Monitoring Design for Fender's Blue Butterfly[1]

A Case Study from the Structured Decision Making Workshop
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Authors: Mikki Collins[2], Michael C. Runge[3], Kurt Rinehart[4], Elizabeth E. Crone[5], Jeff Dillon[1], Greg Fitzpatrick[6], Tyler Hicks[7], Wes Messinger[8], Cheryl B. Schultz[6], Donna C. Brewer[9].

Decision Problem

The USFWS Oregon Fish and Wildlife Office, in collaboration with its management partners, must decide on an affordable, effective monitoring design for the Fender's blue butterfly (FBB) that specifies measurable attributes to be estimated, the level of precision required from the resulting analysis, what data are needed, and how the data are to be collected. The design of the monitoring program needs to stem from the decision contexts in which the information will be used. There are a number of decision contexts in which monitoring information might be used; we focus on two primary settings: 1) evaluation of the status of FBB under the Endangered Species Act (ESA), with possible consideration of reclassification; and 2) evaluation and adaptive guidance of habitat management. The intent is to develop a standardized, systematic, rangewide, long-term monitoring program to evaluate decisions in these contexts.

Status review under the ESA is implicitly tied to a classification decision; species status can influence how scarce recovery resources are allocated between various recovery objectives. The current recovery plan includes quantitative recovery criteria using FBB abundance thresholds and trends as proxies for species persistence. Given the costs and variability associated with current monitoring, however, it is not clear if the monitoring is appropriately designed to effectively assess status.

Several land management agencies and organizations provide site-level habitat management in support of FBB recovery, and face difficult decisions in the face of uncertainty about which practices best promote recovery. Suitable data on FBB abundance relative to site-level habitat management may aid in discerning more effective treatments from among the available options.

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[2] USFWS Oregon Fish and Wildlife Office, Portland, OR, USA, Mikki_Collins@fws.gov
[3] USGS Patuxent Wildlife Research Center, Laurel, MD, USA
[4] University of Vermont, Burlington, VT, USA
[5] Harvard University, Harvard Forest, Petersham, MA, USA
[6] Fitzpatrick Ecological Consulting, LLC, Corvallis, OR, USA
[7] Washington State University, Vancouver, WA, USA
[8] US Army Corps of Engineers, Portland District, Portland, OR, USA
[9] USFWS National Conservation Training Center, Shepherdstown, WV, USA

Background

Legal, regulatory, and political context

Fender's blue butterfly (*Icaricia icarioides fenderi*) was listed as endangered under the ESA in 2000 because of threats from habitat loss, scrub and tree encroachment in native prairies, invasion by non-native plants, and loss of disturbance regimes (USFWS 2000). Critical habitat was designated in 2006 in Benton, Lane, Polk, and Yamhill Counties, Oregon (USFWS 2006).

The U.S. Fish and Wildlife Service (Service) has regulatory responsibility under the ESA for actions such as, determining status, leading recovery planning, and consulting with Federal agencies on actions that might affect the subspecies. In addition, several populations of FBB are found on Service lands (Baskett Slough National Wildlife Refuge), so the Service also has a management responsibility. Fender's blue butterfly populations are also found on other Federal land (U.S. Army Corps of Engineers [ACOE], Bureau of Land Management [BLM]), State land (Oregon State University), land managed by non-government organizations (The Nature Conservancy), and private land. Thus, management responsibility is shared by a number of entities.

Recovery criteria for Fender's blue butterfly. The Recovery Team set recovery targets for the Fender's blue butterfly in terms of "functioning networks" and independent populations (Table 1; USFWS 2010). A functioning network is a meta-population that consists of several potentially interacting subpopulations of Fender's blue butterfly distributed across a landscape. A functioning network must be composed of three or more subpopulations, each occupying habitat of at least the minimum patch size (currently defined as 6 hectares [15 acres]) and separated by no more than the maximum separation distance (currently defined as approximately 2 kilometers [1.2 miles]) from the next nearest subpopulation or connected by stepping-stone patches of lupine less than 1 kilometer (0.6 mile) apart. An independent population is an isolated population that meets certain minimum size and habitat quality criteria, and which would be likely to persist in the long-term. An independent population must be at least the minimum patch size (currently defined as 6 hectares [15 acres]).

Populations must be distributed across the historical range of the species. Three recovery zones have been delineated for Fender's blue butterfly that encompass the historical range: Salem (combines the Salem East and Salem West recovery zones), Corvallis (combines the Corvallis East and Corvallis West recovery zones), and Eugene (combines the Eugene East and Eugene West recovery zones).

To downlist Fender's blue butterfly to threatened, the Recovery Team set an extinction risk threshold of 90 percent probability of persistence for 25 years. To achieve this standard, each recovery zone must have two functioning networks or one functioning network and two independent populations (Table 1). One functioning network in each recovery zone must meet a minimum population criterion (a count of 200 adult butterflies) each year for at least 10 years; the 200 butterflies should be distributed among the subpopulation sites in the network. Two functioning networks or one functioning network and two independent populations in each zone must be protected and managed for high quality prairie habitat.

To delist Fender's blue butterfly, the Recovery Team set an extinction risk threshold of 95 percent probability of persistence for 100 years, believing this is consistent with the standard for recovery (i.e., to reduce the degree of risk to the species to the point that it is no longer in danger of extinction, or likely to become so, throughout all or a significant portion of its range, and it is likely to remain at this low degree of risk into the foreseeable future). This standard may be achieved with a variety of combinations of networks and independent populations in each recovery zone (Table 1), that enhance the security and distribution of Fender's blue butterfly populations across the landscape.

To evaluate progress toward recovery and to allow status assessment under the ESA, the Service perceives the need for a consistent, rangewide monitoring program. Land management agencies have also called for development of a consistent monitoring program to evaluate their contribution toward recovery and to facilitate improved outcomes over time through adaptive management.

Ecological context

Fender's blue butterfly is endemic to the Willamette Valley (Valley) in western Oregon. Today, we know of 17 populations encompassing many "sites" with a survey history on native prairie remnants that total approximately 185 ha in size (USFWS 2010). Many of these populations are small and isolated, occurring only in areas containing the larval host plants, primarily the federally threatened Kincaid's lupine (*Lupinus sulphureus kincaidii = Lupinus oreganus* (Heller)) and longspur lupine (*Lupinus arbustus = L. laxiflorus*), and occasionally sickle-keeled lupine (*L. albicaulis*). Censuses from 1993 to present indicate that the Valley-wide totals fluctuate between 2000 and 6000 individuals (USFWS 2010). Fender's blue butterflies depend on the availability of host plants and native nectar plants, both of which are negatively affected by the encroachment of woody plants and tall exotic grasses. To maintain suitable prairie habitat, management efforts focus on removal of non-native species and encroaching woody species, prescribed burning, mowing, and *de novo* habitat restoration. Aggressive management practices such as burning often result in long-term benefits to populations at the expense of short-term species impacts. Continuing management will be critical for the protection and recovery of Fender's blue butterfly.

