefined threshold. This phenomenon is evident in our simulations because most conservation-failures occurred shortly after simulations started. By later years, population sizes had sufficiently increased that they were able to withstand several consecutive years of negative population growth without falling below the conservation-failure threshold.

Comparison of individual vs. pack removal.–Lethal control actions conducted through random removal of individuals or entire packs had little influence on mean population size over 50 years (Fig. 11a). Mean populations for both removal scenarios reached the density-threshold (N = 1,500) by the 50th year of the simulation. Conservation-failure rates over 50 years were similar if individual wolves (0.05; 95% CI = 0.01 – 0.09) or packs (0.08; 95% CI = 0.03 – 0.13) were removed (Fig. 11b). Entire pack removal (0.01; 95% CI = 0.00 – 0.03) and removal of individuals (0.01; 95% CI = 0.00 – 0.03) resulted in similar estimates of biological-extinction risk over 50 years.

Commented [RL10]: This is a bit surprising. I have some memory of previous work on wolves in Alaska that suggested that wolf populations could sustain relatively high harvest rates (>25%) without causing λ to drop below 1 as a result of wolves' high reproductive rate. So, I'm a little surprised that growth rate is so sensitive to anthropogenic mortality in this model.

Commented [RL11]: Maybe this explains the discrepancy, but the effect still seems awfully strong.

Commented [RL12]: Actually, this is probably what explains it. It seems like this may have more direct management implications worth mentioning too. For example, what population size needs to be attained in order for the wolf population in Oregon to be able to start sustaining an annual harvest of X% and still have risk of falling below your critical population thresholds of <5%?

Commented [RL13]: This result surprises me a little too, given that in the baseline model removal of individuals was random. I would expect this result if the individuals being removed were typically the dominant breeders, because removing packs would, by definition, always include removal of the dominant breeders. If removal of individuals was random, however, then I'd expect the influence on population growth to be reduced, because many of those individuals wouldn't have contributed much to the population growth rate anyway.

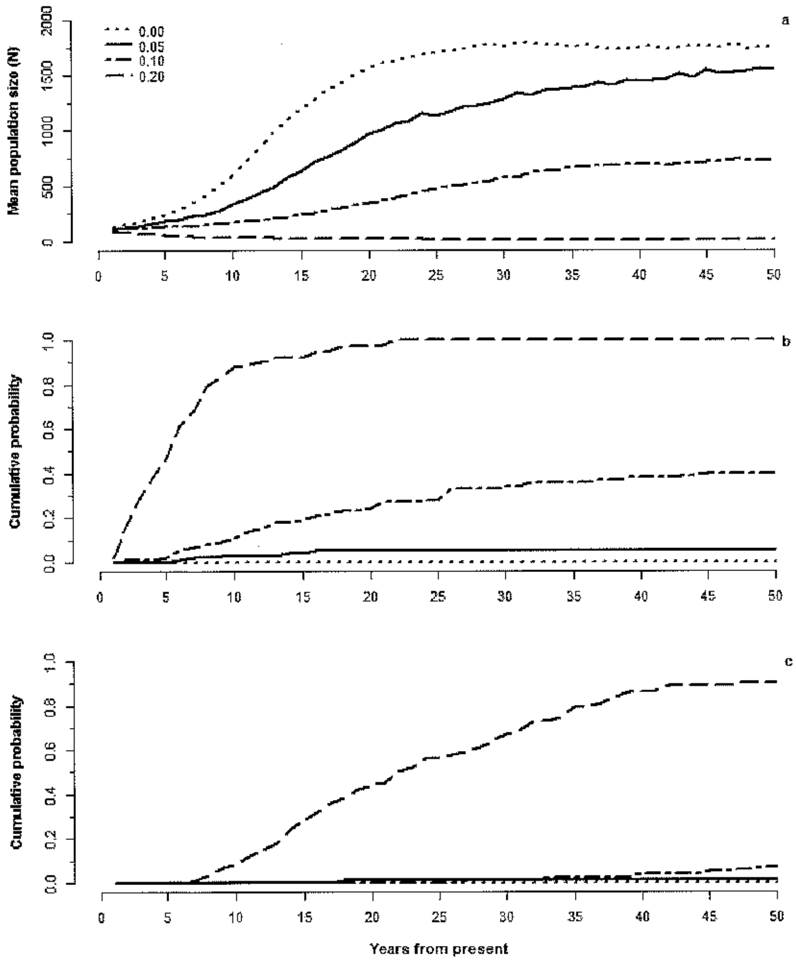

Figure 10. Estimated effect of variation in legal removal rates (proportion of wolves that would have survived the year otherwise) of wolves on (a) mean population size, (b) cumulative probability of conservation-failure (< 4 breeding pairs), and (c) cumulative probability of biological-extinction (< 5 wolves) over the next 50 years in Oregon when the starting population size was 85 wolves. Cumulative probability of conservation-failure or biological extinction represents the cumulative proportion of simulated populations that reached the specified threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. For all simulations, unauthorized morality rates of 0.05 (± 0.03 SD) occurred in addition to varying levels of legal removal.

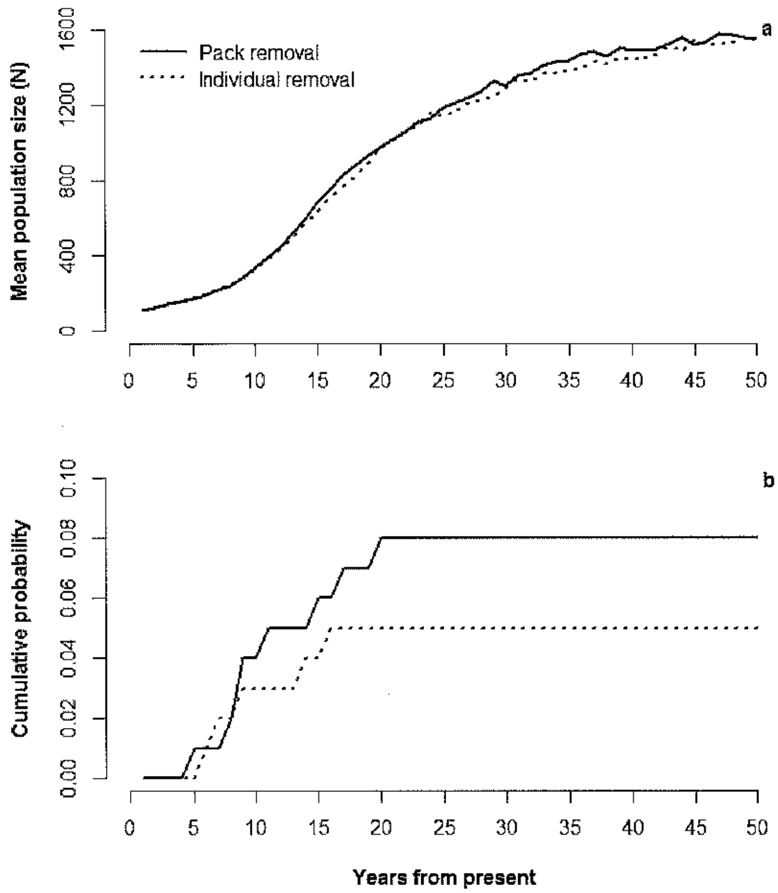

Figure 11. Estimated effect of individual versus pack level legal removal on (a) mean population size and (b) cumulative probability of conservation-failure (< 4 breeding pairs) over the next 50 years in Oregon. Cumulative probability of conservation-failure represents the cumulative proportion of simulated populations that reached the conservation-failure threshold. All estimates generated using 100 realizations of population growth over 50 years using baseline model parameterization. Pack level and individual removal rates were identical for each simulation (0.05 ± 0.03).

Commented [RL14]: If there was any way to put confidence intervals around these predictions it would probably be a good idea. The second panel in this figure doesn't seem to line up very well with the way these results are described in the preceding paragraph (i.e., it looks as if there could be a significant effect of pack vs. individual removal on probability of conservation failure), until you read the confidence intervals in the text and realize that there's a lot of overlap.

Discussion

Our baseline model underestimated population growth rates of wolves compared to observed population counts conducted in Oregon from 2010-2014. This was a consequence of two factors: 1) our baseline model used lower survival rates than were observed from 2010-2014 and 2) at small population sizes demographic stochasticity can have a dramatic effect on population growth rates (Lande 1998, Fox and Kendall 2002). However, our model parameterized with survival rates of wolves radio-collared in Oregon from 2009-2014 allowed our model to track observed population growth rates during this timeframe. We contend these findings suggest our model structure is capable of accurately portraying population dynamics of wolves when survival rates used in the model are representative of current conditions. We used conservative survival estimates in our baseline model to ensure our PVA erred on the side of caution (i.e., precautionary principle; Myers 1993, Meffe et al. 2006). Consequently, our results represent a conservative view of population viability of wolves in Oregon.

If wolf populations in Oregon continue to follow vital rates observed from 2009-2014, our results indicated there would be no risk of conservation-failure or biological-extinction within the next 50 years. It is unlikely wolf populations in Oregon would continue to increase at observed population growth rates because established or exploited wolf populations do not increase as rapidly as protected or recovering populations (Ballard et al. 1987, Hayes and Harestad 2000, Fuller et al. 2003). Therefore, we contend results from our model parameterized with currently observed vital rates may present an overly optimistic view of wolf population dynamics moving forward in Oregon. Using our baseline model parameterized with vital rates obtained from a literature review, we documented a 0%, 3%, and 5% chance of conservation-failure over the next 5,10, and 50 years, respectively (Fig. 4). Most risk of conservation-failure occurs in the short-term (e.g., 15 years) because Oregon's extant wolf population is close to the conservation-failure threshold and a few years of poor population growth could cause the population to decline below the threshold. Furthermore, during the first few years of our simulations, population sizes are small, which allows demographic stochasticity to have a greater effect on population persistence (Vucetich et al. 1997).

Our baseline model suggested risk of conservation-failure was lower for populations that started with 100 or 150 wolves compared to the current population size observed in Oregon (N = 85; Fig. 6). This is not an unexpected finding because larger populations, regardless of species, have a reduced risk of extinction and can withstand longer periods of reduced population growth. These results highlight the importance of creating a buffer between extant population size and conservation-failure thresholds to allow for potential years of negative population growth. Furthermore, increased modeled starting population size will minimize effects of demographic stochasticity and increase population viability. Based on observed population growth rates from 2009-2014 (mean $\lambda = 1.43$) and known reproduction in 13 groups of wolves in 2015, Oregon's wolf population is expected to surpass 100 wolves by the end of the biological year. At this population size, risk of conservation-failure will effectively be eliminated (≤ 0.01).

In general, factors that influenced wolf survival had the greatest effect on intrinsic growth rates of wolves (r) in our simulation models. In our model, pup, yearling, and adult survival all had significant effects on intrinsic growth rates of wolf populations (Fig. 5). However, variation in pup survival had a greater effect on intrinsic growth rates than yearling or adult survival. While population growth rates of most large mammals are usually most sensitive to changes in adult survival, variability in adult survival, in the absence of high levels of anthropogenic mortality, is usually minimal compared to juveniles (Promislow and Harvey 1990, Gaillard et al.

1998, Robinson et al. 2014). The inherent variability in survival of juveniles causes this age class to have a disproportionate effect on population growth rates despite population growth rates being relatively insensitive to variation in this parameter. This does not discount the importance of adult and yearling survival on population growth and viability; rather it highlights the importance of minimizing annual variation and maintaining high survival rates of yearlings and adults.

Prey abundance and vulnerability are thought to influence wolf populations (Fuller and Keith 1980, Hayes and Harestad 2000, Vucetich and Peterson 2004). In our model, we did not explicitly model predator-prey relationships; rather, we used a prey multiplier value that increased stochastic variation in survival rates of wolves to simulate the effects of variation in prey abundance or changes in environmental conditions (e.g., snow depth) that influence vulnerability of prey over time. Effectively, the prey multiplier represented environmental stochasticity that allowed up to a 20% increase in variation in survival rates. Increased variability in survival (i.e., environmental stochasticity) will have negative effects on population growth rates and viability, regardless of the species of interest (Morris and Doak 2002). Consequently, it was expected that increased environmental stochasticity, modeled through our prey multiplier, had a negative effect on simulated wolf populations.

Anthropogenic mortality is the primary factor that influences dynamics of most wolf populations (Creel and Rotella 2010). Our model supported this conclusion because increased levels of anthropogenic mortality had a negative effect on intrinsic growth rates of wolves (Fig. 5). Furthermore, our simulation results indicated that increased rates of anthropogenic mortality resulted in increased risk of conservation-failure and biological-extinction when the initial population was 85 wolves (Fig. 10). Anthropogenic mortality is the parameter in our model over which ODFW has the most control and our results highlight that Oregon's wolf population will continue to increase and become self-sustaining if anthropogenic mortality is limited.

Our baseline model used inputs of 0.05 for both illegal and legal anthropogenic mortality rates (i.e., 5% of wolves that do not die of natural causes will be removed by both illegal and legal mortality sources) and at this rate, risk of conservation-failure was low. If ODFW maintains mortality rates at or below this level, the wolf population is predicted to be at a low risk of conservation-failure (0.05) and biological-extinction (0.01). Sustained, high levels of anthropogenic mortality (e.g., 0.20) in a stochastically varying environment contributed to increased risk of conservation-failure in our simulations; however, this finding is predicated on our staring population size of 85 wolves. Larger populations would be able to sustain this level of anthropogenic mortality without reaching the conservation-failure threshold because there is an increased buffer between extant population size and the conservation-failure threshold. Our model suggested that total anthropogenic mortality rates (i.e., combined illegal and legal mortality) of 0.15 would result in an increasing population on average ($\lambda = 1.03$) but total anthropogenic mortality rates of 0.20 caused wolf populations to decline on average ($\lambda = 0.98$). Previous studies have indicated wolf populations can be sustained with mortality rates up to 0.25 - 0.30 (Adams et al. 2008, Creel and Rotella 2010, Sparkman et al. 2011). As implemented in our model, anthropogenic mortality rates of 0.20 would cause survival rates of adult wolves to be 0.70 (i.e., a mortality rate of 0.30) and the wolf population would decline slightly on average ($\lambda = 0.98$). Consequently, our model matches well with the results previous studies.

Catastrophic reductions in survival of 25% had little effect on population growth rates and viability of wolves if the interval between occurrences was ≥ 50 years (Fig. 8). Widespread, catastrophic events are impossible to predict and little can be done to directly mitigate their

effect. However, general tenants of population ecology provide insight into actions that can minimize their effects on population viability. The primary way to reduce effects of catastrophes on population viability is to maintain larger extant populations. Larger populations are more viable because they have a sufficient number of individuals to withstand population declines. In our model, catastrophic events occurred at the population level. This is likely a biologically unrealistic expectation because catastrophic events are likely to occur in geographic regions (e.g., Blue Mountains or Cascade Range) due to localized differences in environmental conditions. This geographic separation should reduce population level effects of catastrophic events because not all wolves would be subjected to the event in a single year. However, these smaller sub-populations would have a greater risk of localized extinction compared to the larger extant population. This highlights the importance of risk spreading through spatial distribution of wolves in ensuring the long-term viability of wolf populations.

Recruitment of pups into the adult population was a critical factor influencing population dynamics of wolves. While we did not directly include a recruitment parameter in our model, several factors that jointly influence pup recruitment had separate effects on wolf population growth and viability. Variation in mean litter size had a strong effect on intrinsic growth rates of wolves. Increased frequency of reproductive failure had a negative effect on population growth rates and viability. Finally, reductions in survival rates of pups had a negative effect on population growth rates of wolves. Pup production and recruitment affects wolf population growth and viability in two ways. At the end of the biological year, wolf pups typically represent a large fraction of the total wolf population (Fuller et al. 2003). Consequently, any reductions in pup recruitment will slow population growth rates of wolves in the short-term. In the long-term, reduced pup recruitment will affect the number of potential dispersing wolves in the population. Yearling wolves (i.e., recently recruited pups) are most likely to disperse and establish new territories (Gese and Mech 1991, Boyd and Pletscher 1999). Reduced pup recruitment will limit the number of potential dispersers in subsequent years, which should slow the rate of population growth because fewer dispersers will be available to establish territories and contribute to population level reproduction.

In our baseline model, we used a density-threshold value of 1,500 wolves. This value represented the biological phenomenon where population growth of wolves would be limited by availability of vulnerable prey (Fuller 1989, Mech et al. 1998, Fuller et al. 2003) or intraspecific mechanisms (Cariappa et al. 2011); however the ability of wolves to self-regulate through intrinsic mechanisms is thought to be limited (Keith 1983, McRoberts and Mech 2014). Varying the density-threshold value in our model had little effect on risk of conservation-failure at values ≥ 250 wolves. Consequently, we contend our choice of a density-threshold value had minimal effects on our results.

The Oregon Wolf Plan (ODFW 2010) provides guidelines as to when lethal control of wolves can occur. Our results indicated increased levels of anthropogenic mortality negatively affect wolf population growth and viability. However, whether anthropogenic mortality was implemented at an individual or pack-level had little effect on our results. Caution should be used when implementing lethal control to address management concerns. For example, breeder loss can have a significant, negative effect on wolf population dynamics (Brainerd et al. 2008, Borg et al. 2015). Consequently, decisions regarding lethal removal of breeding wolves should be carefully considered.

Commented [RL15]: This is exactly the reason why it surprised me that removal of randomly selected individuals had the same effect on population growth as removal of packs.

Our analysis of wolf-population viability did not explicitly incorporate genetic effects. Genetic viability is a critical concern for any threatened or endangered population (Frankham et

al. 2002, Scribner et al. 2006) especially for extremely small, isolated populations (Frankham 1996). Inbreeding is a potentially serious threat to the long-term viability for small, isolated populations of wolves (Liberg 2005, Fredrickson et al. 2007) but can be minimized through connectivity to adjacent populations. As few as 1-2 immigrants per generation (~5 years) can be sufficient to minimize effects of inbreeding on wolf populations (Vila et al. 2003, Liberg 2005). High levels of genetic diversity in Oregon's wolf population are likely to be maintained through connectivity to the larger northern Rocky Mountain wolf population. Wolves are capable of long-distance dispersal (Fritts 1983, Boyd and Pletscher 1999, Wabakken et al. 2007) which should allow a sufficient number of immigrants to arrive in Oregon so long as sufficient connectivity is maintained between populations in adjacent states (Hebblewhite et al. 2010). While our model did not account for genetic effects, we acknowledge the importance of genetics for isolated populations of mammals and recognize that genetic effects could become important if the Oregon wolf population becomes isolated from the remainder of the northern Rocky Mountain wolf population.

The IBM we used to assess wolf population viability in Oregon should provide a realistic biological representation of wolf population dynamics. However, our IBM does not have a spatial component and does not rely on habitat or other landscape features. Spatially-explicit models could provide a more biologically realistic representation of wolf population dynamics; however, spatially-explicit models require substantial amounts of data that is currently not available in Oregon to effectively parameterize the model. Habitat suitability maps have been developed for Oregon (e.g., Larsen and Ripple 2006), but these maps have not been validated and use of these maps would introduce another unknown source of error in population models. Furthermore, the effects of habitat on survival, reproduction, and dispersal of wolves in Oregon are unknown and it would be impossible to accurately model these effects without unwarranted speculation. For these reasons, we contend our non-spatial analysis of wolf population dynamics is currently the most appropriate approach to model wolf population dynamics and viability because it does not rely on unfounded assumptions that could lead to inappropriate conclusions.

Supplement 1: Population Viability of Wolves in the Eastern Wolf Management Zone.

We used our existing IBM to assess viability of wolves in the eastern Wolf Management Zone (WMZ) of Oregon (see ODFW 2010 for description of eastern WMZ). In this analysis, we restricted our starting population size to those wolves known to occur in the eastern WMZ as of April 1, 2015 ($N = 76$) and set the density threshold to 600 wolves compared to 1,500 wolves used in the statewide analysis. We selected the density-threshold for eastern WMZ using the equations following: Fuller et al. (2003) provided the following equation to estimate expected wolf densities:

$$\text{Wolves}/1{,}000\ \text{km}^2 = 3.5 + 3.27 \times U$$

, where U is the ungulate biomass index (km^2). Using an estimated elk (*Cervus elaphus*) population of 66,000 elk distributed across 53,320 km^2 of summer range habitat in the eastern WMZ (ODFW, unpublished data) and assigning each elk a biomass value of 3, results in a value of U of 3.71 (66,000 × 3/53,320). Based on this value maximum wolf densities were estimated to be 15.64 wolves/1,000 km^2 of summer range elk habitat in the eastern WMZ. This would result in a total population of 834 wolves within 53,320 km^2 of elk summer range habitat in the eastern WMZ. Carbone and Gittleman (2002) provided the following equation to estimate wolf densities based on available primary prey biomass:

$$\text{Number of wolves} = 0.62 \times \text{primary prey biomass}$$

, where primary prey biomass is scaled per 10,000 kg. Currently, the elk population in the eastern WMZ is approximately 66,000 with each elk weighing on average 217 kg (ODFW, unpublished data). This results in approximately 1,432.2 × 10,000 kg of primary prey biomass available to wolves across the eastern WMZ and a maximum population estimate of approximately 888 wolves. To be conservative, we used a density-threshold of 600 wolves in the eastern WMZ.

Remaining methods and parameter inputs for this analysis were identical to those used in the statewide assessment of wolf population viability (Table 1). As with the statewide analysis, we used two metrics to assess population viability: 1) conservation-failure, defined as the population dropping below 4 breeding pairs and 2) biological-extinction, defined as the population having fewer than 5 individuals.

Using our baseline model, simulated wolf populations increased an average of 6% (i.e., $\lambda = 1.06 \pm 0.17$ SD) per year. Over the next 50 years, there was a 0.06 (95% CI = 0.01 – 0.11) probability of the population dropping below the conservation-failure threshold (Fig. S1). Half of the conservation-failures occurred within the first 10 years and by year 20 no additional populations passed the threshold. Of the six simulated populations that fell below the conservation-failure threshold, all eventually surpassed 4 breeding pairs in the future with these populations having 22, 37, 61, 67, 72, and 88 breeding pairs by year 50, respectively. No simulated populations dropped below the biological-extinction threshold over the next 50 years. Risk of conservation-failure in the eastern WMZ was slightly higher, but not significantly different, than risk at a statewide level (0.06 vs. 0.05; Fig. S2). Our simulation results suggested risk of conservation-failure declined with increasing starting population size (Fig. 6), so it was not surprising that the slightly smaller starting population in the eastern WMZ ($N = 76$) had a slightly higher risk of conservation-failure compared to the statewide population ($N = 85$).

