Conservation and Management of the Great Gray Owl 2007-2009: Assessment of Multiple Stressors and Ecological Limiting Factors

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EXECUTIVE SUMMARY

This report summarizes research on Great Gray Owls (*Strix nebulosa*)(GGOW) conducted between 2007-2009 in Yosemite National Park (YNP) that was funded by the Yosemite Conservancy to address the six short-term research objectives described below. Additionally, we include results from our GGOW survey work conducted in 2004-2006 and 2010, to provide summary results from all our GGOW research conducted in YNP to date. The GGOW is a California Endangered Species. An estimated 100-200 pairs of GGOWs occur in California with a limited geographic distribution centered in Yosemite National Park (YNP) and adjacent National Forest lands in the central Sierra Nevada. Significant knowledge gaps exist in the base scientific information regarding conservation status, population genetic status, ecological limiting factors and the multiple stressors that possibly affect the small, geographically-isolated population of GGOWs in the YNP region. Our research study addressed these significant information gaps and assessed monitoring methods and strategies, with the goal of providing information that can inform future management, research, and conservation of GGOWs in YNP. YNP is critical for GGOW conservation as it supports the core distribution of the population in the Sierra Nevada. This study addressed the following six research objectives:

(1) Assess the conservation status of GGOWs in YNP;
(2) Assess the population genetic status of GGOWs in the central Sierra Nevada relative to other North American populations;
(3) Assess GGOW exposure to West Nile Virus and Trichomoniasis;
(4) Evaluate the effectiveness of existing survey protocols for GGOWs;
(5) Develop monitoring options that YNP managers can implement if desired to monitor GGOW occupancy across YNP;
(6) Develop a predictive model for predicting the distribution of GGOW probability of occurrence and habitat suitability YNP.

This research project was successful in meeting the six research objectives. Establishing baseline information on GGOW distribution and abundance across YNP is a primary information need to assess conservation status. Surveys conducted between 2004-2010 documented that GGOWs are widely distributed across YNP. GGOWs were documented at over 90% of sites where they have been reported in the past. Additionally, based on surveys at random locations of suitable habitat that had no previous records of GGOW occurrence across YNP we estimated that GGOW occupancy rates were near 60% of the random sites. These high occupancy rates at historic and random sites indicate that GGOWs are widely distributed across YNP. It is not possible to conclude whether there have been changes in abundance as no information on historic population sizes is available.

Our results indicate that GGOWs in the YNP region are a genetically-unique population that has been isolated from the nearest northern population for over 24,000 years dating back to the Pleistocene Era. Further, genetic analyses indicate that this population has experienced a recent genetic bottleneck and exhibits a small effective population size. Both of these latter factors are of conservation concern.

We screened for, but did not document West Nile Virus (WNV) exposure, or the presence of Trichomoniasis in GGOWs. Given the reported severe effects of WNV on GGOWs and other owl species in the scientific literature, coupled with the small population size of GGOWs in YNP, WNV may continue to pose a risk to GGOWs into the future.

Our field evaluation of survey methods indicated that current protocol survey efforts can be reduced by 33-55% in YNP and still produce results with high confidence based on scientifically-defensible estimates of survey method effectiveness. Using the results from these survey method tests, we developed and statistically-evaluated a suite of occupancy monitoring design options that can inform YNP managers in the development of a monitoring program for GGOWs in YNP. Additionally, we developed a landscape habitat suitability model that predicts the distribution and suitability of GGOW habitat across YNP. This model highlights that high suitability GGOW areas is rare within YNP with only 0.8% of the landscape rated in the highest 20% suitability class. Wet meadows are the key vegetation type, with GGOW habitat consisting of relatively flat, wet meadow areas surrounded by medium-to-dense upper montane conifer forest types between the elevation of 2000 and 2400 meters were most predictive of GGOW presence. This model can assist managers to identify potential GGOW sites and evaluate potential risk to GGOWs and their habitat during management project planning and evaluation.

In summary, results from this research project address several key information needs for GGOWs in YNP and advance the scientific knowledge on this population. Of particular significance, the finding that Sierra Nevada GGOWs are a genetically-unique population will likely result in increased management and conservation focus on this population. YNP is critical to the future viability of GGOWs in the Sierra Nevada because the Park supports the core distribution of this population. Our survey work provides baseline information on GGOW distribution and abundance on GGOWs in YNP. Further, our development of survey methods and monitoring design options provides YNP managers with the tools and solid baseline information on the conservation status of GGOWs that can form the basis of a scientifically-defensible plan for monitoring the genetically-unique population of YNP GGOWs into the future.

INTRODUCTION

Our research program is designed to address the conservation and management needs of the Great Gray Owl (*Strix nebulosa*) (GGOW) in the central Sierra Nevada. An estimated 100-200 pairs of GGOWs occur in California with a limited distribution centered in Yosemite National Park (YNP) and adjacent National Forest lands in the central Sierra Nevada. Significant knowledge gaps exist in the base scientific information regarding conservation status, population genetic status, ecological limiting factors and the multiple stressors possibly affecting the small, geographically-isolated population of GGOWs in the central Sierra Nevada. Our overall research program has both short-term objectives that address several of the current scientific knowledge gaps and long-term objectives that address questions related to GGOW population trends, demography, and habitat quality. In this report we summarize research we conducted 2007-2009 in YNP that was funded by the Yosemite Conservancy to address the six, short-term objectives described below. Additionally, we include results from our survey work conducted in 2004-2006, and in 2010, to provide summary results from all our GGOW research conducted in YNP to date.

Objective #1: Assess the conservation status of GGOWs in YNP

Understanding the distribution and abundance of a species is critical for assessing their conservation status. Ultimately, understanding the ecological limiting factors that determine the distribution and abundance of species of conservation concern should assist in identifying priority management actions. However, in practice it is usually difficult to isolate one key limiting factor. Species are influenced by interacting suites of factors that shape their distribution and abundance over space and time, while in some cases single factors can be identified as the dominant factor. For example, exotic diseases or invasive species may have devastating effects on species that have not co-evolved mechanisms to cope with these novel threats. Thus, when attempting to assess the conservation status of species of concern, such as GGOWs, it is useful to structure the assessment around the concept of identifying the suite of potential ecological limiting factors. We used this concept to structure our approach to assessing the conservation status of GGOWs in YNP. Although it is not possible to fully address each of these factors within the context of a short-term study, this approach does allow us to systematically identify a suite of potential limiting factors, summarize information for these factors, and collect data to address a subset of questions regarding these factors. Comprehensively, our work answers a subset of key, priority questions, and also establishes a baseline on the current status of other factors that can be further addressed through future research and monitoring.

Our first goal was to document the current distribution and abundance of GGOWs across YNP. We addressed this goal by surveying to estimate GGOW occupancy at both historically-occupied sites and random sites across YNP. This provided information on whether GGOWs still occurred at sites where they had been documented in the past (historic sites). Additionally, by also surveying at random sites we were able to assess if GGOWs were more broadly distributed across YNP outside of the historic sites so that we could justifiably generate an estimate of

GGOW occupancy rates across YNP. This updated information on the current distribution and abundance of GGOWs across YNP is the first critical piece of information for assessing the conservations status of GGOWs in YNP. If GGOWs were not detected at historic sites or at random sites, then this would constitute evidence that GGOWs had declined within YNP. Conversely, if GGOWs were relatively abundant and broadly distributed across YNP at historic and random sites then this would provide evidence that GGOWs are still well-distributed across YNP, although no inference can be made regarding changes in population size over time because no baseline information exists on GGOW population sizes in the past. Additionally, this work establishes a baseline against which to monitor future changes in both distribution and abundance.