Several key aspects of the biology and current distribution of Fender's blue butterfly are important for developing a monitoring program.

- Butterfly flights seasons are often short (several weeks) and generally include a short initial tail, a steep peak in abundance, followed by a long right tail. The Fender's blue flight season is generally 6-8 weeks long, with high unpredictability about when the season will start and the number of weeks over which adults will be flying (ranging from 5-10 weeks).
- Fender's blue is distributed over a number of sites and ownerships. There has been considerable discussion in past venues about what constitutes a patch, a site or a population. For purposes of this discussion, each area with a monitoring history is considered a "site." Monitoring for this decision context includes all sites which are under public ownership or private lands managed for conservation. This includes 44 sites.

- Fender's blue adults require warm sunny days, without wind, to feed and reproduce. The Fender's blue flight season occurs in the spring, when annual precipitation is highly variable and therefore, unpredictable. It is believed that there are two types of "wet years" that make abundance monitoring challenging. The first type of wet year is when there is continuous rain that truly negatively affects Fender's blue abundance. The second type of wet year is when there are "sun bursts" between rain showers which are difficult to predict and therefore, do not provide adequate opportunity to assess Fender's abundance given the limited survey time and the number of sites across the species range. Fender's blue site-level egg counts have confirmed that in some of the "wet years" when adult abundance estimates were low, egg counts were seemingly unaffected.
- The Silvery blue butterfly (*Glaucopsyche lygdamus columbia*) is a common butterfly that is virtually indistinguishable from Fender's blue and has an overlapping flight season. This requires well trained surveyors that can capture individual butterflies to accurately assess Fender's blue abundance.

Decision Structure

The focus of the decision analysis is on design of a standardized, rangewide monitoring program for Fender's blue butterflies that will serve several management needs. This is a multiple-objective trade-off problem, as no one monitoring design can achieve all the desired objectives. The analysis here focuses directly on the trade-offs in the monitoring design; it does not focus on structuring the management decisions in which the monitoring data will be used.

Objectives

Five fundamental objectives guide the decision regarding monitoring design for Fender's blue butterflies. These include 1) maximizing the power to determine if the current probability of persistence is above a given threshold, 2) maximizing the power to evaluate effects of habitat management at the site level, 3) minimizing program cost, 4) minimizing the time investment, and 5) minimizing the impact of monitoring on butterflies and habitat. These objectives are discussed below. In addition, several additional objectives were discussed and it was determined these were either nested within the five overarching objectives or less important to the decision context. These included simplifying training, minimizing turnover of observers, minimizing health risk due to poison oak, maintaining a positive public perception of the monitoring program, and minimizing the impact on inference of unpredictable weather during the Fender's blue butterfly spring field season.

<u>Objective 1.</u> Maximize the power to determine if the current probability of persistence is above a given threshold. This objective derives from the ESA status assessment context. If a monitoring program has high power to discern when the population status has improved above the threshold defined in the recovery plan, then reclassification (to threatened, or indeed, delisting) can occur more quickly. Recovery is defined ultimately in terms of probability of persistence, but the minimum adult population size serves as a proxy measure (USFWS 2010). *Measurable attributes:* the probabilities of failing to detect that the population size at a site is greater than 200 when in fact it is (a) 250 and (b) 500. Note that we want to minimize these measurable attributes.

Objective 2. Maximize the power to evaluate the effects of habitat management at the site level. This objective derives from the habitat management context. Land managers would like to be able to determine if their habitat management is contributing to FBB recovery, and would like to be able to compare alternative management regimes. If the monitoring program has high power to compare management regimes, then managers can respond more quickly and more effectively to new information and adaptively pursue the better strategies. *Measurable attribute:* the coefficient of variation of the metric at the network level. Again, note that we want to minimize this attribute.

Objective 3. Minimize the cost of the monitoring program. The monitoring program cost includes costs of monitoring (including staff time and transportation costs), training, and analysis. *Measurable attribute:* dollars per year.

Objective 4. Minimize the time investment. The time required to undertake the monitoring program, which in part reflects the staff necessary, includes monitoring time, travel time, and stand-by time. *Measurable attribute:* person-hours per year.

Objective 5. Minimize the impact of monitoring on butterflies and their habitat. Observers spending time in FBB habitat can inadvertently trample butterfly eggs or young, possibly reducing the survival rate, or can trample host and nectar plants, reducing the habitat available for breeding and feeding. The primary concern is damage to lupine plants, which are the obligate hosts for eggs. Different monitoring methods require different amounts of time in FBB habitat; in particular, egg counts require an extensive amount of time directly in lupine patches. *Measurable attribute:* square meters of trampled lupine across the Valley per year.

Alternative monitoring designs

Alternative monitoring designs need to consider the following design elements: methods of assessing abundance and associated assumptions, frequency of monitoring, weather conditions in which monitoring occurs, number of sites monitored, stratification of sites monitored, and number of observers. Four methods of assessing abundance were considered viable, three using adult numbers to estimate an index of abundance and one using egg numbers to estimate an index of abundance. In addition, several other metrics were discussed. The group decided the other metrics were not viable options due to lack of replicability, cost, or impact on habitat and butterflies.

The first monitoring method is known as "Protocol 1". Protocol 1 includes 5-7 visits per season at each site (all protected and managed sites). Each site has a rectangular grid with 12-m spacing in which the observer walks the centerline and counts all male butterflies observed including perching, basking, and flying butterflies. In addition, an estimate of the Silvery/Fender's blue ratio is assessed by netting a subsample of 20 blue butterflies at each visit (see Schultz and Dlugosch 1999 for full methods). For sites that are visited at least 5 times per season, INCA (insect count analyzer) will be used estimate residence time and an index of population size (Zonneveld 1991, Longcore et al. 2003). For sites not visited 5 times in a season, Schultz and Dlugosch (1999) provide a method for estimating population abundance.

The second method uses distance sampling to count butterflies in combination with INCA to estimate an index of population size (Hicks 2011). Distance sampling is a method for estimating abundance that takes into account the probability of detection, and is implemented by recording the distance from the observer to each observation (Buckland 2001). Distance sampling is used to sample male blue butterflies using systematic transects to provide full coverage of lupine patches using a random start location. Like Protocol 1, distance sampling includes surveys of each site 5-7 times each season and an estimate of the ratio of Silvery to Fender's blue butterflies.

The third method is a rapid assessment protocol, otherwise known as a "peak count". This method includes a single butterfly count on the peak day in the flight season. In this method "sentinels" visit several pre-defined sites early in the season to predict the peak in the butterfly flight season. Peak flight period may be indicated by presence or abundance of females as well as attributes of the habitat such as phenology of lupines. The sentinels then alert the surveyors of the imminent peak.

