Northwest Lion Ecoregional Population Objective Committee | Spring 2022

Photo courtesy of Cody and LeRee Hensen

The Montana Northwest Ecoregional Population Objective Committee met in spring 2022. The committee worked with FWP to define a planning strategy to manage the northwestern lion ecoregional population for population sustainability at a target level that maximizes public satisfaction related to lion hunter opportunity, lion conflict, and ungulate population trends. The committee consisted of citizens representing a broad spectrum of mountain lion stakeholders who reside within or close to the ecoregion.

Committee Members

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Bennie Rossetto, Kalispell

Joshua Baltz, Libby

Josh Letcher, Rexford

Wally Wilkinson, Kalispell

Jason Cataldo, Alberton

Casey Stutzman, Marion

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Terry Comstock, Eureka

Grover Hedrick, Boulder

Committee Facilitators

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Executive Summary

In 2019, Montana Fish, Wildlife and Parks (FWP) began implementing the Mountain Lion Monitoring and Management Strategy (FWP 2019), which outlines the state's new approach to conserving, monitoring, and managing mountain lions within an adaptive management framework. The strategy divides the state into four ecoregions, which delineate the spatial boundaries and scale of all monitoring and management moving forward. Population abundance is estimated in each ecoregion using an integrated population model (IPM) which combines data from mandatory reporting of lion harvest, vital rates estimated from past radio-collar studies, and a field-based spatial capture-recapture (SCR) method for estimating population density relative to habitat quality utilizing lion DNA. The IPM is also used to develop projections of future population change under alternative harvest scenarios that will inform management decisions.

The Northwest Lion Ecoregional Population Objective Committee (LEPOC) was developed to directly engage the public in the management decision-making process upon completion of population monitoring in the Northwest ecoregion. The LEPOC was composed of 10 members of the public who reside within or close to the Northwest ecoregion, and as a committee, represented a broad spectrum of mountain lion stakeholder viewpoints. The objective of the LEPOC was to work with FWP to provide a recommendation to the Commission regarding 1) target population trend over a 6-year period, 2) degree of ecoregional population size change (% up or % down), and 3) Lion Management Unit (LMU) emphases (e.g., older-age class harvest, conflict reduction, aid ungulate populations, more opportunity, etc.).

Over the course of two sessions in early 2022, the LEPOC met to work through a Structured Decision Making (SDM) process. During the first two-day session the committee developed a formalized problem statement, fundamental objectives, and measurable attributes related to the problem statement. The group also identified four alternative target population objectives to be achieved after a 6-year period (10% increase, no change, 15% decrease, and 30% decrease) and requested formalized spatial prescriptions for harvest under two alternative scenarios: 1) proportional to habitat and 2) concentrated in focal areas to aid struggling ungulate populations.

During the second two-day session, FWP presented the requested modeling results for the four population objectives and two spatial alternatives (i.e., proportional to habitat and focal areas). The LEPOC continued through the SDM process by ranking alternative population objectives and spatial alternatives relative to how well they met the LEPOC fundamental objectives. The group, through an iterative process, refined rankings of the alternative objectives and developed additional population objectives for FWP to model. The LEPOC presented FWP a final recommendation of a 12.5% decrease in the Northwest Ecoregion lion population by 2027, with focal areas of higher harvest in LMUs (100,121,122,123, & 124). Pending approval by the Montana Fish & Wildlife and Parks Commission, the harvest prescriptions needed to meet this population objective will be implemented beginning in the 2022-2023 season.

Introduction

Background and Committee Purpose


Photo Credit: Bob Wiesner

In 2019, The Montana Fish and Wildlife Commission adopted the Montana Mountain Lion Monitoring and Management Strategy (Montana Fish Wildlife & Parks, 2019), outlining the new rigorous, scientific approach to Montana's lion monitoring, management, and conservation efforts. This new strategy incorporates previous research findings demonstrating that mountain lion populations in western North America are well connected and are most effectively managed at large spatial scales (Montana Fish Wildlife & Parks 2019). Accordingly, the updated strategy identified four biologically meaningful mountain lion "ecoregions" within the state (Northwest, West-Central, Southwest, and Eastern). These ecoregions are large, contiguous areas of the state within which lion habitat is broadly similar and serve as the spatial framework of FWP's lion management program. The new lion management strategy also directs Montana FWP to utilize an adaptive harvest management process that directly engages the public in the decision-making process. Public involvement is achieved through formulation of ecoregion specific Population Objective Committees that bring a wide range of diverse, and often opposing, views on lion conservation and management to the decision-making table. By incorporating these diverse stakeholders in the decision-making process, FWP hopes to manage the lion ecoregional populations for sustainability at a target level that maximizes public satisfaction related to lion hunter opportunity, lion conflict, and ungulate population trends.

Lion Ecoregional Population Objective Committees (LEPOC) will be developed in each of the 3 western ecoregions: Northwest, West-Central, and Southwest. The LEPOC in each ecoregion will be established upon completion of 2 winters of field monitoring to estimate lion density in each ecoregion. Once completed, these monitoring efforts are integrated with harvest and demographic rates to produce an updated ecoregional lion population estimate. Standardized field monitoring (Montana Fish Wildlife & Parks, 2019) began in the NW ecoregion during the 2019-2020 license year and continued during the 2020-2021 license year, yielding the NW ecoregion population estimate in summer 2021 and LEPOC development during the 2021-2022 winter.

The objective of each LEPOC is to work with FWP to provide a recommendation to the Commission regarding:

- Target population trend over a 6-year period (Increase, Decrease, Stable)
- Degree of ecoregional population size change (% up or % down)
- Lion Management Unit (LMU) emphases (e.g., older-age class harvest, conflict reduction, aid ungulate populations, more opportunity, etc.)

Though the LEPOC will identify a target lion population to achieve in 6 years, they are not charged with recommending season structures, license types, or allocation of harvest among the ecoregion's lion management units to meet the ecoregional population trend objective. Upon completion, FWP will present the LEPOC's recommendations to the Montana Fish and Wildlife Commission for adoption or modification through their public decision-making process, and ultimately implementation. These decisions will be made within the normal Commission process.

Northwest LEPOC Selection

The Northwest LEPOC consisted of 10 citizens representing a broad spectrum of mountain lion stakeholders who reside within or close to the Northwest ecoregion. On September 7, 2021, FWP Helena shared a press release to solicit applications from Montana citizens interested in serving on the LEPOC. The initial application period closed at 5:00 P.M on September 21 but was extended to solicit additional applications to increase the applicant pool and ensure a diverse range of stakeholder groups were represented in the final committee composition. The final deadline for applicant submissions was 5:00 P.M on September 28. Applicants were asked to answer 4 supplemental questions that highlighted their interest in serving on the committee, the experience they would bring to the group, and their demonstrated ability to work in a collaborative setting. A multiple-choice survey question also allowed applicants to note which stakeholder group or groups they identify with and would represent on the committee.

Prior to soliciting applications for the LEPOC, FWP set criteria for the committee selection. With a maximum of 12 members, the committee would be assembled with the goal of capturing the diverse range of viewpoints surrounding lion conservation and management in Montana. Thus, the committee would include 2 members from each of the following stakeholder groups: hound handlers, lion outfitters, livestock producers, deer hunters, elk or sheep hunters, and the public. Due to the limited committee size of 12 members, FWP sought to incorporate the local stakeholder groups directly vested in the conservation and management of lions in the NW ecoregion. Applications were therefore not solicited from national constituency groups, mountain lion researchers, or individuals living outside of the NW ecoregion.

A team of FWP staff from Regions 1, 2, and Helena made initial recommendations to the Director's Office regarding committee member selections from a pool of 31 applicants. This team included Regional Supervisors Jim Williams and Randy Arnold, along with Region 1 and 2 staff, Game Management Bureau Chief Brian Wakeling, and Mountain Lion Monitoring Technician Molly Parks. The FWP Director's Office approved committee member selection and participants were notified of their selection on December 7, 2021. All selection criteria were met or exceeded, with the exception of the livestock producer group. Limited entries from this stakeholder group led to selection of 2 committee members that represent the livestock producer/ranch perspective without directly managing livestock. While 12 committee members were selected, the extended timeline from the September 7 call for applications to the December 7 notification for successful applicants resulted in loss of 2 committee members who were no longer available for participation. This final committee included:

- Joshua Baltz
- Jason Cataldo
- Timmothy Garrison
- Josh Letcher
- Casey Stutzman
- Cody Carr
- Terry Comstock
- Grover Hendrick
- Bennie Rossetto
- Wally Wilkinson

Process

Work Group Meeting Agendas

In response to the Covid-19 pandemic, the LEPOC meetings utilized Zoom (2022) as a virtual platform to host 4 meetings. Meetings were divided into 2 sets of 2-day sessions (January 5-6, 2022 and March 1-2, 2022) and were held each day from 8:00 A.M. to 5:00 P.M. The meetings were recorded and live-streamed on the FWP website and YouTube so the public could observe the deliberations at their convenience. There were also 2 public comment periods, open from 4:00 P.M – 5:00 P.M. on January 5 and March 1 that allowed the public to ask questions or comment on the process. Despite providing this opportunity for public comment, no members of the public engaged in this part of the process.

FWP Helena shared press releases ahead of scheduled LEPOC meetings (December 29, 2021 and February 23, 2022) to notify the public of the upcoming meeting dates, times, agendas, and web links to the live streamed meetings. This information was also posted on the FWP Northwest Lion Ecoregional Population Objective Committee webpage (https://fwp.mt.gov/aboutfwp/nw-mountain-lion-workgroup), along with detailed information needed to make public comment during the public comment periods. Recordings from all meetings were also posted to the website, along with the list of committee members and links to additional lion resources.

Alex McInturff and Sarah Sells facilitated the group through a Structured Decision Making (SDM) process (Runge, Grand, and Mitchell 2013) and guided the committee through the steps of developing a problem statement, identifying fundamental objectives, identifying alternative population objectives, evaluating alternatives, and making a final recommendation (Figure 1).

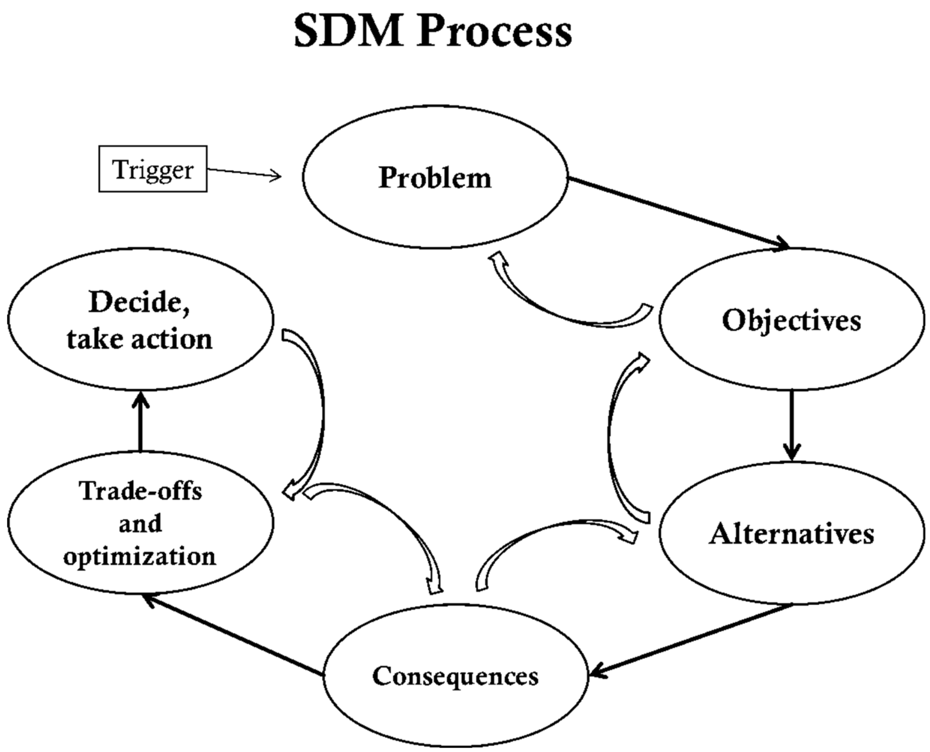

Figure 1. Structured decision making (SDM) process represented by the main steps (ovals and straight arrows). Curved arrows depict how information learned during the process can be used to revisit and revise components produced at earlier steps.

Structured Decision Making

FWP has successfully used SDM to guide citizen work groups to recommended decisions on controversial wildlife management issues, as observed in the 2014 Region 2 Lion Work Group meetings (Montana Fish, Wildlife and Parks 2014; Mitchell et. al 2018). Considering the challenging decision-making process that faced the LEPOC members, SDM was again selected to set participants up for success. The following description of SDM is quoted from Gregory and Keeney (2002):

> *A structured decision making approach helps resource managers by splitting a tough decision into its parts (referred to here as "elements"). For many complex decisions, making a better choice requires that eight key elements be considered... The first five elements – Clarifying the Problem, Identifying Key Objectives, Creating Alternatives, Assessing Consequences, and Explicitly Addressing Tradeoffs (leading to the acronym*

PrOACT, a reminder to be proactive) – constitute the core of a structured approach to decision making (Hammond et al., 1999).

And:

[We emphasize] the importance of using a structured decision process to specify and organize values, use these values to create alternatives, and assess tradeoffs to help achieve a desired balance across key objectives. Although these decision making steps are based on common sense, they are often neglected or poorly carried out as part of the complex evaluations of natural resource options…some of the benefits of using a structured, decision focused approach: new and better solutions, increased and more productive participation by stakeholders, and greater defensibility and acceptance of the resource management evaluation process and its conclusions.