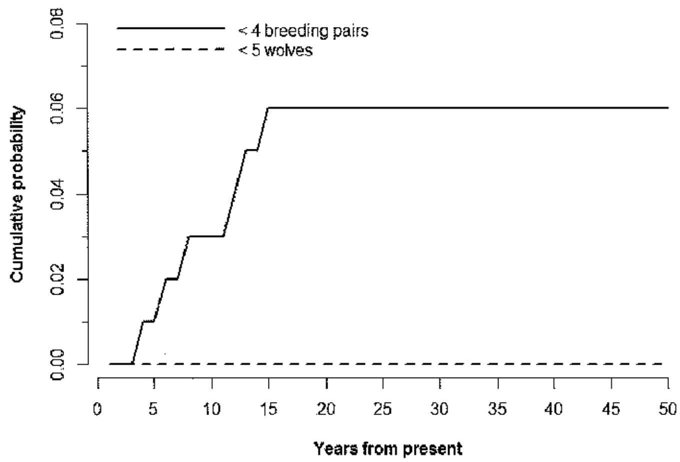

Figure S1. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) or biological-extinction (< 5 wolves) thresholds over the next 50 years in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

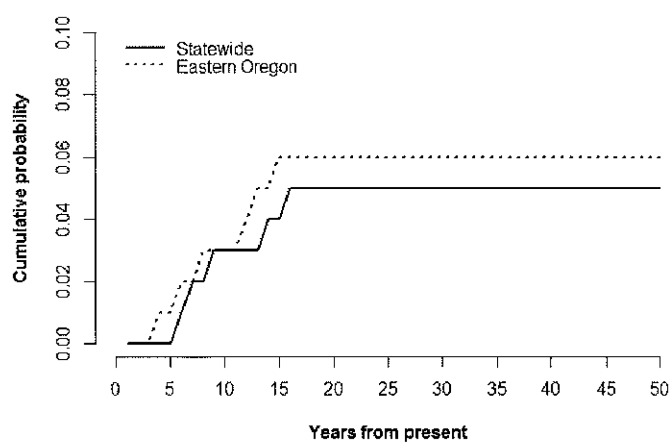

Figure S2. Estimates of cumulative probability of simulated wolf populations reaching the conservation-failure (< 4 breeding pairs) over the next 50 years across the entire state or in the eastern Wolf Management Zone of Oregon. Estimates were generated using our baseline model parameterization with 100 realizations of population growth over 50 years. Cumulative probabilities represent the cumulative proportion of simulations that crossed the threshold of interest.

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October 29, 2015

RE: The Commission's Consideration of a Proposal by the Department of Fish and Wildlife to Remove Gray Wolves from the List of Species Protected by the Oregon Endangered Species Act

Chair Finley and members of the Commission:

On behalf of our organizations and thousands of members and supporters across Oregon and America, we are writing to express our deep concern regarding the state's proposal to remove wolves from the protections of the Oregon Endangered Species Act (OESA). We oppose delisting wolves from OESA at this time, as it is not supported by science, the law, or the Oregon public. As members of the Pacific Wolf Coalition who work on Oregon wolf conservation and recovery, and on behalf of the Pacific Wolf Coalition, we submit the following documents for your consideration:

SCIENCE REVIEW

We provide letters from multiple scientists who have written the commission and who, based on their expertise, conclude that delisting is not warranted.

The Department has recommended that the commission delist wolves. That recommendation is based on the data and analyses the Department developed in a report it prepared entitled "Gray wolf biological status review (ODFW 2015)." Among other things, the status review reports on Oregon's current wolf population, identified suitable habitat and occupancy of suitable habitat by wolves, and includes a population viability analysis (pva) which makes predictions regarding the risk of conservation failure and biological extinction of Oregon's population of wolves.

In April, you received a letter signed by highly-credentialed scientific experts in wolf and mammalian biology, ecology, behavior, evolutionary biology, conservation biology, and environmental philosophy and ethics, all of whom oppose delisting Oregon's wolves and support maintaining continued protections for wolves here.

In recent weeks, you have received additional letters from multiple scientists providing specific comments, conclusions and recommendations regarding the Department's recommendation to delist, and specifically regarding their evaluation of the Department's status review, habitat suitability assessment and population viability analysis (pva). No scientist found that the basis for the Department's recommendation to delist is sound. All scientists found significant reasons not to delist, including fundamental flaws in the pva the results of which cannot be relied upon due to those flaws, and with the Department's finding that wolves are not endangered despite being absent from nearly 90 percent of current suitable habitat.

Though ODFW staff invested a great deal of time and effort into a report to justify delisting, it appears very little consideration was given to information that did not support that conclusion.

LEGAL REVIEW

We provide a concise legal analysis which shows that delisting wolves at this time would run counter to established state laws and administrative rules. We offer a different course of action.

PUBLIC COMMENT AND OPINION REVIEW

We provide a one-page overview of the numbers demonstrating public support for wolves, wolf recovery and continued protections for this endangered native species, which is just starting to return to Oregon.

Like most Americans, Oregonians overwhelmingly support conservation of native wildlife. This one-page review demonstrates clearly that Oregonians continue to overwhelmingly support wolf recovery and continued protections for wolves. Additionally, more than 22,000 comments opposed to delisting and in favor of continued protections for wolves have been submitted to the commission, and we have provided a tally of known comments submitted by individual members of the public.

CONSERVATION GROUPS COMMENTS

To ensure our previously-submitted comments are part of the record, we include copies of letters and written testimony previously given to the Commission by member organizations of the Pacific Wolf Coalition.

A great deal of public comment has been submitted prior to formal rulemaking. It has been confusing to the public to understand deadlines for submission of comments. An email sent by the Department to constituents on October 14 indicated the comment deadline was October 30. A member of the public speaking by phone with Commission staff earlier this week was advised by Commission staff the comment deadline was October 27. A news release issued today by the Department stated that comments would be accepted until November 6. Given this extremely confusing state of affairs, with neither the Commission nor Department staff perhaps knowing what information was being given out by each other to the public, and given there may be legal implications for improper notice of comment deadline dates, we encourage the Commission and Department to give consideration to all previous testimony and other public comment, and all which continues to come in through the Commission meeting date of November 9.

ODFW is charged with a mission to “protect and enhance Oregon’s fish and wildlife and their habitats for use and enjoyment by present and future generations”. Though the agency is wise to consider concerns from a broad spectrum of stakeholders it is important that the agency prioritize its own mission and obligation to conservation of native wildlife in the service of all Oregonians.

The return of wolves has the potential to be one of Oregon’s greatest conservation success stories. Wolf recovery rights a historic wrong. However it also presents unique challenges – and a test - for the agency. The public is watching carefully.

Since a 2013 settlement, Oregon has been a model around the country for balancing conservation, science, and public values against legitimate concerns, misinformation, and old prejudices against this native species.

Upon reaching the milestone of confirmation of four breeding pairs for three consecutive years in Eastern Oregon, the state’s wolf plan called for *consideration* of delisting wolves. Despite claims to the contrary, it did not – nor did conservationists who supported the plan – call for delisting at this point.

Delisting wolves at this time is not supported by science, the law, or the public.

The state does not seem to have given serious consideration to information that supports maintaining protections for wolves. Rather it appears the delisting reports were put together with a predetermined intent to justify delisting. The continued insistence on delisting wolves seems motivated by politics and a specious perception that it would make things easier for the agency. Oregon’s estimated wolf population currently stands at around 80-83 animals, which is a mere five percent of the population which peer-reviewed literature says the state could support. This handful of wolves occupies only 12 percent of identified suitable wolf habitat in the state, and this identified habitat is about half of what once existed as suitable for wolves. This means wolves are absent from nearly 90 percent of current suitable habitat and almost 100 percent absent from historic range. For no other species would these population numbers and this range occupancy be viewed as so successful as to warrant delisting, making it all the more evident that a decision to delist wolves in Oregon would be the result of politics instead of the application of science.

The state has apparently finally decided to respond to repeated calls for its delisting report to be subject to outside peer review. To our knowledge, a peer review request has been made of one outside scientist, Dr. Carlos Carroll. Dr. Carroll's review finds multiple flaws in the delisting report and this alone is reason to give pause. But one scientist does not an "outside panel of scientific experts" make, as is required by the state ESA, and we continue to urge the commission to engage a panel of experts in wolf population modeling, wolf biology, ecology and genetics, and experts in the social dimensions of human-wildlife conflict.

Indeed, many such qualified scientists have submitted comment letters to the commission, concluding that delisting is not warranted at this time and that the delisting report is significantly flawed. Any of these scientists could be contracted to do a more thorough review, or scientific societies, such as the Society for Conservation Biology or the American Society of Mammalogists could be contracted to undertake an independent peer review. Though such a review would take time, there is no compelling reason to rush a delisting.

If reviewers determine the state's delisting report is defensible, the benefit to the state of having a defensible decision with broad public buy-in would be significant. If reviewers determine the state's delisting report is not defensible, getting this legally-required input to consider could save the state an embarrassing and costly legal ordeal in having to defend in court against filings that the state violated OESA in delisting wolves.

Since the settlement agreement between ODFW, the state, conservationists, and the Oregon Cattlemen's Association, Oregon's wolf plan has been working for all but the most intransigent voices. ODFW staff worked under clear defensible guidelines and definitions, prioritized transparency, conservation, and conflict *prevention*. The state can kill wolves but has not had to. Under the Phase I agreement, Oregon was the only state in the nation with a meaningful wolf population that did not kill them. The wolf population grew while conflict remained low and, by many measures, decreased.

Under settlement, ambiguity in the plan that led to unnecessary conflict and controversy was addressed. In Phase II and III that ambiguity is back. Given that the state is now required to begin the 5-year review of the wolf plan and that the status review is in part dependent upon the provisions of the plan, we urge the Commission – as we have all along -- to review the plan concurrently – or in advance of – any decision on the status review. A stronger plan that provided more clarity to stakeholders could be a key step in assuaging concerns over a decision to delist or maintain state endangered species protections for wolves.

We look forward to the day we can celebrate an appropriate delisting of wolves in Oregon. Given that the state has only once before delisted a mammal from the state ESA and wolves were once the center of a purposeful program of extermination, it would be a tremendous achievement. However a premature delisting of wolves without public support would be a tremendous step backwards for the Oregon Department of Fish and Wildlife and a state that prides itself on its conservation ethic in the 21st century.

Therefore we urge the Commission to:

- Conduct the wolf plan review prior to or concurrent with any decisions on the status review and rulemaking.

- Give serious consideration to maintaining protections for wolves.
- Commission an independent review of the state's delisting proposal.
- Work with stakeholders outside time-limited Commission hearings and provide sufficient time to achieve public support for its decision.

On behalf of the Pacific Wolf Coalition, we thank you for consideration of all comments, documents, and recommendations we have provided to you.

Very Sincerely,

Amaroq Weiss
West Coast Wolf Organizer
Center for Biological Diversity

Steven Pedery
Executive Director
Oregon Wild

Nick Cady
Legal Director
Cascadia Wildlands

Danielle Moser
Pacific Northwest Wolf Organizer
Endangered Species Coalition

Science Review

April 14, 2015
Letter to Oregon Department of Fish and Wildlife
From Scientists on Wolf Recovery

We, the undersigned scientists, are writing to express our concern that now is not the time to delist the gray wolf in Oregon. Continued state Endangered Species Act (ESA) protections are essential for allowing existing populations to stabilize and expand into other suitable habitat. Milestones should be celebrated, but meaningful recovery is not complete in significant portions of suitable habitat in the state. Prematurely weakening gray wolf protections is likely to reverse years of progress, put recovery in jeopardy, and exacerbate conflict.[i] [ii] [iii]

We urge ODFW to:

Maintain ESA status for gray wolves and foster coexistence by getting ahead of – rather than reacting to – conflict. Some suggestions for doing this are to:

- *Focus on positive aspects of wolf recovery, native predators, and healthy landscapes*
- *Conduct and facilitate research regarding wolves and conflict deterrence measures and*
- *Provide landowners with information that will assist in reducing potential conflicts*

Like all native wildlife, wolves are an enormous asset to the biological diversity of our state, ecosystem services, and quality of life. Wolf recovery is overwhelmingly supported by Oregonians. After years of making excellent progress toward recovery, it would be a shame to stop before the final goal is accomplished.

We offer our expertise and support for such an effort and extend our thanks to you for your leadership on wildlife conservation issues.

Signed:

Marc Bekoff, Ph.D.
Ecology and Evolutionary Biology
University of Colorado, Boulder
Science Advisory Board, Project Coyote

Robert L. Beschta, Ph.D.
Professor Emeritus
Forest Ecosystems and Society
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Barbara Brower, Ph.D.
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University of Wisconsin-Madison
Science Advisory Board, Project Coyote

Jennifer Wolch, PhD
Berkeley California
Dean, College of Environmental Design
Science Advisory Board, Project Coyote

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[i] Tad Larsen and William J. Ripple, "Modeling Gray Wolf (Canis lupus) habitat in the Pacific Northwest, U.S.A," *Journal of Conservation Planning* Vol 2 (2006) 17-33.

[ii] Oregon Department of Fish and Wildlife," Oregon Wolf Population," http://dfw.state.or.us/Wolves/population.asp, (January 27, 2015)

[iii] Carroll, C., R.F. Noss, N.H. Schumaker, and P.C. Paquet. 2001. "Is the return of the wolf, wolverine, and grizzly bear to Oregon and California biologically feasible?" Pages 25-46 in D.S. Maehr, R.F. Noss, and J.L. Larkin, editors. Large Mammal Restoration: Ecological and Sociological Challenges in the 21st Century. Island Press, Washington, DC.

To the Oregon Fish and Wildlife Commission:

I am submitting these comments regarding the ODFW gray wolf biological status review (ODFW 2015). I am a professional quantitative ecologist and principal scientist with the Wild Nature Institute. I have a Bachelor's degree in Anthropology from University of California, Santa Barbara, a Master's degree in Wildlife Natural Resource Management from Humboldt State University, and a PhD in Biological Sciences from Dartmouth College. I am an expert population biologist who has co-authored two population viability analyses (PVA) for the U.S. Fish and Wildlife Service:

1. N. Nur, R.W. Bradley, D.E. Lee, P.M. Warzybok, and J. Jahncke. 2013. Population Viability Analysis of Western Gulls on the Farallon Islands in relation to potential mortality due to proposed house mouse eradication. Report to the National Fish and Wildlife Foundation and the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California.

2. N. Nur, D.E. Lee, R.W. Bradley, P.M. Warzybok, and J. Jahncke. 2011. Population Viability Analysis of Cassin's Auklets on the Farallon Islands in relation to environmental variability and management actions. Report to the National Fish and Wildlife Foundation and the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California.

I co-authored a comprehensive review of demography and population dynamic models (including PVA) that was part of the California Current Seabird Management Plan for U.S. Fish and Wildlife Service:

N. Nur and D. E. Lee. 2003. Demography and Population Dynamic Models as a Cornerstone of Seabird Conservation and Management in the California Current. *in* California Current System Seabird Conservation Plan (eds. W.J. Sydeman, K.

Mills and P. Hodum). Report to the US Fish and Wildlife Service. PRBO Conservation Science, Stinson Beach, California.

Eight, relevant, peer-reviewed scientific articles that I have had published from my research include the following:

1. D.E. Lee, J. Bettaso, M.L. Bond, R.W. Bradley, J. Tietz, and P.M. Warzybok. 2012. Growth, age at maturity, and age-specific survival of the Arboreal Salamander (*Aneides lugubris*) on Southeast Farallon Island, California. Journal of Herpetology 46:64-71.

2. D.E. Lee, R.W. Bradley, and P.M. Warzybok. 2012. Recruitment of Cassin's Auklet (*Ptychoramphus aleuticus*): Individual age and parental age effects. Auk 129:1-9.

3. D.E. Lee. 2011. Effects of environmental variability and breeding experience on Northern Elephant Seal demography. Journal of Mammalogy 92:517-526.

4. A.C. Brown, D.E. Lee, R.W. Bradley, and S. Anderson. 2010. Dynamics of White Shark predation on pinnipeds in California: effects of prey abundance. Copeia 2010 No. 2:232-238.

5. D.E. Lee and W.J. Sydeman. 2009. North Pacific climate mediates offspring sex ratios in Northern Elephant Seals. Journal of Mammalogy 90:1-8.

6. D.E. Lee, C. Abraham, P.M. Warzybok, R.W. Bradley and W. J. Sydeman. 2008. Age-specific survival, breeding success, and recruitment in Common Murres (*Uria aalge*) of the California Current System. Auk 125:316-325.

7. D.E. Lee, N. Nur, and W.J. Sydeman. 2007. Climate and demography of the planktivorous Cassin's Auklet *Ptychoramphus aleuticus* off northern California: implications for population change. Journal of Animal Ecology 76: 337–347.

8. S.F. Railsback, B.C. Harvey, R.R. Lamberson, D.E. Lee, N.J. Claasen, and S. Yoshihara. 2001. Population-level analysis and validation of an individual-based Cutthroat Trout model. Natural Resource Modeling 15:83-110.

I have also acted as an independent consultant offering expert advice on questions of population management and population viability for management authorities and stakeholders involved in the multi-national Action Plan under the Agreement on the Conservation of Albatrosses and Petrels.

As part of my PhD work at Dartmouth College, I conducted a PVA to explore metapopulation dynamics of giraffe in a fragmented ecosystem in Tanzania:

D.E. Lee. 2015. Demography of Giraffe in the Fragmented Tarangire Ecosystem. PhD Dissertation. Dartmouth College.

My expertise has mostly focused on seabirds and other marine predators, in addition to giraffe, but the mathematics and the biological concepts relevant to PVA are universal and well-established. The universality of the concepts is apparent in the variety of taxa population biologists like me are able to apply our expertise to. For example, my work has encompassed taxa as diverse as cutthroat trout, woodrats, mice, seabirds, seals, salamanders, spotted owls, and giraffes.

I have examined the Oregon wolf PVA and found that details of the model's construction are vague or confused about fundamental aspects of the model, and some outputs seem to disagree with conclusions in the text. The model includes many relevant factors important to wolf population dynamics, but excludes or underestimates others such that I believe that the PVA as it was used is too simplistic and lacks sufficient detail of important demographic processes to realistically estimate probabilities of " conservation failure" or "biological extinction" over time.

It is my expert opinion that the existing PVA is fundamentally flawed and does not provide an adequate or realistic assessment of the Oregon wolf population to meet Criterion 1 or 2 or 4, therefore the delisting requirements are not supported by the results of the PVA as it was performed.

My primary concerns with the Oregon wolf PVA are:

1. The base model seems to produce unrealistically stable and high population growth.
2. Density-dependent survival and reproduction are not included.
3. Dispersal and territory establishment are poorly modeled.
4. Environmental and Demographic stochasticity were not explained clearly enough to convince me that the model was properly constructed.
5. Environmental stochasticity was poorly modeled.
6. Impacts of human-caused mortality were downplayed.
7. Sensitivity analyses were insufficient.

1) The **base model seems to produce unrealistically stable and high population growth**. Perhaps due to unrealistically high estimates of vital rates, or due to unrealistic levels of vital rate variability or covariances of vital rate variability (see below), the population growth rate of the base model is unrealistically high and stable. Page 16 of Appendix B says, "Using our baseline model, simulated wolf populations increased an average of 7% ($\lambda = 1.07 \pm 0.17$ SD) per year." This high growth rate (λ = finite rate of population growth) and its variation are comparable to recent estimates from three populations of wolves over 10 years in the northern Rocky Mountains (Gude et al. 2011). However, a recent meta-analysis of three protected and circumscribed populations monitored over 28–56 years showed population growth rates were very close to $\lambda = 1.0$, with much greater variation (SD = 0.33 to 0.51) than the Oregon wolf

PVA described (Mech and Fieberg 2015). A summary in Fuller et al. (2003) of 19 exploited (hunted) wolf populations monitored for 2–9 years described the average finite population growth rate as $\lambda = 0.995 \pm 0.21$ SD. This leads me to believe that the Oregon wolf PVA underestimated the risk of conservation failure and biological extinction due to structural issues in the model, or due to underestimates of variability or covariation in vital rates.

2) Density dependence in survival, reproduction, and dispersal success should have been included in the model structure. What the PVA authors called density dependence was actually a simply calculated carrying capacity, or theoretical maximum wolf population size, given the current elk population, but was not in any way a realistic modeling of density dependent effects on the growing wolf population. Furthermore, wolf carrying capacity was computed in the PVA using summer elk range, when winter range, the period of greatest food limitation and the greatest limitation on elk spatial distribution, is the more realistic and conservative period during which to estimate carrying capacity.

True **density-dependent** effects would have recognized the documented cumulative effects of an increasing or decreasing wolf population on vital rates of survival, reproduction, and dispersal and territory establishment. It has long been known that intraspecific competition related to territoriality seems to regulate wolf density below that predicted by food availability (Stenlund 1955; Pimlott 1967, 1970; Cariappa et al. 2011). Without true density dependence in vital rates, the Oregon wolf PVA assumes wolf vital rates are the same whether wolf habitat is nearly empty of wolves, or when wolves have nearly filled all the habitat. That true density dependence affects wolf populations was well demonstrated in Cubaynes et al. (2014) where adult survival decreased as wolf density increased, independent of prey density in the area (see

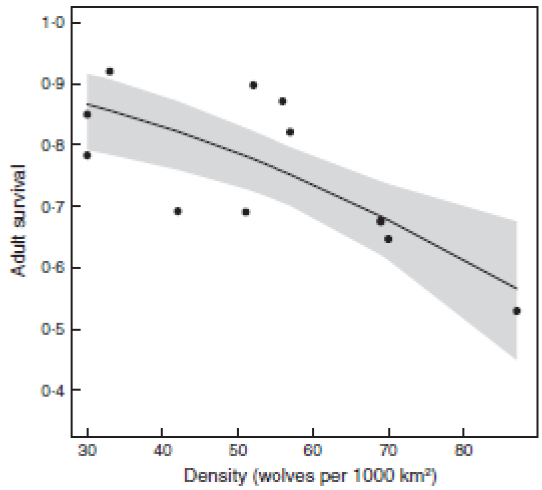

Fig. 3. Annual survival rates of adult wolves in the Northern Range as a function of wolf density in April. The intercept and slope were obtained from a model in which adult survival was modelled as a function of wolf density in April (Model 23), the zone filled with grey represent 95% confidence. Points represent mean survival estimates obtained from a model in which survival was time-dependent (Model 29).

Fig. 3 from Cubaynes et al. 2014, depicted here).

3) Dispersal and territory establishment should have been modeled as a spatially explicit process using a similar spatial simulation as was used for emigration, combined with the habitat model supplied in Appendix A. The PVA uses simple probabilistic rates of dispersal and successful territory establishment. This is unrealistic given that wolves occupy exclusive, defended territories in explicit spatial arrangements, so new territories cannot be established where one already exists (Fuller et al. 2003). This relates also to the unrealistic density dependence mentioned above. Also, wolves dispersing through non-habitat will not have the same survival as wolves dispersing through suitable wolf habitat. A more realistic dispersal process would use the existing wolf habitat map and established wolf territories, keep track of additional territories as the PVA simulation progresses, and when a dispersing individual ends up in an occupied area, it must disperse again until it ends up out of the state, or in unoccupied habitat. Additionally, when wolves are travelling through non-habitat, their survival rates should be lowered to reflect this reality. Human-caused mortality also should be increased when wolves dispersed through non-habitat. Finally, dispersal and territory establishment should have included an environmental stochasticity component.

4) Environmental and demographic stochasticity are two of the most important aspects of population viability analyses, but environmental and demographic stochasticity were poorly described, and even the authors of the Oregon wolf PVA seem confused about this topic.

Appendix B states, "We incorporated environmental stochasticity in our model by randomly drawing vital rate values from a uniform distribution with a predefined mean and standard deviation at each time step of the simulation." What this describes is not environmental stochasticity, this is **demographic stochasticity**, as is stated in the next sentence of Appendix B, "…vital rates were applied at an individual level, which inherently incorporated demographic stochasticity into our model." This confusion over demographic and environmental stochasticity is very disturbing. Nevertheless, we can establish that some level of individual demographic stochasticity is included in the model, but the authors of the PVA are unclear about the details. Drawing from a uniform distribution means all values between the lower and upper boundaries are equally likely to be selected. The authors say the values for vital rates were "from a uniform distribution with a predefined mean and standard deviation", but this is somewhat nonsensical. What I think they mean is that they drew from a uniform distribution where the interval's lower and upper boundaries were defined by the estimate of the vital rate's mean, plus and minus 2 SD, however in Table 1 they say," Values used at each time step of the analysis were randomly drawn from a uniform distribution within the specified standard deviation (SD)." So I am confused about a fundamental aspect of the PVA's construction regarding demographic stochasticity. This is a critical point as defining the uniform distribution as the vital rate's mean ± 1SD would make demographic stochasticity much less than if the uniform distribution's interval was defined as the vital rate's mean ± 2SD.