The fourth method uses egg counts to assess butterfly abundance. At every protected and managed site, each year, 15 sample plots (0.6m x 0.6m) will be randomly placed within lupine patches. Complete count of eggs will be conducted within plots. Area of lupine at the site will be assessed every 2-5 years. From the area of lupine and the density in the sample plot, an annual estimate of the number of eggs can be calculated. From the number of eggs, the number of adults in the population that year can be predicted, based on previous empirical studies (G. Fitzpatrick and T. Hicks, personal communication).

Based on these four methods, 13 alternative rangewide monitoring strategies were developed. Each strategy specifies the monitoring method or methods used, and the subset of sites at which the monitoring is conducted. Unless otherwise noted, all strategies include subsampling to estimate the ratio of Silvery blue butterflies to Fender's blue butterflies.

Alternative Range-wide Monitoring Strategies:

1. Full-scale distance sampling. Conduct distance sampling as described above at all lupine patches >0.2 ha. At small patches (<0.2 ha), use census count.
2. Targeted distance sampling. Conduct distance sampling at 9 focal sites across the range (3 in each zone). At the remaining sites, conduct peak counts.
3. Rotational distance sampling. Conduct distance sampling at 9 focal sites annually; 7 other sites per year surveyed with distance sampling on a 5-year rotation.
4. Full-scale protocol 1. Conduct protocol 1 as described above at all lupine patches >0.2 ha. At small patches (<0.2 ha), use census count.
5. Targeted protocol 1 with peak-counts elsewhere. Conduct protocol 1 at 9 focal sites. At the remaining sites, conduct peak counts.
6. Rotational protocol 1. Conduct protocol 1 at 9 focal sites annually; 7 other sites per year surveyed with protocol 1 on a 5-year rotation.
7. Intensive egg counts. Conduct eggs counts at all managed and protected sites. Include at least 15 lupine sample plots at each site. Note that a Fender's:Silvery ratio is not required.
8. Less-intensive egg counts. Include at least 5 lupine sample plots at each site. Note that a Fender's:Silvery ratio is not required.

9. Peak counts at all sites, with additional counts done at sentinel sites to help determine the timing of the peak.
10. Rotational peak counts. Nine sentinel sites monitored annually. Seven other sites monitored per year on a 5-year rotation.
11. Mixed protocol 1/egg count strategy. Conduct Protocol 1 at all sites, unless weather prohibits, in which case egg counts are conducted. (Thus, this is a combination of strategies 4 and 7).
12. Egg counts and rotational distance sampling. Conduct less-intensive egg counts at all sites every year (5 plots per site). In addition, conduct distance sampling at 9 sites per year on a 5 year rotation.
13. Status quo, consciously designed. Conduct Protocol 1 at select sites (the currently designated sites), peak counts (with ad hoc assessment of peak time) at other sites.

Predictive models

For each of the measurable attributes, we needed a method for predicting the expected performance of each of the alternative monitoring strategies. A separate predictive model was built for each measurable attribute. These models are described below.

For the first three measurable attributes (1a, 1b, and 2), estimates of the variance associated with each monitoring strategy were required. These variances were estimated through analysis of existing data (Table 2).

<u>Measurable attributes 1a and 1b.</u> The probability of failing to detect the population size in a network was greater than 200 when in fact it was 250 (1a, a small mistake) or 500 (1b, a big mistake) was approximated by the probability that the observed index value would fall below 200 when the true value was 250 or 500. To calculate this probability, several steps were taken:

1. The variance on the log-scale of a population index at a site was estimated for each method (Table 2).
2. We approximated the variance of the sum of population counts across sites using the sum of the variances of the population size estimates for each site. The counts at sites not surveyed in a given year were set to 0 with variance of 0. For a rotational design in which 20% of the non-sentinel sites were sampled, only the counts from 20% of the non-sentinel sites were used. We assumed that 50% of the population in a network was located at a focal (or sentinel) site, and the remainder was divided evenly between two satellite sites.
3. The log-scale variance was converted to a variance on the nominal scale through an approximate method. First, a 95% confidence interval on the log-scale was formed from the variance estimate and a mean corresponding to our assumed true population size in each analysis. Second, this confidence interval was transformed to the nominal scale. Third, the range of the nominal-scale confidence interval was divided by 3.92 to estimate the standard error on the nominal scale, and this was squared to estimate the sampling variance on the nominal scale.
4. The desired probability was calculated by assuming the distribution of the observed counts was normal with a mean of the true population size (250 or 500) and a standard deviation corresponding to the sampling variance calculated in step 3.

Measurable attribute 2. The desired metric is the expected coefficient of variation of the index produced by the monitoring program at the network level. This was developed from the sampling variance on the log-scale. The expected variance on the log-scale at the network level was found by taking the weighted average variance across sentinel and other sites (for now weighted evenly across the number of sites). When sites were not surveyed every year, the variance estimates were weighted by the inverse of sampling frequency, i.e., for monitoring once every five years, the sampling variance was multiplied by five. The rationale for this multiplier is that, as t increases, the sampling variance for the metric declines in proportion to $1/t$, where t is the number of years for which data is collected at a site. The variance on the log-scale was converted to variance on the nominal scale in the manner described above. The coefficient of variation was calculated by assuming a mean index of 100 butterflies.

Measurable attribute 3. The estimated annual cost of monitoring was predicted for each monitoring strategy by adding up the expected costs of travel, sampling, training, analysis, and hiring. Note this did not include the one-time cost of training for distance sampling analysis.

Measurable attribute 4. The estimated time required to undertake monitoring on an annual basis was predicted for each monitoring strategy by adding up the expected time required for both sampling and travel. Briefly, these predictions assumed you would hire people in the population centers (there is an undergraduate source in each of three zones). The travel time from population centers to major sites was estimated. For monitoring time, the following time estimates were used for each protocol: Protocol 1, linear relationship between time and area; distance sampling, multiplied protocol 1 time by 2.7 (there might be uncertainty around this multiplier); peak counts, used Paul Hammond's estimated amount of time, scaled to area; egg counts, 1 hour per sample plot. For a more detailed description of these predictions, see Appendix 1.

Measurable attribute 5. The total annual area (m^2) of trampled lupine across the Valley was predicted for each monitoring strategy by multiplying the impact per visit, the number of visits per site, and the number of sites. The impact per visit varies across methods (peak counts, adult counts, and egg counts); an expert judgment of this impact was used. The casual, single visit peak count has an estimated impact of 0.01 m^2 per visit ($impact_p = 0.01m^2$) due to the walk-through used in this method. The multi-visit protocols for distance sampling and "protocol 1" involve more intensive impact per visit of 0.05 m^2 ($impact_a = 0.05\ m^2$). The multiple plot-based egg count methods have the highest impact, with an estimated 0.1 m^2 of lupine trampled per visit ($impact_e = 0.1\ m^2$). For each of the thirteen proposed approaches, the impact estimates were multiplied by the number of sites and the number of visits or plots, and the products summed. Alternative 11 (the mixed protocol 1/egg count strategy) assumes protocol 1 cannot be completed (because of weather considerations) about 1/3 of the time.