FWP began the LEPOC meetings with several presentations to give the participants relevant context and background information. These presentations started with an introduction to the SDM process (Sarah Sells), followed by context and perspective for the LEPOC and how it plays an important role in Montana's lion management (Brian Wakeling). Previous research was presented on the integrated lion-elk management program in the Bitterroot Valley (Kelly Proffitt; Proffitt et al. 2015, 2020), which highlighted findings on the effect of lion harvest on elk recruitment. This research also led to development of the spatial capture-recapture (SCR) lion monitoring method. The final FWP presentation provided a synopsis of the lion ecoregional monitoring and modeling program, including density estimates and results of implementing the new monitoring program in the NW Ecoregion during 2019-21 (Dave Messmer & Molly Parks).

Following these presentations, the discussion centered between the facilitators and committee members. To gain participant and public support for the final recommendations, FWP and the facilitators aimed to allow the committee to identify common values and objectives and reach a mutually agreeable decision that was based solely on the discussion and input from the diverse participants at the table. Competing social values surrounding lion conservation and management were the primary roadblock to a unanimous group decision or public consensus on lion management. Accordingly, rather than participate in the discussion, FWP sought to learn more about these diverse viewpoints from silently observing the group's discussion. If at any point the committee had questions, however, FWP biologists were available to provide any requested information.

Below are the consensus products and recommendations from the LEPOC meetings for the Northwest Ecoregion. The final recommendations are a combination of the target lion population trend and degree of change, identification of focal areas for intensified lion harvest to aid struggling ungulate populations, and a list of additional recommendations that were not a direct charge of the committee, but were important topics that the committee wished to present to the Commission for further consideration. The results from each phase of the SDM process are also described below for transparency and clarity in this decision-making process.

A female lion treed near Libby, Montana.

Problem Statement

In SDM, the problem statement clearly states the challenges of the decision-making issue at hand. Without a clearly defined problem statement, decision-makers could solve the wrong problem, use the wrong tools and information, and invest in the wrong solution. The problem statement is therefore the critical first step to any SDM process. While at first glance this step may seem simple, it often takes an investment of time and effort to arrive at a statement that fully and clearly captures the group's input about the challenges at hand.

The LEPOC spent most of the first meeting day formulating a problem statement. The day started with individual work brainstorming the relevant issues surrounding lion management in Montana and specifically the NW Ecoregion. Next, the committee was divided into small groups of 3-4 members to continue developing a list of the key issues while also beginning to establish a rapport with one another. Day 1 finished with group discussion and development of a draft problem statement encompassing key issues identified. Day 2 began with a brief discussion of the key issues and allowed the committee to refine their problem statement. The final problem statement identified by the LEPOC was:

> *FWP's lion population estimate is approximately 1,376 lions (90% confidence interval = 650 – 2,547) in the Northwest MT Ecoregion. There is uncertainty in this estimate. Many differing opinions exist regarding the optimal/acceptable population for the current carrying capacity in some areas of the ecoregion, which lions share with ungulates and other predators. Population densities vary across the ecoregion and many challenges exist, including diverse user groups, variable access, complex interactions with other species (e.g., wolves), changing habitat conditions, and imperfect population estimates. Mountain lion predation on struggling ungulate populations (e.g., bighorn sheep, mule deer) is also a concern. These challenges can vary over the ecoregion. With the number of Stakeholders involved with mountain lion management (including sportsmen, houndsmen, livestock growers, etc.), we as a group are charged with determining the target population trend (increase, decrease, stable), degree of ecoregional population size change (% up or % down), and LMU emphases, and forwarding this recommendation to FWP. In short, we must identify an acceptable population goal that will be re-evaluated in six years.*

Fundamental Objectives

In SDM, fundamental objectives define what the decision-makers truly care about. For example, if the problem could be solved perfectly, what would it accomplish? Fundamental objectives define the bottom line and what truly matters and form the basis for evaluating how well any potential solution solves the problem at hand.

Over the course of the second day, the committee worked to next identify and refine specific fundamental objectives that a decision on lion population size would address. The facilitators again split the committee into small groups to identify these

A mountain lion sampled by contracted hound handlers near Libby, Montana.

objectives, then brought the group together for discussion to refine the objectives. The final, consensus list of fundamental objectives are below:

Fundamental Objectives

In no particular order:

1. Minimize negative impacts on ungulates
    a. Minimize excessive ungulate predation
    b. Assist in offspring recruitment in struggling ungulate populations (means: reduce lions populations)
2. Maintain healthy lion population as a natural part of the ecosystem
3. Minimize human - lion conflict (livestock/pet)
4. Maximize lion hunter/houndsmen satisfaction:
    a. Lion hunter opportunity
    b. Harvest of lions
    c. Recreational lion chasing (non-harvest)
5. Maximize ungulate hunter satisfaction
6. Maximize social acceptance of lion hunting (means: education)

Alternatives

Alternatives are the third step of the SDM process and define possible options, solutions, and management actions that may be taken to achieve the fundamental objectives. Although we commonly first think about solutions when presented with a problem, good decisions rely on first understanding the details of the problem and the fundamental objectives that should be met.

A main goal of the LEPOC was to determine a desired change to the population (increase, decrease, or remain stable). Accordingly, the LEPOC continued the afternoon work session on the second day by completing an exercise to assign "satisfaction scores" to incremental increases and decreases to the current lion population. Using a metric of percentage change from the current population, members were asked to score how satisfied, or dissatisfied they would be across a range of population change objectives ranging from -100% (decrease) to +100% (increase) in 5% increments. Each committee member was asked to rank their perceived satisfaction for each incremental change on an ordinal scale from 1 to 5 (1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, 5 = very satisfied).

Compiling and plotting results of each participant's survey into one graph enabled visualizing areas of commonality (Figure 2). The combined output of this exercise showed the range of preferences for each group member and provided the necessary information for selecting discrete alternative population objectives. Based on this output, the group selected 4 discrete population change scenarios including a population increase of 10%, maintenance of a stable population, a population decrease of 15%, and a population decrease of 30% (Figure 2). The group also asked FWP to map the population results for each of the 4 scenarios in 2 ways: with lion harvest distributed among LMUs proportional to habitat quality, and with lion harvest distributed among LMUs such that harvest was disproportionately concentrated in certain areas to aid ungulate populations, hereafter referred to as *ungulate focal areas*.

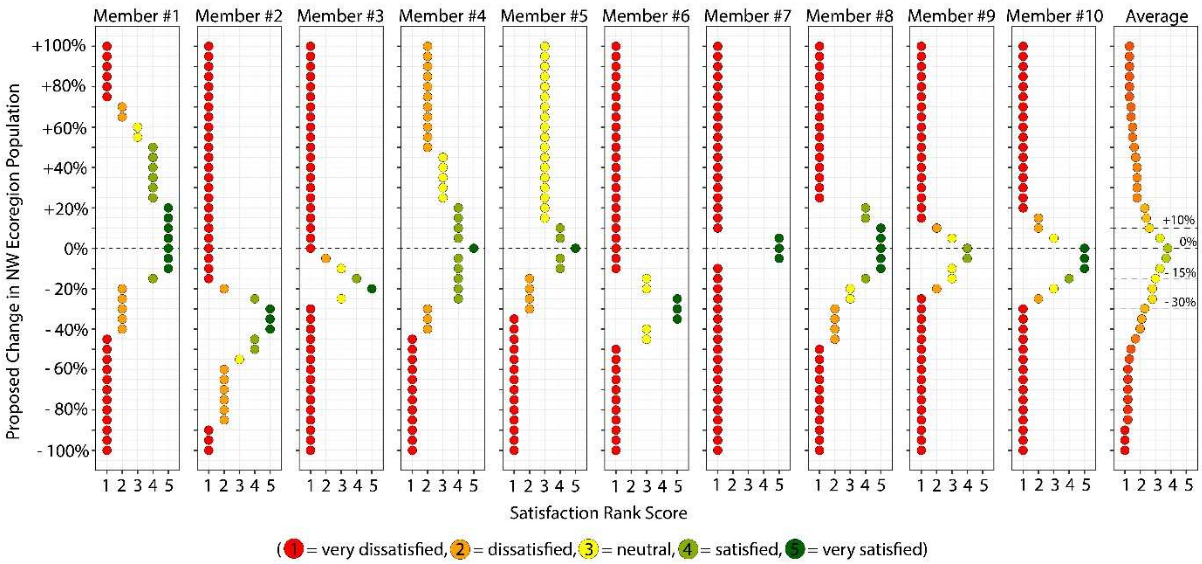

Figure 2. Satisfaction score results to possible changes to the NW Ecoregion lion population, as ranked by each LEPOC group member. The right-most panel shows the average of responses. Dashed lines and percentage values on the average panel show the discrete changes (+10%, no change, -15%, -30%) the group selected and presented to FWP for additional population modeling.

The final set of alternatives the LEPOC asked FWP to simulate prior to the second meeting included 8 alternative scenarios (Table 1).

Table 1. LEPOC Alternatives presented to FWP for modeling

Scenario	Population Objective after 6 years	Spatial Distribution Alternative
1	Decrease population 30%	(A) Proportional to Habitat
2	Decrease population 30%	(B) With Ungulate Focal Area(s)
3	Decrease population 15%	(A) Proportional to Habitat
4	Decrease population 15%	(B) With Ungulate Focal Area(s)
5	Maintain population (stable)	(A) Proportional to Habitat
6	Maintain population (stable)	(B) With Ungulate Focal Area(s)
7	Increase population 10%	(A) Proportional to Habitat
8	Increase population 10%	(B) With Ungulate Focal Area(s)

Consequence Predictions

Under the fourth step of the SDM process, consequences are predicted for each objective under each alternative. For the LEPOC, this first entailed effort by the FWP science team to model the 8 alternative scenarios the group defined.

Modeling Results

Between the January and March LEPOC meetings, the FWP science team was tasked with modelling the committee's 8 requested alternative scenarios (Table 1) using the mountain lion IPM (FWP 2019) to determine the annual level of harvest needed to meet each objective after 6 years. To conduct simulations, the FWP science team used the IPM structure outlined in the Montana Mountain Lion Monitoring and Management Strategy (Appendix 2 of FWP 2019), with two modifications. First, we changed a line of code to indicate that the density estimate based on field monitoring (SCR) is the density of independent-age lions that are available for harvest, i.e., excluding kittens. Second, we added the necessary components to simulate the population into the forecast period (2023-2027). This modification made the *informed prior* (Kruschke & Liddel, 2018) for harvest rates in the forecast period directly related to the proposed increase in harvest.

Without this modification the model may have assumed increases in harvest were coming from a constant harvest rate on an increasing population. The complete modified code is included in Appendix B.

To establish a baseline for comparison, the first simulation represented the mean lion harvest in the NW ecoregion over the last 5 years. This mean was calculated using records from the FWP mandatory reporting database. The initial time step in the 6-year simulation includes the 2021-22 season that was currently ongoing during the LEPOC process, so the total 2021-22 harvest was estimated in order to run simulations. The total 2021-22 harvest was projected by calculating the mean percent of total license-year harvest achieved by February 23 in the previous 15 years (95%) and assuming the 2021-2022 harvest (129 as of Feb 23) would follow the same trajectory (i.e., estimated 2021-22 harvest = 129 × (1/0.95) = 136). Simulation results using the 5-year mean were treated as the status quo scenario, as a basis for understanding how harvest would need to be adjusted to accomplish the alternative population targets identified by the LEPOC and resulted in a prediction for a -2% population decline across the NW ecoregion over the next 6 years if the same harvest levels were to continue each year until 2027.


A female lion sampled near Lincoln, Montana.

Results from the status quo scenario were used to conduct an iterative process to predict the amount of harvest required to achieve 10% population growth, stability, a 15% decline, and a 30% decline at the end of the 6-year simulation period, per the alternative scenarios provided by the LEPOC (Figure 3; Table 2). This iterative process is time consuming and restrictive for

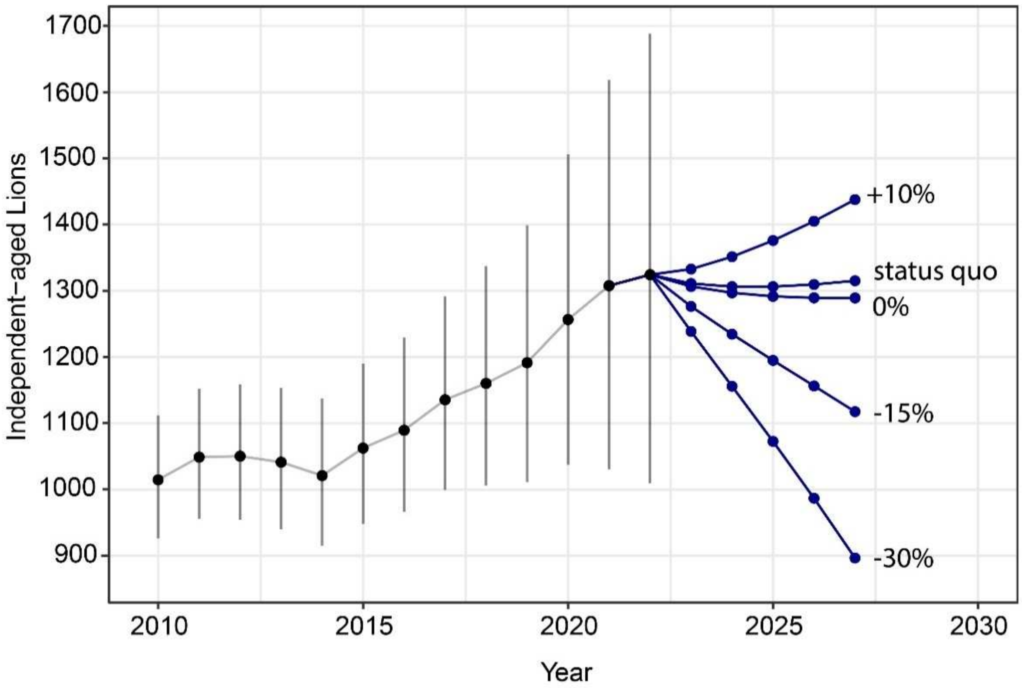

Figure 3. Montana FWP mountain lion IPM timeseries and modeled projections including the 4 LEPOC scenarios (+10%, 0%, -15%, -30%) and the status quo (5-year mean harvest). Black lines show the point estimate and 95% credible intervals and blue points, and lines show the modeled population projections timeseries. Details for each scenario are provided in Table 2.