In addition to addressing the current distribution and abundance of GGOWs across YNP, other key factors we assessed were population genetic status and concerns (objective #2 below), disease risk factors (objective #3 below), and the current landscape distribution and suitability of habitat across YNP (objective #6 below). Each of these study objectives addresses key potential ecological limiting factors and establishes a baseline on the current status of each factor. Additional potential ecological limiting factors that we identified were mortality risk associated with vehicle collision along major highways within and around YNP, and the potential negative disturbance effects associated with human recreation. Twenty-six cases of GGOW mortality due to collisions with vehicles along major highways in the YNP region were documented between 1955-2005 (J. Maurer, S. Stock, S. Thompson, unpublished data, YNP; A. Rich, R. Bridgman, Stanislaus National Forest, personal communication). Thus, given the small estimated size of the GGOW population in the YNP region, vehicle collision mortality may be a significant factor. Disturbance to GGOWs from recreational activities has also been identified as a potential negative factor (Wildman 1992). Given increasing human populations in California, along with associated development pressure and increased demand for recreational activities, human disturbance factors are likely to increase as a risk factor in the future. In YNP, GGOWs are a highly sought after species by birdwatchers, and direct disturbance at GGOW nesting and foraging areas within GGOW sites that are known to the bird-watching community may have negative effects on the species. Although we did not address these two latter factors in our current study, we identified them as potential risk factors that may require additional future management to mitigate risk to GGOWs, and we report on our anecdotal observations on these factors.

Objective #2: Assess the population genetic status of GGOWs in the central Sierra Nevada relative to other North American populations

GGOWs are distributed as a geographically-isolated population in the central Sierra Nevada, with the next closest known populations located in southern Oregon and Idaho. It was unknown if the isolation of GGOWs in the Sierra Nevada is a result of historic evolutionary processes or a more recent phenomena resulting from human impacts and land management practices over the past 160 years. Given this uncertainty, the population genetic status of GGOWs in the Sierra Nevada was unknown. It was unknown if the Sierra population of GGOWs is genetically unique or if they are connected via gene flow to populations to the north. This long-standing and here-to-for unresolved issue was a fundamental knowledge gap for assessing the conservation status of GGOWs in the Sierra, identifying the appropriate degree of conservation concern and efforts that should be directed at this population, and for providing information on conservation genetic issues to inform management of this population. The goals of our work were to assess the population genetic status of the Sierra Nevada population of GGOWs relative to other North American populations and to evaluate the evidence for additional conservation genetic concerns, such as effective population sizes and genetic bottlenecks.

Objective #3: Assess GGOW exposure to West Nile Virus and Trichomoniasis

Disease can function as an important ecological limiting factor in wildlife populations, especially in the case of invasive diseases introduced into naïve populations that have not co-evolved mechanisms to cope with the risk. West Nile Virus (WNV), a mosquito-borne flavivirus, was first detected in eastern North America in 1999 and spread rapidly across the continent, arriving in California in 2003 (Reisen et al. 2004). The recent range expansion of West Nile Virus (WNV) into California poses a potential significant and immediate extinction risk to the small population of GGOWs in the Sierra Nevada. WNV was first detected in southern California in late 2003, spread throughout California in late-summer 2004. WNV has been demonstrated to have high acute species-specific mortality rates in many raptor species (owls, hawks, and their relatives) (Marra et al. 2004, Gancz et al. 2004). Of particular concern, 100% mortality was observed in a captive population of GGOWs in Ontario (n=27) (Gancz et al. 2004). It is uncertain what effect WNV could have on wild GGOWs in California. Effects may range from: (1) 100% acute mortality and extinction; (2) partial mortality resulting in population genetic change and reduction in population size that increases extinction risk due to stochastic and demographic factors; or (3) exposure with no detectable effects on individuals or the population. Documentation of WNV exposure and measures of baseline genetic and health parameters are critical for assessing WNV effects, prediction of population trends, and conservation planning. Observations on acute mortality coupled with the small estimated population size of GGOWs in the Sierra Nevada suggest that WNV may pose a significant risk factor.

When we initiated this project in 2004 our primary focus was on WNV. However, during 2004-2005, colleagues working with the California Department of Fish and Game (CDFG) reported that Trichomoniasis was detected during necropsies of some recent GGOW mortalities. Given this potential additional disease concern, the CDFG requested that we also collect oral swab samples from each GGOW that we captured during our study to screen for Trichomoniasis. Thus, the goals of our research to meet this study objective were to collect samples from all captured GGOW for WNV and Trichomoniasis surveillance screening.

Objective #4: Evaluate the effectiveness of existing survey protocols for GGOWs

Wildlife surveys are conducted to meet multiple management and research objectives, which may range from single-year, project-level inventory needs to monitoring over much longer-term time periods to assess population trends. Recent advances in the design and analysis of wildlife survey data highlight the importance of understanding and quantifying how effective survey methods are for estimating whether a survey site is occupied by the target wildlife species (MacKenzie et al. 2002, 2003, 2006). While managers and researchers are ultimately interested in estimating if a site is occupied by the target species (termed the probability of occupancy), it is also necessary to estimate how well a survey method performs (termed the probability of detection). For example, if all survey sites are occupied by the target species, but the survey method used to sample the sites only has a 30% probability of detecting the species, then the species will not be detected at a large proportion of sites where it is actually present and the naïve survey results will be biased low relative to the true occupancy rate if this effect of the survey method is not understood and factored into the analysis.

Beck and Winter (2000) developed the first survey protocol for GGOWs in the Sierra Nevada. This protocol is currently used by land management agencies charged with protection of GGOWs in the Sierra Nevada. This protocol is based on expert opinion regarding the effectiveness of survey methods, because no quantitative information on probabilities of detection for these methods was available at the time this protocol was developed. Given the importance of understanding the effectiveness of how well survey methods perform, the goal of our research was to field-test the existing survey methods to estimate both probabilities of detections for the methods, and probabilities of occupancy for survey sites across YNP. These results will be of utmost importance to managers charged with protection of GGOWs in the Sierra Nevada because they will provide a quantitative and scientifically-defensible basis for determining how much survey effort (# of surveys) should be targeted at a survey site to meet desired confidence levels of detection. This is important to understand as surveys are commonly used to determine if mitigation measures are necessary if a species is present in a project area where the proposed management activity may have negative effects on the species or its habitat. Additionally, managers are often confronted with limited budgets for field survey work and must weigh competing demands on how best to allocate a fixed number of surveys across multiple potential survey sites. Is it better to do a greater number of surveys at a smaller number of sites, or is it more efficient to conduct a lower number of surveys per site, but survey a larger number of sites? Understanding the probability of detection for GGOW survey methods will allow managers to determine an acceptable level of confidence during the design of survey projects. Surveys are also used to conduct long-term monitoring. Understanding the underlying effectiveness and performance of surveys is necessary to develop defensible monitoring strategies.

Objective #5: Evaluate monitoring options that YNP managers can implement to monitor GGOW occupancy across YNP

Monitoring is often desired to ascertain and track changes in the conservation status and population trends of wildlife species of conservation concern. The design of a scientifically-defensible monitoring plan requires careful consideration of the specific target metrics that will be monitored (e.g., occupancy, survival, reproduction, population trend), identification of desired levels of change that are to be detected, identification and evaluation of survey methods to be used to gather the data, and statistical evaluation of sampling designs to estimate the statistical power of monitoring design options (Thompson et al. 1998). Once the decisions on design criteria are determined and evaluated, then each of the above steps needs to be field-tested through a pilot project, to develop a robust monitoring strategy capable of meeting desired targets. Ultimately, the final monitoring strategy will reflect a balance between the specific desired monitoring information needs identified by managers and the assessment of cost and feasibility to meet the desired information needs.