Measurable attribute 6. An additional concern was raised during analysis, namely, the risk that a particular strategy will result is missing data, because of poor weather conditions. This is particularly true of the strategies that attempt an adult count of some sort at all sites each year. The authors of this report, acting as an expert panel, estimated the average proportion of sites for which data would be missing in a given year. Currently, there is missing data for about 15% of sites each year; this observation served as the upper limit for missing data.

Decision Analysis

The selection of a preferred monitoring strategy was seen as a multiple-objective tradeoff, and multi-criteria decision analysis (MCDA, Herath and Prato 2006) methods were used to inform the decision. Thirteen alternative monitoring strategies were assessed across seven measurable attributes that were meant to reflect the objectives of the decision maker. These results were summarized in a consequence table. Swing weighting methods (Goodwin and Wright 2004; von Winterfeldt and Edwards 1986) were used to place weights on the six measurable attributes.

Consequence table

The consequence table (Table 3) shows the tradeoffs inherent in the decision. No one strategy preformed best on all objectives, nor did any one strategy perform worst on all objectives. The highest precision (and thus best performance on objectives 1 and 2) could be attained with full-scale distance sampling, but this is also the most costly and time-intensive strategy. The least-expensive and least time-intensive strategies were less-intensive eggs counts (#8) and rotational peak counts (#10), respectively; these were both worst on one of the precision measures, and quite high on the others. The methods that used eggs counts, either entirely, or as a back-up when adult counts cannot be completed, provided the best assurance against missing data, but at the cost of increased trampling of lupine.

Swing weighting

Seven experts (all of them authors of this report) were asked to independently assign weights to the objectives using a process called swing weighting. This involves evaluating hypothetical scenarios in which one attribute at a time is "swung" to its best value, while all the other attributes remain at their worst value. The hypothetical scenarios are ranked, based on how the expert views the importance of the objectives—both the objective in itself and the range over which a change is contemplated. Scores are then assigned to the hypothetical scenarios to reflect a finer judgment about the importance of the range on the different attributes.

All of the experts ranked either objective 1b (minimizing a large failure to detect success), 2 (maximizing the precision of the index at the network level), or 3 (cost) as the most important objective, when taking into consideration the range of performance being considered (Table 4). Beyond that, there were subtle differences in the patterns of ranking, but general agreement that objective 1a was of lesser concern than 1b, and the impact on the habitat (objective 5) was of little concern.

Multi-criteria decision analysis

To identify a preferred alternative that balances the tradeoffs across objectives, the consequences are first standardized by scaling each measurable attribute to a 0-1 scale (using the same minimum and maximum values that were used in the swing weighting). Then these standardized scores are weighting across objectives using the swing weights. This produces a composite performance score for each alternative.

Using the mean objective weights across experts, the top ranked monitoring strategies (Fig. 1) were 9 (peak counts with sentinel plots), 5 (targeted protocol 1), and 2 (targeted distance

sampling). The worst performing strategies were 6 (rotational protocol 1), 7 (intensive egg counts), and 10 (rotational peak counts).
When objective weights from individual experts were used, the top ranking strategies changed little (Table 4). Strategy 9 (peak counts with sentinel plots) was ranked first or second by all experts, and strategy 5 (targeted protocol 1) was always in the top 3. Two experts who placed lower weight on cost and time considerations identified strategy 2 (targeted distance sampling) as the top-ranked strategy.

Uncertainty

Uncertainty in two arenas has the potential to influence the recommended alternative: uncertainty in judgments that reflect the values of the decision-makers, and uncertainty in estimates of the consequences. The sensitivity of the decision to the range of objective weights expressed by the panel was investigated (Table 4). The panel consulted represented USFWS, ACOE, several lead field personnel, and some leading academic scientists. Although a larger group of decision makers, including representatives from other regulatory and land management agencies, might identify a wider range of objective weights, it seems this uncertainty has been well articulated. The one critical difference concerned how much weight to place on cost and time considerations—if these are weighted heavily, strategy 9 (peak counts with sentinel plots) is favored; if these are weighted lightly, strategy 2 (targeted distance sampling) is favored.

The influence of uncertainty in the consequences estimation was not investigated in this analysis. The expert panelists did express concern that some of the consequences might be poorly estimated, but an attempt was not made to characterize this uncertainty nor investigate its influence on the results. It is worth noting that the sixth measurable attribute (the proportion of counts missed due to weather) was included to represent a concern about precision. It should be redundant with objectives 1 and 2, but the experts involved in this analysis were concerned that those objectives did not fully incorporate this concern. Improved estimation of the consequences, however, could be achieved with some additional analysis of existing data, if this concern warranted further investigation.

Discussion

The three top-performing monitoring strategies (9, peak counts with sentinel plots; 5, targeted protocol 1; 2, targeted distance sampling) are quite similar in that they involve peak counts at all 44 sites, with something more intensive done at nine sentinel sites. The more intensive work might involve simply monitoring for the occurrence of the peak, the use of "protocol 1", or distance sampling. The preference among these three alternatives largely concerns the tradeoff between precision of monitoring (reflected in objectives 1a, 1b, and 2) and the costs of monitoring (objectives 3 and 4). If the costs of monitoring are less than estimated, or there is less concern about them, then the more intensive methods, which have higher expected precision, are favored. Likewise, if the estimated precision is less than estimated, or the desire for precision is less than judged in this analysis, then the less intensive methods are favored.

The uncertainty around these tradeoffs can be investigated in two ways. First, more careful estimates of cost and time-investment could be developed, either by analysis of past monitoring,

or through adaptive implementation of all three methods. Second, the importance of precision could be more deeply motivated. The monitoring strategy being chosen is not desired for itself—there is no interest in monitoring just to have the data—but rather because the data are expected to serve other decisions. Thus, the importance of precision in the monitoring derives from the use to which the data will be put. The panel distinguished between acceptable degrees of precision (Attributes 1a vs. 1b), however, this distinction has not been functionally linked back to classification decisions. Coarser estimates may be necessary to make monitoring feasible at all, but within the range of attainable precision, coarser estimates make it harder to determine if recovery criteria have been attained and more expensive monitoring may be cost-efficient in the long run if the precision results in a quicker detection that recovery criteria have been achieved. There is a formal method in decision analysis for calculating the expected value of information (Runge et al. 2011), and this method would be valuable here. It requires analysis of the decision for which the information is needed, and compares the expected performance of the decision with and without the information (or with different levels of precision in the information).

One way forward is to begin immediate implementation of the overall framework that the three top strategies share, with adaptive investigation of the three specific methods. This would allow resolution of a number of the uncertainties that remain in this analysis (cost, time commitment, realized precision, and others), while initiating a common monitoring structure across the Valley.