Table 2. Montana FWP mountain lion IPM model scenario parameters used to meet the LEPOC requested population changes after a 6-year period.

Modeling Scenario	Reference Year	Target Pop. Change after 6 years	Total Annual Harvest	Percent Change in Total Annual Harvest (from status quo)	Realized Pop. Change after 6 years
LEPOC Requested	2021	+10%	137	-25%	+10%
LEPOC Requested	2021	0%	176	-4%	0%
Status quo (Reference)	2021	-	183	0%	-2%
LEPOC Requested	2021	-15%	232	+27%	-15%
LEPOC Requested	2021	-30%	289	+58%	-30%

generating additional results quickly when, or if, the SDM process resulted in additional scenarios requested by the LEPOC. Therefore, we developed an additional faster approach that provided nearly identical result to the iterative simulations for the annual harvest required to meet any population objective at the end of the 6-year period. We used initial simulation results of total annual harvest from the 4 population scenarios to develop a (nonlinear) regression model to describe the relationship between the simulated total annual harvest and predicted population change after 6-years (Figure 4). This regression line allowed us to quickly estimate

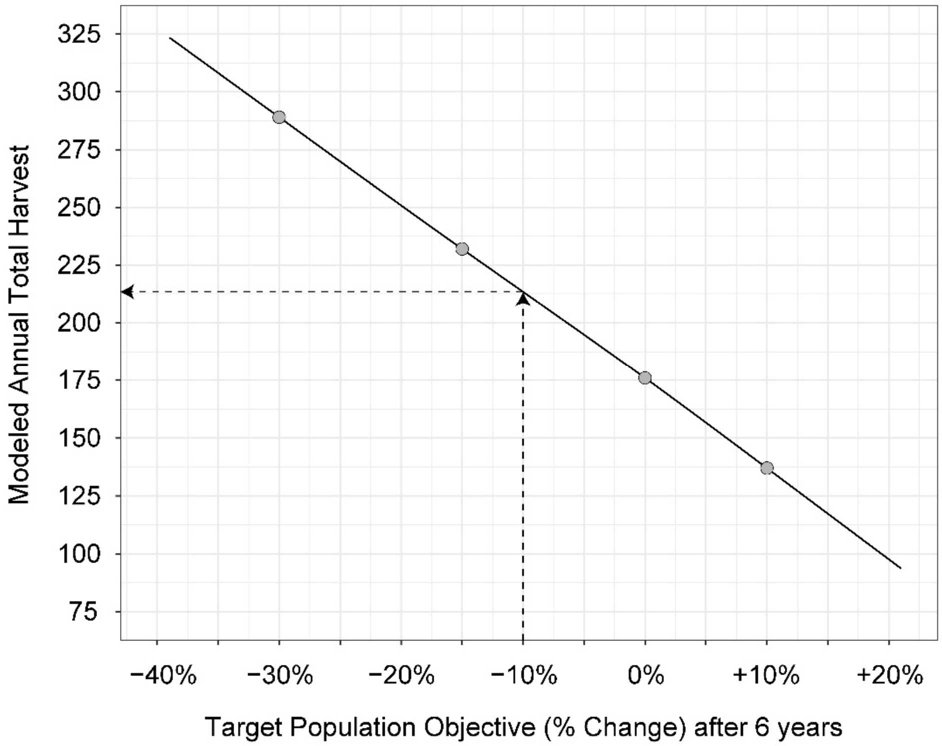

Figure 4. Relationship between population objective after 6 years (as % change) and the required annual harvest. The grey dots show the requested population objectives from the LEPOC (+10%, 0%, -15%, -30%) and the solid black line is a fitted generalized additive model {Target Modeled Annual Harvest ~ f(Population Objective}. Grey dash lines provide an example of how any target objective of percent change, e.g., -10%, can quickly be estimated.

the amount of harvest needed to generate any desired level of population change, and the regression estimates were verified and/or slightly adjusted (e.g., maximum 1-2 lions/year) with IPM simulations, to generate exact harvest levels required to achieve the desired population trajectories. These desired population trajectories are a result of the total ecoregional harvest, regardless of how harvest density is distributed across the landscape.

Each of the 4 population objective scenarios (+10%, stable, -15%, -30%; Figure 3; Table 2) were then applied to the NW Ecoregion using 2 alternative options to distribute harvest among Lion Management Units (LMUs): harvest applied proportional to the amount of habitat across LMUs or with disproportionate harvest concentrated in an ungulate focal area. This exercise required accounting for harvest history and constraints across the NW ecoregion. Over the last 5 years, harvest levels have been distributed proportionally to the amount of habitat among LMUs in the NW Ecoregion, with a few exceptions (Figure 5).

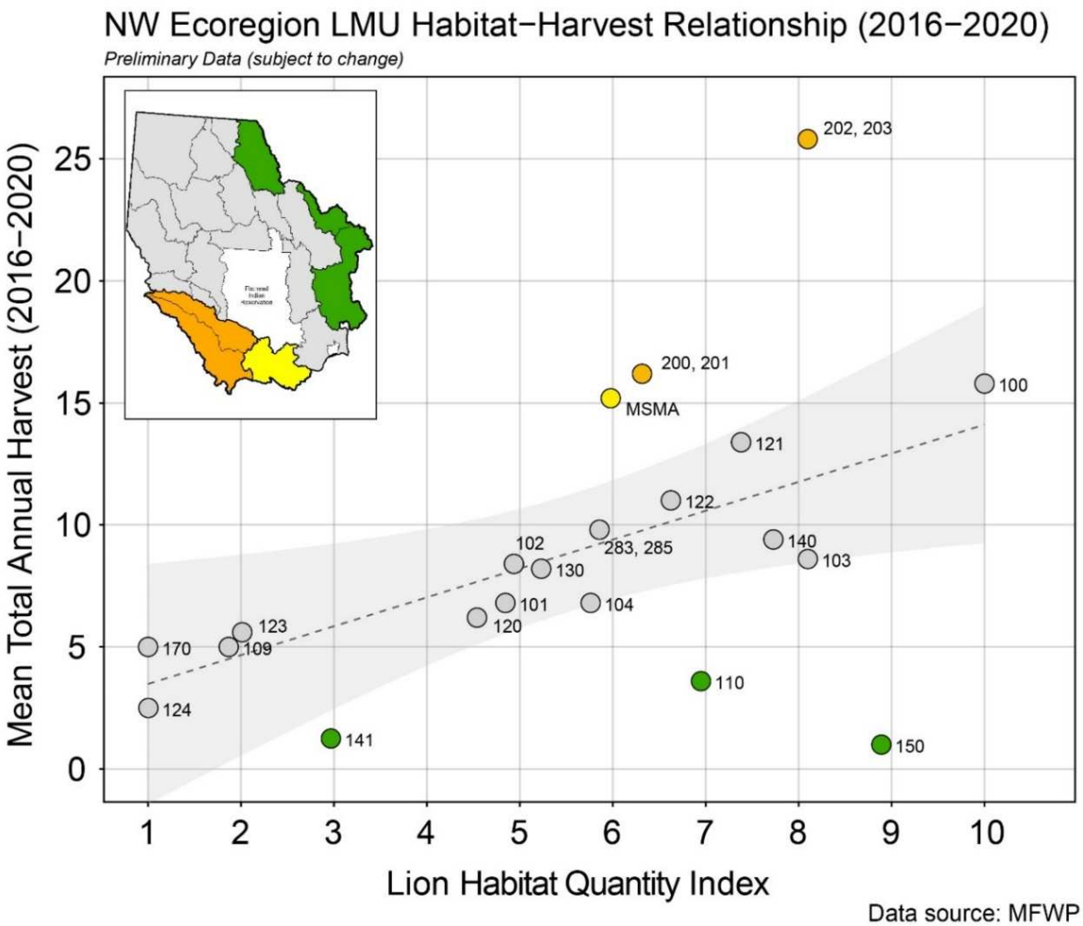

Figure 5. Lion harvest (2016-2020) and habitat quality in the NW Ecoregion. Mean annual lion harvest (2016-2020) in each LMU in the NW Ecoregion is shown plotted against the amount of high-quality habitat (RSF values >0.75). The dashed line shows the fitted linear regression line and the shaded area is the 95% confidence interval. Grey Points reflect the general relationship of harvest proportional to habitat quality. Green points (LMUs 141, 110, and 150) show less harvest than expected given their habitat quality. Orange points (LMUs 200,201 and 202, 203), and yellow points (Missoula Special Management Area; MSMA) show higher harvest than expected, which is due to regulations intended to reduce lion numbers and aid ungulate recruitment or urban conflict (MSMA).

First, despite relatively high harvest quotas and permit levels, backcountry areas with limited and difficult access along the eastern portion of the NW Ecoregion (including LMUs 110, 141, and 150) have disproportionately low harvest. Because of difficult access, this situation is unlikely to change even if quota levels are increased. Second, the Missoula Special Management Area (MSMA) was established decades ago to minimize lion density and distribution in the Missoula metropolitan area. Quotas in this area remain high to reduce conflict and subsequent need for management removals. Third, the area west of Missoula in FWP Region 2 has had high lion harvest quotas and relatively high harvest for approximately 10 years, to reduce lion density and increase ungulate populations. This desired outcome is reflected in the lower lion density estimated in the trend monitoring area that falls within this portion of the NW Ecoregion (Montana Fish, Wildlife and Parks 2022). FWP Region 2 is interested in maintaining this ungulate focal area, albeit reducing the quotas slightly below the average annual harvest to allow for a shift of harvest opportunity to other ungulate focal areas in the ecoregion. Given these constraints, the FWP science team identified another ungulate focal area for consideration by the LEPOC. This focal area would be in FWP Region 1 along the Thompson River drainage to the Idaho border, adjacent to the existing ungulate focal area in FWP Region 2 (Figure 6). This additional focal area was suggested due to perceived impacts of predation on elk recruitment and small, struggling bighorn sheep populations where lion predation is a significant concern. Additionally, FWP is proposing to begin intensive monitoring of elk and

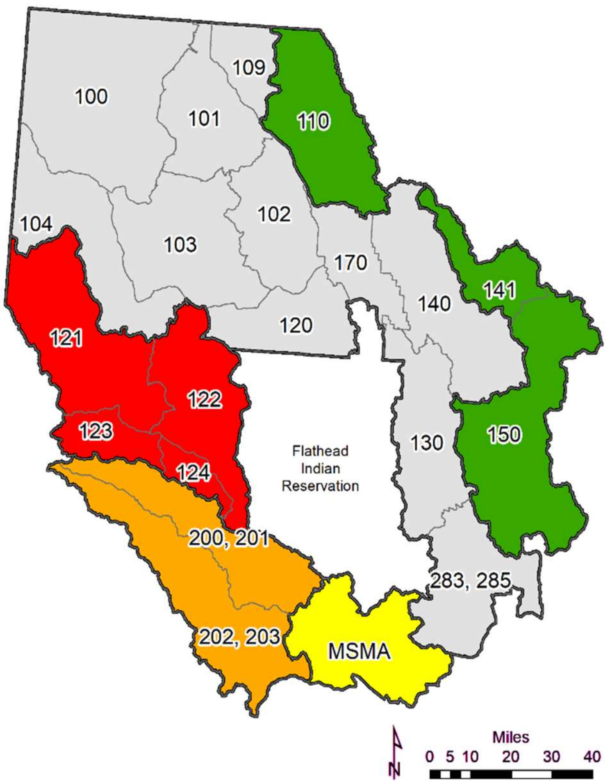

Figure 6. LMUs (2021 License Year) and Lion management zones within the NW Ecoregion. Grey LMUs reflect the general relationship of harvest proportional to habitat quality. The Green Region (LMUs 141, 110, and 150) shows where harvest is less than expected given habitat quality. Orange Region (LMUs 200,201 and 202, 203), and yellow REgion (Missoula Special Management Area; MSMA) show higher harvest than expected based on habitat quality, which is due to regulations intended to reduce lion numbers and aid ungulate recruitment or urban conflict (MSMA).

bighorn sheep populations in this proposed focal area in the coming years, so the effects of increased lion harvest on these ungulate populations can be monitored. To achieve desired effects, harvest density in this new ungulate focal area in FWP Region 1 could be set to a similar level as that in the FWP Region 2 ungulate focal area, given the existing evidence that lion density is in fact lower in that area already. This proposed ungulate focal area was presented to the LEPOC as a possibility for their consideration, noting that it was their prerogative to adjust or suggest the location of ungulate focal area(s) as they saw fit.