5) The effects of **environmental stochasticity** are included in the model as two 'catastrophes,' and a prey multiplier effect. The first catastrophe resulted in complete reproductive failure for that year at the pack level to simulate diseases such as canine parovirus, and occurred with an annual probability of 0.05. The second catastrophe was modeled at the population level "to represent extremely rare, range wide events that may affect wolf populations (e.g., disease, abiotic conditions, prey population crashes)," that occurred with a probability of 0.01 and resulted in a population-wide reduction in survival of 25%. These sorts of catastrophe are indeed useful to include because rare phenomena with large demographic effects are real and often have significant effects on populations. Indeed, in the PVA as constructed, these catastrophes were important effects during early years of the simulations, before population size was large enough to be resilient to catastrophes.

Unfortunately, catastrophes are not realistic proxies for true **environmental stochasticity** in abiotic conditions or prey availability that are typically due to stochastic annual variation in weather patterns. True environmental stochasticity would recognize that all wolf vital rates of age-class specific survival and reproduction usually co-vary among years because they are all correlated with certain weather phenomenon (such as extremely cold, wet winters) either directly, or indirectly through the weather's effects on prey species. Environmental stochasticity should have been modeled as a population-wide, or climate zone region-wide effect whereby all demographic parameters rise or fall together according to either a documented relationship between weather and vital rates, or a relationship between weather and prey species that indirectly affects wolf demographic vital rates.

The Oregon wolf PVA did include a prey multiplier effect (page 12) as environmental stochasticity, where, "Each year of the simulation, the prey multiplier had a 1 out of 3 chance of increasing, decreasing, or remaining the same, respectively. In years the prey multiplier increased or decreased, the maximum change was restricted to 0.10." However, this effect seems too small, or perhaps too limited by not affecting reproduction and dispersal, to realistically simulate true environmental variation.

Several studies have documented that the wolf populations are regulated by food, as a function of prey abundance and their vulnerability to predation (Packard and Mech 1980; Keith 1983; Peterson and Page 1988; Fuller et al. 2003). Because prey condition is highly dependent on weather conditions (Mech and Peterson 2003), wolf demography is also dependent on weather (Fuller et al. 2003). "In Denali National Park, Alaska, where humans also have little effect on the wolf population, the trend in wolf numbers from 1986 through 1994 … was driven by snow depth, which influenced caribou vulnerability (Mech et al. 1998)… As snow depth and caribou vulnerability increased, adult female wolf weights also increased, followed by increased pup production and survival and decreased dispersal (Mech et al. 1998)… In the east central Superior National Forest of Minnesota…from about 1966 to 1983, the wolf population trend followed that of the white-tailed deer herd, which was related to winter snow depth. Thus snow was seen as the driving force in the wolf-deer system (Mech 1990)." From Fuller et al. (2003). In Isle Royale National Park, wolf population growth depended mainly on the number and age structure of the prey population, although density dependence, winter severity, and catastrophic events like disease outbreaks also play important roles (Peterson and Page 1988; Peterson et al. 1998; Vucetich and Peterson 2004).

6) Human-caused mortality impacts were significant, but conclusions downplayed the effect of human-caused mortality. The section on lethal control (page 26, Appendix B) addressed the issue of legal and illegal human-caused mortality, and concluded that reasonable levels of human-caused mortality could result in conservation failure and/or biological extinction. Probability of conservation-failure increased to 0.40 and 1.00, for mean human-caused mortality rates of 0.15 and 0.25, respectively. These results highlight the importance of anthropogenic mortality to population viability of wolves. Probability of biological-extinction was relatively low for all simulations with mean human-caused mortality rates ≤ 0.15.

Additionally, human-caused mortality is likely to increase as the wolf population increases, possibly leading to additional density-dependent mortality. Illegal human-caused mortality has been recorded as 30–34% of total mortality (Liberg et al. 2012; Board 2012).

Oregon Legislative Assembly changed the status of wolves to "special status game mammal" under ORS 496.004 (9). Under this classification, and when in Phase III of the Wolf Plan, controlled take of wolves would be permitted as a management response tool to assist ODFW in its wildlife management efforts. This rule would effectively allow the legal killing of all wolves in excess of the conservation objective of 4 breeding pairs. Reducing the population to such a low number would undeniably result in the impairment of wolf viability in the region. A PVA scenario should be run to quantify the probability of conservation failure and extirpation under this legally permitted management action.

7) The **sensitivity analyses** was simplistic and insufficient in my opinion to characterize true sensitivity of demographic parameters under different scenarios of management and environmental conditions. The PVA was supposed to focus on "determining effects of key biological processes, uncertainty in model parameters, and management actions on wolf population dynamics and viability." I recommend a more detailed and systematic sensitivity analysis where specific parameters are individually varied ± 5, 10, and 15% to determine their impact on population growth rate. Additionally, I recommend that after the model structure and parameter values and variation has been corrected as I suggested above, several realistic management and ecological scenarios be explicitly examined to document realistic probabilities of conservation failure and biological extinction.

Sincerely,

Derek E. Lee

Principal Scientist

Wild Nature Institute

PO Box 165, Hanover, NH 03755

October 25, 2015

Oregon Department of Fish and Wildlife Commission
4034 Fairview Industrial Drive SE
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Chair Finley and Commissioners:

My name is Robert Beschta, I am emeritus professor in the Department of Forest Ecosystems and Society at Oregon State University (professional affiliation provided for informational purposes only). For more than four decades I have participated in research, teaching, and extension activities assessing the effects of land use practices on watersheds and plant communities. Much of that effort was in Oregon but more recently I have done research in Yellowstone National Park and other areas of the American West.

When wolves were extirpated from Yellowstone National Park, increased herbivory by elk soon began to impact plant communities. Over time, and over a wide range of elk densities, the park's aspen, willow, cottonwood, alder, and a wide range of berry-producing shrubs were less able to establish and grow above the browse level of elk; tall forbs and native grasses were also impacted. As a consequence, streams eroded and incised, riparian habitat for birds and other wildlife became limited, and beaver disappeared.

After seven decades of absence, wolves were returned to the park in the mid-1990s thus completing the wild predator guild. With the return of this apex predator, changes to previously browsing-suppressed plant communities began to occur. Initially these effects were small and local but over time the effects have become more widespread. Increasingly aspen and riparian plant communities have become more robust, increasingly plants are growing above the browse level of elk, stream banks are stabilizing, more birds have habitat, and beaver are returning. These effects did not happen overnight, but have become more pronounced over the last several years. It is important to note that Yellowstone is not a unique, stand-alone experiment. Improving plant communities have also been observed in other areas of western North America where formerly extirpated wolves have returned.

Like Yellowstone, wolves were extirpated from Oregon and were absent over many decades. Elk numbers, which had been reduced to only a few thousand in the early 1900s have since increased greatly and in 2011 Oregon's total elk numbers were 3rd highest of 11 western states (based on estimates of the Rocky Mountain Elk Foundation). And, like Yellowstone, wolves have returned.

Oregon's wolf conservation and management plan indicates "Wolves need to be managed in concert with other species and resource plans." Most people would likely assume "other species" simply means elk. I would strongly suggest that we need to look deeper.

Deciduous woody plant communities on public lands in eastern Oregon, plant communities such as those associated with aspen and riparian areas, have experienced major declines over much of the 20th century with adverse consequences to terrestrial wildlife species as well as aquatic species, such as salmon. While outmoded livestock practices have been a major reason for this decline, herbivory by wild ungulates, principally elk, is now a significant factor in many areas and may limit recovery of degraded plant communities even if livestock impacts are minimized.

Whether the positive ecosystem effects found in Yellowstone and other areas following the return of wolves will occur in Oregon is not yet known. However, if wolves are going to be a factor in the recovery of degraded aspen stands and riparian plant communities on public lands in eastern Oregon, I would strongly indicate that delisting this keystone species is a move in the wrong direction.

Sincerely,

Robert L. Beschta

Robert L. Beschta, PhD

4005 NW Princess St.

Corvallis, OR 97330

October 27, 2015

Dear Commissioners,

Soon the Commission will decide whether to remove wolves from the Oregon state list of endangered species. For reasons outlined below, we urge the Commission to refrain from removing wolves from Oregon's endangered species list at this time.

Because Oregon state law requires delisting decisions be based on the best-available science, the Oregon Department of Fish and Wildlife has made a concerted effort to perform scientific analyses to evaluate the appropriateness of removing wolves from Oregon's endangered species list. That analysis is reported in a document entitled, *Updated biological status review for the Gray Wolf (Canis lupus) in Oregon and evaluation of criteria to remove the Gray Wolf from the List of Endangered Species under the Oregon Endangered Species Act*. Hereafter we refer to that document as ODFW (2015).

While the analyses described in ODFW (2015) are important, those analyses are also, by themselves, an insufficient application of best-available science. A sufficient application of best-available science also requires analyses, like those reported in ODFW (2015), to be adequately vetted by the scientific community through an independent review process. To our knowledge, that vetting has not to have taken place. In particular, we are especially concerned that the extinction risk analysis and its interpretation has not been adequately vetted.

This scientific vetting is especially critical because discourse arguing for state delisting is enabled only because the U.S. Congress removed wolves from the federal list of protected species in 2011. But delisting action was based entirely and overtly on political circumstances, not best-available science. That circumstance heightens the need for Oregon to offer due diligence with respect to best-available science, where the federal government has failed.

ODFW (2015) includes analyses which strongly suggests that wolves should remain listed at this time. In particular, ODFW (2015) indicates

1) that Oregon has 106,853 km^2 of currently suitable range for wolves. That is, range with sufficient prey and habitat where wolf-human conflicts are relatively minimal (as indicated by road density and land uses such as agriculture and developed areas).
2) wolves currently occupy about 12,582 km^2.

ODFW (2015) also implies that former range of wolves (i.e., range occupied before humans drove wolves to an endangered status) would have been greater than the current suitable range.

To summarize, ODFW (2015) indicates that wolves in Oregon currently occupy *less than* 12% of their former range and only about 12% of current suitable range. Comparing that circumstance conditions with Oregon's Endangered Species Act provides important context for informing Oregon's listing judgment. In particular, the Act states that an endangered species is one that is "…in danger of extinction throughout any significant portion of its range within this state." By that standard wolves are endangered because the species remains extirpated from nearly 90% of its currently suitable range (and extirpated from an even greater proportion of the range that wolves occupied before human persecution).

Oregon state law does not require wolves to occupy all of their former range. Oregon state law does not even require wolves to occupy all of the currently suitable range. However, it is untenable to think that being extirpated from nearly 90% of current suitable range (a subset of former range) would qualify the species for delisting.

This comparison between the language of Oregon's law and wolves' circumstance in Oregon is robustly supported by considerable scholarship and judicial opinion. Some of that peer-reviewed scholarship and judicial opinion is presented in Vucetich et al. (2006); Tadano (2007); Enzler & Bruskotter (2009); Geenwald (2009); Kamel (2010); Carroll et al. (2010), Bruskotter et al. (2013). If the Commission would be interested in a more detailed account of this scholarship for itself or its constituents, we would happily provide such an account upon request.

We fully understand that wolves can be a challenging species to manage. And we appreciate that delisting may seem a solution to that challenge. However, two very important considerations suggest otherwise. *First*, Oregon already has many tools for managing wolf-human conflicts. Vigilant and judicious use of those tools is the key to effectively managing wolf-human conflicts. That much is clearly demonstrated by the good work of the Commission and ODFW. However, it is difficult to envision how wolf-human conflicts would be more effectively managed as a result of premature delisting.

Second, the consequences of acting in haste or inconsistently with principles outlined here increase the risk that other decisions pertaining to delisting and natural resource management in general would be made out of political convenience rather than principle of law and science.

For these reasons, we urge you to refrain from removing wolves from Oregon's list endangered species at this time.

Sincerely,
John A. Vucetich, Professor of Wildlife, Michigan Technological University

Jeremy T. Bruskotter, Associate Professor, School of Environment and Natural Resources, The Ohio State University

Michael Paul Nelson, Ruth H. Spaniol Chair of Renewable Resources and Professor of Environmental Ethics and Philosophy, Oregon State University

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28 October 2015

To the Oregon Fish and Wildlife Commission:

The following comments relate to the proposal to delist gray wolves in Oregon, entitled "Updated biological status review for the Gray Wolf (Canis lupus) in Oregon and evaluation of criteria to remove the Gray Wolf from the List of Endangered Species under the Oregon Endangered Species Act (Oregon Department of Fish and Wildlife (ODFW), October 9, 2015)" hereafter "ODFW Review 2015".

I have been studying wolf-human interactions for 16 years and ecology generally for >25 years. I've published >50 scientific articles on ecology, conservation and human dimensions. **My lab group is the only one in the world to have measured changes in individual humans' tolerance for wolves over time and attitudes under changing policies on lethal management and delisting.** We have also studied poaching (illegal take) iin several peer-reviewed scientific publications. More information about my lab and our work on wolves can be found on our webpage: http://faculty.nelson.wisc.edu/treves/.

My comments address human tolerance for wolves, illegal take, and the public trust. I restrict my comment to two points:

(1) Oregon's delisting criteria have not been met,
and
(2) The main threat to wolf population viability is not adequately understood by any state or federal agency yet, therefore the expected benefits of delisting are unlikely to manifest and the likely costs are not well addressed by current regulatory mechanisms.

By Oregon law ORS 496.17, state delisting can occur if all of five conditions are met. I address the first and fifth here.

1. The species is not now (and is not likely in the foreseeable future to be) in danger of extinction in any significant portion of its range in Oregon or in danger of becoming endangered; and

5. Existing state or federal programs or regulations are adequate to protect the species and its habitat.

Comment 1. **The criteria for state delisting have not been met.**

The phrase "**The species is not now… in danger of extinction in any significant portion of its range in Oregon**" has two implications. The first relates to historic range and the second to not being endangered.

The historic range of the wolf in Oregon was the entire state (*1*) as the ODFW Report 2015 correctly noted and visible in Appendix A for map of historic range in the U.S. Habitat suitability analyses for wolves confirm that prey availability and human-caused mortality are the major factors limiting wolves from recolonizing a region, e.g., (*2*). If one limits the geographic extent considered to be wolf range to those areas where people want wolves to live, one opens the door to illegal and otherwise unacceptable human-caused mortality determining where wolves can live. The legal and biological flaws in this line of thinking have been described and rejected for federal delisting of the gray wolf (*3*). In simple terms, the ODFW **should not define wolf range based on interest group anger or some unquantified social acceptance, because that opens the door to a form of extortion by intolerant communities**, "We'll kill wolves that move here." Threats posed by people are something to combat.

Instead available range should be defined by the biological capacity of wolves to find what they need to reproduce in an area and the acceptable recolonization might be determined by legal standards (see below).

With this biological logic in mind, the gray wolf is currently present in less than 6% of the state's land area now (ODFW Review 2015), approximately equivalent to Douglas County, OR. Now imagine if the 3% of Oregon's human population in Douglas County were the only ones to benefit from the presence of an endangered species (e.g., Washington Ground Squirrel or Lower Columbia River Coho Salmon). Wouldn't other counties' residents demand access without extreme efforts? Currently, too few citizens have access to the benefits generated by wolves in Oregon, which include aesthetic, ecological, and uses that deplete the asset (if that depletion leaves the asset unimpaired). Furthermore, future generations of Oregonians have a right to those benefits also. That point is emphasized by the case law upholding the public trust doctrine in Oregon. Wildlife belongs to all state citizens by Oregon law as a trust asset [1]. That trust obligation limits the allocation of assets such as wildlife to private interests, e.g., livestock producers demanding lethal control of wolves (*1*). That trust obligation also curbs the eagerness of administrative agencies to allocate assets,

> "In *Morse v. Department of State Lands*,[2] the 1979 Oregon Supreme Court remanded the director's decision to issue a permit authorizing a fill for an airport runway extension because he failed to determine whether the public need for the project outweighed damage to public use of trust resources…" (p. 686, section 6.2) in (*4*)

Therefore I recommend the Commission consider all current citizens and the rights of future generations for whom the trust is held.

I recommend that 'a significant portion of range' be interpreted so as to defend against litigation. **I recommend 'a significant portion of range' be defined as one of the following geographic extents: at least one breeding pair in every county or breeding pairs in a majority of counties.**

Furthermore, the current population size of wolves in Oregon "As of July 2015, there were 16 known groups or packs of wolves containing a male-female pair (Table 2), and the mid-year minimum population (non-pup) was 85 wolves." (ODFW Review 2015). A recent illegal shooting has probably lowered that number while emphasizing the role of negligent hunters in illegal take (http://www.statesmanjournal.com/story/news/2015/10/19/man-shot-and-killed-wolf-could-face-charges/74223524/). At a population size <85, the addition of a few extra wolf deaths in a year can stop

[1] State v. McGuire, 33 P. 666 (Or. 1883)

[2] *Morse*, 590 P.2d at 715; After *Morse*, the Oregon legislature amended the Submerged and Submersible Lands Act to require the director to find that the "public need" for the project outweighs harm to public rights of navigation, fishery, and recreation. OR. REV. STAT § 196.825(3) ("The director may issue a permit for a project that results in a substantial fill in an estuary for a nonwater dependent use only if the project is for a public use and would satisfy a public need that outweighs harm to navigation, fishery and recreation and if the proposed fill meets all other criteria ... [in the Act].").

or reverse population growth. As the ODFW Review 2015 noted, wolves are highly susceptible to human causes of mortality and many of these mortalities go undetected and unreported (cryptic poaching). The ODFW Review 2015 reported illegal take was the leading cause of death among wolves in a small sample of recovered mortalities. For a quantitative example from another state, we estimated an average of 44% (SD 4%) of Wisconsin wolves aged >7.5 months died each year after delisting procedures began and the state regained intermittent authority for lethal control (*6*). **The majority of those wolf deaths went undetected and nearly half of all deaths were poached wolves. If that pattern applies after delisting in Oregon, one should expect 34–41 yearlings and adult wolves to die in the year that follows. Most will go undetected.** Overcoming such high mortality rates would require higher than average population growth seen in the Oregon population (Table 2, ODFW Review 2015). Chronic, undetected, human-caused mortality challenges the success of Oregon's wolf recovery.

Moreover hopes that delisting or state authority for lethal control will reduce poaching have been fostered by a flawed analysis (*7*), see (*1*) and (*6*) for why it is flawed. The actual conclusion should be just the opposite, namely delisting and legal culling authority increased poaching in Wisconsin[3].

In sum, the Oregon wolf population has not met the first criterion for delisting, whether measured by geographic distribution or population size.

The next comment speaks directly to the fifth requirement that, "**Existing state or federal programs or regulations are adequate to protect the species**"

Comment 2. **The main threat to wolf population viability is not adequately understood by any state or federal agency yet, therefore the expected benefits of delisting are unlikely to manifest and the likely costs are not well addressed by current regulatory mechanisms.**

The ODFW correctly identifies the major threat to wolf population viability is human tolerance manifested through illegal take (poaching) mainly, "Since human tolerance has been and remains the primary limiting factor for wolf survival, building tolerance for this species will require acceptance of the Plan's approach to addressing wolf conservation and human conflicts." (p. 3, ODFW Wolf Conservation and Management Plan, December 2005 and Updated 2010)" hereafter "ODFW Plan 2010") and same sentence on p. 34 of the ODFW Review 2015. One should expect the major threat to a listed species to be well understood and abated if delisting will succeed. Unfortunately the threat is neither **well understood nor abated currently**. Our evidence that **illegal take has not been abated** comes from the section above and data on illegal take in the past as well as the likely prospect that **illegal take is likely to increase** as we explain below. The evidence that **human tolerance is not well understood by the ODFW** comes from the ODFW Review 2015 and the ODF Plan 2010.

The ODFW Plan 2010 and ODFW Review 2015 are not up-to-date on research relating to human tolerance for wolves despite 36 instances in which those documents mentioned "tolerance" or "attitude". There are over 100 scientific, peer-reviewed articles on human attitudes to wolves (*3*), and >10 recent studies from the USA address what to expect in human tolerance for wolves after intervention or after policies change (*3, 8-16*). The ODFW Review 2015 does not cite a single one of those studies or anything by the leaders in the field, which suggests that **the ODFW has not considered the scientific evidence for the major threat to Oregon wolves**.

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[3] Please contact the author for evidence to support this assertion in a report under review.

Instead, the ODFW Review 2015 cites wolf biologists who have never collected human dimensions data when making a claim about human tolerance, "There are many references which relate human tolerance to successful wolf management (Mech 1995, Bangs et al. 2004, Smith 2013)." Had the ODFW reviewed the expert scientific literature rather than biologists' opinions, they would have learned the following:

Public acceptance for lethal control has declined significantly since the 1970s and the public prefers non-lethal methods for managing wildlife. Tolerance for carnivores and inclinations to poach them are not well predicted by wealth or economic losses but rather by peer networks and social norms that foster resistance to authority and anti-establishment actions. Those inclined to poach tend to justify their actions by over-estimating how many of their neighbors and associates do so. Tolerance for bears declined when messaging was purely negative or concerns hazards posed by wildlife. Tolerance for wolves declined after delisting and legalization of lethal management, probably because people perceived the government was sending a signal that wolves have less value or illegal take will not be enforced. The implementation of lethal control did not raise tolerance for wolves after 8 years and the inauguration of public wolf-hunting did not raise tolerance for wolves after one year. Messaging that includes a sizeable component of information on benefits is more likely to raise tolerance for carnivores than messaging that focuses on costs and risks.

The available evidence suggests delisting and legalizing or liberalizing lethal control is more likely to **increase poaching which is the major threat to wolves in the USA** than decrease it.

Despite the latest results described above, the scientific community still does not know enough to abate poaching, which we believe is generated by intolerance. Perpetrators of poaching are poorly studied. That creates uncertainty about who would poach a wolf, under what conditions, and where. It is widely believed that the average human's tolerance in areas inhabited by wolves will predict behaviors that harm or help wolf conservation. If that hypothesis is false, concerns with social tolerance are misplaced and attention should focus on a few perpetrators and their social networks that promote law-breaking, rather than on the general public

I conclude that state delisting might have costs that the ODFW has not anticipated and is currently ill-equipped to understand let alone abate.

Furthermore the ODP Plan 2010 is liable to lead to an increase in poorly understood take in the wake of delisting. "A delisting decision by the Commission is not expected to significantly affect the management of wolves. This is because the Wolf Plan and associated OAR's guide the management of wolves regardless of OESA listing status, and a delisting decision would not inherently alter the management aspects of the Wolf Plan." (ODFW Review 2015). That is unfortunate because **delisting should lead to a change in management to reduce legal AND illegal killing and increase messages about the benefits of wolves to Oregon ecosystems and citizens.**

Of particular concern is whether the ODFW has correctly described the future costs and benefits of its management efforts that affect wolf survival and reproduction. Lethal management raises such concerns because there has never been a rigorous scientific experiment to test if killing wolves actually prevents future wolf predation on livestock (*17-19*).