Value of decision structuring

A number of insights arose through conduct of a formal structured decision analysis. First, the participants were able to separate objectives from alternatives and focus on the reasons that motivated alternative monitoring designs. Second, there was a realization that the aspirations for precision in monitoring might not be as high as previously assumed. None of the participants put very high weight on objective 1a, which would have allowed fairly precise detection of when the butterfly population at a site surpassed a threshold of 200; instead, objective 1b, which was a less precise version, was deemed more important. For habitat management at a small number of critical sites, the desire for precision might be higher, to allow more responsive adaptive management, but this could be achieved through augmented monitoring at those sites rather than a more intensive strategy at all sites. Third, the participants realized that they are worried about how best to spend a small amount of money, not only on monitoring, but also on management. To some extent, money spent on monitoring is money not spent on management, thus it is important to allocate resources wisely. Fourth, one of the concerns about egg counting was found to be of significantly less importance that expected. Damage to butterflies and lupine from monitoring activities has been cited as a reason to avoid egg counts, but the estimated impact, even of the most intensive method, was fairly minimal (88 m^2/yr) compared to the total area of lupine in the Valley. Egg counts were not, however, favored in the analysis, largely because they also had a lower expected precision due to the weak link between the egg population in one year and the adult population in the next. Fifth, new insights arose as to standardizing the peak count method to make it more rigorous and repeatable and seeing the various techniques as complementary and conducive to tailoring efficient mixed strategies. Finally, the concern about missing data, which occurs to some extent every year because of poor weather conditions, is still not fully understood. Does missing data undermine the desired inferences, or is the current

magnitude of missing data largely inconsequential? What are the specific concerns about missing data?

Further development required

The next step is to review this decision analysis with the larger Fender's blue butterfly community at the April 2011 annual coordination meeting. First, this larger group can provide feedback on whether the prototype analysis presented here adequately captures the key elements of the decision. Second, if changes to the monitoring protocol are desired for the 2011 season, planning needs to start fairly quickly.

To implement a systematic and coordinated monitoring program for the entire Valley, precise protocols will need to be developed, staff will need to be hired, training sessions will have to be organized, and a common database format will need to be designed. During or after the field season, the precise analytical methods will have to be finalized.

Adaptive implementation of the top three monitoring strategies would allow a common structure to be initiated, while testing the capability of the community to utilize this structure and while resolving several key uncertainties. The uncertainties of particular concern are the precision that can be achieved through each of the three alternative strategies, and the cost and time commitments associated with them. It is presumed that after some period of adaptive implementation, the uncertainties would be resolved enough to settle on a single strategy for the foreseeable future.

Prototyping process

In the process of developing the analysis presented in this report, the participants explored alternate perspectives of the question: How best to monitor FBB? Monitoring data on FBB are intended primarily to inform classification and habitat management decisions and one of the key difficulties endemic to the FBB system is estimating population abundances with a high level precision. The various methods that have been or could be used for FBB monitoring offer different levels of precision and carry different costs of implementation. This suggests that a comparison of monitoring methods will include trade-offs between cost and precision. To make trade-offs between one method and another (or varying levels of intensity for a given method) it is important to know the value to place on the information that is gained or foregone (increased or decreased precision) when choosing one method over another. Prior to developing the analysis described in this report, we explored two other prototypes that looked at the decision contexts in which the monitoring information would be used, to begin to understand the value of that information.

Our initial approach was to use the reclassification context to clarify what is needed from the monitoring data. We began by exploring the consequences of misclassification (e.g., classifying the FBB as endangered when it truly warrants threatened status, etc). During this exercise, the participants felt that moving toward a revisitation of the recovery criteria would be impractical. The recovery criteria had already been the object of considerable work while writing the recovery plan and the participants felt that this direction was not conducive to tackling the current problem, the implementation of monitoring.

We turned next to the question of what information is needed to inform site-level habitat management in support of FBB recovery. After a presentation of the various management actions that are used for restoration and recovery of the prairie system upon which the FBB depends, we bundled different variations of these strategies into management portfolios. Each portfolio was a set of actions (e.g., burning of all lupine patches on a 3-5 year rotation, broad-spectrum herbicide applications, and fall mowing) and we tailored the different portfolios to represent some very aggressive management approaches, a very conservative approach, and some intermediate approaches. Once identified, these portfolios could then be evaluated in a consequence table to clarify their costs and benefits relative to the FBB. At this point, the participants expressed concern that the information needed to address site-level management (e.g., controlled, experimental comparisons of FBB response to treatments) was exceedingly difficult to attain and possibly inconsistent with the FBB species-level recovery monitoring. At this point it was apparent that the way forward was to address the monitoring design directly and the participants shifted their attention to producing the prototype discussed in this report.

The analysis described herein was also conducted in the spirit of prototyping, identifying what the group felt were the major factors that influenced the decision regarding monitoring design. Greater insights about the tradeoffs among objectives might be achieved through integrating the three prototypes developed, because the decision contexts in which the monitoring data will be used can inform the importance of precision in the monitoring design.

Recommendations

Based on this decision analysis, the authors of this report make the following recommendation for the 2011 field season, for consideration by the larger Fender's blue butterfly management community.

In 2011, implement the peak count method across the range of the species, that is, at 44 sites (less the sites selected for more intensive methods). The count protocols will need to be clarified and standardized, but will involve three elements: (a) a method for estimation of the peak of the flight period, likely by repeated visitation to representative "sentinel sites"; (b) counts of adult male FBB near the peak flight period at all sites; and (c) an estimate of the ratio of Silvery to Fender's blue butterflies for each site. Staffing needs will need to be articulated, and training will need to be scheduled.

In addition, implement pilot testing of three methods. First, the sentinel plot method for estimation of the peak of the flight period needs to be tested. Second, implement pilot testing of distance sampling at Basket Slough (3 sites) and Fern Ridge. Third, continue implementation of protocol 1 at Willow Creek. The purpose of the second and third methods is, in particular, to obtain estimates of the costs of implementing those protocols and the precision that can be expected from them.

After the 2011 season, the analysis in this report needs to be updated, using information from the pilot data. If the information is adequate to identify a single preferred alternative, then that can be implemented in 2012. If not, the allocation of sites among the three methods should reflect the improved understanding, and the need to resolve the remaining uncertainty.

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Tables

Table 1. Distribution and abundance goals for Fender's Blue Butterfly (USFWS 2010).