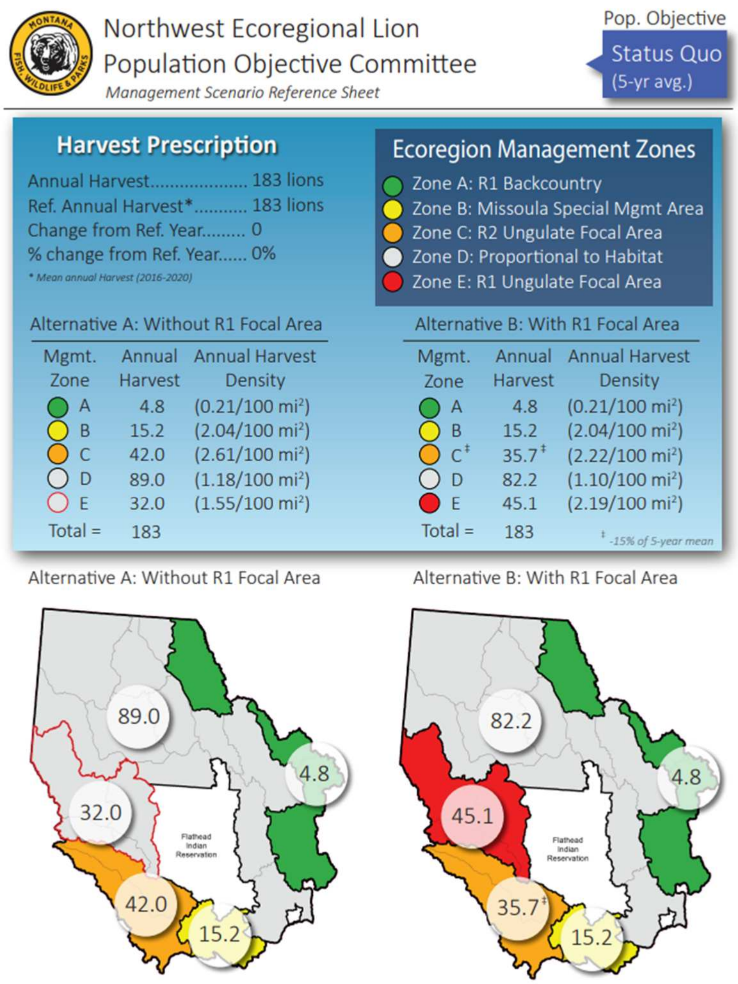

Figure 7. Northwest Lion Ecoregional Population Committee Informational Sheet illustrating status quo harvest allocation (5-year average annual harvest). Maps show spatial alternatives where numbers within the circles indicate annual harvest prescription for the management (colored) zones for which they overlap.

Given this harvest history, the constraints on additional harvest in some areas, and the proposed additional ungulate focal area in FWP Region 1, the FWP science team provided the LEPOC with informational reference sheets on how harvest could be distributed for each of the 4 population objective scenarios proportional to the amount of habitat across LMUs (Alternative A) or disproportionate harvest concentrated in an ungulate focal area (Alternative B). Because SDM typically includes the current management scenario for comparison to new alternatives, FWP also provided maps and information on the Status Quo 5-year average lion harvest scenario under Alternatives A and B (Figures 7 & 8). In total, 10 alternative scenarios (4 population objective + status quo scenarios each with two spatial alternatives for distributing harvest among LMUs)

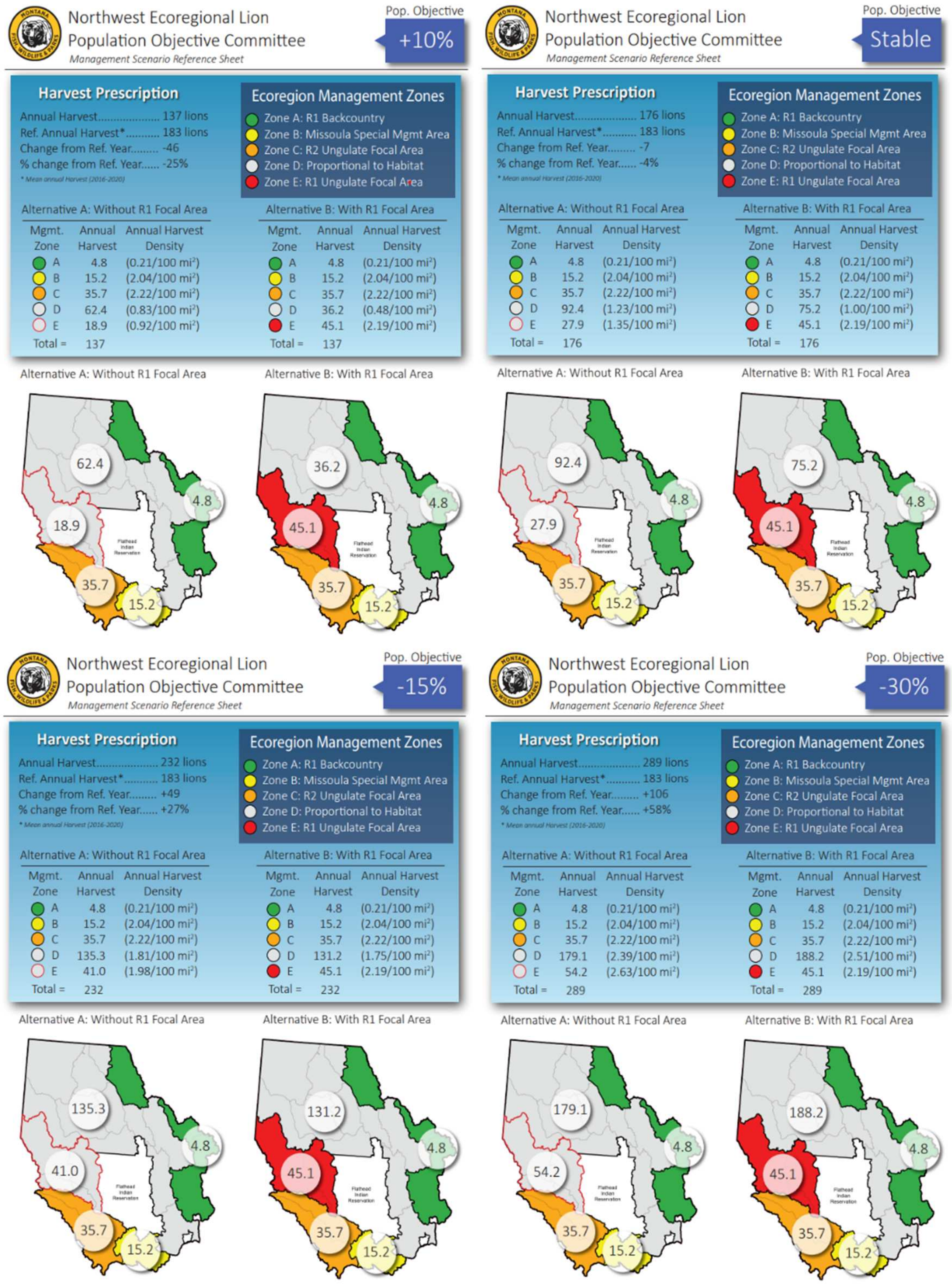

Figure 8. Northwest LEPOC Informational Sheets illustrating lion harvest allocation for 10% population increase, stable population trend, 15% decrease, and 30% decrease. Maps show spatial alternatives where numbers within the circles indicate annual harvest prescription for the management (colored) zones for which they overlap. Each sheet is provided at full resolution (8.5” x 11”) in Appendix A.

were presented to the LEPOC for their consideration, with ample time for discussion and questions, at the beginning of their second meeting on March 1, 2022.

Committee Predictions of Consequences

The committee next predicted consequences for each of the 8 alternative harvest scenarios using their expert judgement. Facilitators provided each committee member with a table listing the 9 fundamental objectives and alternative harvest scenarios. The committee members worked independently to predict how well each alternative would meet fundamental objectives using a constructed scale of 1-5 (1=strong negative effect, 2=some negative effect, 3=no change, 4=some positive effect, 5=strong positive effect).

To predict consequences for the 8 alternatives, LEPOC members considered measurable attributes associated with each fundamental objective (Table 3)

Table 3. The NW Ecoregion LEPOC Fundamental Objectives and Measurable Attributes

Obj	Fundamental Objective	Measurable Attribute
1	Minimize excessive ungulate predation	Effect on excessive ungulate predation
2	Assist in offspring recruitment in struggling ungulate populations	Effect on ungulate recruitment in struggling populations
3	Maintain healthy lion population as a natural part of the ecosystem	Effect on health of lion population as part of ecosystem
4	Minimize human-lion conflict (livestock/pet)	Effect on human lion conflict (livestock/pet)
5	Maximize satisfaction: lion hunter opportunity	Effect on satisfaction in lion hunter opportunity
6	Maximize satisfaction: harvest of lions	Effect on satisfaction in harvest of lions
7	Maximize satisfaction: recreational lion chasing (non-harvest)	Effect on satisfaction in recreational lion chasing
8	Maximize satisfaction: ungulate hunters	Effect on ungualte hunter satisfaction
9	Maximize social acceptance of lion hunting	Effect on social acceptance of lion hunting

Each working group member then scored out their estimated consequences for each alternative (Table 4).

Table 4. Consequence Score Table. Each of the fundamental objectives are organized by row on the left, and each column on the right represents the predicted consequences for a given population objective presented to FWP for modeling. Spatial alternatives are nested within individual population objectives as "Alt. A" and "Alt. B" in accordance with the exclusion or inclusion of an ungulate focal area, respectively.

Population Objective		Status quo		+10%		Stable		-15%		-30%	
Obj.	Fundamental Objective	Alt. A	Alt. B	Alt. A	Alt. B	Alt A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B
1	Minimize excessive ungulate predation	2.7	3.3	1.7	2.1	2.8	2.8	3.8	4.2	4.3	4.5
2	Assist in offspring recruitment in struggling ungulate populations	2.7	3.4	1.6	2.0	2.6	2.9	4.0	4.3	4.2	4.5
3	Maintain healthy lion population as a natural part of the ecosystem	3.3	3.5	2.9	2.8	3.1	3.3	2.8	2.8	2.4	2.5
4	Minimize human-lion conflict (livestock/pet)	2.8	3.1	2.0	2.2	2.6	2.7	3.5	3.7	3.9	4.0
5	Maximize satisfaction: lion hunter opportunity	3.0	3.3	2.7	3.0	2.8	3.0	3.1	3.2	3.3	3.2
6	Maximize satisfaction: harvest of lions	2.9	2.8	2.4	2.7	2.7	2.6	3.3	3.2	3.7	3.5
7	Maximize satisfaction: recreational lion chasing (non-harvest)	3.2	2.8	3.7	3.5	3.5	3.4	2.8	2.7	1.9	1.7
8	Maximize satisfaction: ungulate hunters	2.4	3.2	1.5	2.4	2.4	2.7	3.6	4.0	4.4	4.7
9	Maximize social acceptance of lion hunting	3.0	3.5	3.1	3.1	3.1	3.3	2.6	2.9	2.1	2.2

Trade-offs

After predicting consequences, the next step of the SDM process entails assessment of trade-offs. This requires evaluating alternatives based on the relative consequences each has on fundamental objectives. To facilitate these comparisons, scores can be normalized and weighted, as follows.

Normalized Scores

Scores from the consequence table were next normalized onto a 0-1 scale (0 = worst case outcome comparing across the alternatives for any given objective, and 1 = best case scenario for that objective). This provided easier comparisons of consequences across alternatives and objectives. (Table 5).

Table 5. Normalized Scores. Color shading refers to how well each alternative meets that objective (red = worst among alternatives for a particular objective, green = best among alternatives). Accordingly, a column with more green in it and minimal red indicates that alternative is expected to perform better at meeting objectives than a column with extensive red.

	Status Quo		+10%		No Change		-15%		-30%	
LEPOC Objectives	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B
Minimize excessive ungulate predation	0.36	0.57	0	0.14	0.39	0.39	0.75	0.89	0.93	1
Assist in offspring recruitment in struggling ungulate populations	0.38	0.62	0	0.14	0.34	0.45	0.83	0.93	0.9	1
Maintain healthy lion population as a natural part of the ecosystem	0.82	1	0.45	0.36	0.64	0.82	0.36	0.36	0	0.09
Minimize human − lion conflict (livestock/pet)	0.4	0.55	0	0.1	0.3	0.35	0.75	0.85	0.95	1
Maximize satisfaction: lion hunter opportunity	0.5	1	0	0.5	0.17	0.5	0.67	0.83	1	0.83
Maximize satisfaction: harvest of lions	0.38	0.31	0	0.23	0.23	0.15	0.69	0.62	1	0.85
Maximize satisfaction: recreational lion chasing (non−harvest)	0.71	0.52	0.95	1	0.86	0.81	0.52	0.48	0.1	0
Maximize satisfaction: ungulate hunters	0.28	0.53	0	0.09	0.28	0.38	0.66	0.78	0.91	1
Maximize social acceptance of lion hunting	0.64	1	0.71	0.57	0.71	0.86	0.36	0.57	0	0.07

Weighted Scores

Not all fundamental objectives may be equally important. Accordingly, after predicting the consequences of each alternative on the 9 fundamental objectives and reviewing the table of normalized scores, the committee was next asked to rank the 9 objectives in order of importance (1=most important, 9=least important). Participants also provided a 0-100 score for each objective to represent the relative importance of the objectives. For example, a participant may have felt that minimizing lion conflict with livestock and pets is the most important objective and given that objective a score of 100, while maximizing the social acceptance of lion hunting was the least important and given that objective a score of 50, meaning they felt it was exactly half as important. Through the weighting of ranked objectives, facilitators and committee members could better understand the relative importance of each objective to visualize the impacts and tradeoffs for the various alternatives. The fundamental objectives were weighted and ranked by the LEPOC to produce average ranks and scores (Table 6).