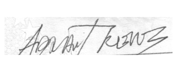
Also Oregon's state delisting would presumably activate the hunting and trapping of wolves as a "special status game mammal" under ORS 496.004 (9). (While the state wolf Plan indicates that controlled take of wolves could not occur until wolves enter into Phase III, ODFW has publically indicated that the population goals established in the Plan for moving into Phase III could be met as early as 2017. The Plan also advises that it is expected that wolves will have been delisted by the time Phase III management regimes and the availability of controlled take of wolves begins. With these guidelines and the timeline ODFW has indicated, controlled take of wolves will follow delisting in short order but without scientific basis.) The expectation that "controlled take of wolves would be permitted as a management response tool to assist ODFW in its wildlife management efforts" presumes public hunting is a useful management response. **Setting aside private hunters desires to hunt or revenue generation from hunting, what conservation purpose does hunting play in a population recovering from extirpation?**

Reviews of this question find little or no benefit of public hunting and trapping for conserving large carnivores (*20-24*). Furthermore, studies of cougars suggest public hunting can exacerbate problems with domestic animal owners (*25*). It may seem obvious that killing a wolf in the act of chasing, biting or otherwise attacking livestock will save that animal but the vast majority of lethal management is done far from the livestock and long after an attack has occurred. Under such indirect circumstances, lethal management is not clearly effective. Consider the unsettled dispute about lethal management of Northern Rocky Mountain wolves despite twenty years of lethal management (*26, 27*). Another concern is that the ODFW over-states the problem of livestock depredation in the following quote, "The challenges of wolves in areas with livestock are well documented, and wolves prey on domestic animals in all parts of the world where the two coexist". This over-states the challenge posed by livestock predation because it ignores years of evidence that a minority of wolf packs are involved in domestic animal depredations and the geographic locations of such attacks are predictable (*14, 28, 29*). Moreover it ignores the many non-lethal methods that are more effective than lethal control and have not had detectable side-effects and counter-productive results such as higher livestock predation.

I recommend the ODFW pay close attention to research by independent scientists with academic freedom (not USDA-WS which has a financial conflict of interest and not hunter interest groups for the same reason) who have reviewed the evidence on whether killing wolves – either through public hunting or by USDA-WS contract – will prevent livestock predation. Otherwise, and until the scientific community finds consensus on this evaluation, any such killing authorized and condoned by ODFW is not based on best science. Indeed it is being conducted in the absence of scientific justification and may be in violation of the public trust duties of the state, as mentioned previously.

In conclusion, I find (**1) Oregon's delisting criteria have not been met**, and **(2) The main threat to wolf population viability is not adequately understood by any state or federal agency yet, therefore the expected benefits of delisting are unlikely to manifest and the likely costs are not well addressed by current regulatory mechanisms.**

Thank you for reading my comments.



Adrian Treves, PhD

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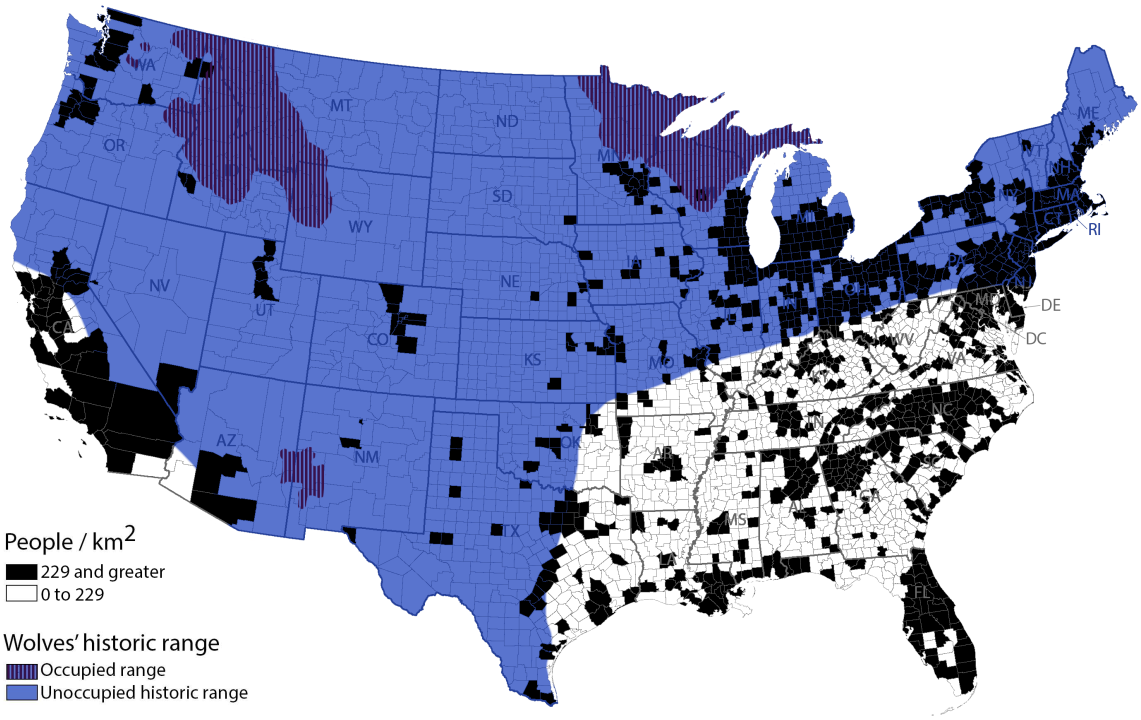
Appendix A.

Blue area is the historic range of the gray wolf in the conterminous United States. Hatched gray areas are the current range of breeding pairs of wolves as of 2013. The dark polygons show relative human population density (*1*).



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Comments re: ODFW's gray wolf delisting recommendation and status review

October 29th 2015

To the Oregon Fish and Wildlife Commission:

This comment concerns the document "Updated biological status review for the Gray Wolf (*Canis lupus*) in Oregon and evaluation of criteria to remove the Gray Wolf from the List of Endangered Species under the Oregon Endangered Species Act (Oregon Department of Fish and Wildlife (ODFW), October 9, 2015)" in particular to the Appendix B "Assessment of Population Viability of Wolves in Oregon" hereafter termed "the PVA".

My name is Guillaume Chapron, I am Associate Professor in quantitative ecology at the Swedish University of Agricultural Sciences and my research focuses on large carnivore conservation and management, with a particular emphasis on modeling and viability analysis. I have more than a decade of experience in this field and my research has been published in the top U.S. and international peer-reviewed scientific journals (see e.g. Chapron et al. 2014. *Science* 346 (6216): 1517-1519, Bauer, Chapron et al. 2015. *PNAS.* 10.1073/pnas.1500664112).

I submit this comment to help the commission in meeting the requirement outlined in OR ESA that listing decisions be based on "documented and verifiable science".

My first comment is to congratulate ODFW for providing details on the PVA and sharing the R source code of the PVA. Such openness and transparency are not so common among agencies and deserve to be praised, as they open up for the possibility of constructive criticism. My comments are the following:

1) The PVA is not statistically correct.

A PVA typically functions by running multiple stochastic (i.e. random) trajectories of a simulated population and counting the resulting number of extinct trajectories. For example, if one would simulate 1000 trajectories and obtain 137 extinct trajectories among these 1000, the extinction probability would be 13.7%. A critical part of a viability model is therefore how stochastic processes are modeled. I have reviewed the source code of the PVA written in the R language and the way stochasticity is modeled is not correct. Taking the example of survival events, stochasticity is modeled by generating a random number from a uniform distribution between 0 and 1 (as I understand it, this amounts to demographic stochasticity), and then comparing that number with another number. This latter number is randomly generated from a uniform distribution with parameters (mean-SD, mean+SD) and, as I understand it, this amounts to environmental stochasticity. This approach is fundamentally wrong for two reasons. First, the breadth of the latter distribution is restrained and values lower than mean-SD and larger than mean+SD are by default impossible (which roughly means 32% of all possible values, see the "68–95–99.7 rule", noting that excluding the lowest values will have the most severe impact on extinction risk). Second, all values are equally likely, which is typically not the case when estimating parameters from field data as one gets a normal (or bell-shaped) parameter distribution. The PVA therefore restricts possibilities of extinction and adds noise in parameters that could be more informative. The proper way to model environmental and demographic stochasticity for survival is by using a beta-binomial mixture where beta distributed values (with shape parameters obtained through the method of moments with mean and SD) are randomly generated to serve as parameters of the binomial distribution.

The same problem is also present for litter size, where the PVA uses a uniform distribution between 2 and 8. This means that litter sizes of 1 are impossible and that litter sizes of e.g. 2, 3, 4, etc till 8 are all equally likely. This approach is simply inconsistent with wolf biology. One could use a Gamma-Poisson mixture to generate stochastic integer numbers with some environmental stochasticity.

Environmental stochasticity in the PVA is in practice implemented by sampling a vector with stride of 0.01 or 0.001. However I noticed the stride was different between environmental (0.001) and demographic (0.01) stochasticity for poaching and this is also not correct.

Finally, because the model has a quite a few parameters, I believe that running 100 trajectories is not enough to get informative and converging estimates of extinction risk and 1000 trajectories would have been a minimum. I consider the points raised in this section justify the rejection of the PVA without further consideration.

2) The PVA is not properly validated.

Calibrating and validating a complex Individual Based Model is important but can also be challenging. For the OR wolf PVA this seems to have been done by comparing simulations with a time series of 5 years. I do not believe this is statistically rigorous. Modern algorithms such as Approximate Bayesian Computation with prior-posterior inference or Pattern Oriented Modeling would be more suitable here. Note that the PVA has probably quite a few weakly identifiable parameters (pairs of different parameter values giving the same model fit). Importantly, it is not because the model was published in a peer-reviewed journal that this implies the model is validated or correct (see previous point showing it is not) and I recommend the OR wolf PVA and its R source code be peer-reviewed in an open and transparent process. Finally, I would like to point to the fact that the initial population is randomly assigned across age and social classes, which suggests the population did not start at an asymptotic stage, and early oscillations of the population structure may have affected simulations and the results of the sensitivity analysis.

3) The PVA does not use realistic parameter values or scenarios.

The PVA is parameterized with a very low poaching rate. This is not in line with what has been found in other wolf or large carnivore populations. Using a hierarchical Bayesian state-space model I have found that half the mortality of wolves in Sweden was due to poaching and that two third of poaching was not observed (Liberg, Chapron, et al. 2015. Proceedings of the Royal Society B 279 (1730): 910-915). There has been several documented cases of illegal take in OR and the total number is likely higher as illegal activities are typically under-reported. The PVA also assumes that survival rates were not influenced by social status of the animal but I question whether this is realistic as some social classes are exposed to higher mortality risks by being more active in hunting large prey.

A critical assumption of the PVA is that the past is a proper representation of the future, in particular regarding human induced mortality rates. However, the PVA in this case is actually being used to make a decision making the future different from the past (delisting). Therefore, justifying delisting based on a PVA assuming that parameters will remain constant for the next 50 years is inadequate as parameters are likely to change as soon as and if delisting happens—especially if the state moves to initiate legal hunting and/or trapping of wolves. Indeed, the PVA actually documents the effect of such changes and finds that the probability of conservation failure dramatically increases with legal mortality. A proper interpretation of the actual PVA results would actually support not delisting the wolves in OR.

Another critical assumption in the PVA is the annual immigration of 3 wolves in OR. This raises two questions. First, a population is generally considered as viable when considered as a stand-alone population and not through the regular addition of individuals. Second, the persistence of this flow of immigrants is doubtful as, for example, adjacent states are attempting to dramatically reduce their wolf populations.

4) A PVA is not the appropriate tool.

The PVA completely ignores long-term viability and the ability of OR wolves to adapt to future environmental change. However, there is a substantial amount of literature of the need for populations to have a genetically effective population size of at least *Ne*=500 to be considered as genetically viable and a large number of viability analyses in the conservation literature have used a package called VORTEX to include genetics aspects in viability estimates. It is unfortunate the PVA ignores such aspects and this precludes using the PVA to reach conclusions on the long-term viability of OR wolves and hence meet the requirement of OR ESA.

Worth noting is that under no possibility could a population of ~85 individuals be considered as not warranting listing under the IUCN Red List, which is a globally recognized authority in assessing species extinction risks. Similarly, the Mexican wolf population is today larger than the OR wolf one but is not at all considered as recovered by Federal authorities. There appears to be little substance for ODFW to consider a population of ~85 wolves as being recovered.

ODFW finds that the wolf is not now (and is not likely in the foreseeable future to be) in danger of extinction throughout any significant portion of its range in Oregon. However, ODFW makes this statement by implicitly removing "any significant portion of its range", as only the outcome of a non-spatial PVA is considered sufficient. The reality is that the wolf is past being in danger of extinction throughout many significant portions of its range in OR because it occupies only 12% of its suitable habitat (so is extinct in 88% of its suitable habitat). The interpretation of this section of OR ESA by ODFW is an illegitimate interpretation that implies the suitable habitat where the species has become extinct is no longer considered as part of the species range and included in recovery targets. This interpretation also runs contrary to recent scientific literature on significant portion of range.

Finally, there has been an impressive amount of research on the ecological role wolves can play in shaping ecosystems and the report by ODFW does not consider fulfilling this role as a criteria for delisting.

Based on the points raised above, I conclude that the PVA does not provide support for delisting wolves in OR.

Yours sincerely

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October 28, 2015

Scientific peer review comments on Oregon Department of Fish and Wildlife Review of the Biological Status of the Gray Wolf

Thank you for your invitation to submit comments on the updated biological status review document of October 9, 2015. My research as a wildlife ecologist with the Klamath Center for Conservation Research in Orleans, California, has focused on habitat, viability, and connectivity modeling for a diverse group of threatened and endangered species ranging from large carnivores to rare and endemic plant species. I have also served on the Science and Planning Subgroup of the Mexican Wolf Recovery Team. I welcome the opportunity to use this expertise to evaluate the document.

Firstly, I wanted to commend the Oregon Department of Fish and Wildlife (ODFW) for its work over the past decade to advance wolf recovery in Oregon, and specifically on the work that went in to preparation of the biological status review document. On the whole, the document is well-written, factual, and informative. However, there are several areas where the document could be improved to better reflect current science. Although the document states that a change in status (delisting) of Oregon wolf populations will have little practical short-term effect on management of the species in the state, it is nonetheless important that any status determination reflect best available science.

The population viability analysis (PVA) completed by ODFW to support the status report provides relevant information concerning some factors effecting population status. The PVA results support the intuitive conclusion that the relatively high reproductive rate shown in many colonizing wolf populations make them fairly resilient to extirpation in the short term in the absence of high human-associated mortality rate (such as from hunting or lethal control programs). This conclusion can be drawn from simple deterministic PVA models. The PVA associated with this status review expands on this conclusion by using a stochastic individual-based model to evaluate factors (such as disease outbreaks or other chance events) that may threaten small populations, even if these populations on the whole show positive population growth. However, I have two areas of concern with the PVA, and with the resulting conclusion as to the resilience of the current Oregon wolf population:

1) the manner in which stochastic factors are parameterized in the PVA is overly optimistic;

2) the PVA does not incorporate the effects of small population size and isolation on genetic threats to population viability. Instead the status review relies on a brief qualitative discussion which does not accurately represent what is currently known about genetic threats to small wolf populations.

Treatment of stochastic factors

The ODFW PVA incorporates stochastic factors such as disease outbreaks or prey decline in two ways (PVA p 14):

1) An effect on reproduction via a 5% chance per pack of reproductive failure in any year. Importantly, these reproductive failures were not correlated between packs, so population-level reproductive output did not experience "bad years".
2) An effect on population-level survival where survival was reduced by 25% on average once in 100 years.

The PVA does not document the source of these parameter estimates, but they appear highly optimistic when compared to data from well-studied wolf populations such as in the Yellowstone region. In terms of stochastic factors affecting reproduction, effects of disease outbreaks on fecundity (considered broadly to include pup survival) are often correlated between packs in a population, which increase the effect of this factor on viability. Additionally, the ODFW PVA's mean interval of 100 years between catastrophes likely underestimates the frequency of events impacting population-level survival rates. If only rare “catastrophic” events are considered, then a 25% decrement likely underestimates the effect of such an event on survival. In contrast to the parameters used in the ODFW PVA, Almberg et al. 2010 concluded based on data for the Yellowstone region that “wolf managers in the region should expect periodic but unpredictable CDV-related population declines as often as every 2–5 years”.

Treatment of genetic issues associated with population size and isolation

Recent wolf PVAs (e.g., Carroll et al. 2013) have explicitly incorporated the effects of genetic factors on population viability. In contrast, the ODFW PVA omits quantitative consideration of genetic factors, which may cause its results to be overly optimistic. The status review relies on statements such as “In context of a larger meta-population, Oregon’s wolf population is neither small, nor isolated” (p 20). This statement is so general as to be uninformative. Wolves were historically present throughout their range in the lower 48 states as a largely continuous population with some degree of genetic isolation by distance (Vonholdt et al. 2011). The current Oregon wolf population is small and relatively isolated when compared to historic conditions, and thus genetic factors are of potential concern. This is true even when Oregon’s wolves are considered in a metapopulation context. The fact that wolves are good dispersers even in the current landscape may reduce genetic effects associated with small population size but will not eliminate these effects.

The review implicitly assumes that wolf populations in other states within the metapopulation will remain at their current size and continue to be a robust source of dispersing individuals. For example, on page 18, the document states “We contend that high levels of genetic diversity in Oregon wolves will be maintained through connectivity to the larger NRM wolf population.” However, one cannot assume that populations in adjacent states will remain at current levels. The Idaho wolf population could potentially be reduced fivefold from its recent peak level, to a minimum of 150 wolves, under current state management regulations. Any such reduction would reduce dispersal into Oregon below that evident in the last decade. Additionally, if, in the longer term, hunting is permitted after delisting of Oregon wolves, this increased human-caused mortality, even if sustainable from a demographic perspective, would be expected to reduce immigration from the NRM population.

More generally, the document's statement (p 17) that "Small populations of wolves are unlikely to be threatened by low genetic diversity" is not consistent with the latest research on small wolf populations. For example, the wolf population in Isle Royale National Park has long been used as an example of the ability of a small, isolated wolf population to persist. However, recent developments have demonstrated the high risks associated with genetic inbreeding in this population (Raikkonen et al. 2009), which as of early 2015 had dwindled to 3 individuals (Vucetich and Peterson 2015). Similarly, the Finnish wolf population has decreased in size in recent years to the point where it has become genetically depauperate (Jansson et al. 2012).

Given these potential risks, a precautionary management approach is appropriate in order to avoid undermining the progress to date in recovering Oregon's wolf populations. Management of wolves in the Eastern Wolf Management Zone (WMZ) should ensure that the rate of dispersal to western Oregon during the period in which the western population is still being established is not reduced, so that wolf populations in the Western WMZ can be founded with the broadest sample of genetic representation from the larger metapopulation, in order to avoid future genetic problems. Continued frequent dispersal into the Western WMZ will also facilitate the establishment of wolf populations is all "significant portions of range" in western Oregon where habitat remains suitable for wolves.

Sincerely,

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Legal Review

October 29, 2015

Cascadia Wildlands Legal Memo
Oregon Gray Wolf Delisting
Oregon Department of Fish and Wildlife Commission

There are several particularly relevant statutory requirements concerning the listing and delisting of endangered and threatened species under Oregon law. The Commission must (1) determine whether or not the natural reproductive potential of the species is in danger of failure, ORS 496.172; (2) consider the species deterioration of range and habitat, overutilization for scientific, commercial, educational, or recreational purposes, and the extent of existing federal and state regulations, ORS 496.176(3); and finally (3) a delisting rule "shall be based on documented and verifiable scientific information about the species' biological status," ORS 496.176(3).

In determining whether or not to list a species, the Commission must determine whether or not the natural reproductive potential of the species is in danger of failure. ORS 496.172. The statute specifically provides:

> (2) The commission, by rule, may add or remove any wildlife species from either list, or change the status of any species on the lists, upon a determination that the species is or is not a threatened species or an endangered species.
>
> (3) A determination that a species is a threatened species or an endangered species shall be based on documented and verifiable scientific information about the species' biological status. To list a species as a threatened species or an endangered species under ORS 496.004 and 496.171 to 496.182, the commission shall determine that the natural reproductive potential of the species is in danger of failure due to limited population numbers, disease, predation or other natural or human actions affecting its continued existence and, to the extent possible, assess the relative impact of human actions. In addition, the commission shall determine that one or more of the following factors exists:
>
>> (a) That most populations are undergoing imminent or active deterioration of their range or primary habitat;
>> (b) That overutilization for commercial, recreational, scientific or educational purposes is occurring or is likely to occur; or
>> (c) That existing state or federal programs or regulations are inadequate to protect the species or its habitat.

ORS 496.176. Oregon law maintains that a species should be retained on the endangered species if there is still a danger of species conservation failure. ORS 496.176(2), (3); OAR 635-100-0112.

As an initial point, extensive, unsolicited review from interested members of the scientific community have argued that these requisite five factors listed above have not been met.

Based on current, verified wolf numbers in the state, ODFW admits there is a 5-6% risk of survival failure in the state. ODFW states that Oregon's wolf population is "close to the conservation-failure threshold" and admit that a “few years” of low population growth rates could “cause the population to decline below the threshold” (p. 69). A delisting rule at this time with this risk of survival failure is inconsistent with ORS 496.176(2), (3). It is not unreasonable to ask the state to wait to delist until this risk no longer exists; ODFW claims Oregon’s wolves are likely to surpass 100-150 in “1 to 3 years”, and that the threat of extinction or conservation failure will then be eliminated. (p. 69). This finding itself precludes outright removal of the gray wolf from the state list.

Further regarding the Department’s study, Oregon law requires that a delisting rule “shall be based on documented and verifiable scientific information about the species’ biological status.” ORS 496.176(3). “The commission by rule many remove a wildlife species from the state list upon a review of the best available scientific and other data which meets the criteria set forth below. The scientific information shall be documented and verifiable information related to the species’ biological status.” OAR 635-100-0112. “Documented and verifiable scientific information” is defined as scientific information reviewed by a scientific peer review panel of outside experts. OAR 635-100-0010(16). In other words the five listing/delisting factors described above must be met/or not met in order remove a species from the endangered species list, and determinations and analysis regarding those factors must be subjected to an external peer review.

ODFW or the Commission has yet to have the delisting proposal reviewed by an external peer review panel. It appears that the Department reached out to a singular scientist, Carlos Carroll for external review of the rule. This does not qualify as review by a scientific peer review panel, there are set processes to follow and societies that can be contracted to conduct an unbiased, legitimate, external peer review. Furthermore, there has been extensive unsolicited feedback from the scientific community that points out the flaws and inadequacies of the Department’s population viability analysis, and recommends conducting a formal external peer review.

Regardless, Carlos Carroll determined that the Department’s population viability analysis which placed the rate of conservation failure at five to six percent was overly optimistic in a number of ways, thus under representing risk of species failure in the state. Additionally, Carroll determined that the Department disregarded the genetic threat to wolves in Oregon and that this also ultimately led to an overly optimistic finding regarding potential population failure.

As such, preliminary scientific review indicates that the Department’s delisting determination is not based on the best available science and even assuming the Department’s overly optimistic modeling, there is still a substantial risk of conservation failure precluding delisting.

To proceed in a legally secure fashion, we recommend the Commission postpone any determination on the proposed delisting rule until after review by a peer review panel of scientists. Given early scientific indications that the current study by the Department is overly optimistic and flawed, we would further recommend that the Department postpone delisting efforts until confirmed wolf numbers and distribution have increased. It would also benefit the Department to postpone delisting efforts until after the five year review has been completed given that the Department would have a better understanding of the regulatory framework for the following five years.

Please contact Nick Cady, Legal Director of Cascadia Wildlands with any questions regarding this memo.

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Public Comment and Opinion Review

Oregonians Support Protecting Wolves

There is overwhelming support from Oregonians to keep wolves protected. Listed below is a comprehensive report, detailing public comments submitted and independent polling results.