Occupancy monitoring is one approach for tracking the conservation status of a species over time. In an occupancy monitoring framework, the parameter that is being estimated and tracked over time is occupancy, which is monitored by estimating the proportion of total survey sites that is occupied by the target species over time. From a management and conservation perspective, monitoring the proportion of sites occupied over time provides valuable information on the distribution and abundance of the target species. From a funding perspective, occupancy is generally easier and more economical to measure (i.e., is the species present at a survey site) than are more expensive approaches needed to estimate population size, survival, reproduction and population growth rate (e.g., traditional demographic approaches involving extensive banding or radio-telemetry of individuals over multiple years). For species such as GGOWs that are territorial and pairs maintain exclusive home ranges, changes in the proportion of survey sites occupied over time are closely associated with changes in the territorial bird population size. Thus, monitoring of occupancy for territorial species that maintain exclusive home ranges, such that only one home range can occur in a survey site, can provide a cost-effective option for assessing changes in distribution, and changes in occupancy rates are highly correlated with change in the size of the territorial population.

The goals of our research to meet this objective were to develop and statistically evaluate alternative sampling designs that can be used to monitor GGOW occupancy across time. This work was based on the evaluation of survey methods conducted under Objective #4 described above. Using the probabilities of detection and occupancy estimated from our GGOW survey method field test, we were then able to estimate how sample size (number of survey sites) affects the statistical power of alternative design options to detect various levels of change in occupancy over time. These results are valuable because they provide YNP managers with defensible scientific information that can inform decisions on monitoring design options and associated costs for monitoring GGOWs in YNP.

Objective #6: Develop a predictive model for predicting the distribution of GGOW probability of occurrence and habitat suitability across YNP

Understanding the distribution and habitat associations of a species is a fundamental piece of information for assessing conservation status and developing conservation strategies. While previous studies have documented within home range habitat characteristics and the importance of large diameter, broken-top conifer snags for nest trees and meadows providing foraging habitat for key vole and pocket gopher prey species (Winter 1980, 1986, Beck and Craig 1991, Bull and Duncan 1993, Hayward and Verner 1994, Greene 1995, Rich 2000), no information is available at larger spatial scales to address landscape habitat suitability and the distribution of suitable habitat across YNP. We addressed this information need by modeling GGOW distribution and probability of occurrence at the landscape spatial scale across YNP using program Maxent (Phillips et al. 2006). Maxent is a geographic distribution modeling tool useful for predicting species distribution and probability of occurrence. We modeled the distribution and probability of occurrence of GGOWs across YNP using the data on GGOW occurrence records generated from our surveys conducted at historic and random sites in 2008-2009 (see Objectives #1 and 3# above). These occurrence records provided a current set of location records collected from across the entire range of GGOWs in YNP, and thus were appropriate for modeling and assessing the current distribution and probability of occurrence to meet this study objective. These results are significant in that they provide the first landscape assessment of the distribution of GGOW habitat by suitability class. This information provides managers with defensible information on GGOW habitat suitability that can be used to identify priority areas for GGOW management and to refine assessment of potential impacts from management activities based on the habitat suitability value of the area. For example, managers may decide to accept lower levels of potential negative effects from management activities at high suitability sites, whereas there may be a greater tolerance for risk at sites with very low predicted habitat suitability.

METHODS

Overview of Project Schedule

This report provides a summary of all work funded by Yosemite Conservancy for the years 2007-2009. In addition we include results from our work conducted during 2004-2006 and during 2010. Thus, this report provides a summary of all GGOW research conducted between 2004-2010 in YNP.

In 2004-2006 and 2010 we focused our research on surveying historic GGOW sites in YNP. Surveys conducted in 2004-2006 established baseline occupancy at historic GGOW sites and facilitated our 2007-2009 surveys. In 2010 we continued surveys at historic sites to maintain a consistent monitoring effort over the study period to provide data on annual variation in occupancy across years. Full details on all research methods are provided below in the METHODS section.

Our work in 2007 focused on conducting standardized nocturnal broadcast-meadow search surveys at sites within YNP that had historic records of GGOWs. Our goal was to continue quantitative evaluation of GGOW survey methods to develop scientifically-defensible methods on which to base future inventory efforts and to develop monitoring strategy options. Our second primary goal in 2007 was to focus efforts on capturing GGOWs to collect blood and feather samples necessary to meet the short term objectives of conducting the population genetic analysis, to screen blood samples for West Nile Virus antibodies, and to collect oral swabs to test for Trichomoniasis. Additionally, a lab component of our 2007 work focused on identifying and screening microsatellite markers necessary to conduct the population genetic analyses.

Our work in 2008 and 2009 focused on two primary field goals and three laboratory goals. Our first field goal across these two years was to significantly expand the number of meadow systems that we surveyed in order to have an adequate sample of both historic and randomly-selected meadow samples to meet our short-term objectives of assessing GGOW conservation status, evaluating the survey protocol and developing monitoring strategy options. A secondary field goal in 2008 was to collect additional feather and blood samples of GGOWs to increase our sample size for the population genetic analysis. Our first lab goal during this period was to complete the population genetic analyses and disease screening assessment from the feather and blood samples collected in 2007-2008. Our second lab goal was to complete the analysis of the survey protocol evaluation to estimate probabilities of occupancy and probabilities of detection, and to generate an assessment of monitoring strategy design options. Our final lab goal was to develop a predictive habitat model for GGOWs in YNP. These final two lab goals were dependent on the survey field data collected in 2008 and 2009.

In addition to meeting the above-stated short-term objectives, the work conducted and feather/blood samples collected in 2007-2009 also contributed to the long-term research objectives of our research program, because these data will be used to evaluate non-invasive methods for using molted feathers to genetically identify individual GGOWs, data which can then be used for demographic monitoring purposes to monitor GGOW survival, dispersal, and population trends.

Specific Methods

Field Surveys

We conducted standardized protocol surveys at historic sites in YNP during each year in 2004, 2005, 2007, 2008, 2009 and 2010. We conducted standardized protocol surveys at random sites in YNP during 2008 and 2009. We sampled at both historic and random sites to assist us in meeting the multiple objectives of the overall project. First, we needed to identify as many sites occupied by GGOWs as possible to facilitate efficient collection of blood and feather samples to meet our population genetic and disease screening study objectives. Thus, we focused on surveying sites where GGOWs have been documented based on past research and wildlife sightings. We consulted with Jeff Maurer (YNP wildlife biologist, personal communication) to guide us in the identification of sites with documented GGOW records. We designated these sites as “historic sites” for our purposes as they were selected based on past records of GGOW occurrence.

While surveying at historic sites likely provided the most efficient approach for locating GGOWs for genetic and disease sampling, we also wanted to address our additional study objective to field test the effectiveness of GGOW survey protocols. Meeting this protocol-testing objective required sampling across a broad range of conditions over which the protocol would be applied during a typical management inventory or monitoring effort. Thus, we desired to test the protocol at a wider sample of sites in conjunction with the historic sites. This was to address the concern that biased results could occur if we only tested the protocol at known historic sites where the detection rates of GGOWs could potentially be different from what we might observe across a wider range of site conditions. To address this concern we identified a set of potential additional sites to sample across YNP and then randomly selected a sample from these sites where we tested the survey protocol. To select random sites for sampling, we developed a sampling frame of all potential survey sites across YNP based on elevation and habitat-vegetation type rules provided by Jeff Maurer (YNP wildlife biologist, personal communication). Using these rules and the vegetation coverage provided by YNP (*yose_97veg_final_poly.shp*) we considered 3 vegetation types (seasonal to intermittently flooded meadows, semi-permanently and permanently flooded meadows, and upland herbaceous) as suitable GGOW habitat and used an upper elevation limit of 2485m (8200ft). This resulted in a total of 1125 patches of suitable habitat. We then uniquely numbered each individual patch of suitable habitat, and calculated the total amount of suitable habitat within a 0.8-km radius circle around the centroid of each individual patch of suitable habitat. We used a radius of 0.8-km as it was approximately the average size of a breeding season home range of GGOWs in YNP based on previous telemetry work (Winter 1986, van Riper and van Wagtendonk 2006). We then identified all of the circles that contained a minimum of 10 acres of suitable habitat as potential GGOW sites. Previous work suggested a minimum amount of 14 acres of suitable habitat was necessary to support a pair of GGOWs. We decided to reduce the minimum amount to 10 acres to capture the possibility that some sites with less than 14 acres may support GGOWs given uncertainty surrounding this lower bound. This exercise resulted in a total of 580 possible sample sites. The final result of this exercise was to create a sampling frame of 580 possible GGOW sites across YNP. We then used a random number generator to select our random sample from this sampling frame that we then surveyed for GGOWs.