Table 6. LEPOC Fundamental Objective rankings, scores, and weights

Obj.	Fundamental Objective	*Average Rank*	*Final Rank*	*Average Score*	*Weight (% of Total)*
1	Minimize excessive ungulate predation	2.6	1	93.6	13.0%
2	Assist in offspring recruitment in struggling ungulate populations	3.2	3	90.7	12.6%
3	Maintain healthy lion population as a natural part of the ecosystem	3.0	2	89.9	12.5%
4	Minimize human - lion conflict (livestock/pet)	5.0	4	75.3	10.5%
5	Maximize satisfaction: lion hunter opportunity	5.9	7	79.8	11.1%
6	Maximize satisfaction: harvest of lions	6.0	8	77.6	10.8%
7	Maximize satisfaction: recreational lion chasing (non-harvest)	5.6	5	73.2	10.2%
8	Maximize satisfaction: ungulate hunters	5.6	5	79.3	11.0%
9	Maximize social acceptance of lion hunting	8.1	9	58.7	8.2%

To produce the final table to depict consequences and tradeoffs, the weights on objectives (Table 6) were multiplied by the normalized scores (from Table 5) and then summed to represent the overall amount of support for each alternative (Table 7).

Table 7. Weighted-Normalized Scores. The degree of green indicates which alternative best meets that objective and the degree of red shows which alternative does worst on meeting that objective. Final Scores provide a measure of overall performance for each alternative

	Status Quo		+10%		No Change		-15%		-30%	
LEPOC Objectives	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B	Alt. A	Alt. B
Minimize excessive ungulate predation	0.05	0.07	0.00	0.02	0.05	0.05	0.10	0.12	0.12	0.13
Assist in offspring recruitment in struggling ungulate populations	0.05	0.08	0.00	0.02	0.04	0.06	0.10	0.12	0.11	0.13
Maintain healthy lion population as a natural part of the ecosystem	0.10	0.13	0.06	0.05	0.08	0.10	0.05	0.05	0.00	0.01
Minimize human − lion conflict (livestock/pet)	0.04	0.06	0.00	0.01	0.03	0.04	0.08	0.09	0.10	0.10
Maximize satisfaction: lion hunter opportunity	0.06	0.11	0.00	0.06	0.02	0.06	0.07	0.09	0.11	0.09
Maximize satisfaction: harvest of lions	0.04	0.03	0.00	0.02	0.02	0.02	0.07	0.07	0.11	0.09
Maximize satisfaction: recreational lion chasing (non−harvest)	0.07	0.05	0.10	0.10	0.09	0.08	0.05	0.05	0.01	0.00
Maximize satisfaction: ungulate hunters	0.03	0.06	0.00	0.01	0.03	0.04	0.07	0.09	0.10	0.11
Maximize social acceptance of lion hunting	0.05	0.08	0.06	0.05	0.06	0.07	0.03	0.05	0.00	0.01
Final Score (sum of scores/sum of weights)	0.49	0.67	0.21	0.33	0.43	0.51	0.63	0.71	0.66	0.67

Decision simplification and trade-offs

The above table enabled the group to eliminate each "Alt A" option from further consideration, as each was outperformed by the "Alt B" variation. In other words, modeled scenarios with ungulate focal areas always outperformed those without. The group also removed Objective 2 from further consideration because it essentially duplicated Objective 1 (as visible in the above table) and consolidated the "Status Quo" alternative with the "Stable" alternative after concluding the alternatives had no significant difference in required harvest levels to achieve them. Continued discussion identified the need to clarify the intent of each objective, and the reduced consequence table also required the LEPOC to predict consequences for the reduced set and reweight the importance of each objective (Table 8).

Table 8 Reduced Weighted Scores

Obj.	Objectives	Weight (% of Total)	+10% Alt. B	Status Quo or Stable	-15% Alt. B	-30% Alt. B
1	Minimize excessive ungulate predation	15%	0.00	0.05	0.12	0.15
3	Maintain healthy lion population as a natural part of the ecosystem	13%	0.06	0.13	0.05	0.00
4	Minimize human - lion conflict (livestock/pet)	13%	0.00	0.04	0.11	0.13
5	Maximize satisfaction: lion hunter opportunity	13%	0.00	0.13	0.08	0.08
6	Maximize satisfaction: harvest of lions	14%	0.00	0.08	0.14	0.12
7	Maximize satisfaction: recreational lion chasing (non-harvest)	11%	0.11	0.11	0.03	0.00
8	Maximize satisfaction: ungulate hunters	13%	0.00	0.05	0.10	0.13
9	Maximize social acceptance of lion hunting	9%	0.09	0.09	0.06	0.00
	Final Score (sum of weighted scores/sum of weights)		0.26	0.67	0.69	0.60

Starting fresh on the morning of March 2, the conversation continued to determine how to proceed. The committee explored splitting views from ungulate hunters and mountain lion hunters/outfitters, which clarified the key differences among groups (Tables 9 & 10):

Table 9. Reduced Weighted Scores Lion Hunters and Outfitters

Obj.	Objectives	Weight (% of Total)	+10% Alt. B	Status Quo or Stable	-15% Alt. B	-30% Alt. B
1	Minimize excessive ungulate predation	14%	0.00	0.05	0.12	0.14
3	Maintain healthy lion population as a natural part of the ecosystem	15%	0.10	0.15	0.08	0.00
4	Minimize human - lion conflict (livestock/pet)	12%	0.00	0.02	0.09	0.12
5	Maximize satisfaction: lion hunter opportunity	14%	0.07	0.14	0.07	0.00
6	Maximize satisfaction: harvest of lions	13%	0.06	0.13	0.13	0.00
7	Maximize satisfaction: recreational lion chasing (non-harvest)	12%	0.12	0.12	0.00	0.00
8	Maximize satisfaction: ungulate hunters	11%	0.00	0.04	0.09	0.11
9	Maximize social acceptance of lion hunting	10%	0.10	0.10	0.09	0.00
	Final Score (sum of weighted scores/sum of weights)		0.45	0.75	0.66	0.37

Table 10. Reduced Weighted Scores Ungulate Hunters and Others

Obj.	Objectives	Weight (% of Total)	+10% Alt. B	Status Quo or Stable	-15% Alt. B	-30% Alt. B
1	Minimize excessive ungulate predation	16%	0.00	0.05	0.12	0.16
3	Maintain healthy lion population as a natural part of the ecosystem	11%	0.02	0.11	0.02	0.00
4	Minimize human - lion conflict (livestock/pet)	13%	0.00	0.04	0.12	0.13
5	Maximize satisfaction: lion hunter opportunity	11%	0.00	0.08	0.08	0.11
6	Maximize satisfaction: harvest of lions	15%	0.00	0.07	0.13	0.15
7	Maximize satisfaction: recreational lion chasing (non-harvest)	10%	0.10	0.10	0.06	0.00
8	Maximize satisfaction: ungulate hunters	14%	0.00	0.06	0.10	0.14
9	Maximize social acceptance of lion hunting	9%	0.09	0.07	0.03	0.00
	Final Score (sum of weighted scores/sum of weights)		0.20	0.57	0.66	0.70

The group was then able to eliminate +10% alternative as it was outperformed by the remaining alternatives under consideration. This also revealed minimal difference in the absolute predicted performance for Objective 5, leading to its removal from the consequence table to further simplify the decision (Table 11).

Table 11. Final Consequence Table

Obj.	Objectives	Weight (% of Total)	+10% Alt. B	Status Quo or Stable	-15% Alt. B
1	Minimize excessive ungulate predation	15%	0.00	0.10	0.15
3	Maintain healthy lion population as a natural part of the ecosystem	13%	0.13	0.05	0.00
4	Minimize human - lion conflict (livestock/pet)	13%	0.00	0.11	0.13
6	Maximize satisfaction: harvest of lions	14%	0.00	0.14	0.09
7	Maximize satisfaction: recreational lion chasing (non-harvest)	11%	0.11	0.03	0.00
8	Maximize satisfaction: ungulate hunters	13%	0.00	0.08	0.13
9	Maximize social acceptance of lion hunting	9%	0.09	0.06	0.00
	Final Score (sum of weighted scores/sum of weights)		0.33	0.57	0.49

The group then focused on the 15% decline option and investigated how to modify it for maximal satisfaction among the different perspectives in the LEPOC. Several participants voiced concerns regarding the allocation of the harvest across the ecoregion, noting that the 15% total population decline with disproportional harvest allocation among LMUs (due to implementation of an ungulate focal area) would result in greater than a 15% decrease in select portions of the ecoregion to meet the overall population objective. Additional discussion prompted consideration of a maximum 15% reduction in harvest in a significant portion of Region 1, though this would result in a total ecoregional population decrease of less than 15%. In contrast to this concern, other participants feared anything less than a 15% decline in the total lion population would fail to provide adequate relief for struggling ungulates or reduction in urban lion conflicts. These concerns prompted facilitators to take several polls to clarify participant desires for additional alternatives. Based on the results of the polls and further committee discussion, several modifications were presented for consideration. For participants concerned with accepting any alternative that is less than a 15% total population decrease, incorporating an additional ungulate focal area in the NW corner of the ecoregion was an acceptable compromise. Thus, the committee requested FWP model a new set of scenarios for consideration: 10% decrease with the currently proposed ungulate focal area, and 10% decrease with an expanded ungulate focal area to include the NW corner of the ecoregion (LMUS 100, 101, 103, 104).

During lunch break on March 2nd, FWP science team modelled the new scenarios and presented the results after the break. Facilitators asked committee members once more to predict consequences of the new alternatives on the fundamental objectives and updated the consequence table for use in the deliberations. Participants continued to advocate for their preferred alternative, voicing additional concerns. One committee member urged caution to avoid causing massive swings to the population and noted preference for small, incremental changes. Others continued to highlight worry for struggling ungulate populations, noting the importance of managing all carnivores. Yet another concern added to the discussion was the CWD prevalence around Libby and hesitation to further restrict lion harvest in that area to bolster big game populations there, given an effort was already underway to reduce deer density in the Libby CWD zone. The newly modelled ungulate focal area that now included the NW corner of the ecoregion also made several participants uncomfortable because lion harvest would be intensified in a much larger portion of Region 1.

Negotiations continued through the early afternoon as the group sought a modified alternative that would be acceptable to all parties. Further polls by facilitators led the group to a final set of alternatives to select from: 15% population decrease with the FWP proposed ungulate focal area (LMUs 121, 122, 123, and 124) or 10% population decrease with the FWP proposed ungulate focal area plus an additional focal area in LMU 100.

Work Group Final Recommendation

On the afternoon of March 4, after extensive deliberation, the LEPOC decided to split the difference between the final 2 alternatives under consideration (10% decrease and 15% decrease in the ecoregional lion population). The committee opted to recommend to the Fish and Wildlife Commission a 12.5% decrease in the NW Ecoregion lion population over the next 6 years with lion harvest disproportionately concentrated in ungulate focal areas in LMUs 100, 121,122,123,124, 200, 201, 202, and 203 (Figure 9).

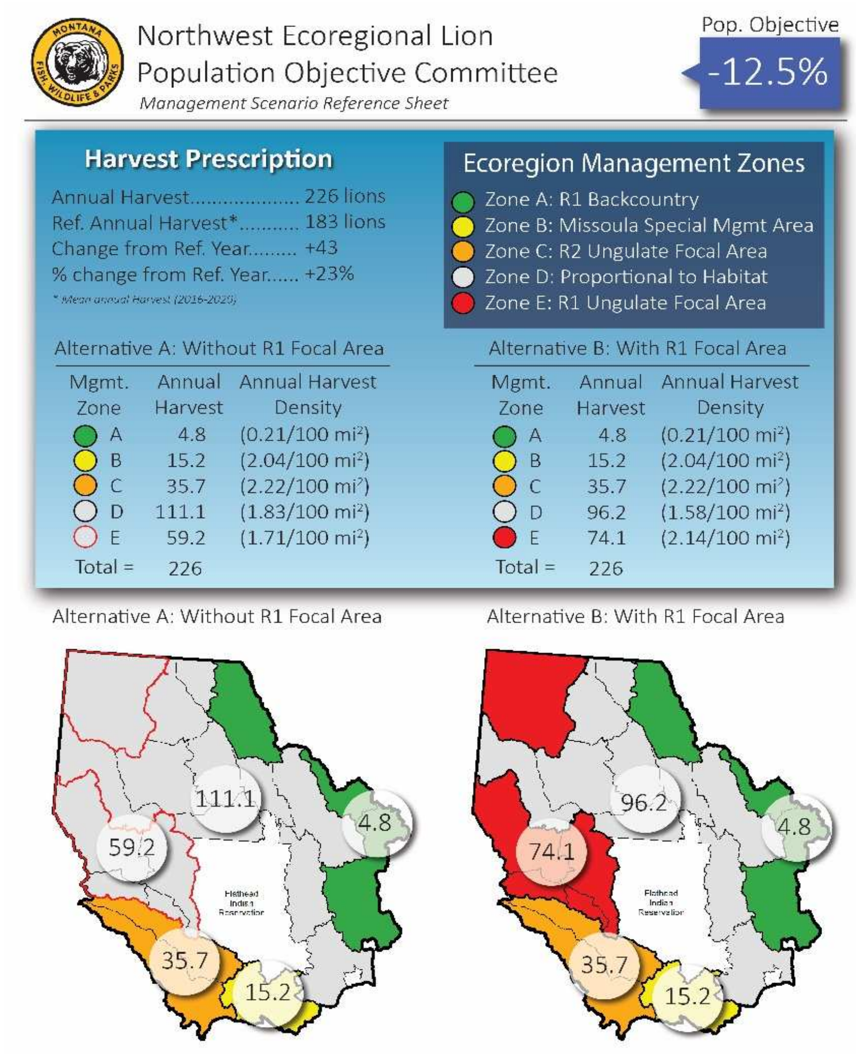

Figure 9. Northwest Lion Ecoregional Population Committee Informational Sheet illustrating LEPOC final recommendation. Maps show spatial alternatives where numbers within the circles indicate annual harvest prescription for the management (colored) zones for which they overlap.