Total number of public comments submitted between October 2014 and October 2015:

- 96% of 10,671 comments submitted to and published by the ODFW Commission have been in favor of wolf conservation.
- Conservation organizations have submitted additional 24,467 comments in favor of wolf conservation and maintaining protections that are not included above including:
  - Oregon Wild members – 3,227 petition signatures, 378 e-mails to Governor Brown, 2,253 e-mails to the legislature, 1,483 e-mails to federal representatives, 1,592 e-mails to Governor Kitzhaber, and 2,413 emails to the ODFW Commission
  - Cascadia Wildlands members - 432 e-mails
  - Center for Biological Diversity – 2,361 e-mails
  - BARK – 206 e-mails and 300 petition signatures
  - Endangered Species Coalition – 473 petition signatures, 457 emails to the ODFW Commission
  - Wild Earth Guardians – 7,004 comments
  - Western Environmental Law Center – 274 petition signatures
  - Forcechange petition – 1,614 signatures
- An overwhelming majority of testimony in front of the commission has been in favor of maintaining protections but has not been well documented.

Polling Results

- **2015 Poll: Over 60% support for continued state ESA protections across all demographics**
  Mason-Dixon Polling & Research, Inc. an independent research agency conducted a poll commissioned by Oregon Wild in the spring of 2015. Oregonians supported continuing state ESA protections for wolves across every demographic. Statewide support was at 66%. 60% of rural Oregonians and 64% of Republicans supported continued state ESA protection.

- **2013 Poll: Overwhelming majorities support wolf conservation, protections, and recovery**
  Conducted in early September, 2013 for Defenders of Wildlife by Tulchin Research, shows that most Californians, Oregonians and Washingtonians want wolf recovery efforts to continue:
  - More than two-thirds in each state agree that wolves are a vital part of the America's wilderness and natural heritage and should be protected in their state (OR – 68%; WA – 75%; CA – 83%)
  - More than two-thirds in each state agree that wolves play an important role in maintaining deer and elk populations, bringing a healthier balance to ecosystems (OR – 69%; WA – 74%; CA – 73%)
  - At least two-thirds in each state support restoring wolves to suitable habitat in their states (OR – 66%; WA – 71%; CA – 69%)
  - Large majorities in each state agree that wolves should continue to be protected under the Endangered Species Act until they are fully recovered (OR – 63%; WA – 72%; CA – 80%)

- **2011 & 2015 Poll: Eastern Oregonians support moderate positions on wolves**
  In 2011 and 2015, the University of New Hampshire's Carsey School of Public Policy polled residents in Baker, Union, and Wallowa County on their views of wolves. A distinct and decreasing minority (33% and 27%) supported the elimination of wolves. While moderate views increased in a statistically significant manner.

- **1999 Poll – 70% support return of wolves to Oregon**
  A 1999 poll of Oregonians cited by ODFW in the 2005 Wolf Conservation Plan (page 6) showed 70 percent support wolves returning to the state.

2010 Plan Review Comments

Over 90% of 20,000 public comments submitted during the 2010 Wolf Plan Review favored stronger protections for wolves

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HOW THE POLL WAS CONDUCTED

This poll was conducted by Mason-Dixon Polling & Research, Inc. of Jacksonville, Florida from May 26 through May 28, 2015. A total of 625 registered Oregon voters were interviewed statewide by telephone.

Those interviewed on land-lines were selected by the random variation of the last four digits of telephone numbers. A cross-section of exchanges was utilized in order to ensure an accurate reflection of the state. Those interviewed on cell phones were selected from a list of working cell phone numbers. Quotas were assigned to reflect voter registration by county.

The margin for error, according to standards customarily used by statisticians, is no more than ±4 percentage points. This means that there is a 95 percent probability that the "true" figure would fall within that range if all voters were surveyed. The margin for error is higher for any subgroup, such as a gender or regional grouping.

QUESTION: There are currently 77 known gray wolves in the state of Oregon that are protected under the state's endangered species act. Some are seeking to remove these protections and make it easier to kill a wolf. Do you support or oppose keeping current protections for Oregon's gray wolves?

	SUPPORT	OPPOSE	UNDECIDED
STATE	66%	30%	4%
REGION	**SUPPORT**	**OPPOSE**	**UNDECIDED**
Portland Metro	72%	25%	3%
Willamette Valley	65%	30%	5%
Rural Oregon	60%	36%	4%
SEX	**SUPPORT**	**OPPOSE**	**UNDECIDED**
Men	61%	31%	8%
Women	70%	29%	1%
AGE	**SUPPORT**	**OPPOSE**	**UNDECIDED**
18-34	71%	26%	3%
35-49	68%	27%	5%
50-64	65%	30%	5%
65+	60%	37%	3%
PARTY REGISTRATION	**SUPPORT**	**OPPOSE**	**UNDECIDED**
Democrat	74%	25%	1%
Republican	64%	30%	6%
Independent	59%	35%	6%

DEMOGRAPHICS

PARTY REGISTRATION:		
	Democrat	243 (39%)
	Republican	190 (30%)
	Independent or Other	192 (31%)
AGE:	18-34	122 (20%)
	35-49	157 (25%)
	50-64	181 (29%)
	65+	160 (25%)
	Refused	5 (1%)
SEX:	Male	308 (49%)
	Female	317 (51%)
REGION:	Portland Metro	275 (44%)
	Willamette Valley	165 (26%)
	Rural Oregon	185 (30%)

September 12, 2013

To: Interested Parties
From: Ben Tulchin and Ben Krompak, Tulchin Research
Re: **New Poll Finds Strong Support for Wolf Protection in Western States**

Tulchin Research recently conducted a survey on issues relating to the protection and restoration of wolves in California, Oregon, and Washington State. We interviewed 500 registered voters in California, 300 voters in Oregon, and 300 voters in Washington. Our research finds overwhelming majorities of voters in all three states are supportive of efforts to restore wolves to suitable habitat in the region and believe that wolves should continue to be protected under the Endangered Species Act until they are fully recovered.

Voters Overwhelmingly Favor Wolf Restoration

We asked voters about their attitudes toward restoring wolves to the region and found strong support for these efforts in all three states. Asked whether they would support or oppose restoring wolves to suitable habitat in their state, 69 percent of California voters say they support this as do 66 percent of voters in Oregon and 71 percent of Washington State voters.

"Do you support or oppose restoring wolves to suitable habitat in your state?"			
	California Voters	Oregon Voters	Washington Voters
Total Support	**69%**	**66%**	**71%**
Total Oppose	15%	23%	17%
Undecided	15%	11%	12%

Support for wolf restoration is both broad and deep and extends across the political spectrum, with sizable majorities of Democrats, Republicans, and Independents in all three states favoring the restoration of wolves. Restoration is also supported by wide majorities of both men and women and among voters both under and over age 55.

CALIFORNIA VOTERS "Do you support or oppose restoring wolves to suitable habitat in your state?"							
	BY PARTY			GENDER		AGE	
	Democrats	Republicans	Independents	Men	Women	Age 18-54	Age 55+
Support	**74%**	**58%**	**74%**	**69%**	**69%**	**75%**	**65%**
Oppose	12%	25%	11%	14%	16%	12%	20%
Undecided	14%	18%	15%	16%	14%	14%	15%

OREGON VOTERS "Do you support or oppose restoring wolves to suitable habitat in your state?"							
	BY PARTY			GENDER		AGE	
	Democrats	Republicans	Independents	Men	Women	Age 18-54	Age 55+
Support	**82%**	**51%**	**61%**	**61%**	**72%**	**70%**	**63%**
Oppose	11%	40%	21%	27%	19%	20%	25%
Undecided	8%	9%	18%	12%	10%	10%	12%

WASHINGTON VOTERS "Do you support or oppose restoring wolves to suitable habitat in your state?"							
	BY PARTY			GENDER		AGE	
	Democrats	Republicans	Independents	Men	Women	Age 18-54	Age 55+
Support	**82%**	**61%**	**73%**	**69%**	**73%**	**75%**	**67%**
Oppose	11%	21%	17%	19%	15%	16%	18%
Undecided	8%	18%	9%	12%	12%	9%	15%

Voters Support Continued Endangered Species Act Protection for Wolves

With the federal government proposing to remove wolves from the Endangered Species list and end the protections that go along with that, we asked voters their opinions about the matter. By wide margins, voters in all three states believe that "wolves should continue to be protected under the Endangered Species Act until they are fully recovered." Eight in ten California voters (80 percent) agreed with the statement, as did 72 percent of voters in Washington and 63 percent of Oregon voters.

Please tell me whether you agree or disagree with the following statement: *Wolves should continue to be protected under the Endangered Species Act until they are fully recovered.*			
	California Voters	Oregon Voters	Washington Voters
Total Agree	**80%**	**63%**	**72%**
Total Disagree	13%	32%	22%
Don't Know/No Answer	7%	5%	6%

Voters See Wolves as Part of our Natural Heritage, Recognize Role in Maintaining Healthy Deer and Elk Populations

Voters broadly believe that "wolves should be protected in our state" as they are "a vital part of America's wilderness and natural heritage," including 83 percent of California voters, 68 percent of Oregon voters, and 75 percent of Washington voters agreeing with this statement. Additionally, strong majorities of voters in all three states agree that "wolves play an important role in maintaining health deer and elk populations" and thus "restoring wolves to forests and wilderness areas in our state will bring a healthier balance to our ecosystem." This view is held by 73 percent of California voters, 69 percent of Oregon voters, and 74 percent of Washington voters.

"Now I'm going to read you a few statements about policies toward wolves. Please tell me whether you agree or disagree with each statement."						
	California Voters		Oregon Voters		Washington Voters	
	Total Agree	Total Disagree	Total Agree	Total Disagree	Total Agree	Total Disagree
Wolves should be protected in our state. Wolves are a vital part of America's wilderness and natural heritage.	**83%**	11%	**68%**	26%	**75%**	20%
Wolves play an important role in maintaining healthy deer and elk populations. Restoring wolves to forests and wilderness areas in our state will bring a healthier balance to our ecosystem.	**73%**	15%	**69%**	**23%**	**74%**	19%

California Voters Support Protections for Wolves Crossing Over from Other States

In California, we specifically asked voters about policy regarding wolves who cross over into the Golden State from other states. Nearly eight in ten California voters (79 percent) agree that "we should take steps to protect wolves who cross over into California and ensure they reach appropriate habitat."

Please tell me whether you agree or disagree with the following statement: *We should take steps to protect wolves who cross over into California and ensure they reach appropriate habitat.*	
Total Agree	**79%**
Total Disagree	14%
Don't Know/No Answer	7%

Conclusion

In conclusion, this poll demonstrates that voters in California, Oregon, and Washington strongly support restoring wolves to suitable habitat in their states and believe that wolves should continue to be protected under the Endangered Species Act until they are fully recovered.

Survey Methodology: From September 4-8, 2013, Tulchin Research conducted a telephone survey among 500 registered voters in California, 300 registered voters in Oregon, and 300 registered voters in Washington. The margin of error for this survey is +/- 5.66 percentage points among voters in Oregon and Washington. The margin of error among California voters is +/- 4.38 percentage points.

Endangered Species Act Summary

Methodology

This study was commissioned by the Endangered Species Coalition and conducted by Harris Interactive, using the Harris Poll National Quorum®. A total of 1,009 telephone surveys were conducted among adults aged 18 and over within the United States between February 16th to 20th, 2011. Figures for age, sex, race/ethnicity, education, region, number of adults in the household, and number of phone lines in the household were weighted where necessary to bring them into line with their actual proportions in the population.

In this summary, statistical testing was conducted between regions and between party ID. Uppercase letters indicate significant differences between the subgroups at the 95% confidence level.

Summary of Findings

- Overall, there is strong support for the Endangered Species Act (84%), with Democrats having the strongest support (93%).
- Most Americans believe the ESA is a safety net providing balanced solutions to save wildlife, plants and fish that are at risk of extinction (64%), with Democrats the most likely to believe this (76%).
  - While the majority of Republicans also believe the ESA is a safety net (49%), they are more likely than those who support other parts to believe the ESA is used by environmentalists and their lawyers to hinder growth and progress (43%).
- The majority of Americans believe decisions about whether to remove the Endangered Species Act's protections should be based on science, not politics (63%).
- The majority of Americans agree that:
  - Decisions about wildlife management and which animals needs protection should be made by scientists, not politicians (92%);
  - The ESA has helped hundreds of species recover from the brink of extinction (90%);
  - The gray wolf is a vital part of America's wilderness and natural heritage (87%);
  - The ESA is a successful safety net for protecting wildlife, plants, and fish from extinction (87%); and,
  - The ongoing recovery of gray wolves in the Northern Rockies could be one of America's greatest wildlife success stories if the Endangered Species Act is kept in place until the states have science-based management plans approved (78%).

Detailed Findings

1. As you may know, the Endangered Species Act is an environmental law established to protect all wildlife, plants and fish that are in danger of extinction. Based on what you know, would you say that you strongly support, somewhat support, somewhat oppose, or strongly oppose the Endangered Species Act?

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Strongly support	44%	44%	46%	45%	42%	31%	58%[EG]	41%
Somewhat support	40%	41%	39%	40%	39%	42%	35%	44%
Somewhat oppose	7%	7%	7%	8%	7%	14%[F]	1%	7%[F]
Strongly oppose	6%	6%	4%	6%	7%	9%	4%	4%
Don't know/ refused	3%	2%	3%	1%	6%[C]	3%	2%	4%
Support (T2B)	84%	85%	85%	85%	80%	74%	93%[EG]	85%[E]
Oppose (B2B)	13%	12%	11%	14%	14%	23%[FG]	6%	11%

2. Some people say the Endangered Species Act has been used by environmentalists and their lawyers to hinder economic development, while others say it is a safety net providing balanced solutions to save wildlife, plants and fish that are at risk of extinction. Which is closer to your point of view?

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
The ESA is a safety net providing balanced solutions to save wildlife, plants and fish that are at risk of extinction	64%	57%	70%[A]	68%	60%	49%	76%[EG]	63%[E]
The ESA is used by environmentalists and their lawyers in the western United States to hinder growth and progress	26%	33%[B]	20%	24%	29%	43%[FG]	17%	27%[F]
Don't know/Refused	10%	11%	10%	7%	11%	9%	7%	10%

3. Some members of Congress are proposing legislation to remove the gray wolf from the Endangered Species Act's protections. Which of the following points of view is closest to your own?

   Some/others say the gray wolf isn’t endangered anymore and protection under the endangered species act is no longer needed. They say that since environmentalists' lawsuits and the federal courts are interfering with sound wolf management, the Congress has no choice but to turn wolf management decisions over to the states. In this view it is believed states are better equipped than the federal government to manage their own wildlife, and wolf numbers are now high enough to sustain a hunt.

   Some/others say that decisions about whether to remove the Endangered Species Act's protections should be based on science, not politics. Gray wolves should continue to receive federal protection until they are fully recovered and the states have implemented effective, science-based management plans that will protect gray wolves at sustainable levels for generations to come.

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Decisions about whether to remove the Endangered Species Act's protections should be based on science, not politics	63%	61%	65%	65%	62%	54%	70%[E]	64%
The gray wolf isn't endangered anymore and protection under the endangered species act is no longer needed	29%	33%	26%	29%	31%	39%[F]	24%	29%
Don't know/Refused	7%	6%	9%	7%	7%	7%	6%	7%

4. Please tell me how strongly you agree or disagree with each of the following statements.

a. The gray wolf is a vital part of America's wilderness and natural heritage

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Strongly agree	50%	50%	40%	53%[B]	53%	36%	62%[EG]	45%
Somewhat agree	37%	40%[D]	50%[CD]	33%	26%	42%[F]	30%	42%[F]
Somewhat disagree	6%	3%	6%	7%	8%	10%[F]	2%	7%[F]
Strongly disagree	4%	4%	1%	2%	8%[BC]	8%[FG]	2%	3%
Don't know/ refused	4%	3%	2%	5%	4%	4%	4%	3%
Agree (T2B)	87%	90%[D]	90%[D]	86%	80%	78%	92%[E]	87%[E]
Disagree (B2B)	10%	7%	8%	9%	16%[A]	18%[FG]	4%	10%

b. The Endangered Species Act is a successful safety net for protecting wildlife, plants and fish from extinction

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Strongly agree	48%	52%	46%	45%	50%	35%	62% EG	43%
Somewhat agree	39%	34%	42%	42%	37%	42% F	29%	47% F
Somewhat disagree	5%	6%	6%	4%	5%	11% FG	2%	4%
Strongly disagree	5%	4%	3%	6%	6%	9%	5%	4%
Don't know/ refused	3%	3%	3%	3%	2%	3%	3%	2%
Agree (T2B)	87%	86%	88%	86%	87%	77%	90% E	90% E
Disagree (B2B)	10%	11%	9%	10%	11%	20% FG	7%	8%

c. The Endangered Species Act has helped hundreds of species recover from the brink of extinction, such as the bald eagle, the gray whale, the Florida panther and gray wolves in the Northern Rockies

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Strongly agree	55%	48%	53%	57%	59%	47%	65%[EG]	53%
Somewhat agree	35%	39%	37%	33%	31%	40%	30%	37%
Somewhat disagree	4%	3%	5%	3%	4%	6%[F]	<1%	4%[F]
Strongly disagree	3%	3%	1%	2%	4%	4%	2%	2%
Don't know/ refused	4%	6%[D]	3%	4%	1%	3%	3%	4%
Agree (T2B)	90%	88%	90%	90%	91%	87%	94%[E]	90%
Disagree (B2B)	6%	6%	6%	6%	8%	10%[F]	3%	6%

d. Decisions about wildlife management and which animals need protection should be made by scientists, not politicians

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Strongly agree	71%	68%	72%	73%	72%	59%	82%[EG]	69%
Somewhat agree	21%	22%	20%	21%	19%	29%[F]	12%	24%[F]
Somewhat disagree	4%	5%	4%	4%	3%	5%	3%	4%
Strongly disagree	2%	2%	2%	1%	5%	5%	2%	1%
Don't know/ refused	2%	3%	2%	1%	<1%	2%	1%	2%
Agree (T2B)	92%	90%	92%	94%	92%	88%	95%	93%
Disagree (B2B)	6%	7%	6%	5%	8%	10%	5%	5%

e. The ongoing recovery of gray wolves in the Northern Rockies could be one of America's greatest wildlife success stories if the Endangered Species Act is kept in place until the states have science-based management plans approved

		Region				Party ID		
	Total	North-East (A)	Midwest (B)	South (C)	West (D)	Total GOP (E)	Total DEM (F)	Total IND (G)
Strongly agree	37%	32%	30%	44%[B]	41%	24%	51%[EG]	35%[E]
Somewhat agree	40%	46%[D]	49%[D]	37%	33%	43%	36%	41%
Somewhat disagree	10%	9%	10%	8%	13%	16%[F]	4%	12%[F]
Strongly disagree	5%	5%	3%	4%	9%	9%	4%	4%
Don't know/ refused	7%	8%	9%	8%	4%	8%	6%	7%
Agree (T2B)	78%	78%	78%	80%	73%	67%	86%[EG]	77%
Disagree (B2B)	15%	14%	13%	12%	23%[C]	25%[F]	8%	17%[F]

Blue Mountain Wolf Poll Results

On April 6 - 8, 1999, the polling firm of Davis & Hibbitts conducted a telephone poll of 600 registered Oregon voters. Questions focused on the possible return of wolves to Oregon. The results have an error rate of +/- 4%.

Below are highlights of the poll results:

- 61% of those surveyed had heard or read about a gray wolf crossing into Oregon from Idaho.
- In all, 70% of survey respondents favored the recovery of wolves in Oregon, either through active reintroduction by wildlife agencies or by allowing wolves entering Oregon from other states to remain here.
- 57% of respondents felt that wild wolves should be allowed to stay in Oregon when they return here on their own; 13% believed that wild wolves should be actively reintroduced into Oregon; only 23% felt that wolves should not be allowed in Oregon at all.
- On a region-by-region basis, there was little variance among those favoring active wolf reintroduction in Oregon:

  Metropolitan Portland = 14%
  Willamette Valley = 12%
  North Coast = 11%
  Southwestern Oregon = 13%
  Eastern Oregon = 13%

- On a region-by-region basis, there was also surprisingly little variance among those agreeing that wolves who enter Oregon on their own should be allowed to remain here.

  Metropolitan Portland = 60%
  Willamette Valley = 56%
  North Coast = 61%
  Southwestern Oregon = 54%
  Eastern Oregon = 45%

- Two-thirds (66%) of those surveyed felt that the best reason to support the return of wild wolves to Oregon is, "We owe it to future generations to leave the most complete ecosystem possible, including predator species like wolves."
- When told that the non-profit conservation organization Defenders of Wildlife will compensate ranchers for any livestock losses caused by wild wolves, 66% of those polled said they would favor having wild wolves in Oregon.

For more information, please contact the Oregon Natural Desert Association at (503) 525-0193 or glyons@onda.org.

In April of 1999 the firm Davis & Hibbitts completed a public opinion poll demonstrating that the majority of Oregonians support wolves in Oregon. Over 600 people participated in the poll, representing all regions of the state and a diversity of ages and political persuasions. The poll was conducted not long after a wild gray wolf from Idaho, known as B-45, had migrated into Oregon and was subsequently captured and returned to Idaho.

- **"Have you heard or read anything recently about a wolf that crossed over from Idaho into eastern Oregon?"**
  Yes: **61%** No: **38%** Don't know: **1%**

- **"Which one of the following comes closer to your point of view?"**
  Wildlife officials made the right decision to capture the wolf and return it to Idaho: **40%**
  The wolf should have been left alone and allowed to continue to roam freely: **48%**
  Don't know: **12%**

- **"Which one of the following options do you think is best when it comes to having wild wolves in Oregon?"**
  Wild wolves should be actively reintroduced in Oregon by having wildlife agencies transplant them into the state: **13%**
  Wild wolves should be allowed to stay in Oregon when they return to Oregon on their own: **57%**
  Wild wolves should not be allowed in Oregon, and if they do come into the state, they should be removed: **23%**
  Don't Know: **7%**

- **"Rate the following reason [for allowing wolves to stay in Oregon]:"**
  - "Elk and Deer Populations would be healthier and stronger, because wolves prey on older and weaker animals."
    Very Good: **14%** Good: **45%** Poor: **23%** Very Poor: **8%** Don't Know: **10%**
  - "Wolves belong here because they were part of Oregon's ecosystem for thousands of years before being exterminated. They belong here so that we can have the most natural and complete ecosystem possible."
    Very Good: **19%** Good: **43%** Poor: **22%** Very Poor: **8%** Don't Know: **9%**
  - "Wolves have a right to exist in Oregon, even if they occasionally prey on livestock."
    Very Good: **11%** Good: **46%** Very Poor **12%** Don't Know **6%**
  - "We owe it to future generations in Oregon to leave the most complete ecosystem possible, including predator species like wolves."
    Very Good: **21%** Good: **45%** Poor: **20%** Very Poor: **8%** Don't Know **6%**
  - "Even though I might never see a wolf, it would be nice to know wolves are living in Oregon."
    Very Good: **16%** Good: **43%** Poor: **25%** Very Poor **11%** Don't Know: **5%**
  - "Wolves would increase tourism in areas of Oregon where they exist."
    Very Good: **4%** Good: **17%** Poor: **43%** Very Poor: **26%** Don't Know: **11%**

- **"If wild wolves are allowed in Oregon, should livestock ranchers be compensated for any loss they have because of wolf predation?"**
  Yes: **53%** No: **36%** Don't Know: **12%**

- **"If you knew that Defenders of Wildlife, a private, non-profit organization, will compensate ranchers for any livestock losses caused by wild wolves, would you favor or oppose having wild wolves in Oregon?"**
  Total Favor: **62%** Total Oppose: **32%** Don't Know: **6%**

Table Q11A

Q11. AREA

	TOTAL	AGE 18-34	AGE 35-54	AGE 55+	GENDER MALE	GENDER FEMALE	PARTY DEM	PARTY REP	PARTY IND/OTHER/NONE	AREA TRI-COUNTY	AREA WILLAMETTE VALLEY	AREA NORTH COAST	AREA SOUTHWEST	AREA EAST
TOTAL	600	75	205	314	294	306	266	221	113	258	162	36	84	60
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
TRI-COUNTY	258	33	89	138	126	132	125	80	53	258	-	-	-	-
	43%	44%	41%	46%	43%	43%	47%	36%	47%	100%	-	-	-	-
WILLAMETTE VALLEY	162	27	67	65	80	82	70	62	30	-	162	-		-
	27%	36%	33%	21%	27%	27%	26%	28%	27%		100%	-	-	-
NORTH COAST	36	-	12	24	18	18	16	15	5	-	-	36	-	-
	6%	-	6%	8%	6%	6%	6%	7%	4%	-	-	100%	-	
SOUTHWEST	84	9	25	50	41	43	33	41	10	-	-	-	84	-
	14%	12%	12%	16%	14%	14%	12%	13%	9%	-	-	-	100%	-
EAST	60	6	16	37	29	31	22	23	15	-		-	-	60
	10%	8%	8%	12%	10%	10%	8%	10%	13%	-	-	-	-	100%

Table 001A

Q1. HAVE YOU HEARD OR READ ANYTHING RECENTLY ABOUT A WOLF THAT CROSSED OVER FROM IDAHO INTO EASTERN OREGON?