The standardized protocol that we field-tested consisted of 4 visits/year to each sample site. Three visits were nocturnal broadcast surveys (NBS) and the fourth visit was a diurnal meadow search (MS). The objective of the surveys was to estimate occupancy at each site. Although not a specific objective of our study, we also opportunistically recorded information on GGOW reproduction at each site if we located nests or detected young owls. While the existing Beck and Winter (1991) protocol requires a total of six visits per year (5 NBS, 1 MS), our pilot testing of our broadcast surveys at the beginning of our study suggested that we had fairly high probabilities of detection. Thus, we decided to reduce the number of broadcast survey visits per year from five to three. This was a scientifically-defensible decision because we were able to meet our objective of estimating probabilities of detection and occupancy, which require multiple visits per year to separately estimate. Additionally, by reducing the number of visits to each site, we were then able to visit a larger number of sites with lower survey effort per site. This resulted in higher cost efficiency, which benefitted this and future research efforts.

NBSs were conducted using a 10-minute track of GGOW calls at a series of fixed-location survey points established within each site. The network of survey points was established around the perimeter of the meadow habitat at each survey site with the goal of providing 100% survey coverage of each site. Individual survey points within the network were spaced at approximately 400 m, or closer if tighter spacing was needed to provide 100% meadow coverage. Based on pilot-testing at the beginning of our study we estimated that the 400m spacing was reasonable as most of our GGOW detections were within 200-300m of our observers. A team of two observers conducted each survey. We used two observers because of safety concerns for our field technicians working at night in remote locales, and also because having two observers likely increases the probability of detecting the range of GGOW vocalization types as compared to a single observer. NBS were conducted between April-August each year. NBS were conducted between dusk and dawn (1 hour after sunset or 1 hour before sunrise), with most surveys conducted between dusk and 0200 hours. NBS were not conducted if it was raining or snowing, or if winds were greater than 5 mph, because precipitation and wind would make it difficult or impossible to detect GGOW vocal responses. Surveys were conducted at a site until a GGOW was detected or all of the survey points at the site had been surveyed using the 10-minute protocol. If a GGOW was detected, we recorded the type of detection (visual, vocal, both), the number and sex of each bird, the type of vocalization (e.g., male territorial series call, female whoop, juvenile begging call, etc.), and the estimated distance and direction of the detection from the survey point.

Our goal was to distribute the three NBS/year across the GGOW breeding period with the first survey conducted during the courtship period (April-May), the second survey conducted during the incubation/nestling period May-July), and the third visit to correspond with the fledgling dependency period (July-August). The timing of reproduction varied annually for GGOWs and the timing of each reproductive period varied across years. Additionally, due to heavy spring snow depths, we were not able to gain access to some of the high elevation sites until May/June in some years. Because of these factors, our survey effort was not always evenly distributed across each of the periods in some years, although our effort was broadly distributed across the entire breeding period in all years and across the study. Thus, we were able to sample across the range of annual and within-season conditions that may contribute to variation in survey protocol effectiveness. A copy of the field survey data collection form is provided in APPENDIX I.

MS surveys were conducted once per year at each site. MSs consisted of 1-2 observers walking the edge of the forest-meadow ecotone, visually searching the area within approximately 50-100 feet on either side of the forest-meadow edge to locate feathers, pellets, or sign to establish GGOW occupancy/use of the site. Because GGOWs commonly hunt along meadow edges throughout the breeding period, molted feathers and pellets are frequently located around favored perches and foraging areas within each site. Feathers and pellets accumulate across the breeding season between April-August. Therefore, MSs were conducted in late-August through September to coincide with the time when feathers and pellets may be most abundant. Observers searched the entire meadow edge at each site to locate feathers and pellets. Observers recorded the location of all feathers and pellets using a hand-held GPS unit and collected and stored them in labeled envelopes.

Population Genetics, Disease Screening and Capture Methods

It was necessary to capture GGOWs at occupied sites to collect blood and feather samples to address our study objectives regarding the population genetic status of the YNP GGOW population and to screen for West Nile Virus exposure and Trichomoniasis. Blood samples were required for the population genetic analyses (nuclear microsatellite genotypes and mitochondrial sequence). We conducted most of our capture efforts during 2007 and 2008. Given the State-endangered conservation status and small population size of GGOWs in YNP and the central Sierra Nevada, and concerns regarding any possible negative effects of capture and handling, we developed and implemented a very specific protocol documenting our methods. The detailed capture, handling, and health assessment protocol, along with the experience and qualifications of our research team members, is documented in APPENDIX II. Full details on the micro-satellite development, population genetic analyses, and disease screening are documented in our publications on these issues (Hull et al. 2007, Hull et al. 2010a, Hull et al. 2010b). A copy of the banding data collection form is located in APPENDIX I.

Estimation of Probabilities of Detection and Occupancy

We conducted the formal analysis of the field survey protocol data set in winter-spring 2010 to estimate probabilities of detection and occupancy. We then conducted the simulation modeling of monitoring design options based on the results from the survey data analyses (described in next section). All analyses were conducted with Jim Baldwin, Research Statistician with the Pacific Southwest Research Station in Albany, California. We analyzed all survey data collected using the standardized protocol between 2004-2009 at both historically occupied and randomly selected sites on both National Forest Service (Stanislaus National Forest - SNF) and National Park Service (Yosemite National Park - YNP) lands in order to increase our sample sizes and also to assess if the protocol performs consistently across a range of site conditions. The survey data, consisting of 3 nocturnal broadcast surveys and one diurnal meadow search at each site, were analyzed using Proc NLMIXED in SAS version 9.1 to estimate the probabilities of detection (P[d]) for the survey protocol and to assess whether there are differences in P[d] across the four categories of sites (YNP-random sites, YNP-historical sites, SNF-random sites, SNF-historical sites). This design is necessary as there may be differences in P[d] associated with both ownership and whether a site has had GGOW occupancy at some time in the past (historic sites) versus random sites (not ever surveyed). A total of 22 historic sites and 50 random sites were sampled in YNP for protocol testing, while 17 historic sites and 39 random sites were sampled on the Stanislaus National Forest. Random sites were generally only surveyed in 1 year whereas historic sites were surveyed in nearly each year.

Occupancy Monitoring Design Options

In order to assess occupancy monitoring design options we conducted simulation modeling to estimate the power of alternative design options to detect 10%, 20% and 30% declines in GGOW occupancy over a ten year period across YNP. These simulations provide estimates of the sample sizes required to detect a given decline with known power across a range of input parameters. Simulation models were developed using the program SAS to generate power and sample size estimates. We used overall P[d] estimates for the 3 broadcast and 1 meadow search survey protocol for these simulations, with a P[d] = 0.500 for a single broadcast survey visit and a P[d] of 0.900 for a single meadow search. We used an initial probability of occupancy (P[o]) of 0.600. These estimates of P[d] and P[o] are based on the results from our random GGOW surveys sites and provide the best currently available estimates of these parameters that are representative of GGOWs across YNP. We ran simulations for three levels of alpha: 0.05, 0.10, and 0.20. Alpha values are for one-sided tests to detect population declines. We had 9 combinations of population decline and alpha levels, and we ran each of the 9 combinations across the number of monitoring sample sites ranging from 10-200 at increments of 10. We ran 1,000 simulations for each combination of alpha level, level of population decline and sample size to generate an estimate of the power for each sampling design option.