Following the consensus decision on this recommendation and the end of the working group meetings, some LEPOC members expressed dissatisfaction that the ungulate focal area was added in LMU 100 in the Libby area. They felt that CWD concerns in ungulate populations in that area outweigh the desire for increased ungulate density there. FWP staff encouraged those committee members to make their concerns known during the Fish and Wildlife Commission decision making process prior to new regulations being finalized.

Further Recommendations

Throughout the 4 days of meetings, the LEPOC identified a variety of topics that they believed were important to share with the Fish and Wildlife Commission, despite falling outside of the scope of the committee's charge. These additional concerns and recommendations are as follows.

- Other predators, especially wolves, also need a predator management approach for the benefit of ungulates in this same area. Why sacrifice lions if ungulates will be killed by other predators? E.g., in areas of ungulate decline, we need broader wolf and bear harvest opportunity.
- Habitat concerns—as above, why sacrifice lions if ungulates can't be supported by habitat?
- There is uncertainty in the lion population estimate. This makes it difficult to precisely prescribe lion harvest rates.
- There are concerns that snaring of other predators impacts lions (FWP can pull together data, but there is a lot of uncertainty about the level of underreporting).
- Recreational lion hunting is an important livelihood and way of life.
- FWP should publicize the science and analysis work they did in support of the LEPOC to increase understanding of the LEPOC recommendation.
- During the legal harvest season, consider offering a license for problem lions rather than having someone go in and remove them.
- Consider mountain lion opportunity areas in specific areas (smaller than the LMU scale) where bighorn sheep populations (plus other ungulates, e.g., mule deer) are in decline/too low.

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Appendix A. LEPOC Informational Reference Sheets

Northwest Ecoregional Lion Population Objective Committee

Management Scenario Reference Sheet

Pop. Objective

5-yr avg.

Harvest Prescription

Annual Harvest.................... 183 lions
Ref. Annual Harvest*........... 183 lions
Change from Ref. Year......... 0
% change from Ref. Year...... 0%

** Mean annual Harvest (2016-2020)*

Ecoregion Management Zones

- Zone A: R1 Backcountry
- Zone B: Missoula Special Mgmt Area
- Zone C: R2 Ungulate Focal Area
- Zone D: Proportional to Habitat
- Zone E: R1 Ungulate Focal Area

Alternative A: Without R1 Focal Area

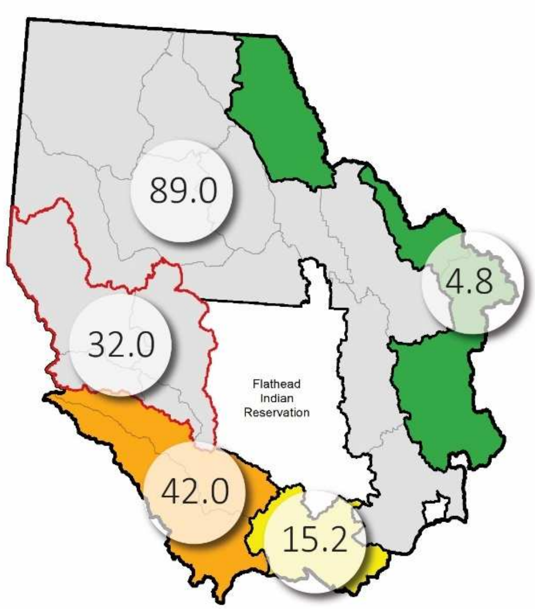
Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi²)
B	15.2	(2.04/100 mi²)
C	42.0	(2.61/100 mi²)
D	89.0	(1.18/100 mi²)
E	32.0	(1.55/100 mi²)
Total =	183	

Alternative B: With R1 Focal Area

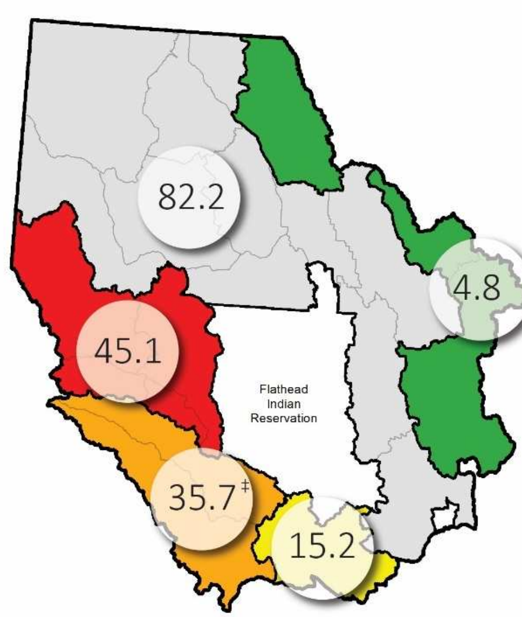
Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi²)
B	15.2	(2.04/100 mi²)
C ‡	35.7 ‡	(2.22/100 mi²)
D	82.2	(1.10/100 mi²)
E	45.1	(2.19/100 mi²)
Total =	183	

‡ -15% of 5-year mean

Alternative A: Without R1 Focal Area



Alternative B: With R1 Focal Area



Northwest Ecoregional Lion Population Objective Committee

Management Scenario Reference Sheet

Pop. Objective

+10%

Harvest Prescription

Annual Harvest.................... 137 lions
Ref. Annual Harvest*........... 183 lions
Change from Ref. Year......... -46
% change from Ref. Year...... -25%

** Mean annual Harvest (2016-2020)*

Ecoregion Management Zones

- Zone A: R1 Backcountry
- Zone B: Missoula Special Mgmt Area
- Zone C: R2 Ungulate Focal Area
- Zone D: Proportional to Habitat
- Zone E: R1 Ungulate Focal Area

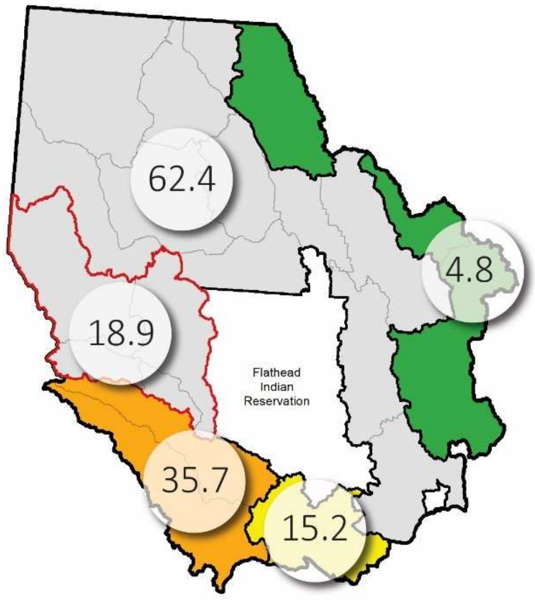
Alternative A: Without R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	62.4	(0.83/100 mi^2)
E	18.9	(0.92/100 mi^2)
Total =	137	

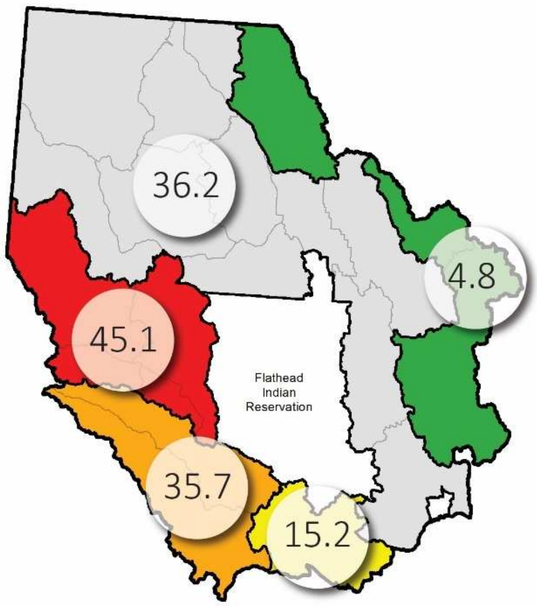
Alternative B: With R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	36.2	(0.48/100 mi^2)
E	45.1	(2.19/100 mi^2)
Total =	137	

Alternative A: Without R1 Focal Area



Alternative B: With R1 Focal Area



Northwest Ecoregional Lion Population Objective Committee

Management Scenario Reference Sheet

Pop. Objective

Stable

Harvest Prescription

Annual Harvest.................... 176 lions
Ref. Annual Harvest*........... 183 lions
Change from Ref. Year......... -7
% change from Ref. Year...... -4%

** Mean annual Harvest (2016-2020)*

Ecoregion Management Zones

- Zone A: R1 Backcountry
- Zone B: Missoula Special Mgmt Area
- Zone C: R2 Ungulate Focal Area
- Zone D: Proportional to Habitat
- Zone E: R1 Ungulate Focal Area

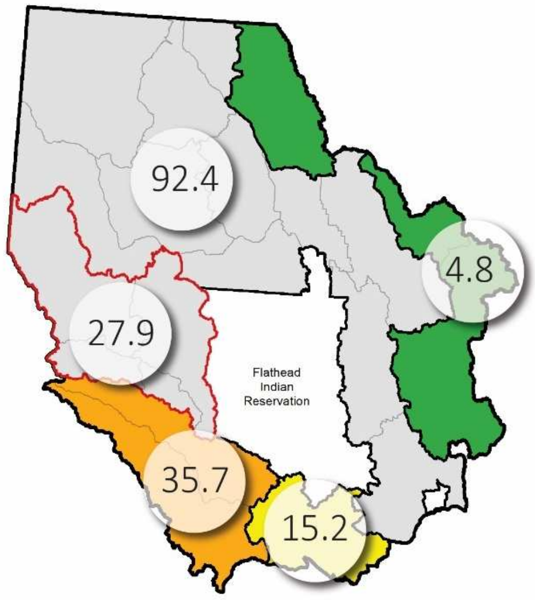
Alternative A: Without R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	92.4	(1.23/100 mi^2)
E	27.9	(1.35/100 mi^2)
Total =	176	

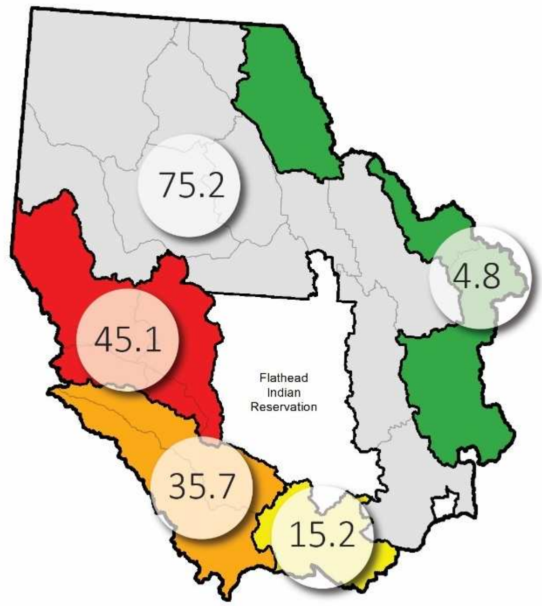
Alternative B: With R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	75.2	(1.00/100 mi^2)
E	45.1	(2.19/100 mi^2)
Total =	176	

Alternative A: Without R1 Focal Area



Alternative B: With R1 Focal Area



These reference sheets are examples only. This information is for workshop purposes only.