		AGE			GENDER		PARTY			AREA				
	TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI-COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL	600 100%	75 100%	205 100%	314 100%	294 100%	306 100%	266 100%	221 100%	113 100%	258 100%	162 100%	36 100%	84 100%	60 100%
YES	365 61%	35 47%	109 53%	220 70%	198 67%	167 55%	166 62%	140 63%	59 52%	176 68%	97 60%	19 53%	34 40%	39 65%
NO	229 38%	39 52%	95 46%	90 29%	93 32%	136 44%	96 36%	80 36%	53 47%	81 31%	63 39%	15 42%	49 58%	21 35%
DON'T KNOW	6 1%	1 1%	1 *	4 1%	3 1%	3 1%	4 2%	1 *	1 1%	1 *	2 1%	2 6%	1 1%	- -

Table 0C2A

Q2. WHICH ONE OF THE FOLLOWING COMES CLOSER TO YOUR POINT OF VIEW? A-WILDLIFE OFFICIALS MADE THE RIGHT DECISION TO CAPTURE THE WOLF AND RETURN IT TO IDAHO. OR B-THE WOLF SHOULD HAVE BEEN LEFT ALONE AND ALLOWED TO CONTINUE TO ROAM FREELY.

		AGE			GENDER		PARTY			AREA				
	TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI COUNTY	WILLA METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL	600 100%	75 100%	205 100%	314 100%	294 100%	306 100%	266 100%	221 100%	113 100%	258 100%	162 100%	36 100%	84 100%	60 100%
STATEMENT A	241 40%	21 28%	68 33%	150 48%	113 38%	128 42%	96 36%	108 49%	37 33%	95 37%	67 41%	14 39%	33 39%	32 53%
STATEMENT B	285 48%	47 63%	109 53%	125 40%	146 50%	139 45%	138 52%	88 40%	59 52%	133 52%	71 44%	18 50%	42 50%	21 35%
DON'T KNOW	74 12%	7 9%	28 14%	39 12%	35 12%	39 13%	32 12%	25 11%	17 15%	30 12%	24 15%	4 11%	9 11%	7 12%

Table 004AA

Q4A. RATING OF THE FOLLOWING REASON: ELK AND DEER POPULATIONS WOULD BE HEALTHIER AND STRONGER, BECAUSE WOLVES PREY ON OLDER AND WEAKER ANIMALS.

			AGE			GENDER		PARTY			AREA				
		TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI-COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL		600	75	205	314	294	306	266	221	113	258	162	36	84	60
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
VERY GOOD	1	85	9	34	41	54	31	45	22	18	43	27	3	4	8
		14%	12%	17%	13%	18%	10%	17%	10%	16%	17%	17%	8%	5%	13%
GOOD	2	269	46	109	111	127	142	117	94	58	123	67	14	44	21
		45%	61%	53%	35%	43%	46%	44%	43%	51%	48%	41%	39%	52%	35%
POOR	3	137	12	41	83	68	69	52	64	21	48	36	15	19	19
		23%	16%	20%	26%	23%	23%	20%	29%	19%	19%	22%	42%	23%	32%
VERY POOR	4	48	3	8	37	27	21	20	19	9	16	17	4	5	6
		8%	4%	4%	12%	9%	7%	8%	9%	8%	6%	10%	11%	6%	10%
DK/NA		61	5	13	42	18	43	32	22	7	28	15	-	12	6
		10%	7%	6%	13%	6%	14%	12%	10%	6%	11%	9%	-	14%	10%

Table 004CA

Q4C. RATING OF THE FOLLOWING REASON: WOLVES HAVE A RIGHT TO EXIST IN OREGON, EVEN IF THEY OCCASIONALLY PREY ON LIVESTOCK.

			AGE			GENDER		PARTY				AREA			
		TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI-COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL		600 100%	75 100%	205 100%	314 100%	294 100%	306 100%	266 100%	221 100%	113 100%	258 100%	162 100%	36 100%	84 100%	60 100%
VERY GOOD	1	65 11%	10 13%	28 14%	27 9%	41 14%	24 8%	35 13%	14 6%	16 14%	35 14%	18 11%	2 6%	5 6%	5 8%
GOOD	2	278 46%	43 57%	99 48%	131 42%	128 44%	150 49%	127 48%	93 42%	58 51%	128 50%	68 42%	17 47%	44 52%	21 35%
POOR	3	151 25%	11 15%	54 26%	85 27%	69 23%	82 27%	62 23%	65 29%	24 21%	58 22%	43 27%	11 31%	16 19%	23 38%
VERY POOR	4	72 12%	8 11%	12 6%	52 17%	38 13%	34 11%	30 11%	32 14%	10 9%	23 9%	24 15%	5 14%	10 12%	10 17%
DK/NA		34 6%	3 4%	12 6%	19 6%	18 6%	16 5%	12 5%	17 8%	5 4%	14 5%	9 6%	1 3%	9 11%	1 2%

Q4D. RATING OF THE FOLLOWING REASON: WE OWE IT TO FUTURE GENERATIONS IN OREGON TO LEAVE THE MOST COMPLETE ECOSYSTEM POSSIBLE, INCLUDING PREDATOR SPECIES LIKE WOLVES.

			AGE			GENDER		PARTY			AREA				
		TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI-COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL		600 100%	75 100%	205 100%	314 100%	294 100%	306 100%	256 100%	221 100%	113 100%	258 100%	162 100%	36 100%	84 100%	60 100%
VERY GOOD	1	125 21%	24 32%	51 25%	50 16%	70 24%	55 18%	68 26%	32 14%	25 22%	67 26%	33 20%	4 11%	12 14%	9 15%
GOOD	2	268 45%	39 52%	97 47%	126 40%	126 43%	142 46%	111 42%	102 46%	55 49%	122 47%	63 39%	16 44%	43 51%	24 40%
POOR	3	122 20%	9 12%	36 18%	77 25%	57 19%	65 21%	50 19%	51 23%	21 19%	42 16%	41 25%	11 31%	11 13%	17 28%
VERY POOR	4	49 8%	2 3%	10 5%	37 12%	30 10%	19 6%	18 7%	20 9%	11 10%	12 5%	14 9%	4 11%	12 14%	7 12%
DK/NA		36 6%	1 1%	11 5%	24 8%	11 4%	25 8%	19 7%	16 7%	1 1%	15 6%	11 7%	1 3%	6 7%	3 5%

Table 004EA

Q4E. RATING OF THE FOLLOWING REASON: EVEN THOUGH I MIGHT NEVER SEE A WOLF, IT WOULD BE NICE TO KNOW WOLVES ARE LIVING IN OREGON.

			AGE			GENDER		PARTY			AREA					
		TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI-COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL		600 100%	75 100%	205 100%	314 100%	294 100%	306 100%	266 100%	221 100%	113 100%	258 100%	162 100%	36 100%	84 100%	60 100%
VERY GOOD	1	96 16%	19 25%	36 18%	40 13%	56 19%	40 13%	53 20%	21 10%	22 19%	56 22%	24 15%	3 8%	9 11%	4 7%
GOOD	2	258 43%	36 48%	97 47%	120 38%	120 41%	138 45%	121 45%	88 40%	49 43%	110 43%	66 41%	17 47%	39 46%	26 43%
POOR	3	147 25%	12 16%	48 23%	87 28%	69 23%	78 25%	53 20%	70 32%	24 21%	55 21%	45 28%	9 25%	19 23%	19 32%
VERY POOR	4	68 11%	6 8%	15 7%	47 15%	39 13%	29 9%	25 9%	29 13%	14 12%	22 9%	22 14%	4 11%	12 14%	8 13%
DK/NA		31 5%	2 3%	9 4%	20 6%	10 3%	21 7%	14 5%	13 6%	4 4%	15 6%	5 3%	3 8%	5 6%	3 5%

Q4F. RATING OF THE FOLLOWING REASON: WOLVES WOULD INCREASE TOURISM IN AREAS OF OREGON WHERE THEY EXIST.

			AGE			GENDER		PARTY			AREA				
		TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI-COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL		600 100%	75 100%	205 100%	314 100%	294 100%	306 100%	266 100%	221 100%	113 100%	258 100%	162 100%	36 100%	84 100%	60 100%
VERY GOOD	1	21 4%	5 7%	7 3%	9 3%	13 4%	8 3%	12 5%	5 2%	4 4%	13 5%	3 2%	1 3%	4 5%	- -
GOOD	2	100 17%	16 21%	35 17%	46 15%	53 18%	47 15%	52 20%	29 13%	19 17%	43 17%	23 14%	7 19%	15 18%	12 20%
POOR	3	258 43%	27 36%	85 41%	143 46%	123 42%	135 44%	103 39%	105 48%	50 44%	106 41%	68 42%	20 56%	40 48%	24 40%
VERY POOR	4	158 26%	18 24%	55 27%	85 27%	78 27%	80 26%	69 26%	57 26%	32 28%	68 26%	52 32%	7 19%	14 17%	17 28%
DK/NA		63 11%	9 12%	23 11%	31 10%	27 9%	36 12%	30 11%	25 11%	8 7%	29 11%	16 10%	1 3%	11 13%	7 12%

Table 005A

Q5. IF WILD WOLVES ARE ALLOWED IN OREGON, SHOULD LIVESTOCK RANCHERS BE COMPENSATED FOR ANY LOSS THEY HAVE BECAUSE OF WOLF PREDATION?

		AGE			GENDER		PARTY			AREA				
	TOTAL	18-34	35-54	55+	MALE	FE-MALE	DEM	REP	IND/ OTHER/ NONE	TRI COUNTY	WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
TOTAL	600	75	205	314	294	306	266	221	113	258	162	36	84	60
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
YES	315	50	87	174	158	157	136	123	56	136	85	17	37	40
	53%	67%	42%	55%	54%	51%	51%	56%	50%	53%	52%	47%	44%	67%
NO	214	20	87	106	109	105	96	74	44	91	60	11	38	14
	36%	27%	42%	34%	37%	34%	36%	33%	39%	35%	37%	31%	45%	23%
DON'T KNOW	71	5	31	34	27	44	34	24	13	31	17	8	9	6
	12%	7%	15%	11%	9%	14%	13%	11%	12%	12%	10%	22%	11%	10%

Table 007A

Q7. AGE

	TOTAL	AGE 18-34	AGE 35-54	AGE 55+	GENDER MALE	GENDER FE-MALE	PARTY DEM	PARTY REP	PARTY IND/ OTHER/ NONE	AREA TRI-COUNTY	AREA WILLA-METTE VALLEY	AREA NORTH COAST	AREA SOUTH-WEST	AREA EAST
TOTAL	600	75	205	314	294	306	266	221	113	258	162	36	84	60
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18 - 34	75	75	-	-	38	37	23	29	23	33	27	-	9	6
	13%	100%	-	-	13%	12%	9%	13%	20%	13%	17%	-	11%	10%
35 - 54	205	-	205	-	105	100	84	71	50	85	67	12	25	16
	34%	-	100%	-	36%	33%	32%	32%	44%	33%	41%	33%	30%	27%
55 OR OLDER	314	-	-	314	148	166	159	118	38	138	65	24	50	37
	52%	-	-	100%	50%	54%	59%	53%	34%	53%	40%	67%	60%	62%
REFUSED	6	-	-	-	3	3	1	3	2	2	3	-	-	1
	1%	-	-	-	1%	1%	*	1%	2%	1%	2%	-	-	2%

Table 009A

Q9. PARTY

	TOTAL	AGE 18-34	AGE 35-54	AGE 55+	GENDER MALE	GENDER FE-MALE	PARTY DEM	PARTY REP	PARTY IND/ OTHER/ NONE	AREA TRI-COUNTY	AREA WILLA-METTE VALLEY	AREA NORTH COAST	AREA SOUTH-WEST	AREA EAST
TOTAL	600	75	205	314	294	306	266	221	113	258	162	36	84	60
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
DEMOCRAT	266	23	84	158	127	139	266	-	-	125	70	16	33	22
	44%	31%	41%	50%	43%	45%	100%	-	-	48%	43%	44%	39%	37%
REPUBLICAN	221	29	71	118	107	114	-	221	-	80	62	15	41	23
	37%	39%	35%	38%	36%	37%	-	100%	-	31%	38%	42%	49%	38%
INDEPENDENT/ OTHER/NONE	113	23	50	38	60	53	-	-	113	53	30	5	10	15
	19%	31%	24%	12%	20%	17%	-	-	100%	21%	19%	14%	12%	25%

ED FOR ANY LOSS THEY HAVE BECAUSE OF WOLF PREDATION?

AREA			
WILLA-METTE VALLEY	NORTH COAST	SOUTH-WEST	EAST
162	36	84	60
100%	100%	100%	100%
85	17	37	40
52%	47%	44%	67%
60	11	38	14
37%	31%	45%	23%
17	8	9	6
10%	22%	11%	10%

Conservation Groups Comment Letters

Chair Finley & Commissioners,

The Pacific Wolf Coalition (www.pacificwolves.org/about-us/) is a coalition of over 30 organizations that represent more than two million members in Oregon and across America. We have a shared vision of significant and sustainable populations of wolves restored across their historic habitats in Washington, Oregon, and California filling their critical roles in nature and providing hope and inspiration to communities across the region. As Steering Committee members, we are writing today on behalf of - and with concurrence from - the Pacific Wolf Coalition.

In recent years, Oregon has done an admirable job balancing the concerns of various stakeholders, prioritizing non-lethal conflict deterrence, and increasing public transparency. We join conservation-minded people and organizations in applauding the results of those efforts. Without killing wolves – despite the authority to do so – Oregon's wolf population has grown in number and range all while conflict has remained low (and by many measures declined). We urge the Commission to be cognizant of cautionary tales from other states and Oregon's own past experience.

The growth in Oregon's wolf population has triggered what is officially called a "delisting process". However as the state reviews the status of wolves, the outcome of that process should flow from a strict adherence to the law informed by the best available science and public comment that honors Oregon's conservation values.

Oregon has a great deal of unoccupied wolf habitat and significant threats to the species remain. With only 77 known wolves in the state still primarily confined to the northeastern-most corner, we urge you to take a cautious approach and not prematurely strip wolves statewide of the basic protection of the State Endangered Species Act.

Very Sincerely

Josh Laughlin,
Chair, Pacific Wolf Coalition Steering Committee
Cascadia Wildlands, Eugene, OR

Amaroq Weiss
Member, Pacific Wolf Coalition Steering Committee
Center for Biological Diversity,Petaluma, CA

Diane Gallegos,
Member, Pacific Wolf Coalition Steering Committee
Wolf Haven International, Tenino, WA

Joseph Vaile
Member, Pacific Wolf Coalition Steering Committee
KS-Wild,Ashland, OR

Karin Vardaman
Member, Pacific Wolf Coalition Steering Committee
California Wolf Center, Julian, CA

Pam Flick
Member, Pacific Wolf Coalition Steering Committee
Defenders of Wildlife, Sacramento, CA

Rob Klavins
Member, Pacific Wolf Coalition Steering Committee
Oregon Wild, Enterprise, OR

CENTER for BIOLOGICAL DIVERSITY Because life is good.

VIA Electronic Transmission

April 14, 2015

Oregon Department of Fish and Wildlife Commission
4034 Fairview Industrial Drive SE
Salem, OR 97302
Odfw.commission@state.or.us

Chair Finley and Commissioners:

On behalf of our 17,279 members and supporters in Oregon, the Center for Biological Diversity urges you to maintain protection for Gray Wolves (*Canis lupus*) under Oregon's Endangered Species Act. (OESA). The protections of OESA, along with rules enacted as part of a settlement agreement to a legal challenge brought by the Center and allies in 2011, have enabled Oregon's wolf population to grow from its first recolonizing wolf pack in 2008 to the estimated 77 wolves in the State today. Current scientific understanding about what constitutes a recovered species strongly supports our perspective that wolf recovery in Oregon is still in its early stages and that continued protections under OESA are appropriate and necessary.

At the Commission's April 24th meeting in Bend, the Oregon Department of Fish and Wildlife (Department) will recommend that the Commission commence a process to remove the Gray Wolf from Oregon's list of endangered species. In addition, there is the potential for specific interest groups which are opposed to wolf recovery in Oregon to petition the State to delist wolves. Delisting wolves in Oregon is extremely premature and we urge the Commission to reject any such recommendation or petition for the following reasons:

- **Oregon's wolves are nowhere near recovered.** Oregon currently has a population of only 77 wolves in nine packs and six additional pairs which, in sum, occupy at best only 11.8 percent of suitable wolf habitat in the State. Peer-reviewed scientific literature indicates that Oregon has suitable habitat of 68,500 square kilometers, capable of supporting approximately 1,450 wolves. (Larsen and Ripple, 2006.) The Department itself has conducted a habitat analysis, as part of its Biological Status Review for the Gray Wolf that will be presented at the Commission's April 24th meeting. The Department's analysis concluded that suitable wolf habitat in Oregon is even greater than that estimated by Larsen and Ripple, *i.e.*, at 106,853 square kilometers, and found that wolves currently occupy only

11.8 percent of potential wolf range in the State. (Biological Status Review, at pp. 12-13.) OESA requires that any findings decision by the Commission to delist must be made on the basis of scientific information and other biological data. If wolves are delisted at their current low numbers and while occupying such a small portion of suitable wolf habitat in the State, the highly contentious politics associated with wolf recovery, rather than science, will have prevailed.

- **Oregon's Wolf Conservation and Management Plan does not require that wolves be state-delisted once the wolf population has had at least four successful breeding pairs for at least three consecutive years at this point.** Nor does the state wolf Plan pre-suppose that delisting is appropriate at this point. Reaching this specific population objective merely triggers a status review. (Oregon Wolf Conservation and Management Plan (2010, revised) at pp. iii, 26-30.) The Commission must make its own evaluation, after receiving scientific information and other biological data pertinent to the five listing/delisting criteria set forth under OESA. We believe that information and data support maintaining protections.

- **Oregon's small wolf population has grown to where it is today only because of the existence of essential protections under OESA, and a model set of rules for coexisting with wolves to reduce unnecessary conflict.** Removing those protections now misleads the public into thinking "mission accomplished." No species in American history – including in Oregon -- has suffered more persecution than the wolf. As witnessed by the actions in the Oregon legislature each year – including this year, in which four bills introduced by wolf opponents are now in play – threats to this species' continued existence remain. Removing state protections for wolves at this time is premature and would be an enormous setback in keeping wolf recovery on track for success.

- **Wolves in Oregon deserve a shot at real recovery.** Oregon's natural heritage includes our magnificent wildlife and wolves are a part of that heritage. The Department's Biological Status Review points, even, to the economic benefits of wolves for the State, due to the ecotourism opportunities provided by wolf presence and wolf-viewing activities. (Biological Status Review, at p. 22.) Wolves deserve continued protections to ensure this natural heritage, and ecological and economic opportunities, will exist for future generations of Oregonians.

<u>Conclusion</u>

Oregon's wolf population stands at only 77 wolves, as of the end of 2014, occupying less than 12 percent of identified suitable wolf habitat in the State. It is only within the past year that the first breeding pair west of the Cascades has been confirmed. It is a population that is still in the early stages of recovery, and the Department's mandate, as overseen by the Commission, is to protect and conserve all the state's wildlife, but especially its threatened and endangered species.

We urge you to follow the law, the science and the strong conservation-minded values of our state to preserve our natural heritage and keep wolves protected under the Oregon Endangered Species Act at this time. Thank you for this opportunity to provide comments.

Sincerely,

Amaroq Weiss

West Coast Wolf Organizer

Center for Biological Diversity

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CENTER for BIOLOGICAL DIVERSITY
Because life is good.

April 24, 2015

Testimony of Center for Biological Diversity
To the Oregon Fish and Wildlife Commission

Chair Finley and Commissioners:

My name is Amaroq Weiss, I am the West Coast Wolf Organizer for the Center for Biological Diversity, and my comments are delivered on behalf of our more than 17,000 Oregon members and supporters.

There is simply no science anywhere on earth that would find that a population of 77 animals is biologically recovered. A population of any species that numbers only 77 observed individuals is, in fact, in danger of becoming extinct now.

Population viability analysis is based on survivorship and mortality. To overcome stochastic events, such as disease, there must be sufficient numbers of the species to weather the storm (Shaffer, 1981). For example, in Yellowstone National Park, canine parvovirus and distemper are suspected causes of a 51 percent wolf pup mortality documented in 1999 and 68 percent pup mortality in 2005 (Smith and Almberg, 2007). Were this to occur in Oregon now or in the near future, it would cripple the state's wolf population. For this and other reasons, there is no way that Oregon's tiny wolf population can be considered secure.

Numerous studies have found that minimum viable populations are more in the range of around 4,000 to 5,000 individuals (Reed et al. 2003; Traiil et al. 2007). An "effective" population size of 500 breeding individuals is necessary to avoid the effects of genetic inbreeding (Soule and Wilcox, 1980; Frankel and Soule, 1981; Soule, 1986; Franklin and Frankham, 1998). Effective population size is defined as the number of breeding individuals within the total population; to maintain 500 breeding individuals requires a total population of 2,500-5,000 individuals (Frankham, 1995). All of this science, which collectively represents dozens of studies, shows that 77 individuals is far below what is needed to maintain a secure population.

The northern Rocky Mountains states are required to each maintain at least 15 breeding pairs of wolves at all times, or else face federal relisting as endangered. Even this low number is 3 times the four breeding pairs the Department maintains is viable right now. The Mexican gray wolf population in the Southwest currently numbers 109 individuals and is classified as endangered.

To be biologically recovered also requires much greater distribution across suitable habitat than that currently occupied by wolves in Oregon. The Department's modeling studies showed more than 106,000 square kilometers of suitable wolf habitat in the state yet wolves currently inhabit less than 12 percent of that area.

Amaroq Weiss, West Coast Wolf Organizer • 925 Lakeville Street #333 • Petaluma, CA 94952
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With respect to numbers and distribution, there could not be a more stark contrast in Oregon than the disparity between wolves, cougars and black bears. According to Department figures and maps, 25,000-30,000 black bears and 5,700 cougars can be found at moderate or high numbers across two-thirds of the state; both can be found on rare occasion or at low numbers in the remainder of the state (ODFW, 2012; ODFW, 2006; ODFW webpages). These are species which by number and geographic distribution exemplify viable populations that do not need the protections of the state endangered species act and for which there is ample social tolerance. In contrast, Oregon has only 77 wolves and they occupy less than 5 percent of the entire state. (Figure 1.)