Evaluation of Passive Integrated Transponders for GGOW Demographic Studies

We explored the effectiveness of reading Passive Integrated Transponder (PIT) tags under field conditions using two initial laboratory tests, followed by field tests. First, to simulate the range of possible behaviors that an owl might exhibit when taking a lure from the plate-reader, we manually moved PIT tags through the field of detection at slow-to-fast rates, and at different heights from the plate-reader. This was done to simulate the types of approaches an owl might make, ranging from a faster “fly-by” grab to a slower “plunge-pause” attack. We worked with BioMark, the manufacturing company to maximize the reading distance and sensitivity of the plate-reader. Our second test involved fitting a live, captive, free-moving Great Horned Owl with the same PIT tag-color band unit that we use on GGOWs to determine how well the PIT tags were read when on a live bird. A lure was placed on the reader-plate and, similar to how sampling would be conducted in the field for GGOWs, the Great Horned Owl was allowed to fly in to capture the lure. Based on these laboratory tests we then field-tested the plate-reader by placing in the field at six GGOW territories where birds had been marked with a PIT tag. The six field trials were conducted at active nest sites (3 trials) and at four meadow foraging locations near hunting perches (3 trials). In each trial the plate-reader was placed within 20-30 m of the nest or perch and baited with a live mouse.

Habitat Modeling

We developed a habitat suitability model to estimate the distribution and abundance of GGOW habitat across YNP. We used program Maxent (version 3.3.3., Phillips et al. 2006) to model GGOW distribution and habitat suitability. Maxent is a geographic distribution modeling program that generates a spatial probability distribution using GGOW locations and habitat data. The spatial probability distribution can be interpreted as a probability of occurrence or suitability for GGOWs (Phillips et al. 2006, Jepsen 2010). We used the GGOW locations from our 2008-2009 surveys at historic and random GGOW survey sites to develop a breeding season distribution and habitat suitability model for GGOWs in YNP. Full details on modeling methods are presented in APPENDIX III. In overview, we randomly selected a single detection location at each site where GGOWs were detected on surveys and summarized topographic and habitat variables within a 200-m radius circle around each GGOW location. Maxent determined the best model and scored each 200-m circle with a continuous probability of occurrence value between 0-100. We used a GIS moving window application to generate a continuous probability of occurrence surface across the range of the GGOW in YNP. We lumped the continuous values into 10% probability classes and generated a map of GGOW distribution and predicted probability of occurrence across YNP. We then assessed the percent contribution of the topographic and habitat variables to the best model generated by Maxent.

RESULTS

Field Surveys: Overview and Annual Results

Overview: A total of 23 historic sites were surveyed to protocol or visited in one or more years between 2004-2010. A total of 52 random sites were surveyed to protocol or visited during 2007-2010. An additional single random site was visited once but not surveyed to protocol because it was a permanently flooded meadow.

2004: Sixteen sites were surveyed to protocol in 2004. GGOWs were detected in 11 of 16 sites. Of the 11 occupied sites, pairs were detected at 9 sites and single owls at the other 2 sites. A single nest producing 2 young was documented.

2005: Twenty-three sites were surveyed to protocol in 2005. GGOWs were detected at 17 sites, with pairs documented at 6 sites and single GGOWs detected at the remaining 11 sites. No nests or young were observed during 2005, indicating that this was a very low reproductive year for GGOWs in the Sierra Nevada.

2006: A total of 12 sites were visited in 2006. Eight of the sites were occupied, with pairs detected at 3 sites and single GGOWs documented at the other 8 sites. Two nests were located. We did not conduct protocol surveys during 2006. Rather, our research focus was on attempting to locate core areas and nests at historic GGOW sites to facilitate capture of owls for blood-population genetic sampling in 2007. Thus, occupancy in 2006 is based on whether we observed GGOWs at these sites.

2007: Twenty-four sites were surveyed to protocol during 2007. We also conducted reconnaissance visits to an additional three sites where GGOWs have been reported. We detected GGOWs at 15 of 24 sites surveyed to protocol and not at any of the 3 sites that were visited. Nesting was documented at 11 sites based on presence of an active nest or the presence of fledglings during the post-fledging dependency period. We detected 16 fledglings, three of which appeared to have died prior to dispersing. We documented five cases of GGOW mortality in Yosemite during 2007, plus 2 additional cases on USFS lands. None of the five GGOWs that were reported dead from YNP had been captured or handled.

2008: Twenty historic meadow sites and 33 random meadow sites were surveyed using the standardized survey protocol between April and September 2008. A total of 248 broadcast, meadow search, and follow-up searches were conducted in YNP during 2008. We detected GGOWs at 19 of 20 (95%) of the historic sites and 20 of 33 (61%) random sites for a total of 39 YNP sites with GGOW detections. Of the 19 historic sites with detections, GGOWs were detected at 16 sites (84%) on both the broadcast and meadow searches, at 2 sites (11%) only on broadcast surveys, and at one site (5%) only on a meadow search. Of the 20 random sites with detections, GGOWs were detected on both broadcast and meadow searches at 13 sites (65%), only on broadcast surveys at 2 sites (10%), and only on meadow searches at 5 sites (25%).

In contrast to 2007 when we focused on finding nests to facilitate capture of GGOWs, our 2008 work was focused on conducting more extensive surveys across a much larger number of sites. Correspondingly, we only located nests during our surveys or during limited nest searches conducted opportunistically as time allowed. We documented 3 nests in YNP during 2008. Of these 3 nests, one failed, one fledged a single young, and the third fledged 2 young.

We did not document any cases of GGOW mortality in YNP during 2008. We did document two cases of GGOW mortality due to vehicle collisions outside YNP. An adult GGOW was killed by a vehicle collision along Hwy 108 on the Summit Ranger District, Stanislaus National Forest (Adam Rich, pers comm., Stanislaus NF). A second GGOW was hit by a vehicle near Midpines and was reported to us by Stanislaus National Forest biologists (Roy Bridgman, pers. comm., Stanislaus NF). We located this individual (adult female) and transported her to the Lindsay Wildlife Museum in Walnut Creek, California, for treatment. She had apparently been injured and on the ground for a minimum of 4 days prior based on accounts from the biologists and reports of the fire fighters who made the initial discovery. Due to extensive broken wing damage and poor physiological condition, likely associated with how long the bird had been injured on the ground, the bird had to be euthanized at the Lindsay Wildlife Museum under the care and direction of Dr. Nancy Anderson. We then transferred the carcass to UC Davis for necropsy by Dr. Leslie Woods. Dr. Woods concluded that this individual exhibited no signs of disease as had been reported in other GGOWs from the Sierra Nevada.

2009: Fourteen historic meadow sites and 12 random meadow sites were surveyed using the standardized survey protocol between April and September 2009. We detected GGOWs at 12 of 13 (92%) of the historic sites and 7 of 12 (58%) random sites for a total of 19 of 25 YNP sites with GGOW detections. Of the 13 historic sites with detections, GGOWs were detected at 9 sites (84%) on both the broadcast and meadow searches, at 1 site (11%) only on broadcast surveys, and at one site (5%) only on a meadow search. Of the 7 random sites with detections, GGOWs were detected on both broadcast and meadow searches at all 7 sites (100%).

In contrast to 2007 when we focused on finding nests to facilitate capture of GGOWs, our 2009 work was similar to 2008 in that we focused on conducting more extensive surveys across a much larger number of sites. Correspondingly, we only located nests during our surveys or during limited nest searches conducted opportunistically as time allowed. We documented 4 nests in YNP during 2009. Of these 4 nests, one failed, two fledged a single young each, and one nest fledged two young.

We documented two cases of GGOW mortality during 2009. In both cases we found a pile of GGOW feathers and could not determine the cause of death. The first case was documented in YNP on 21 May 2009 and the second was located on the Stanislaus National Forest on 7 August 2009.

2010: Sixteen sites were surveyed in 2010. We conducted a single, non-protocol survey at the New Alder site and documented a nest that produced 2 young. The other fifteen sites were surveyed to protocol. GGOWs were detected at 14 of the 15 sites. Of these 14 occupied sites, pairs were documented at 7 sites and single owls at 5 sites, with occupancy at 2 sites determined by the presence of molted feathers. Nesting was documented with the observation of two juveniles at one of the 14 occupied sites.