Northwest Ecoregional Lion Population Objective Committee

Management Scenario Reference Sheet

Pop. Objective

-15%

Harvest Prescription

Annual Harvest.................... 232 lions
Ref. Annual Harvest*........... 183 lions
Change from Ref. Year......... +49
% change from Ref. Year...... +27%

** Mean annual Harvest (2016-2020)*

Ecoregion Management Zones

- Zone A: R1 Backcountry
- Zone B: Missoula Special Mgmt Area
- Zone C: R2 Ungulate Focal Area
- Zone D: Proportional to Habitat
- Zone E: R1 Ungulate Focal Area

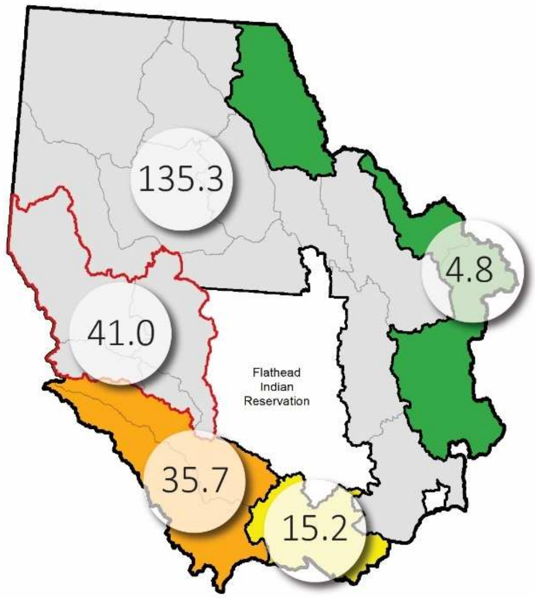
Alternative A: Without R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	135.3	(1.81/100 mi^2)
E	41.0	(1.98/100 mi^2)
Total =	232	

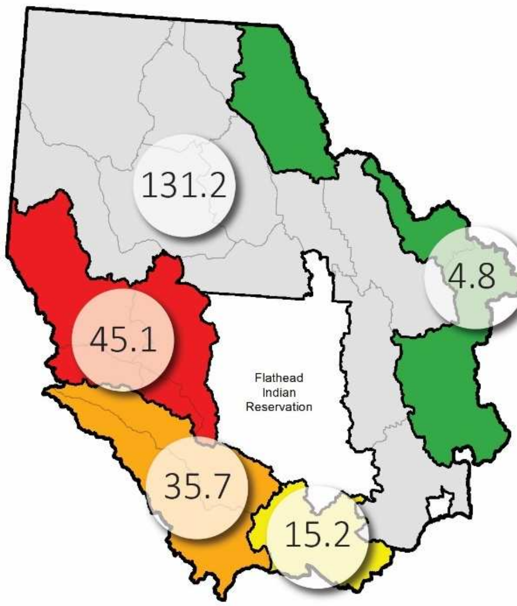
Alternative B: With R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	131.2	(1.75/100 mi^2)
E	45.1	(2.19/100 mi^2)
Total =	232	

Alternative A: Without R1 Focal Area



Alternative B: With R1 Focal Area



Northwest Ecoregional Lion Population Objective Committee

Management Scenario Reference Sheet

Pop. Objective

-30%

Harvest Prescription

Annual Harvest.................... 289 lions
Ref. Annual Harvest*........... 183 lions
Change from Ref. Year......... +106
% change from Ref. Year...... +58%

** Mean annual Harvest (2016-2020)*

Ecoregion Management Zones

- Zone A: R1 Backcountry
- Zone B: Missoula Special Mgmt Area
- Zone C: R2 Ungulate Focal Area
- Zone D: Proportional to Habitat
- Zone E: R1 Ungulate Focal Area

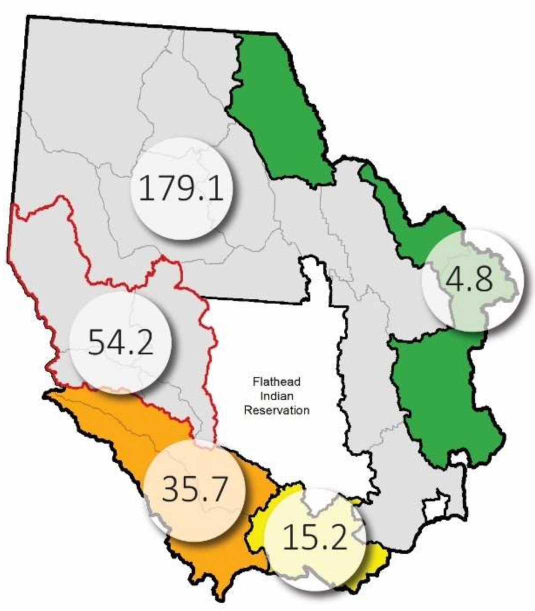
Alternative A: Without R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	179.1	(2.39/100 mi^2)
E	54.2	(2.63/100 mi^2)
Total =	289	

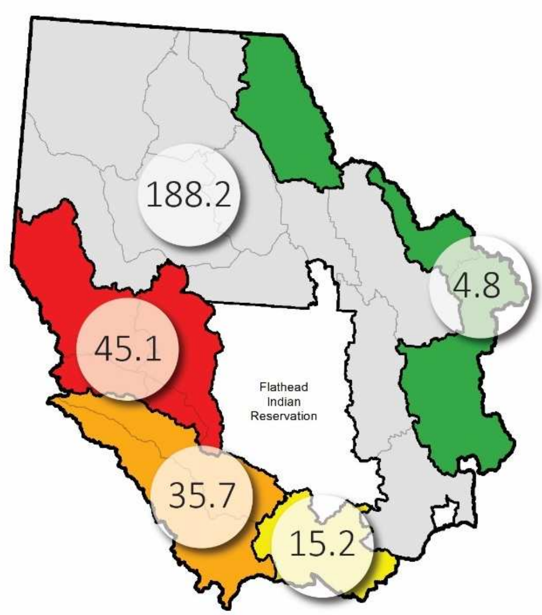
Alternative B: With R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	188.2	(2.51/100 mi^2)
E	45.1	(2.19/100 mi^2)
Total =	289	

Alternative A: Without R1 Focal Area



Alternative B: With R1 Focal Area



Northwest Ecoregional Lion Population Objective Committee

Management Scenario Reference Sheet

Pop. Objective

-12.5%

Harvest Prescription

Annual Harvest.................... 226 lions
Ref. Annual Harvest*........... 183 lions
Change from Ref. Year......... +43
% change from Ref. Year...... +23%

** Mean annual Harvest (2016-2020)*

Ecoregion Management Zones

- Zone A: R1 Backcountry
- Zone B: Missoula Special Mgmt Area
- Zone C: R2 Ungulate Focal Area
- Zone D: Proportional to Habitat
- Zone E: R1 Ungulate Focal Area

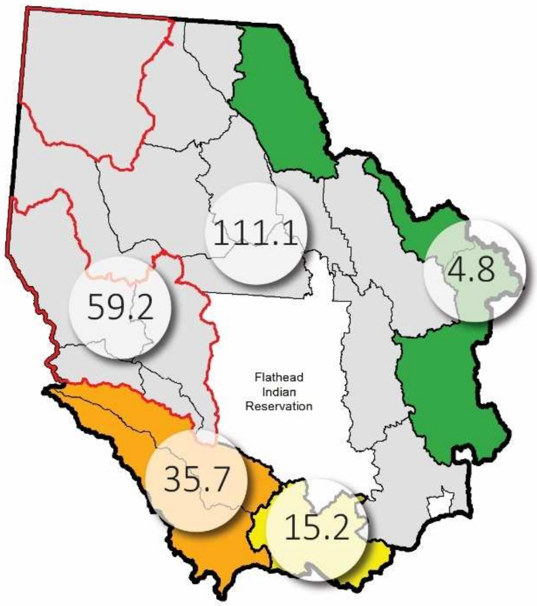
Alternative A: Without R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	111.1	(1.83/100 mi^2)
E	59.2	(1.71/100 mi^2)
Total =	226	

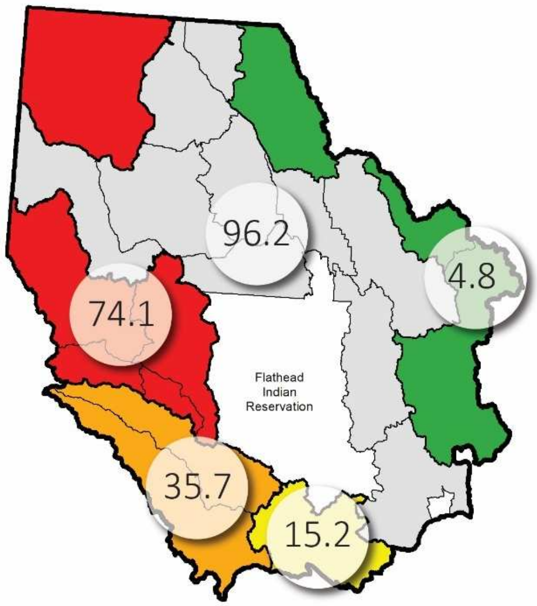
Alternative B: With R1 Focal Area

Mgmt. Zone	Annual Harvest	Annual Harvest Density
A	4.8	(0.21/100 mi^2)
B	15.2	(2.04/100 mi^2)
C	35.7	(2.22/100 mi^2)
D	96.2	(1.58/100 mi^2)
E	74.1	(2.14/100 mi^2)
Total =	226	