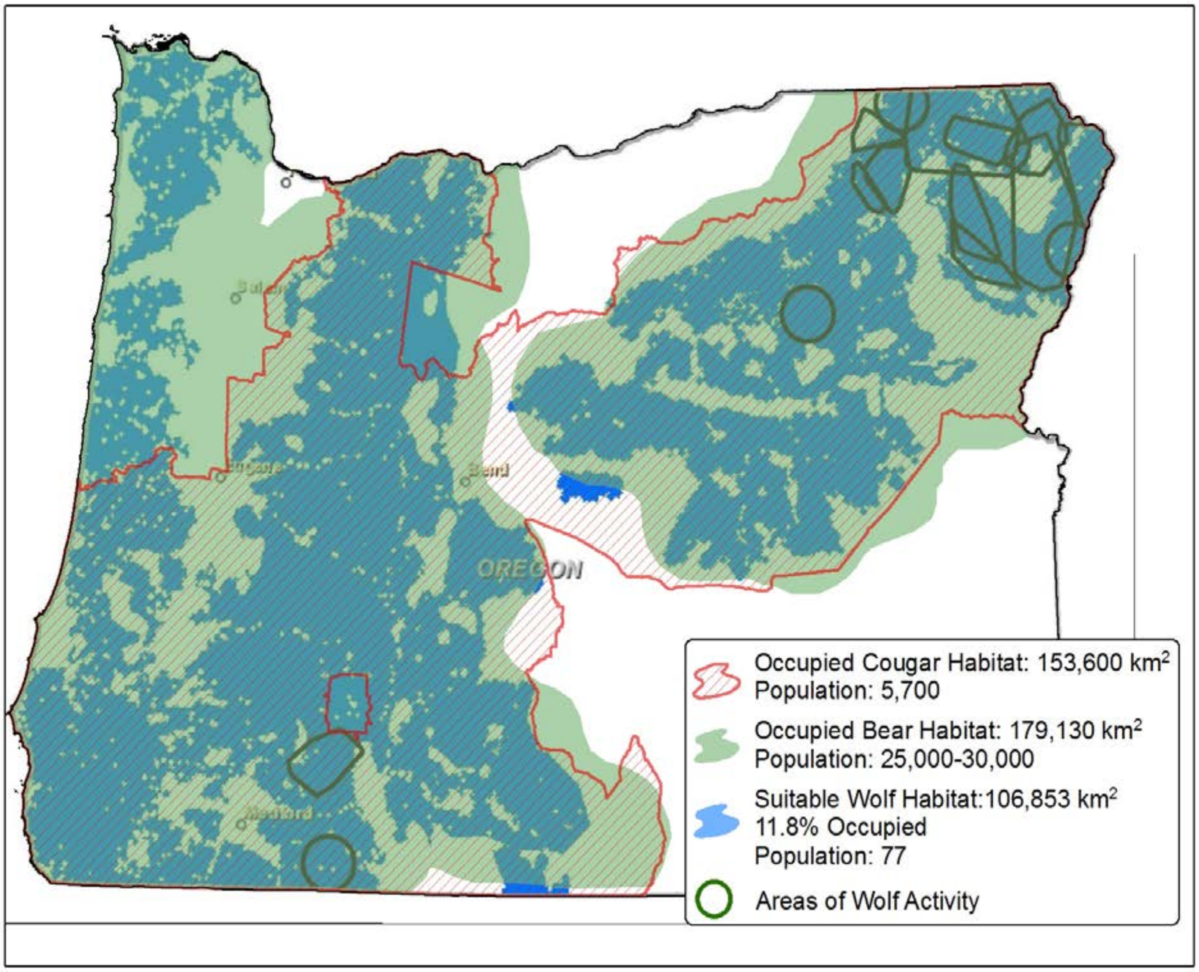

Figure 1. Geographic Distribution of Populations of Cougars, Black Bears and Wolves in Oregon. *Sources of cougar and black bear occupied habitat are the 2006 Oregon Cougar Management Plan (map at p. 5, Figure 1) and 2012 Oregon Black Bear Management Plan (map at p. 10, Figure 1). We digitized those areas identified on the maps as containing high or medium presence of cougars and black bear to calculate square kilometers of occupied habitat. Those portions of this composite map which are white are areas indicated by ODFW as also being occupied by cougar and black bear but only at low levels or appearing rarely. Source for suitable wolf habitat and areas of wolf activity is ODFW's 2015 gray wolf biological status review (map at Appendix A, Figure 5). Composite map prepared by Curt Bradley, Center for Biological Diversity.*

Wolf recovery in Oregon is on track for success, precisely because of the protections wolves receive under the state endangered species act and model rules adopted as part of a settlement agreement from a 2011 lawsuit in which our organization was involved. But wolf recovery is still in its infancy and the science tells us there is a ways to go yet.

For the reasons stated above, we recommend that you commission an independent scientific peer review of the Department's analysis and proposal, with the peer review results to be made public before arriving at your own decision. We are aware of several highly-credentialed wolf biologists and habitat modeling experts to recommend as potential peer reviewers and will submit to you a follow-up letter with a list of names and contact information for each one.

We greatly appreciate this opportunity to address you today.

Sincerely,

Amaroq Weiss
West Coast Wolf Organizer
Center for Biological Diversity
707-779-9613
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Cascadia Wildlands
we like it wild.

April 24, 2015

Cascadia Wildlands Testimony
Oregon Department of Fish and Wildlife Commission

Good afternoon Chair Finley and members of the commission,

My name is Nick Cady. I am the Legal Director of Eugene-based Cascadia Wildlands, a regional non-profit conservation organization representing 15,000 members and supporters. Cascadia Wildlands educates, agitates, and inspires a movement to protect and restore Cascadia's wild ecosystems. We envision vast old-growth forests, rivers full of wild salmon, wolves howling in the backcountry, and vibrant communities sustained by the unique landscapes of the Cascadia bioregion.

Cascadia Wildlands was one of the parties that negotiated the Oregon settlement that established a system of rules for wolf management. These rules permit the killing of wolves that chronically depredate on cattle, compensate livestock producers for losses, pay ranchers to implement non-lethal preventative measures, and overall have emphasized the implementation of responsible ranching practices that aim to prevent conflict with wolves. Under this settlement, we have seen wolf populations rise, and conflicts with livestock decrease. We currently have 77 wolves in the state, and this past year we saw the first pack establish itself in the state's western recovery zone. Wolf recovery is moving along.

We are here today considering recommendations by the Department that the Commission delist the gray wolf at this early juncture in wolf recovery. Wolves have just moved out of the first recovery phase in the state's eastern recovery zone, and have according to ODFW populated just 11% of suitable habitat in the state. Cascadia Wildlands believes that an effort to delist the wolf is premature, solely because population numbers are not high enough. Keep in mind the reintroduction of wolves in the northern Rockies started with 66 wolves, we have just 10 more.

We have analyzed ODFW's status review, and believe the agency and its staff have done a tremendous job anticipating and accounting for threats to gray wolves in modeling the future well-being of the species. We have just started looking at the status review, but applying the agency's model, it appears that the species has a 6% chance of dropping below the conservation threshold when factoring in human wolf mortality. I believe this 6% chance is based upon the assumption that 10% of wolves will be killed next year by humans, or about 7 wolves. If the percentage of wolves killed by human increases only slightly to 15%, the probability of conservation failure increases to 53%. This is a difference of 3 to 4 wolves being killed, a very slim margin of error, that would lead to over a 50% chance of Oregon experiencing conservation failure. This wild swing in conservation success probability is largely due to current low numbers of wolves. The model, when applied to wolf populations of over 100 individuals, reduced the probability of failure to under one percent.

This raises significant questions. What is the state going to do to ensure that wolf take levels do not exceed or even approach this threshold? While some level of human mortality is under state control (i.e. lethal control in response to chronic depredation), much of human caused mortality is not (i.e. traffic accidents, poaching, incidental trapping). If the state is going to engage in a rule-making process, concrete assurances should be built in so that this level of wolf mortality will not be reached or even approached given the very small margin of error. Delisting could be a signal to some that it is open season for wolves, could reduce poaching penalties, and we need to avoid any increases in wolf mortality.

While we know that 77 wolves is a minimum count, we should be using precautionary principles and numbers when gambling on this species future. We have also yet to see the implementation of the relaxed standards for state use of lethal control under Phase II. Cascadia Wildlands would urge the commission to wait a year or two for full delisting, until we can confirm wolf population numbers that would greatly reduce the risk of conservation failure. Organizationally, we could understand if the commission moved to down-list the species and categorize the gray wolf as threatened as opposed to endangered. But complete delisting, and a Departmental gamble on a few wolves killed or not being killed, is not a proper exercise of caution.

The extensive non-lethal efforts and stakeholder outreach by the Department have made Oregon the model for wolf conservation. Delisting will signal a sharp departure away from these efforts that have made wolf recovery a success so far in this state. Wolf recovery is currently working wonderfully. Waiting for a year or two, when the Department can say with total confidence that there is less than a 1% chance of conservation failure with higher margins of error, seems like the smart play. There is an old saying, “If it ain’t broke, don’t fix it.”

Thank you for your time today.

Sincerely,

Nick Cady
Cascadia Wildlands

OREGON WILD

Protecting Oregon's wildlands, wildlife, and waters since 1974. www.oregonwild.org

April 20, 2015

Oregon Fish and Wildlife Commission
Chair Michael Finley
4034 Fairview Industrial Drive SE
Salem, OR 97302

Dear Chairman Finley,

On behalf of Oregon Wild's more than 15,000 members and supporters from all across Oregon, we are writing today to follow up on our March 4th letter and again urge the Commission to ensure the progress Oregon has made in reducing conflict over wolf conservation is not undermined. Specifically we are writing to urge the Commission to follow the process outlined in the Oregon Wolf Conservation and Management Plan, and the requirements of the state Endangered Species Act, and conduct a fair, science based, and transparent status review for Oregon's 77 gray wolves.

We are troubled by statements and actions of agency staff and others that give the impression that stripping endangered species protection from these animals is a foregone conclusion, regardless of what the law requires or the preponderance of the best available science says. To ensure public trust, full consideration of the facts, and broad acceptance of the final decision, <u>we urge the Commission to give equal consideration to maintaining protections and to commission an independent scientific review of the final staff proposal that would be made available to the public prior to a Commission decision</u>.

As we discussed in greater detail in our previous letter, Oregon has set the national standard for balancing legitimate concerns of livestock interests and the Oregon public's conservation values in a clear and coherent manner. Without killing wolves –despite the authority to do so – Oregon is arguably the only state in the nation to achieve the mutual goals of keeping wolf recovery on track while minimizing conflict. Oregon has emphasized transparency, clear guidelines, and basic common-sense preventative measures aimed at reducing conflict before resorting to often-counterproductive and always-controversial lethal control. By nearly all accounts, the plan is working.

The recent success of the Wolf Conservation and Management Plan flows from the historic 2013 settlement agreement between ODFW, the conservation community, and livestock interests and the clear sideboards it created. It has moved us in a direction that provides clarity, requires basic non-lethal measures to prevent conflict, and increases public trust in the agency and acceptance of native wildlife.

The credibility of ODFW staff, and the agency as a whole, suffered significant losses from past controversial decisions to pursue the killing of wolves in response to pressure from the livestock industry. A premature effort to strip state endangered species protections from Oregon's fragile population of 77 known wolves would further erode the agency's credibility with conservation-minded Oregonians at a time when it is asking for increased funding from their scarce tax dollars. Such a move would be unwise both for wolf-recovery, and for the long term viability of the agency.

In the coming days, Oregon Wild will be closely reviewing the ODFW staff document regarding wolves and their status as endangered species. Together with thousands of other interested Oregonians, we will be carefully examining this document to determine whether it does include a full, rigorous, and impartial analysis of the best available science regarding wolf management and recovery, and to ensure what the agency proposes meets the requirements of the law.

Based on our initial analysis, coupled with a preliminary review of relevant science, data, and statute, as well as discussions with independent scientists and other stakeholders, we remain extremely skeptical that removing Oregon's 77 known wolves from the state's Endangered Species list is justified by science, public opinion, or economic data. To assuage these concerns, we urge the Commission to consider an independent, impartial scientific review of the staff proposal to be conducted and made public prior to a decision.

We have indicated to our members and supporters that this is the beginning of a transparent public process and look forward to engaging in it as constructive partners. We agreed to the wolf conservation plan, settlement, and this process. Though we have, and will continue to raise concerns in appropriate venues, we continue to stand by those agreements in good faith. To ensure all parties are given a full and equal opportunity to weigh in, we urge ODFW to oppose efforts from the Oregon Cattlemen's Association to strip ODFW's authority on this matter by way of HB3515.

We eagerly anticipate the day when we can celebrate an appropriate delisting of wolves that will ensure a long-term, meaningful, and sustainable recovery. We look forward to engaging in the status review in a more thorough manner in the coming weeks.   Rather than turn back the clock and invite controversy, we urge the Commission to give serious consideration to maintaining protections for wolves under the state Endangered Species Act and to build on the success of the last three years by maintaining the clear coherent guidelines that have gotten us this far.

Sincerely,

Sean Stevens
Executive Director
Oregon Wild
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ss@oregonwild.org

Chair Finley, Commissioners:

My name is Wally Sykes, from Joseph, Oregon. I'm a member of the Wallowa County Wolf Compensation Committee, Co-Founder of Northeast Oregon Ecosystems and a member of the Pacific Wolf Coalition.

Like many others, I was drawn to Wallowa County by its spectacular landscapes, wilderness and wildlife. For twenty years I've enjoyed the animals surrounding my cabin, including elk, bear, cougar, bobcat, and now wolf.

Many people in the county share my values and appreciation of wolves and, though reluctant to speak publicly, are deeply troubled by the proposal to strip protections from wolves.

Oregon is a state distinguished for its reverence and protection of its natural heritage, including diverse wildlife, and Oregonians will not understand, nor will I, why wolves should be delisted when they are so few and restricted to so small a part of the state.

Oregon's wolf management plan has a set a national standard for enlightened, scientifically rational wolf management. The ODFW has been exemplary in its adherence and transparency.

Yet, since the first pups appeared in 2008 only 77 wolves are now confirmed in Oregon's 97,000 square miles, occupying less than 12% of potential habitat. Dispersal has been slow, hampered by Interstates 84 and 5, and this is unlikely to change. Seventy-seven wolves is far below the accepted minimum for long-range genetic viability in any species and the Idaho gene pool is diminishing. Idaho intends to reduce its wolf numbers to around 150, below genetic minimums, and its population is descended from the even smaller number re-introduced to Central Idaho.

ODFW Staff recommend delisting, stating it will not change wolf management. This then raises the question: why delist at all? Oregon conservationists rightly worry that without listed status, wolves could lose protections during the Wolf Plan Review later this year. For the same reason, Oregonians are concerned that the successful emphasis on nonlethal tools and management may erode.

I will add that I fully endorse the positions expressed by Oregon Wild in its letter to you of April 20, especially the call for an independent review of the final ODFW delisting proposal.

I urge the Commission to maintain Endangered Species status for wolves.

Thank you.

June 5, 2015

Testimony of Center for Biological Diversity
To the Oregon Fish and Wildlife Commission

Chair Finley and Commissioners:

My name is Amaroq Weiss, I am the West Coast Wolf Organizer for the Center for Biological Diversity, and my comments are delivered on behalf of our more than 17,000 Oregon members and supporters.

Twelve years ago, when I lived in Oregon, your predecessors appointed me to be a stakeholder in the Department's state wolf planning process, to represent all wolf advocacy groups.

When the project was completed, those of us who advised and helped write the Plan knew four things for certain:

1. The Plan was the result of substantial social and political compromise;
2. A future delisting assessment of wolves would be based on science, as required by state law;
3. On reaching a benchmark of four breeding pairs for three consecutive years in the eastern half of the state, management strategies would automatically shift from Phase I to Phase II; and
4. That same benchmark would result in a status review regarding delisting.

What we did not – and could not – know at the time was, upon reaching that benchmark, how many wolves would there be in Oregon and would they be well-distributed?

We've reached that benchmark, and we now know that Oregon's wolf population stands at 77 observed wolves, 70 of which live in the eastern half of the state.

Amaroq Weiss, West Coast Wolf Organizer • 925 Lakeville Street #333 • Petaluma, CA 94952
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These wolves comprise the source population for dispersers to the west-side. And these wolves are now subject to the more aggressive, less conservative wolf-livestock conflict management strategies of Phase II.

Phase I required four wolf-caused losses in six months before resorting to lethal control. In Phase II, only two losses need occur. In Phase I, wolves could be killed if caught in the act of attacking. Phase II allows wolves to be killed if merely observed chasing livestock.

Wolves are now at significantly greater risk of being killed than was the case when the Department conducted its population viability analysis.

That analysis specifically assessed risk of conservation failure based on the number of wolves killed annually. It concluded that a slight uptick in the number of wolves killed would cause that risk to skyrocket from six percent to 50 percent.

We therefore urge you to apply the science-based "precautionary principle" and not consider delisting at this time. You'll have a much more accurate scientific assessment of the risk of conservation failure after the Department collects several years' worth of data and determines the impact of Phase II management actions on mortality of Oregon's core wolf population.

Thank you for this opportunity to address you today.

Sincerely,

Amaroq E. Weiss

Amaroq Weiss, M.S., J.D.
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OREGON WILD
Protecting Oregon's wildlands, wildlife, and waters since 1974. www.oregonwild.org

June 5, 2015

Oregon Fish and Wildlife Commission
Chair Michael Finley
4034 Fairview Industrial Drive SE
Salem, OR 97302

Dear Chairman Finley & Commissioners,

On behalf of Oregon Wild's more than 15,000 members and supporters from across the state, I am writing to follow up on the April Commission hearing and our previous correspondence regarding the pending status and plan reviews for wolves. While it's important to celebrate Oregon's recent progress on wolf recovery, we want to reiterate our serious concern with a premature delisting as well as our continued interest in finding a win-win solution that keeps our state on the positive path forward that began under the settlement agreement of 2013.

We were pleased to see the Commission reiterate that maintaining protections is a viable option while also signaling an interest in something other than an all-or-nothing approach that would be a setback for wolves, the agency, and the public. We stand ready to participate in constructive discussions with the agency and other stakeholders.

Since 2013, Oregon has provided the best model in the country for achieving the goals of wolf recovery ***and*** reducing conflict. This has occurred without killing wolves. Rather than making a radical course correction, we urge the state to work with responsible stakeholders and chart a path forward that doubles down on the success outgoing Director Roy Elicker cited when he declared progress on wolves as among his proudest accomplishments during his long tenure.

Public input

The Commission's implementing statute (ORS 496.090) states: "All members of the commission shall represent the public interest of the state…" We appreciate efforts to refocus the Commission and the agency on its mission to protect and restore fish, wildlife, and their habitat for *all* Oregonians.

At the April 24th Commission hearing in Bend, you received overwhelming public testimony in favor of wolf conservation and maintaining the endangered species status of wolves. Dozens of citizens from diverse backgrounds took a day off work, traveled great distances, and waited through a long meeting for a 3-minute opportunity to share their concerns. Such support is in line with mainstream Oregon values that include support for conservation generally and wolf recovery specifically.

Attached, please find a petition with over 2,500 signatures supporting maintaining protections for wolves in Oregon. The geographic scope of the rapidly growing list demonstrates that Oregon is seen around the country and the world as a model for balancing legitimate concerns against science-based management informed by our highest conservation values.

Support for the plan: Setting the record straight

We were particularly struck by the testimony of Oregon Cattlemen's Association (OCA) President Ray Sessler. He, and others representing the livestock industry, implored the Commission to honor the writers of the wolf plan. He sat side-by-side with a former ODFW staffer who helped write the plan and said in no uncertain terms that delisting at this time is not what the authors of the plan had in mind.

We are pleased that the OCA is now supporting the wolf plan. The 2005 plan was the result of tremendous compromise. Many of those compromises were the result of good-faith efforts to assuage the livestock industry. Though the plan was subject to immediate, vociferous, and singular opposition from the OCA, conservationists stood by the compromise plan. Even the 2011 legal challenge and resulting settlement were based on adherence to the spirit of the wolf plan and the letter of the law.

In addition to opposing legislation needed to fully implement the plan, the OCA has introduced and supported no less than 8 bills in the state legislature since 2009 to undermine the plan and/or restrict the Commission's authority on wolves. Just days before last April's hearing, the OCA introduced a bill (HB3515) that was intended to circumvent the public status review process called for in the plan.

Since the 2013 settlement agreement between conservationists, the state, and the OCA, most parties have lived up to their agreements. Unfortunately new leadership from the OCA has frequently been derisive of the plan, its provisions, the agency, agency staff, and non-lethal measures to prevent conflict.

The settlement agreement was limited to Phase I with an understanding that there would be disagreements about Phase II that could be addressed during the next public review of the plan (2015). The settlement also reaffirmed the wolf plan - including the provision that "[o]nce the conservation population objective is achieved, the process to ***consider*** delisting will be initiated" (emphasis ours, repeated several times in the plan). To be clear, the plan does not *require* delisting as asserted by some delisting proponents.

Process:

Though we have concerns about the wolf plan and continue to believe delisting at this time would be premature, we are committed to participating in the process. Given that the status review is contingent upon the existing regulatory mechanisms (the plan), we urge the Commission to empower agency staff to work with stakeholders on the plan and status reviews concurrently.

Though some recent actions by the OCA leadership have given us pause, and some may never be satisfied with anything less than everything they want, we believe there is a path forward where all legitimate concerns from responsible stakeholders can be addressed. We call on ODFW and the state to proactively facilitate discussions to achieve that end.

Delisting

We continue to believe that a delisting at this time is not supported by the public, independent science, or the law. While there may be legitimate disagreements over the particular immediate effect of delisting, delisting is consequential. Were it not, we would argue that is a case for maintaining the status quo.

While delisting is consequential, there is no emergency need for it. The reduced protections of Phase II cited by the OCA are already in place in Eastern Oregon where wolves are more common than the rest of the state, but still largely absent. Elk herds in wolf country are above objective. Income from the livestock industry in Wallowa County has increased every year since wolves returned. Incidents of depredation decreased last year and there have been no confirmed depredations in over 8 months. Compensation is available to those claiming loss and trying to prevent conflict.

It seems the staff's case for delisting is not based on the idea that wolves have in fact recovered in Oregon. Rather, the delisting recommendation is based on a number of models and questionable predictions (including unrealistically low levels of human-caused mortality, and speculative assumptions about maintained state and federal policies). If those models and assumptions hold true, the staff report maintains it is unlikely wolves will face extinction in the near-term and may therefore be delisted. This argument does not comport with common understanding of wildlife protections nor does it comply with the letter or intent of statute.

Though they have made tremendous progress, by any unprejudiced measure - including ecological function - wolves have not yet recovered in Oregon.

In addition to considering *maintaining* endangered species protections for Oregon's wolves, we urge the state to give serious consideration to downlisting, and partial delisting bounded by existing agency boundaries (Hwy 97/20/395 and Hwy 395/78/95) as well as those informed by current wolf populations (such as creating a new wolf management zone bounded by I-84, I-82, Washington, & Idaho), and providing certainty by reviewing the plan and status concurrently.

We also urge staff and the Commission not to dismiss calls echoed by several individuals and organizations to conduct an independent peer-review of the staff report(s) on potential delisting. Such a review, done carefully would take time. However it may play an important part in the public process. If all stakeholders are to have faith in the Commission's final decision, it is in the interest of the Department for it to be a defensible one.