Population Genetics, Disease Screening, and Capture Methods

***Collection of DNA* Samples:** We captured and sampled a total of 32 GGOWs during this study. Seventeen of these birds were sampled in YNP and 15 were sampled from the Stanislaus National Forest. All GGOWs captured and sampled by PSW and UC Davis personnel over the study appeared healthy and vigorous and no apparent signs of disease or poor health were noted. We used the 26 samples collected in 2006 and 2007, along with 3 additional samples contributed by colleagues with the California Department of Fish and Game, to conduct the population genetic and disease analyses. In total, we had 29 samples available from the central Sierra population of GGOWs to use in the population genetic analyses. Our collaborators from other study sites provided 25 samples from southern Oregon, 22 from eastern Idaho, 9 from northern Oregon, and 8 from western Canada. In sum, we had 93 total usable samples available for our population genetic analyses. Along with the original 26 samples, the additional six samples collected in 2008 and 2010 are being used in further assessment of potential DNA-based monitoring methods.

Population Genetic Analyses: GGOW specific microsatellites were identified in collaboration with Genetic Identification Services (Hull et al. 2007). This collaboration has resulted in the creation of four novel microsatellite (highly variable genetic markers used in population identification and parentage analysis) enriched libraries. We developed 37 microsatellite primers that were used to conduct the population genetic analyses, investigate individual identification from feather samples, and that could also be used for additional genetic analyses in multiple Strix species (Hull et al. 2007). Further screening and evaluation of the primers resulted in 30 microsatellite primers that we used in the population genetics study.

Based on both mitochondrial and microsatellite data sets, our population genetic analyses indicate that the central Sierra Nevada population of GGOWs is genetically unique and distinct from the next closest known geographical population in southern Oregon and other western populations in northern Oregon, Idaho, and western Canada (Hull et al. 2010). The magnitudes of genetic differences observed between the Sierra Nevada population and Pacific Northwest populations are equal or greater than those documented among recognized subspecies of many North American raptors. Further, the results document that the Sierra Nevada population has a low estimated effective population size and the lowest levels of genetic diversity across the populations that were sampled in this study. Additionally, the Sierra Nevada population appears to have experienced significant genetic bottlenecks. Collectively, these results indicate that the Sierra Nevada population of GGOWs is a distinct evolutionary lineage from populations to the north and that conservation genetic risk factors (e.g., low effective population size, unique genetic structure, low genetic diversity) should be addressed in the development of management and conservation strategies for this population (Hull et al. 2010).

Our preliminary test of using DNA from molted feathers collected during meadow searches to identify individual GGOWs was partially successful in that we were not able to amplify DNA from the molted body contour feathers but that we were able to amplify DNA from 6 flight feathers collected from a GGOW carcass that had been exposed to the environment (Hull et al., unpublished data). These results suggest that DNA can be amplified from feathers that have been exposed to the environment for an extended period of time. Importantly, there are also promising alternative DNA extraction and amplification methodologies becoming available that may lead to future successes in using these microsatellite markers on molted feathers.

Disease Sampling Results: We collected oral swab samples for Trichomoniasis testing from each of the eighteen GGOWs captured in 2007. All samples were screened at the Veterinary Medical Teaching Hospital at the University of California, Davis. All eighteen samples were negative for Trichomonias.

Of the 29 blood/genetic samples available for the central Sierra population, we were able to obtain adequate samples to test for West Nile Virus antibodies in 22 individuals (samples sizes: 2005 = 1; 2006 = 2; 2007 = 19). All 22 individual samples tested negative for WNV antibodies (Hull et al. 2010).

Estimation of Probabilities of Detection and Occupancy

We estimated the probability of GGOW occupancy at historic sites as 0.944 (SE + 0.058) in 2007, 0.999 (SE = 0.211) in 2008, and 0.981 (SE = 0.223) in 2009. At random sites, which were only surveyed in 2008 and 2009, we estimated probability of occupancy as 0.612 (SE = 0.089) in 2008 and 0.600 (SE = 0.147) in 2009. These results indicate that GGOW occupancy at historic sites is high and nearly all sites were occupied. The results from the random sites suggest that about 60% of the sites are estimated to be occupied by GGOWs. This is an interesting result and suggests that there may be more GGOWs distributed across YNP than previously estimated.

Single survey-visit estimates for probability of detection (P[d]) at historic sites were 0.668 (SE = 0.035) for broadcast surveys and 0.839 (SE = 0.047) for meadows searches (TABLE 1). At random sites, single-visit P[d] estimates were 0.515 (SE = 0.065) for broadcast surveys and 0.895 (SE = 0.70) for meadow searches. These numbers are relatively high single survey-estimates for surveys of wildlife species and indicate that both methods are effective for detecting GGOWs, particularly the meadow search method.

Using the P[d] estimates we then estimated what the probability of detection would be for various combinations of broadcast surveys and meadow searches. These estimates indicated that an overall P[d] would be 0.95 for a 1 broadcast survey and 1 meadows search combination, 0.98 for a 2 broadcast survey and1 meadows search combination, and 0.99 for a 3 broadcast survey and meadow search combination (TABLE 2). Given that the current GGOW protocol (Beck and Winters 2000) used by management agencies requires 5 broadcast surveys and 1 meadow search per year, our results provide a scientifically defensible basis for reducing survey effort by 50-60%. This will result in reduced potential disturbance to GGOWs, significant cost-savings to fund inventory and monitoring efforts, and reduced safety risk to field personnel who must conduct the nocturnal broadcast surveys. From an inventory and monitoring perspective, these results suggest that for a given cost, we can survey 2-3 times more sites with a 2 or 3-visit protocol as compared to the current 6-visit protocol used by managers. Conversely, the same number of sites could be monitored for 1/3 to ½ of the cost. This ability to survey more sites, with lower effort per site, will be important for future long-term monitoring designs and objectives as this larger sample size of survey sites will improve the precision of our estimate of the number of occupied sites over time, which is the parameter of interest.

Occupancy Monitoring Design Options

Results from our simulation modeling indicate that power is low to detect 10% and 20% declines in occupancy over a 10 year period across each of the three alpha levels and across samples sizes ranging up to 200 (TABLE 3). However, designs targeted to detect 30% declines in GGOW occupancy have generally high power across all alpha levels and >90% power can be obtained with samples size of about 40-50 sites per year. These results provide the basis for designing future monitoring options. We focused on a range of reasonable input parameters to investigate this range of options. Additional simulation modeling work can be conducted to explore other combinations of input parameters as defined by managers, regulators, and decision-makers who are interested in comparing alternative monitoring design options.

Evaluation of Passive Integrated Transponders for GGOW Demographic Studies

In 2007 we evaluated the performance of the PIT tag reader-plate. We conducted approximately 50 trials of manually passing the PIT tag-color band over the reader-plate at varying speeds and heights simulating the range of conditions we would expect to encounter with foraging GGOWs in the field. PIT tags were successfully read on all passes within about 1.5 ft. of the plate. We conducted 10 trials with the Great Horned Owl. PIT tags were successfully read on all of these trials. Both of these results indicate that PIT tags can be reliably recorded in the field and support further use of PIT tags for addressing demographic research and monitoring questions.

In 2008, we field tested the PIT tag plate-reader at six sites (3 nests, 3 meadow hunting perches) where owls had been captured and marked with a PIT tag in 2007. We detected and successfully read the PIT tags on owls at two sites (TABLE 4). At three sites the mouse was not disturbed and at the fourth site the mouse had its head eaten by an unknown predator. It was unlikely a GGOW ate the mouse at this site because the owl would have carried-off the mouse.

Our testing suggests that PIT tags may be a feasible method for collecting demographic information on GGOWs. However, it will be labor-intensive and involve capture of GGOWs to mount PIT tags. Therefore, we recommend that PIT tagging be suspended as a monitoring option pending full evaluation of the effectiveness of non-invasive monitoring techniques.