Alternative A: Without R1 Focal Area



Alternative B: With R1 Focal Area



Appendix B: IPM JAGS code

```
model{
  #  Naming
  #  Parameter names begin with a capitalized letter
  #  Data are all lower case
  #  Indexing always follows - DAU, Year, Age, Sex
  #  If fewer indices are needed they follow the same order despite
  #   omissions

  #  Priors
  #  Pregnancy rates - [age, sex, mean:tau]
  Preg[1] ~ dnorm(preg[3,1,1], preg[3,1,2])T(0,0.5)
  Preg[2] ~ dnorm(preg[4,1,1], preg[4,1,2])T(0,0.5)

  #  Fetus Counts - [age, sex, mean:tau]
  FC[1] ~ dnorm(fc[3,1,1], fc[3,1,2])T(0,3)
  FC[2] ~ dnorm(fc[4,1,1], fc[4,1,2])T(0,3)

  #  Survival
  #  Priors on survival - First age class, not available for harvest, so
  #   survival is the only parameter
  #  Informative prior stored as probability
  yS_mu ~ dnorm(means[1,1,1], means[1,1,2])T(0,1)

  #  Transform probability back to real scale and use as the intercept
  for(u in 1:ndau){
    for(yr in 1:nyr){
      for(s in 1:2){
        logit(S[u,yr, 1, s]) <- log(yS_mu/(1 - yS_mu))
        H[u,yr,1,s] <- 0
        O[u,yr,1,s] <- 0
      }
    }
  }


  #############################################
  #  Priors on survival - Juveniles - two sexes, cause specific mortality
  for(s in 1:2){
    #  Informative priors are stored as probabilities
    jS_tmp[1,s] ~ dnorm(means[2,s,1], means[2,s,2])T(0, 1)
    jS_tmp[2,s] ~ dnorm(meanh[2,s,1], meanh[2,s,2])T(0, 1)
    jS_tmp[3,s] ~ dnorm(meano[2,s,1], meano[2,s,2])T(0, 1)

    #  Transform probability to real scale
    for(i in 1:3){
      jS_mu[i,s] <- log(jS_tmp[i,s]/jS_tmp[3,s])
    }

    tauj[s] ~ dunif(0, 20)


    #  Describe rate as function of linear predictor and define link
    #   function
    for(u in 1:ndau){
      for(yr in 1:17){
        j_yr[yr,s] ~ dnorm(0, tauj[s])
        log(jS_log[u,yr,s]) <- jS_mu[1,s] + j_yr[yr,s]
        log(jH_log[u,yr,s]) <- jS_mu[2,s]
```

```
        log(jO_log[u,yr,s]) <- 0
        jSums[u,yr,s] <- jS_log[u,yr,s] + jH_log[u,yr,s] + jO_log[u,yr,s]
        S[u,yr,2,s] <- jS_log[u,yr,s]/jSums[u,yr,s]
        H[u,yr,2,s] <- jH_log[u,yr,s]/jSums[u,yr,s]
        O[u,yr,2,s] <- jO_log[u,yr,s]/jSums[u,yr,s]
      }
    }
  }


  #  Forecast period only: Priors on survival - Juveniles - two sexes, cause specific
mortality

  for(s in 1:2){
    #  Informative priors are stored as probabilities
    jS_tmp2[1,s] ~ dnorm(means[2,s,1], means[2,s,2])T(0, 1)
    jS_tmp2[2,s] ~ dnorm(meanh[2,s,1], meanh[2,s,2])T(0, 1)
    jS_tmp2[3,s] ~ dnorm(meano[2,s,1], meano[2,s,2])T(0, 1)

    #  Transform probability to real scale
    for(i in 1:3){
      jS_mu2[i,s] <- log(jS_tmp2[i,s]/jS_tmp2[3,s])
    }


  #  Describe rate as function of linear predictor and define link
    #   function
    for(u in 1:ndau){
      for(yr in 18:nyr){
          log(jS_log2[u,yr,s]) <- jS_mu2[1,s]
          log(jH_log2[u,yr,s]) <- log((harv[u,yr,2,s]/ (N[u,yr,2,s]+2)) /
(jS_tmp2[3,s] + .001)) # add 2 and .001 because division by 0 will crash simulation
          log(jO_log2[u,yr,s]) <- 0
          jSums2[u,yr,s] <- jS_log2[u,yr,s] + jH_log2[u,yr,s] + jO_log2[u,yr,s]
          S[u,yr,2,s] <- jS_log2[u,yr,s]/jSums2[u,yr,s]
          H[u,yr,2,s] <- jH_log2[u,yr,s]/jSums2[u,yr,s]
          O[u,yr,2,s] <- jO_log2[u,yr,s]/jSums2[u,yr,s]
      }
    }
  }


  ###########################################

  ###############################################
  #  Priors on survival - SubAdults - two sexes, cause specific mortality
  for(s in 1:2){
    #  Informative priors are stored as probabilities
    sS_tmp[1,s] ~ dnorm(means[3,s,1], means[3,s,2])T(0, 1)
    sS_tmp[2,s] ~ dnorm(meanh[3,s,1], meanh[3,s,2])T(0, 1)
    sS_tmp[3,s] ~ dnorm(meano[3,s,1], meano[3,s,2])T(0, 1)

    #  Transform probability to real scale
    for(i in 1:3){
      sS_mu[i,s] <- log(sS_tmp[i,s]/sS_tmp[3,s])
    }

   taus[s] ~ dunif(0, 20)

    #  Describe rate as function of linear predictor and define link
    #   function
    for(u in 1:ndau){
      for(yr in 1:17){
```

```
        s_yr[yr,s] ~ dnorm(0, taus[s])
        log(sS_log[u,yr,s]) <- sS_mu[1,s] + s_yr[yr,s]
        log(sH_log[u,yr,s]) <- sS_mu[2,s]
        log(sO_log[u,yr,s]) <- 0
        sSums[u,yr,s] <- sS_log[u,yr,s] + sH_log[u,yr,s] + sO_log[u,yr,s]
        S[u,yr,3,s] <- sS_log[u,yr,s]/sSums[u,yr,s]
        H[u,yr,3,s] <- sH_log[u,yr,s]/sSums[u,yr,s]
        O[u,yr,3,s] <- sO_log[u,yr,s]/sSums[u,yr,s]
      }
    }
  }


  #  Forecast period only: Priors on survival - subAdults, two sexes, cause specific
mortality
  for(s in 1:2){
    #  Informative priors are stored as probabilities
    sS_tmp2[1,s] ~ dnorm(means[3,s,1], means[3,s,2])T(0, 1)
    sS_tmp2[2,s] ~ dnorm(meanh[3,s,1], meanh[3,s,2])T(0, 1)
    sS_tmp2[3,s] ~ dnorm(meano[3,s,1], meano[3,s,2])T(0, 1)

    #  Transform probability to real scale
    for(i in 1:3){
      sS_mu2[i,s] <- log(sS_tmp2[i,s]/sS_tmp2[3,s])
    }

    #  Describe rate as function of linear predictor and define link
    #   function
    for(u in 1:ndau){
      for(yr in 18:nyr){
        log(sS_log2[u,yr,s]) <- sS_mu2[1,s]
        log(sH_log2[u,yr,s]) <- log((harv[u,yr,3,s]/ (N[u,yr,3,s]+2))/ (sS_tmp2[3,s] +
.001)) # add 2 and .001 because division by 0 will crash simulation
        log(sO_log2[u,yr,s]) <- 0
        sSums2[u,yr,s] <- sS_log2[u,yr,s] + sH_log2[u,yr,s] + sO_log2[u,yr,s]
        S[u,yr,3,s] <- sS_log2[u,yr,s]/sSums2[u,yr,s]
        H[u,yr,3,s] <- sH_log2[u,yr,s]/sSums2[u,yr,s]
        O[u,yr,3,s] <- sO_log2[u,yr,s]/sSums2[u,yr,s]
      }
    }
  }
  ########################################################

  #########################################################
  #  Priors on survival - Adults, two sexes, cause specific mortality
  for(s in 1:2){
    #  Informative priors are stored as probabilities
    aS_tmp[1,s] ~ dnorm(means[4,s,1], means[4,s,2])T(0, 1)
    aS_tmp[2,s] ~ dnorm(meanh[4,s,1], meanh[4,s,2])T(0, 1)
    aS_tmp[3,s] ~ dnorm(meano[4,s,1], meano[4,s,2])T(0, 1)

    #  Transform probability to real scale
    for(i in 1:3){
      aS_mu[i,s] <- log(aS_tmp[i,s]/aS_tmp[3,s])
    }

    taua[s] ~ dunif(0, 20)

    #  Describe rate as function of linear predictor and define link
    #   function
    for(u in 1:ndau){
      for(yr in 1:17){
        a_yr[yr,s] ~ dnorm(0, taua[s])
```

```
        log(aS_log[u,yr,s]) <- aS_mu[1,s] + a_yr[yr,s]
        log(aH_log[u,yr,s]) <- aS_mu[2,s]
        log(aO_log[u,yr,s]) <- 0
        aSums[u,yr,s] <- aS_log[u,yr,s] + aH_log[u,yr,s] + aO_log[u,yr,s]
        S[u,yr,4,s] <- aS_log[u,yr,s]/aSums[u,yr,s]
        H[u,yr,4,s] <- aH_log[u,yr,s]/aSums[u,yr,s]
        O[u,yr,4,s] <- aO_log[u,yr,s]/aSums[u,yr,s]
      }
    }
  }


   # Forecast period only: Priors on survival - Adults, two sexes, cause specific
mortality
  for(s in 1:2){
    #  Informative priors are stored as probabilities
    aS_tmp2[1,s] ~ dnorm(means[4,s,1], means[4,s,2])T(0, 1)
    aS_tmp2[2,s] ~ dnorm(meanh[4,s,1], meanh[4,s,2])T(0, 1)
    aS_tmp2[3,s] ~ dnorm(meano[4,s,1], meano[4,s,2])T(0, 1)

    #  Transform probability to real scale
    for(i in 1:3){
      aS_mu2[i,s] <- log(aS_tmp2[i,s]/aS_tmp2[3,s])
    }

    #  Describe rate as function of linear predictor and define link
    #   function
    for(u in 1:ndau){
      for(yr in 18:nyr){
        log(aS_log2[u,yr,s]) <- aS_mu2[1,s]
        log(aH_log2[u,yr,s]) <- log((harv[u,yr,4,s]/ (N[u,yr,4,s]+2)) / (aS_tmp2[3,s]
+ .001)) # add 2 and .001 because division by 0 will crash simulation
        log(aO_log2[u,yr,s]) <- 0
        aSums2[u,yr,s] <- aS_log2[u,yr,s] + aH_log2[u,yr,s] + aO_log2[u,yr,s]
        S[u,yr,4,s] <- aS_log2[u,yr,s]/aSums2[u,yr,s]
        H[u,yr,4,s] <- aH_log2[u,yr,s]/aSums2[u,yr,s]
        O[u,yr,4,s] <- aO_log2[u,yr,s]/aSums2[u,yr,s]
      }
    }
  }

  ############################################################

  ###  Prior on first year population size
  #  Indexing - Year, Age, Sex
  for(u in 1:ndau){
    N[u,1,1,1] ~ dnorm(n1[1,2], 1/n1[1,2])T(0,) #
    N[u,1,1,2] <- N[u,1,1,1] # DJM: males = females

    for(a in 2:nage){
      for(s in 1:2){
        N[u,1,a,s] ~ dnorm(n1[a,s+1], 1/n1[a,s+1])T(0,) #
      }
    }

    yN[u,1] <- N[u,1,1,1] + N[u,1,1,2]
    fN[u,1] <- N[u,1,2,1] + N[u,1,3,1] + N[u,1,4,1]
    mN[u,1] <- N[u,1,2,2] + N[u,1,3,2] + N[u,1,4,2]
    totN[u,1] <- yN[u,1] + fN[u,1] + mN[u,1]
  }

  ###  Process model - 4 ages, 2 sex
  #  Using normal approximation because it is fast and mixes well
```

```
  #  Sex = 1 is a female
  #  Indexing follows - DAU, Year, Age, Sex
  for(u in 1:ndau){
    for(yr in 2:nyr){
      #  Kittens
      #  Normal approximation of Poisson
      nMu[u,yr,1,1] <-
        ((N[u,yr,3,1] * 0.5 * FC[1] * Preg[1]) +
           (N[u,yr,4,1] * 0.5 * FC[2] * Preg[2])) *
        S[u,yr-1,1,1]
      nMu[u,yr,1,2] <- nMu[u,yr,1,1]

      N[u,yr,1,1] ~ dnorm(nMu[u,yr,1,1], 1/(nMu[u,yr,1,1]))
      N[u,yr,1,2] <- N[u,yr,1,1]

      for(s in 1:2){
        #  Juveniles
        #  Normal approximation of Binomial
        nMu[u,yr,2,s] <-
          (1 - O[u,yr-1,2,s]) * (N[u,yr-1,1,s] + 2 - min(harv[u,yr-1,2,s], N[u,yr-
1,1,s])) # min() ensures harvest < N

        nTau[u,yr,2,s] <- 1/((N[u,yr-1,1,1] + 2 - min(harv[u,yr-1,2,s], N[u,yr-
1,1,s])) *
                              (O[u,yr-1,2,s]) * (1 - O[u,yr-1,2,s]))

        N[u,yr,2,s] ~ dnorm(nMu[u,yr,2,s], nTau[u,yr,2,s])

        #  SubAdults
        #  Normal approximation of Binomial
        nMu[u,yr,3,s] <-
          (1 - O[u,yr-1,3,s]) * (N[u,yr-1,2,s] + 2 - min(harv[u,yr-1,3,s], N[u,yr-
1,2,s])) # min() ensures harvest < N

        nTau[u,yr,3,s] <- 1/((N[u,yr-1,2,s] + 2 - min(harv[u,yr-1,3,s], N[u,yr-
1,2,s])) *
                              (O[u,yr-1,3,s]) * (1 - O[u,yr-1,3,s]))

        N[u,yr,3,s] ~ dnorm(nMu[u,yr,3,s], nTau[u,yr,3,s])


        #  Adults
        #  Normal approximation of Binomial
        #  Female Other Mortality shared between the sexes
        nMu[u,yr,4,s] <-

          (N[u,yr-1,3,s] + N[u,yr-1,4,s] + 2 - min(harv[u,yr-1,4,s], N[u,yr-1,4,s])) *
# min() ensures harvest < N
          (1 - O[u,yr-1,4,s])

        nTau[u,yr,4,s] <-
          1/((N[u,yr-1,3,s] + N[u,yr-1,4,s] + 2 - min(harv[u,yr-1,4,s], N[u,yr-
1,4,s])) *
               (O[u,yr-1,4,s]) * (1 - O[u,yr-1,4,s]))


        N[u,yr,4,s] ~ dnorm(nMu[u,yr,4,s], nTau[u,yr,4,s])

      }

      #  Totals in each year
      yN[u,yr] <- N[u,yr,1,1] + N[u,yr,1,2]
      fN[u,yr] <- N[u,yr,2,1] + N[u,yr,3,1] + N[u,yr,4,1]
```

```
      mN[u,yr] <- N[u,yr,2,2] + N[u,yr,3,2] + N[u,yr,4,2]
      totN[u,yr] <- yN[u,yr] + fN[u,yr] + mN[u,yr]
      indN[u,yr] <- fN[u,yr] + mN[u,yr] # independent aged lions only
    }
  }

  ####################  Observation Models
  #  Indexing/columns always follows
  #    1   2     3    4    5    6
  #  DAU, Year, Age, Sex, Mean, Tau

 #  Abundance Observation - [dau, yr] - (DJM: this is where SECR estimates go) - this
can be commented out to ignore

  # for(i in 1:nyr){ # DJM: changed 'nn' to 'nyr'
  #   ndat[i,5] ~ dnorm(totN[1,ndat[i,2]], ndat[i,6])T(0,) #DJM: [i,5] = Mean,
[i,2]=Year, [i,6]=Tau
  # }

  # can't loop above b/c NA years - give individual values for each period with an
ecoregion estimate: e.g., 18=Year, 5=pop est Mean,
  # indN indexing is [DAU, Year], indN = totN - yN i.e., no kittens
  ndat[18,5] ~ dnorm(indN[1,18], ndat[18,6])T(0,)

  #  OBSERVED: Harvest Observations - [dau,yr,a,s]
  for(u in 1:ndau){
    for(yr in 1:17){  #note constricted range (leaves out license year 2021 which is
not complete as of 2022-01-31)
      for(a in 1:nage){
        for(s in 1:2){
          harv[u,yr,a,s] ~ dbinom(H[u,yr,a,s], round(N[u,yr,a,s]))
        }
      }
    }
  }


    #  Survival Observations - (DJM: not applicable)
  # for(i in 1:ns){
  #   sdat[i,5] ~ dnorm(S[1, sdat[i,2], sdat[i,3], sdat[i,4]], sdat[i,6])T(0, 1)
  # }
  # #  Harvest Mortality Rate Observations
  # for(i in 1:nhm){
  #   hmdat[i,5] ~ dnorm(H[1, hmdat[i,2], hmdat[i,3], hmdat[i,4]], hmdat[i,6])T(0, 1)
  # }
  # #  Other (Non-Harvest) Mortality Rate Observations
  # for(i in 1:nom){
  #   omdat[i,5] ~ dnorm(O[1, omdat[i,2], omdat[i,3], omdat[i,4]], omdat[i,6])T(0, 1)
  # }

  #  Derived - the constant is added to avoid division by 0
  for(u in 1:ndau){
    for(yr in 1:nyr){
      mf[u,yr] <- (mN[u,yr] + 0.001)/(fN[u,yr] + 0.001)
    }
  }

  #  Incomplete vectors cannot be monitored, so aribitrary value is given
  #  to the first year
  #  Same constant trick is used here for the division
  #  Using the log and exp handles 0 gracefully, recall that
  #  log(x) + log(y) = log(xy), so the geometric mean is calculated using
  #  an algebraic rearrangment that is more robust to 0's
```

```
  for(u in 1:ndau){
    lambda[u,1] <- 1
    for(yr in 2:nyr){
      lambda[u,yr] <- (totN[u,yr] + 0.001)/(totN[u,yr-1] + 0.001)
      logla[u,yr] <- log(lambda[u,yr])
    }
    geoLambda[u] <- exp((1/(nyr-1))*sum(logla[u,2:(nyr)]))
  }
}
```