DOWNLISTING GOALS		
Downlisting goals are set at a 90 percent probability of persistence for 25 years. Attainment of these population targets in all three recovery zones, together with the criteria for distribution, habitat quality and management described in USFWS (2010), would indicate that the species' status has improved and could be considered for reclassification to threatened. Note that the minimum population size in the table represents the minimum population count in a network in each of 10 consecutive years. The average population size in a network corresponding to these minima would be substantially larger.		
Recovery Zone*	**Number of functioning networks (FN) and independent populations (IP) in a recovery zone**	**Minimum population size in one network/zone over 10 years**
Salem (Salem East + Salem West)	2 FN or 1 FN + 2 IP	200
Corvallis (Corvallis East + Corvallis West)	2 FN or 1 FN + 2 IP	200
Eugene (Eugene East + Eugene West)	2 FN or 1 FN + 2 IP	200
DELISTING GOALS		
Delisting goals are set at a 95 percent probability of persistence for 100 years. Each row below represents a combination of functioning networks and independent populations within a recovery zone. If each of the three recovery zones meets the criteria in one row below, the species would be projected to have a 95 percent probability of persistence for 100 years. Attainment of these population targets, together with the criteria for distribution, habitat quality and management described in USFWS (2010), would indicate that the species has recovered and could be considered for delisting. Note that the minimum population size in the table represents the minimum population count in a network or independent population in each of 10 consecutive years. The average population size in a network or independent population corresponding to these minima would be substantially larger.		
Number of functioning networks (FN) and independent populations (IP) in a recovery zone	**Minimum population size per network over 10 years**	**Minimum population size per independent population over 10 years**
2 FN + 0 IP	4500	n/a
2 FN + 2 IP	800	3000
2 FN + 2 IP	1000	1000
2 FN + 3 IP	1500	500
2 FN + 3 IP	1000	700
2 FN + 3 IP	1500	300
3 FN + 0 IP	1000	n/a
3 FN + 1 IP	800	200
3 FN + 2 IP	500	250
4 FN + 0 IP	400	n/a
*Population targets for Fender's blue butterfly were set for the following recovery zones: Salem (Salem East + Salem West), Corvallis (Corvallis East + Corvallis West) and Eugene (Eugene East + Eugene West).		

Table 2. Estimated sampling variances on the log-scale for different monitoring methods.

Method	**Estimation of variance of ln(Index)**
Protocol 1, $s^2_{P1} = 0.522$	Estimated from Kalman filter analysis (Grewal and Andrews 1993) of Willow Creek data (this is the only time series long enough for Kalman filter analysis)
Egg counts, $s^2_{eggs} = 0.787$	Among-plot variance from egg count data (G. Fitzpatrick and T. Hicks, personal communication); variance of the mean across *n* plots is the among-plot variance divided by *n*
Distance sampling, $s^2_{DIST} = 0.042$	Sampling variance plus sampling variance of the mean estimated from multiple counts. Variance of multiple counts estimated from distance sampling data (Hicks 2011), excluding last (very small) days. Sampling variance is variance divided by the number of samples
Adults inferred from egg counts (for combining both, or using eggs to infer adults > 200), $s^2_{egg\rightarrow ad} = 0.941$	Sampling variance of egg counts plus residual variance from regression of ln(egg counts) vs. ln(adult population size).
Peak counts, $s^2_{peak} = 0.602$	Observation variance from Protocol 1, plus variance among days. Variance among days estimated from distance sampling data (Hicks 2011), excluding last (very small) days, and one obvious non-peak count.

Table 3. Consequence table showing the predicted outcomes associated with thirteen alternative monitoring strategies against seven measurable attributes. The strategies with the best performance for each objective are highlighted in green, those with the worst performance are highlighted in pink.

.	**Objective**	1a P(fail to detect I>200| 250	1b P(fail to detect I>200| 500	2 CV (index) at network level	3 Cost	4 Time	5 Impact on habitat	6 Prop-ortion missed data
	Units	Prob.	Prob.	%	$/yr	Hrs/yr	m^2/yr	Prop.
	Desired direction	Min	Min	Min	Min	Min	Min	Min
No.	**Monitoring Strategy**							
1	Full-scale distance	0.00	0.00	5.0%	31,364	1146	15	0.10
2	Targeted distance	0.23	0.01	12.0%	19,895	657	3	0.02
3	Rotational distance	1.00	0.00	9.0%	23,459	834	6	0.02
4	Full-scale protocol 1	0.30	0.06	19.0%	21,297	543	15	0.10
5	Targeted protocol 1	0.31	0.07	19.8%	12,554	398	4	0.02
6	Rotational protocol 1	0.73	0.27	31.0%	12,654	373	6	0.02
7	Intensive egg counts	0.43	0.29	6.0%	18,720	684	88	0.00
8	Less-intensive egg counts	0.44	0.33	10.0%	7,593	244	22	0.00
9	Peak counts	0.33	0.10	20.0%	10,369	229	0	0.02
10	Rotational peak counts	0.70	0.30	34.0%	8,841	179	0	0.00
11	Mixed protocol 1/egg, full-scale	0.35	0.15	21.0%	23,259	711	40	0.00
12	Egg count + distance, rotation	0.55	0.26	9.0%	15,143	709	25	0.00
13	Status quo, designed	0.32	0.08	20.0%	7,960	232	4	0.15
	Used in Swing Weighting:							
	Worst Case	1.00	0.325	45%	31,364	1100	88	0.15
	Best Case	0.00	0.00	5%	7,593	150	0.16	0.00

Table 4. Individual and consensus weights, with top 3 preferred alternatives. The highest ranked objective is highlighted in tan for each expert. The top two performing alternatives using the consensus weights are highlighted in light green and light yellow, respectively.

Expert	Objective Weights							Top Alternatives		
	1a	1b	2	3	4	5	6	1	2	3
1	0.104	0.177	0.188	0.208	0.125	0.052	0.146	9	5	2
2	0.014	0.278	0.208	0.222	0.167	0.028	0.083	9	5	13
3	0.054	0.204	0.215	0.161	0.129	0.043	0.194	9	5	2
4	0.128	0.149	0.213	0.128	0.213	0.043	0.128	9	5	8
5	0.145	0.241	0.217	0.205	0.084	0.012	0.096	2	9	5
6	0.024	0.235	0.224	0.188	0.188	0.047	0.094	9	5	13
7	0.135	0.213	0.225	0.135	0.112	0.045	0.135	2	9	5
Mean	0.086	0.214	0.213	0.178	0.145	0.038	0.125	9	5	2