Habitat Modeling

We used program Maxent to develop a predictive distributional and habitat suitability model for GGOWs across YNP based on breeding period observation records we recorded during our 2008-2009 surveys (see APPENDIX III for modeling details). Results indicated that high suitability areas are extremely rare across YNP, with only 0.8% of the habitat rated in the 80-100% probability classes and 1.4% in the 60-79% probability classes (FIGURE 1, TABLE 4). Wet meadow habitat areas made the greatest contribution (76%) to the total model as measured by relative increase in regularized gain (TABLE 5). While wet meadows strongly predicted occurrence of great gray owls, several habitat types (barren, other, montane hardwood, sub alpine conifer, and shrub) were found to have strong negative correlations with owl occurrence and contributed 14% to the model. Elevation accounted for 4% of model contribution and the remaining 6% was distributed evenly amongst the remaining 11 habitat variables. Response curves based on individual variables and model results indicated that relatively flat, wet meadow areas surrounded by medium-to-dense upper montane conifer forest types between the elevation of 2000 and 2400 meters were most predictive of owl presence. Riparian, grassland, and aspen vegetation types, though contributing only a small amount to the overall model, all showed positive correlations with owl presence.

DISCUSSION

Our 2007-2009 research was highly successful relative to meeting project objectives and generating new information to address several of the key information gaps for GGOWs in the central Sierra Nevada. In addition, our 2004-2006 and 2010 survey results contributed to our focused efforts in 2007-2009. Our population genetic results addressed the long-standing question regarding whether the central Sierra Nevada population of GGOWs is genetically unique. The results of the population genetic analyses indicate that the central Sierra Nevada population of GGOWs is genetically unique and warrants designation as a distinct sub-species. In addition to increasing the basic scientific knowledge base on the evolution of GGOWs, these results clarify a fundamental conservation issue for this population of GGOWs. These findings will undoubtedly lead to increased conservation and management focus on this sub-species.

This increased focus will generate increased demand for information on the status and population trends of this sub-species by management and regulatory agencies, and interested publics. The other components of our research provide scientific direction and basis for future inventory and monitoring efforts, and provide a foundation for addressing the longer-term fundamental questions regarding GGOW population trends and habitat quality issues (i.e., is habitat associated with variation in survival and fecundity; are there source-sink population dynamics operating between National Park Service and National Forest lands).

The results from our population genetics assessment also further highlights the importance of YNP to the conservation of this distinct sub-species of GGOWs as the majority of known historic occupied sites are distributed within YNP. Further, our survey results from random sites sampled across YNP indicate that there are additional occupied sites distributed across YNP, suggesting a larger population within the Park than had previously been estimated. This provides further evidence that the majority of GGOW sites and population, and the core geographic distribution, in the central Sierra Nevada is contained within YNP.

Our 2007-2009 survey results and occupancy analyses indicate that GGOWs occupy nearly all of the historic sites that were identified in YNP. We have now been conducting annual surveys at 20 or so historic sites between 2004-2010. These sites have shown high and consistent annual occupancy across the years of this study with greater than 90% of sites occupied in each year based on the naïve criteria of whether we detected an owl at a site in each year. Additionally, our modeled occupancy estimates suggest occupancy rates of about 95% for 2004-2009 at the historic sites. Together, all lines of evidence suggest that there is high and constant GGOW occupancy at the majority of 20 or so historic sites we have been monitoring.

Of particular note, we detected GGOWs at 27 of 45 random meadow sites surveyed during 2008-2009. In addition, we detected GGOWs at 1 of 5 random sites sampled in 2005 or 2006. Occupancy modeling estimated that probability of occupancy was about 60%. These results suggest that there are additional GGOW pairs distributed across YNP and the population is larger than previously thought. These results, in conjunction with our habitat modeling work, may allow us to generate a more refined estimate of GGOW population size in YNP pending further development of methods to refine estimates of the potential number of home ranges that could be present in YNP given the fragmented and dispersed nature of meadow distribution across the entire Park.

Although not a primary focus of our research objectives, we did anecdotally record all information on nest locations and reproduction that we observed during each year. We hoped that we would detect annual variation in GGOW reproduction, weather, and prey populations such that our evaluation of survey methods would be conducted across a range of possible environmental conditions. We think that the environmental conditions we experienced over the duration of the study do capture a representative spread of the range of conditions and annual variation. We documented relatively high reproduction in terms of reproductive pairs and total number of fledglings produced in 2007. The high reproduction was most likely a result of favorable weather and prey conditions. The spring of 2007 had little precipitation and early snow melt-out at the higher elevation sites. Although we did not directly sample prey, it anecdotally appeared to be a high prey year based on the presence of abundant fresh vole sign (fresh runways after snowmelt) in the occupied meadow systems. In contrast, reproduction was lower in 2008 and 2009. Additionally, no reproduction was recorded at the historic sites that were surveyed in 2005. We now have conducted standardized surveys using broadcast and meadow search methods across multiple years to capture a range of environmental conditions, ranging between a year with no documented GGOW reproduction (2005), through a year with high reproduction (2007). Thus, we have confidence that the survey results and recommendations are applicable across the current range of annual variation in reproduction and environmental conditions that occur within the study area.

Our research represents the first quantitative assessment of the effectiveness of GGOW survey protocols that has been conducted. Our results suggest that both broadcast and meadow search methods are effective for documenting occupancy of GGOWs. Factors that contribute to this effectiveness include use of a high quality broadcast system that is capable of clearly projecting clean recordings of GGOW calls. This is important because key GGOW calls such as the male series are very low frequency and high quality equipment allows for such calls to be clearly broadcast. Second, observers must have adequate hearing ability to detect the full range of frequencies associated with the variety of GGOW calls. For example, we found that one of the observers in the early year of the study could not hear the low frequency call of a male GGOW at distances of greater than 200-300 meters as compared to his field partner. Third, we recommend use of a standardized recording for all survey work to provide consistency. Our survey track is 10 minutes long and contains a series of territorial, aggressive and contact calls spaced throughout the track with listening periods in between call series. Although other combinations of call types and call sequences could be used, we found that our survey track resulted in high probabilities of detection and recommend that if other survey tracks are developed that they also be field-tested to evaluate their effectiveness. Fourth, field surveyors need to receive training on GGOW and other owl calls so they can detect the owls. Additionally, field surveyors need to be trained on how to search for and identify GGOW feathers that are encountered during meadow searches. In sum, we conclude that standardized survey protocols and methods, in conjunction with thorough training for field surveyors, hearing tests for surveyors, and use of high quality broadcast equipment are key components for effective and efficient future survey efforts. The high success rates we documented may not be attainable if any of these factors are ignored or inadequately addressed.

Using our estimates of single-visit P[d] for broadcast and meadow search methods we were able to estimate the overall P[d] for various combinations of visit numbers and types. These results indicate that efforts to determine GGOW occupancy within YNP sites can be reduced by 50-67%, with the ultimate amount determined by the level of confidence that YNP wildlife managers want to accept in their future inventory and monitoring efforts. For example, an overall survey combination of 1 broadcast and 1 meadow search has an estimated P[d] of 0.95, whereas adding additional broadcast visits can increase that P[d] to 0.99 for a 3 broadcast and 1 meadows search protocol. In essence, these results suggest that GGOW occupancy should be detected virtually 100% of the time using the 3 broadcast/1 meadow search protocol. Thus, our results can provide scientifically-defensible guidance for managers who must continually evaluate trade-offs between the level of desired confidence in the survey results versus the financial costs associated with each option.

Our simulation modeling of occupancy monitoring strategy design options provides a tool that can be used to estimate the sample size required to detect a desired decline in occupancy with known power across a range of design options. In the series of simulations that is presented we focused on using a survey protocol consisting of 3 broadcast visits and 1 meadow search. We used this protocol for these simulations because of the near 100% P[d] that we estimated from our evaluation of the survey data. The results generated from this tool provide YNP wildlife managers and decision-makers with a scientifically-defensible basis to make informed decisions regarding investment versus return in future monitoring programs designed to track declines in GGOW occupancy across YNP.