<u>Cautionary tales</u>

Oregon's nascent wolf recovery is on track. However it would be dangerous to assume we can declare "mission accomplished". Cautionary tales exist that argue for a conservative approach. On Isle Royale, despite no human conflict and a sufficient prey-base, the population has plummeted from fifty related wolves to three. With overly aggressive management, Mexican Wolf recovery stalled out between 40 and 50 wolves for the better part of a decade. Other cautionary tales exist with wolves and other wildlife around the world.

At the April hearing it was asserted that wolves released into Idaho (to whom all tested Oregon wolves share some relation) were not themselves genetically related. That appears to be incorrect. Follow up discussions with those who directly participated in the capture and release of those wolves indicate that while such protocol may have been the official order of the day, it was not strictly followed.

Seventy-seven known related wolves is not a resilient population.

It is hard to imagine the agency considering a similar course based on the same set of facts for any other species – elk, meadowlark, salmon, etc. It is therefore difficult to avoid the conclusion that defending delisting would be based on political considerations rather than biological or broad social concerns or adherence to the agency's laudable mission.

Conclusion

Over the last several years, when it comes to wolves, ODFW has succeeded in beginning to rebuild a fragile trust with the broad public. At a time when the agency is in need of broad public support, it would be prudent to keep in mind the mission of the agency to “protect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations.” While all interests should be appropriately considered, it is the Department of Agriculture that is charged with protecting the economic interests of the livestock industry.

We urge the department to:

1. *Proactively* engage responsible stakeholders in a constructive dialogue to identify areas of common ground that will keep wolf recovery on track with minimal acrimony.
2. Take a cautious approach and consider all options including
   a. Conducting the wolf plan and status review concurrently
   b. Giving full consideration to maintaining listing status, downlisting, and partial state delisting along boundaries including state, federal, and practical boundaries like I-84.
   c. Carrying successful parts of Phase I of the settlement agreement into Phase II
3. Solicit an independent scientific review of staff recommendations that could lead to delisting.

Sincerely,

Robert Klavins
Northeast Oregon Field Coordinator
Oregon Wild
541.886.0212
rk@oregonwild.org

cc: Curt Melcher
Brett Brownscombe
Richard Whitman
Russ Morgan
Roblyn Brown

Enc: Petition with 2,500+ supporters in favor of maintaining endangered species protections for Oregon Wolves.

CENTER for BIOLOGICAL DIVERSITY Because life is good.

October 9, 2015

Testimony of Center for Biological Diversity
To the Oregon Fish and Wildlife Commission

Chair Finley and Commissioners:

My name is Amaroq Weiss, I am the West Coast Wolf Organizer for the Center for Biological Diversity, and my comments are delivered on behalf of our more than 17,000 Oregon members and supporters.

We've previously submitted written comments and testified that it is our view that state-delisting wolves is, at this time, premature. The number of wolves in Oregon and the amount of habitat across which they are distributed is simply too low to determine the species is recovered.

The Department updated its gray wolf status review with population figures as of July 15, 2015, of 85 wolves. This is five percent of the total number which published, peer-reviewed literature has indicated the state could support.

These 85 wolves occupy only 12.4 percent of the Department's estimate of habitat suitable for wolves within the state, and probably occupy less than that since the Department has indicated its estimate of total suitable habitat is conservative.

We are hard-pressed to think of another species which, upon reaching five percent of what the state could support, distributed across only twelve percent of suitable habitat, the state would declare "mission accomplished, recovered to where the protections of the state endangered species act are no longer needed."

Your decision of whether to initiate a formal rule-making process to delist will presumably be based on the Department's status review reports and its resultant recommendation to delist. You will also be considering other information, comments and testimony you receive on this issue. The Oregon endangered species act requires that all listing and delisting decisions be based on "documented and verifiable

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science." According to the statute, "verifiable" means "scientific information reviewed by a scientific peer review panel of outside experts who do not otherwise have a vested interest in the process." (ORS 496.176). In our prior comment letters and testimony to you on the issue of state-delisting of Oregon's wolves, we have urged you to commission a peer review of the Department's gray wolf status review report. With the issuance of the Department's updated status review report, we renew our request for peer review, which in fact is required, by law.

Thank you for this opportunity to address you today.

Sincerely,

Amaroq Weiss, M.S., J.D.
West Coast Wolf Organizer
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Cascadia Wildlands
we like it wild.

October 8, 2015

Cascadia Wildlands Testimony
Oregon Department of Fish and Wildlife Commission

Good afternoon Chair Finley and members of the commission,

My name is Nick Cady. I am the Legal Director of Eugene-based Cascadia Wildlands, a regional non-profit conservation organization representing 15,000 members and supporters. Cascadia Wildlands educates, agitates, and inspires a movement to protect and restore Cascadia's wild ecosystems. We envision vast old-growth forests, rivers full of wild salmon, wolves howling in the backcountry, and vibrant communities sustained by the unique landscapes of the Cascadia bioregion.

Gray Wolf Delisting

Cascadia Wildlands is here today to stress again that a move to delist gray wolves in Oregon is premature. Wolves have just moved out of the first recovery phase in the state's eastern recovery zone, and have according to ODFW populated just 11% of suitable habitat in the state. The population numbers are simply not high enough.

We have analyzed ODFW's status review, and believe that the results of that study do not warrant delisting. Based on current confirmed wolf numbers in the state, there is still a risk of the species experiencing conservation failure. If the Commission were to delay listing efforts until the population state wide increases, this risk can be eliminated.

Secondly, we would request that the Department seriously analyze the option of down-listing the species, or moving the species from endangered to threatened. It is unclear why this logical and viable next step continues to be ignored. Also, if the Commission does determine that the Department should move forward, we believe that it is necessary for the Department to conduct an external peer review of delisting and the science behind the delisting.

When it comes to the well-being of an endangered species, we should be using precautionary principles and numbers when gambling on this species future. Cascadia Wildlands would urge the commission to wait a year or two for full delisting, until we can confirm wolf population numbers that would greatly reduce the risk of conservation failure, or presently consider down-listing the species.

The extensive non-lethal efforts and stakeholder outreach by the Department have made Oregon the model for wolf conservation. Delisting will signal a sharp departure away from these efforts that have made wolf recovery a success so far in this state. Wolf recovery is currently working wonderfully. The Department should wait for higher confirmed wolf population, so the state can say with total confidence that there is not a chance of conservation failure in Oregon.

Cougar "Target Zone" Management Proposal

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www.CascWild.org

Cascadia Wildlands would also like to weigh in briefly today on the Cougar "Target Zone" Management proposal. We have already submitted substantive comments on this proposal. But we would urge the Commission to look at the studies surrounding this proposal.

These exact measures have been tried before in the past to boost deer numbers, and it has not worked. This has been scientifically proved. We should not be using taxpayer money to fund controversial wildlife culling programs that we know will be ineffective. Again, Commissioners if you have not already, please take a look at the studies we have provided that clearly demonstrate that a cougar cull will not improve deer numbers and is a waste of Departmental resources.

Thank you for your time today.

Sincerely,

Nick Cady
Cascadia Wildlands

October 29, 2015

Cascadia Wildlands Testimony
Oregon Department of Fish and Wildlife Commission

Good afternoon Chair Finley and members of the commission,

My name is Nick Cady, I am the Legal Director of Eugene-based Cascadia Wildlands, a regional non-profit conservation organization representing 10,000 members and supporters. Cascadia Wildlands educates, agitates, and inspires a movement to protect and restore Cascadia's wild ecosystems. We envision vast old-growth forests, rivers full of wild salmon, wolves howling in the backcountry, and vibrant communities sustained by the unique landscapes of the Cascadia bioregion.

We are here today to respond to the recommendation by the Department of Fish and Wildlife ("Department") to delist the gray wolf from the state Endangered Species Act at this early juncture in wolf recovery. We currently have a minimum of 77 confirmed wolves in the state, and Americans have been following with awe the reestablishment of wolves in eastern Oregon and the budding wolf population in Oregon's western recovery zone. Wolf recovery is moving along, and in much part, due to the tireless work of Department staff.

As an initial note, Cascadia has been very disappointed in that it seems the Department is trying to take the most expeditious route out of the wolf management in Oregon. This approach might be predictable and acceptable if the federal U.S. Fish and Wildlife had not already delisted the eastern portion of Oregon and has a pending proposal to delist the entire state in an attempt to do the exact same thing. Oregon's Endangered Species Act explicitly contemplates recovery of a species to follow a specific path: a species is endangered, then downlisted to threatened, and if recovery continues and there is no threat of conservation failure, the species is moved to the sensitive species list and continued to be monitored.

Neither the Department nor the Commission has considered or even mentioned moving wolves from endangered to threatened, making it patently clear that the agency is just attempting to take the easiest route, and not the route best for wolf recovery. This is inappropriate because of the duty owed to Oregonians that widely and enthusiastically support the recovery of gray wolves and have supported the expenditure of public funds to this end.

Secondly and most importantly, Cascadia and numerous other organizations have repeatedly stressed the premature nature of the proposed wolf delisting in Oregon. I think the common-sense conclusion of an analysis of the numbers and distribution in the state is that the species should remain listed until is population and distribution is more prolific. We have provided our own analysis of the delisting document developed by the Department, and we believe that as required by Oregon law, the best available science indicates that wolves are not recovered and are still at risk of failure.

The only way that the Department can move forward with scientific and legal confidence is if it conducts an independent, external peer review of the delisting proposal and analysis provided by the Department. This is plainly required by Oregon law. ORS § 496.171; OAR 635-100-0100(16). The law states that any removal of a species from the endangered or threatened species list must be supported by “verifiable” scientific information. The Department’s own regulations elaborate and define verifiable to mean “scientific information reviewed by a scientific peer review panel of outside experts.” *Id.* The regulations go even further and explicitly describe our present situation, where the Department is singularly relying upon its own study, its own information it must be again “peer reviewed by outside experts.” *Id.*

A peer review is legally, scientifically, and practically the only way forward for the Department to delist gray wolves.

Again, we would urge the Department to exercise precautionary principles when dealing with all wildlife under its jurisdiction. Oregon is changing, and with it so must the Department. More and more Oregonians are enjoying non-consumptive wildlife experiences and are moving here for jobs because of the easy access to Oregon’s beautiful public lands and rivers and the wildlife therein. The Department has a duty to cater to the interests of this evolving public body not the least because the Department is beginning to rely upon general fund dollars, and this reliance will only continue to increase.

But specifically with wolves and other carnivores, caution needs to be exercised because of the irrational fear and vitriol that drove this species and most predator species across our country to the brink of extinction. Still to this day the number one factor weighing on wolf recovery is the level of human-caused mortality.

We are strongly concerned that delisting could signal to some that it is “open season” on wolves or a reduction in poaching penalties. It is critical we avoid any increases in wolf mortality during this early recovery period. Just last month the alpha pair of the Sled Springs pack was mysteriously found dead near Enterprise. This is not tolerable in Oregon.

The extensive non-lethal efforts and stakeholder outreach by the Department have made Oregon the model for wolf conservation in the nation. Delisting will signal a sharp departure away from these efforts that have made wolf recovery a success so far in this state. Conducting an external scientific peer review on the Department’s proposal to ensure it can move forward with legal and scientific confidence is the right path forward.

Thank you for your time today.

Sincerely,

Nick Cady, Legal Director
Cascadia Wildlands
PO Box 10455
Eugene, Oregon 97440

October 9, 2015

Oregon Fish & Wildlife Commission
Attn: Chair Michael Finley
4034 Fairview Industrial Drive SE
Salem, OR 97302

Dear Chair Finley & Commission Members,

On behalf of Oregon Wild's more than 16,000 members and supporters across the state, we want to express our serious concern with prematurely delisting wolves from the state Endangered Species Act.

As you know, Oregon Wild has been deeply involved in wolf recovery including the landmark settlement agreed to by conservationists, the state, and the livestock industry and adopted by this Commission in 2013. Since that time, Oregon has been viewed around the nation as a model for balancing science, conservation values, and legitimate concerns.

The wolf management plan calls for consideration of delisting wolves at this time. We appreciate that you have taken on this task. However, it's important to recognize the word "consideration" does not imply a predetermined outcome.

Delisting at this time and under these circumstances is not supported by science, the law, or the public. At the last hearing there was a unanimous call to "stick to the plan". The most touching testimony may have been the schoolteacher who submitted dozens of children's letters and drawings. However, the most striking was from a former ODFW staffer involved with writing the plan. Sitting next to the president of the Cattlemen's Association and able to speak freely, he indicated in no uncertain terms that delisting at this time was not what was intended by the authors of the plan. As an organization which has supported the plan since its promulgation – something that distinguishes us from the Cattlemen – we agree.

We appreciate that the Commission called on staff to revisit more defensible options than simple statewide delisting. However, it still appears staff gave little serious thought to maintaining listing. In one and a half pages of a 100-plus page document the notion is simply discounted based on the specious, unscientific, and speculative assumption that the public's overwhelming support of wolves will decrease or that the vocal minority who already dislike wolves will dislike them even more if they are endangered. In several polls across the West and in Oregon, large majorities of citizens agree that wolves are a vital part of our natural heritage and should continue to be protected until they are fully recovered. With roughly 80 confirmed wolves, Oregon's gray wolf population is not yet recovered.

We have a number of questions and concerns about the latest iteration of the delisting report and are still going through it. However, the issues we have raised in previous testimony and letters remain. And if it is important for the public to accept the Commission's decision, we again urge an independent review.

The insistence on justifying delisting seems grounded in an unfortunate political miscalculation. At best, it an understandable desire to maintain maximum discretion for agency staff on a controversial issue. However, that ignores the important lessons we have learned over the past 7 years since wolves began to retake their rightful place on the Oregon landscape. Delisting without carrying forward successful parts of Phase I is a recipe for more controversy, not less.

We must flag that the wolf plan calls for a review every 5 years. Since the plan was adopted by rule in October, 2010, it is a legal obligation that is now due. Reviewing the wolf plan concurrent with the status review may provide an opportunity for the agency and public to move forward with minimal acrimony.

Since settlement, under Phase I, the wolf plan provided certainty for all responsible stakeholders. It focused on transparency. And it allowed for defensible decisions. No one got everything they wanted. But it has worked for all but the most intransigent voices. Wolf numbers are up. Depredations are down.

I appreciate the opportunity to share our perspective. We look forward to continuing to work on this issue with you. At Oregon Wild, we take seriously our mission to protect Oregon's wildlands, wildlife, and waters as an enduring legacy. And I feel it's important to remind you of yours: *"to protect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations."*

Sincerely,

Jonathan L. Jelen
Development Director
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Enc: Petition with over 3,200 supporters in favor of maintaining endangered species protections for Oregon's wolves.

October 9th, 2015

Oregon Fish and Wildlife Commission
Chair Michael Finley
4034 Fairview Industrial Drive SE
Salem, OR 97302

Dear Chairman Finley and members of the Commission,

My name is Danielle Moser and I am the Pacific Northwest Wolf Organizer for the Endangered Species Coalition. The Endangered Species Coalition is a national network of hundreds of organizations working to protect our nation's disappearing wildlife and last remaining wild places.

We realize the wolf plan requires consideration of delisting, but does not mandate it. Therefore, on behalf of the Endangered Species Coalition and our members in Oregon and across the country, we urge you to keep the gray wolf listed. Additionally, there are proposals in Congress to remove further protections from wolves, which makes it more imperative that state protections remain in place.

Stakeholders on all sides clearly believe this to be a consequential decision. The staff report seems to say it is not. As the report stated, "Delisting decision by the Commission is not expected to significantly affect the management of wolves." If that is the case, it seems like a persuasive argument for maintaining the status of wolves. Furthermore, if the only reason to remove wolves from the endangered species list is political and not scientific, then I would ask you to take a deeper look at recent public opinion polls. In 2015, Mason-Dixon Polling & Research, Inc. an independent research agency conducted a poll in Oregon for support of wolves. 66% across the state, with 60% in rural Oregon support continued protections for gray wolves.

Based on my initial reading of the report, I have a few questions regarding the population: The state has increased the wolf count to 85 known wolves. What was the methodology for counting the wolves? Was it as rigorous as last year's report? Did the ODFW add confirmed wolves to the previous 77 count or did they reconfirm each 77, plus the additions? Furthermore, were the recent two confirmed dead wolves subtracted from the total?

We appreciate the Commission's updated biological status review report. We have a responsibility to use the best available science to leave behind a legacy of protecting all endangered species for our children and future generations. We hope and encourage the Commission to do this when determining the gray wolf's future here in Oregon.

Thank you.

Danielle Moser
Endangered Species Coalition
dmoser@endangered.org

California Wolf Center

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Dear Commission Members,

California is in the middle one of the most inspiring conservation stories in the state's history; the return of the gray wolf. The Golden State has its first wild wolf pack since 1924. We owe this success to the natural behavior of wild wolves and the protection from the state of Oregon. Without a strong wild population of wolves in Oregon, the recolonization of California is not possible.

The California Wolf Center is leading the wolf recovery effort in our state and we have had quite a bit of success so far. We have formed working relationships with the ranching community, launched outreach in Northern California, raised the funds for coexistence and have the support of our Department of Fish and Wildlife. However, the foundation we have laid means nothing if wolves do not have the opportunity to travel into our state.

In 2011 OR-7, an Imaha pack member and Oregon native, began wolf recovery in California with his trek of more than 1,000 miles. His brother, OR-9, did not have the same chance. OR-9 dispersed into Idaho and was legally killed by a hunter. The legality of this kill was ensured by the lack of endangered species protection in the state. Oregon's state protections are the only reason OR-7 had the opportunity to take those landmark steps into California.

Those steps were not only a uniting event for California, but served as a map for the Shasta pack to find their home in this state. The breeding female of the Shasta pack began her life in Oregon, part of the Imaha pack as well. Once again, Oregon's state protections are the only reason California has a wild wolf pack.

This long awaited homecoming of one of our native predators is celebrate by over 80% of Californians. The conversation to delist gray wolves in Oregon may seem like a local decision, but that could not be furthest from the truth. The entire state of California is more than affected by this decision as well. The connectivity of wolf populations ensures that the loss of necessary protections in one place will be detrimental to the recovery of wolves in another. Please consider California's right to future wolves when making this decision.

Sincerely,

Christina Souto
California Wolf Center
Associate Director of Development and Communications

Oregon Department of Fish and Wildlife
11/6/2015

Summary of responses received by ODFW as part of an internal solicitation for scientific review of the technical document contained within Appendix B, titled *Assessment of Population Viability of Wolves in Oregon*

The Oregon Department of Fish and Wildlife requested a courtesy review of the "Assessment of Population Viability of Wolves in Oregon" that will be presented at the November 9^{th}, 2015 Commission meeting. We sent the document to 8 scientists and received responses back from 4 individuals. When soliciting a review, we explicitly expressed the individuals should focus on the validity of our population viability analysis (PVA) and not provide input on the process of delisting wolves. All reviewers provided their comments electronically on the Word document we provided with our analysis. Reviewers had until November 5^{th}, 2015 to return comments. Our summary and response to reviews received by this date follows. We did not respond to each individual comments made by each reviewer.

Dr. Joe Bull – University of Copenhagen, Co-author of published model modified by ODFW to conduct PVA of wolves in Oregon

Dr. Bull's review of our model was positive and did not identify any major issues with our approach or conclusions. He stated, *"Overall I think the application of the model makes sense, as do the conclusions drawn, although I had some questions which I think need addressing. Also, I think the language around the way the results are presented needs modifying in some cases to reflect the degree to which conclusions can be drawn from a modelling exercise like this."*

Dr. Bull included 37 unique comments in the document and 6 technical edits to improve wording. Of 37 comments, 11 were general statements, 3 provided suggestions for rewording, and 21 areas where additional details might improve the document.

Dr. Jon Horne – Idaho Department of Fish and Game, Research Biologist

Dr. Horne stated, *"All in all a very well-done and thorough analysis. But there were a couple of very big issues. I didn't take much time to say all the good stuff I was thinking or really read the Discussion so in the interest of time, here you go".*

While his review had the most suggestions regarding our modeling approach, he never indicated our model was fundamentally flawed nor were our conclusions inappropriate. His primary concern centered around our use of uniform distributions to randomly draw vital rates. He had some confusion about how we were implementing this based on our description in the text. We agree that our writing was a bit confusing and could be improved, but Dr. Horne was able to determine that we used a uniform distribution. Dr. Horne did not explicitly say our approach was wrong, rather he identified alternative statistical distributions that might have been more appropriate statistically. We agree, there are alternative distributions available. However, we contend our use of the uniform distribution is appropriate and allowed us to implement a more conservative population model for the following reasons:

- Other distributions will have a central mean vital rate that is most commonly chosen through random sampling. This reduces overall variation in randomly drawn vital rates. Using a uniform distribution, we increase variation (i.e., all outcomes are equally likely) in randomly drawn vital rates.
- Increased variation in vital rates will cause a population to perform worse on average – this caused our approach to be conservative.
- Modeling with reduced variation in vital rates would cause a more optimistic view of population viability. We used a conservative approach to follow the precautionary principle.

In total, Dr. Horne provided 16 comments on our analysis. Of 14 comments not related to our use of uniform distributions, 6 were general statements and 8 were suggestions to increase clarity in the document. Dr. Horne, did not review the discussion section of our document.

Dr. Katie Dugger – U.S. Geological Survey, Oregon Cooperative Wildlife Research Unit, Assistant Unit Leader

Dr. Dugger had an overall favorable impression of our analysis and stated *"This was a substantial effort to predict wolf population growth in Oregon relative to conservation and management objectives. You used a rigorous modeling approach and what appears to be the best data available. Most of my attached comments suggest that you increase transparency of the modeling process by including more information regarding 1) the source(s) of the data you used in your model (i.e., full citations should be provided somewhere for vital rates in Table 1), and 2) when data was not available, how/why you decided to use the specific vital rates or values you chose (i.e., based on info for another species, "expert opinion" or just a "best guess"??). In some cases a better explanation of assumptions (and why you made them) would be helpful too"*.

Dr. Dugger's greatest concern in our modeling approach was related to our application of density-dependence because the numbers used to estimate this value had the most uncertainty. We don't necessarily disagree with Dr. Dugger on this point. However, we contend that this had little influence on our conclusion that wolves have a low risk of extinction in near term. Our model was designed to assess risk of extinction for a small population. Density-dependent factors would not occur until we had a large population and a large population would indicate an extremely secure and recovered wolf population.

In total, Dr. Dugger provided 22 comments on our analysis. Of these comments, 8 were suggestions to provide additional details in the text, 10 were general statements, and 4 provided suggested wording changes or changes to organization of the document.

Dr. Ryan Long – University of Idaho, Assistant Professor

Dr. Long provided the most positive review of our PVA. He stated, *"This was obviously a hell of a modeling effort, and I enjoyed reading it, so thanks for the opportunity. I have a handful of comments and/or questions scattered throughout, but certainly nothing major. As with any model like this, it would be easy to spend a bunch of time trying to pick apart your choices for parameterizing various components of the model, and ask a bunch of detailed questions about why you did one thing or another. There really doesn't seem to be much point in that here though. This is a rigorous, well thought-out modeling effort that appears to take full advantage* *of every bit of relevant data you could get your hands on. As you explain multiple times in the report, your results are likely conservative, and frankly, I find them very convincing".* We fully agree with this statement by Dr. Long. There are many options available when developing a model, but our approach was valid and rigorous.

In total, Dr. Long made 15 comments addressing our PVA. Of these comments, 9 were general statements and 6 were suggestions to provide additional details in the text.

Summary

Overall, we received 4 positive reviews from scientists that did not identify fatal flaws in our analysis approach. Most reviewers explicitly indicated our modeling approach was sound. Based on our review of comments received, there was only one major comment related to the technical application of our PVA. We provide a response to this comment and contend that our approach is sound and is a more conservative modeling approach than that suggested. For the most part, reviewers made suggestions to improve the clarity of our report and in general, we agree with these suggestions.