Figures

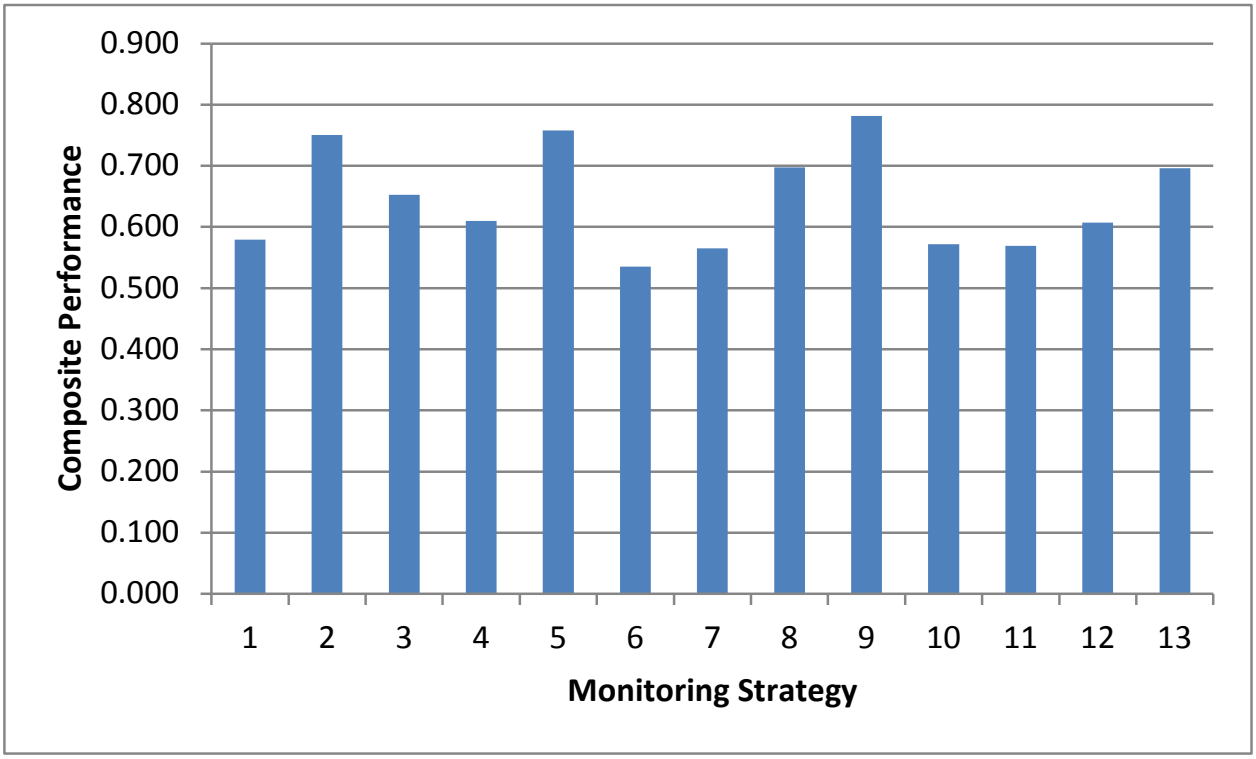


Figure 1. Composite performance of the alternative monitoring strategies, using the mean weight on the objectives.

Appendix 1
Time Estimates for Fender's Monitoring Alternatives

1.) Full-scale Distance Sampling

Monitoring = 44 sites with 8 visits annually. Time to conduct surveys calculated from linear relationship between Protocol 1 survey time and prairie size with Distance sampling requiring 2.7 time greater time (see Alternative 4). One complete survey of all sites would require 119.6 hours with 8 visits per site, 119.6 hrs * 8 visits = 957 hours.

Travel = Travel time to all sites is 24 hrs with 8 visits. Total travel time is (24 hours * 8 visits) 189 hours.

Personnel = 12 full season surveyors, 1 DS analyst & INCA modeler

2.) Target Distance Sampling

Monitoring = 9 "priority" sentinel sites surveyed 8 times across the flight season using Distance sampling (mean 5.7 hrs/site). The remaining 35 sites will be surveyed using peak count methods (mean 3.9 hrs/site). Total monitoring time is: (5.7 hrs * 8 visits * 9 sites) + (3.9 hrs * 35 sites) = 547 hours.

Travel = Estimated minimum (60 hrs) and maximum (160 hrs) potential travel time and use the mean of the two values. Total travel time = (60 hrs + 160 hrs)/2 = 110.

Personnel = 5 full season surveyors and 5 partial season surveyors.

3.) Rotational Distance Sampling

Monitoring = 16 sites are monitored annually (9 annually & 7 on a rotation) 8 times each flight season (Mean DS = 5.7 hrs). Total monitoring time: (16 sites * 8 visits * 5.7 hr = 730).

Travel = Estimated minimum (24 hrs) and maximum (183 hrs) potential travel time and use the mean of the two values. Total travel time = (24 hrs + 183 hrs)/2 = 104.

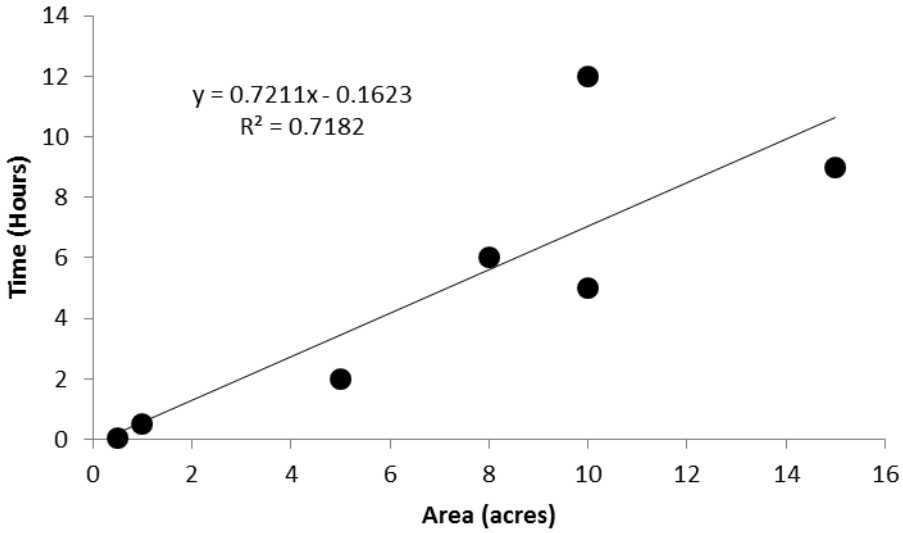
Personnel = 9 full season surveyors, 1 DS analyst

4.) Full Scale Protocol 1

Monitoring = 44 sites with 8 visits annually. Time to conduct surveys calculated from linear relationship (see below) between Protocol 1 survey time and prairie size with where: Time to survey using P1 = Acres * 0.7211 – 0.1623 . One complete survey of all sites would require 44.3 hours with 8 visits per site (44.3 hrs * 8 visits = 354 hours).

Travel = Travel time to all sites is 24 hrs with 8 visits. Total travel time is (24 hours * 8 visits = 189 hours).

Personnel = 10 full season surveyors, no specialized analyst needed



5.) Target Protocol 1

Monitoring = 9 "priority" sentinel sites surveyed 8 times across the flight season using protocol 1 (mean 2.1 hrs/site). The remaining 35 sites will be surveyed using peak count methods (mean 3.9 hrs/site). Total monitoring time is: (2.1 hrs * 8 visits * 9 sites) + (3.9 hrs * 35 sites) = 288 hours.

Travel = Estimated minimum (60 hrs) and maximum (160 hrs) potential travel time and use the mean of the two values. Total travel time = (60 hrs + 160 hrs)/2 = 110.

Personnel = 5 full season surveyors and 5 partial season surveyors.

6.) Rotational Protocol 1

Monitoring = 16 sites are monitored annually (9 annually & 7 on a rotation) 8 times each flight season (Mean DS = 2.1 hrs). Total monitoring time: (16 sites * 8 visits * 2.1 hr) = 269.

Travel = Estimated minimum (24 hrs) and maximum (183 hrs) potential travel time and use the mean of the two values. Total travel time = (24 hrs + 183 hrs)/2 = 104.

Personnel = 5 full season surveyors.

7.) Intensive Egg Count

Monitoring = ~ 15 plots per site, 44 sites, at 1 hr/plot = 660 hours

Travel = Travel time to visit each site once = 24 hrs

Personnel = 6 egg counters working 40 hours/week for 3 weeks

8.) Less Intensive-Egg

Monitoring = 5 plots per site, 44 sites, at 1 hr/plot = 220 hrs

Travel = Total travel time to visit each site once = 24 hrs

Personnel = 3 egg counters working 40 hours/week for 2 weeks

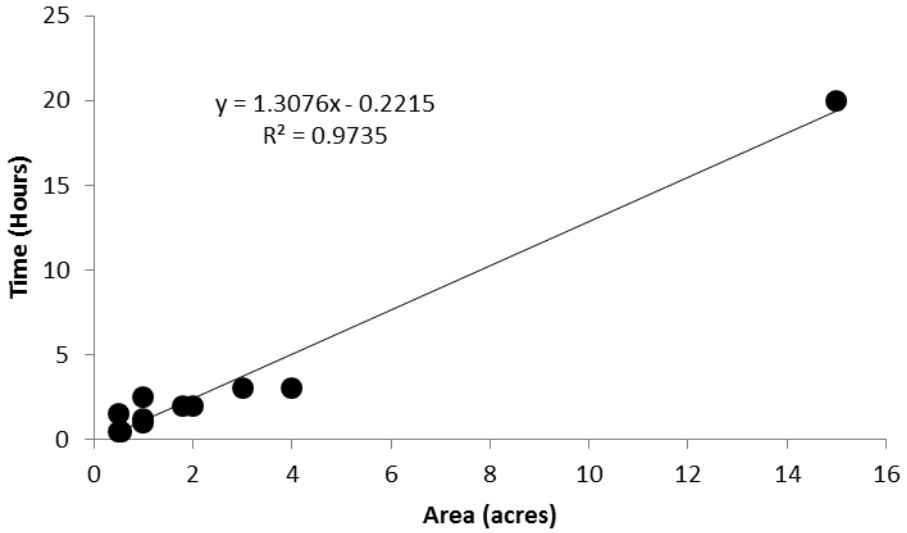
9.) Targeted Peak Count

Monitoring = 44 sites with 1 visit annually. Nine sites to be monitored ~ 5 times throughout the season as sentinel sites to detect peak. Time to conduct surveys calculated from linear relationship (see below) between Hammond survey times and prairie size where: Time to

survey using P2 = Acres * 1.3076 – 0.2215. One complete survey of all sites would require 190 hours.

Travel = Sentinel sites monitored 5 times per season with 1 hr travel time to each across 3 zones. Travel time to visit each site once = 24 hrs. Total travel time: (5 visits * 1 hr + 3 zones) + 24 hours = 39 hours.

Personnel = 3 full time season surveyors who monitor sentinel sites. 3 partial season surveyors to survey peak count location away from sentinel sites.



10.) Rotational Peak Count

Monitor = The mean time to complete a site using peak count method is 3.9 hr. In the rotational alternative 16 sites are counted once annually. To account for monitoring time, 20% of the survey time to monitor the 9 sentinel sites was added to the overall effort. Total travel time is: (3.9 hrs * 16 sites) + (3.9 * 16 * 0.2 correction factor) = 75

Travel = Estimated minimum (24 hrs) and maximum (183 hrs) potential travel time and use the mean of the two values. Total travel time = (24 hrs + 183 hrs)/2 = 104.

Personnel = 3 full season surveyors, and 2 partial season surveyors.

11.) Mixed Protocol 1/Egg Count

Monitoring = Attempt to survey all 44 sites with 8 visits annually. Time to conduct surveys calculated from linear relationship (see Alternative 4) between Protocol 1 survey time and prairie size. Assumed failure rate of 1/3 where ~15 sites would not be sufficiently surveyed to estimate brood size. Instead egg counts (15 hrs) would be conducted at each failed site. Total monitoring time would be: (44 hours * 8 visits * 2/3 sites) + (15 sites * 15 hrs/site) = 460 hours.

Travel = Travel time to all sites is 24 hrs with 8 visits plus revisiting 1/3rd of sites once for egg counts. Total travel time is: (24 hours * 8 visits) + (1/3 * 24 hours * 8 hrs) = 251 hours.

Personnel = 5 full season surveyors, 3 egg counters at 40/hrs/week for 1.5 weeks.

12.) Egg + Rotation Distance Sampling

Monitor = Egg count 5 plots per site at all 44 sites with 1 hr/plot. In addition, 9 sites will be surveyed 8 times with an average time of 5.7 hrs per site. Total monitor time: (5 egg plots * 1 hr/plot * 44 sites) + (5.7 hrs * 8 visits * 9 sites) = 630 hours.

Travel = Total travel time to visit each site once is 24 hrs. Mean time to travel to individual sites across three zones is 6.9 hrs with 8 visits across the season. Total travel time is: (6.9 hrs * 8 visits) + 24 hrs = 79 hours.

Personnel = 5 full season surveyors, 3 egg counters working 40/hrs for 2 weeks.

13.) Status Quo

Monitor = Using protocol 1 survey Fir Butte, Fern Ridge, Coburg, and Willow Creek 5 times (22 hrs to complete). Survey remaining sites using peak counts only with one visit (82 hours). Total monitor time: (22 hrs * 5 visits) + 82 hrs = 192 hours.

Travel = Average travel time to 4 protocol sites (Fern Ridge monitored by ACOE) is 4 hours. Estimated travel time to visit remaining sites is 20 hours (single visit). Total travel time: (5 visits * 4 hours) + 20 hours = 40 hours.

Personnel = 3 full season surveyors.

DEFINITIONS FOR PERSONNEL
Full Season Surveyor = (2 weeks ¼ time, 4 weeks ½ time)
Partial Season Surveyor = (3 weeks ½ time)

Table A-1. Description of estimated times (hours/season) for alternatives 1-13 for monitoring FBB.

Alternative	Description	Monitoring	Travel	Total (hr)
1	Full-scale DS	957	189	1146
2	Targeted DS	547	110	657
3	Rotational DS	730	104	834
4	Full-scale P1	354	189	543
5	Targeted P1	288	110	398
6	Rotational P1	269	104	373
7	Intensive Egg	660	24	684
8	Less-intensive Egg	220	24	244
9	Full-scale Peak	190	39	229
10	Rotational Peak	75	104	179
11	Mixed P1/Egg	460	251	711
12	Egg + DS	630	79	709
13	Status quo	192	40	232