MANAGEMENT SUMMARY AND RECOMMENDATIONS

In this report we summarize the work we have conducted between 2007-2009 in YNP that addresses the following short-term objectives:

1. Assess the conservation status of GGOWs in YNP;
2. Assess the population genetic status of GGOWs in the central Sierra Nevada relative to other North American populations;
3. Assess GGOW exposure to West Nile Virus and Trichomoniasis;
4. Evaluate the effectiveness of existing survey protocols for GGOWs;
5. Develop monitoring options that YNP managers can implement if desired to monitor GGOW occupancy across YNP;
6. Develop a predictive habitat model for predicting the distribution of GGOW habitat across YNP.

In addition to the above reported research we have also been addressing several other lines of research that provide value-added benefits to this project and YNP, in addition to contributing towards basic and applied conservation efforts for GGOWs in the broader central Sierra Nevada. First, we have provided extensive distributional records for other owls species detected while conducting surveys for GGOWs. This information provides YNP biologists with valuable records on the distribution of forest owls, which are poorly studied taxa. Second, we have developed a distributional model that identifies and ranks GGOW winter habitat within YNP and across the broader central Sierra Nevada. Eric Jepsen completed this work in 2010 as part of his MSc thesis at the UCD. This work is now being incorporated into fledging discussion among public stakeholder groups interested in developing a conservation plan for GGOW habitat in the central Sierra Nevada. The results from Eric's work provide the only information available to begin discussing prioritization of areas for protection, conservation easements, or purchase and transfer to land management agencies. Third, we have collaborated with Kurt Fristup, a sound engineer with the National Park Service, to conduct an extensive field-test of passive Automated Recording Units (ARUs) for inventory and monitoring of GGOW occupancy, pair status, and reproductive status. These methods were pilot tested in 2008 and fully field-tested in 2009. This work is being conducted as part of Joe Medley's MSc project at UCD. Preliminary results are very promising and we expect that ARUs may provide a completely non-invasive monitoring approach for future inventory and monitoring of GGOWs. We further expect that the ARU approach will have value as a multi-species monitoring approach. As part of his MSc thesis at Humboldt State University, Ryan Byrnes is analyzing the ARU recordings to evaluate their potential use as a multi-owl species monitoring tool. Finally, we have begun exploratory analyses to begin to assess whether genetic techniques and the valuable genetic database we have established can be used to genetically identify individual GGOWs from molted feathers commonly collected during non-invasive meadow searches.

We think it is time to discuss possible future steps to build on the foundation of information that we have collected and to develop a framework to address monitoring and research needs across the range of the Sierra Nevada Great Gray Owl. Specifically, given that this population of GGOWs appears to be genetically unique, we can anticipate increased future demand for valid monitoring information to track population trends. Second, we can anticipate increased demand for information on habitat quality issues that relate to GGOW survival, reproduction and recruitment parameters, and that address possible source-sink habitat quality issues between YNP and the surrounding NFS lands. Our genetic results suggest that there is additional within-population genetic structuring that appears to be associated with YNP versus NFS lands, or possible environmental factors associated with this difference in jurisdiction. We suggest that our work to date provides direction on options to proceed. Our ARU and standard survey work suggests that we can develop cost-effective and scientifically-valid designs for broad-scale monitoring of GGOW occupancy of meadow systems, with the additional possibility that the ARUs may also provide additional information on the specific locations that GGOWs are using within a meadow site, as well as their social (e.g., pair status) and reproductive (e.g., number of fledglings detected) status. While occupancy monitoring will provide an estimate of the number of occupied sites over time, a valid and valuable empirically-derived metric for monitoring population trend, we recommend that we take advantage of the unique opportunity we have to extend our genetic work and determine if we can use the molted feathers collected during occupancy surveys to identify and monitor the survival, reproduction and recruitment of GGOWs. This, in conjunction with habitat characteristics, will allow us to address the critically important habitat quality issues necessary to inform conservation and recovery planning in the central Sierra Nevada.

We have tested and evaluated the basic information pieces to accomplish the above goal. We have tested and evaluated the performance of the survey methods and we have developed the genetic markers to facilitate development of the molted feather identification method. The piece to be completed requires a focused effort and associated funding to fully develop, test and validate the method for amplifying DNA from the molted feathers. We strongly recommend that this be a top priority for subsequent investment and research. For example, with a validated feather method we can envision a possible monitoring design that would use non-invasive ARUs across a single visit at each site to determine occupancy and reproduction, coupled with two meadow searches early and late in the breeding period to collect feathers for genetic sampling and subsequent mark-recapture analysis to estimate lambda, apparent survival, and recruitment patterns and dynamics. This would not only provide the future anticipated GGOW monitoring information but would also be a basic scientific advancement in the development and synthesis of novel methodologies to address important management and conservation issues.

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TABLE 1. Single-visit detection probability estimates for broadcast and meadow search surveys for Great Gray Owls at historic and random sites in Yosemite National Park, 2004-2009.

Site Status	Survey Type	Estimate	Standard Error	Approximate 95% Confidence Intervals	
				Lower	Upper
Historic	Broadcast	0.668	0.035	0.600	0.736
	Meadow Search	0.839	0.047	0.747	0.931
Random	Broadcast	0.515	0.065	0.388	0.642
	Meadow Search	0.895	0.070	0.756	1.000

TABLE 2. Estimated probability of detecting Great Gray Owls at occupied sites with various combinations of broadcast surveys (1-3 visits) and a single meadow search at historic and random sites in Yosemite National Park.

Number of Surveys		Historic	Random
Broadcast	Meadow Search		
0	1	0.834	0.894
1	0	0.668	0.515
2	0	0.890	0.765
3	0	0.963	0.886
1	1	0.947	0.949
2	1	0.982	0.975
3	1	0.994	0.988

TABLE 3. Simulated power and annual sample size estimates for occupancy monitoring design options to detect 10%, 20%, or 30% declines in occupancy across a ten year period over three alpha levels (0.05, 0.10, 0.20). Further details on input model parameters are presented in the text of this report. Power estimates >0.800 are identified in bold.

	Alpha = 0.05			Alpha = 0.10			Alpha = 0.20		
	Population Decline			Population Decline			Population Decline		
# Samples	10%	20%	30%	10%	20%	30%	10%	20%	30%
10	0.088	0.143	0.603	0.161	0.241	0.590	0.291	0.396	0.566
20	0.108	0.204	0.763	0.192	0.322	0.748	0.333	0.491	0.720
30	0.127	0.260	**0.857**	0.218	0.390	**0.844**	0.367	0.564	**0.817**
40	0.144	0.313	**0.914**	0.242	0.451	**0.902**	0.397	0.624	**0.880**
50	0.160	0.363	**0.948**	0.263	0.505	**0.939**	0.423	0.675	**0.921**
60	0.175	0.410	**0.968**	0.284	0.554	**0.962**	0.448	0.718	**0.948**
70	0.190	0.455	**0.981**	0.304	0.599	**0.976**	0.470	0.755	**0.966**
80	0.205	0.497	**0.989**	0.322	0.639	**0.985**	0.492	0.787	**0.978**
90	0.219	0.536	**0.993**	0.340	0.675	**0.991**	0.511	**0.815**	**0.985**
100	0.233	0.574	**0.996**	0.358	0.708	**0.994**	0.530	**0.839**	**0.990**
120	0.247	0.608	**0.998**	0.375	0.738	**0.997**	0.548	**0.859**	**0.994**
130	0.261	0.641	**0.999**	0.391	0.765	**0.998**	0.565	**0.878**	**0.996**
140	0.275	0.671	**0.999**	0.407	0.790	**0.999**	0.581	**0.893**	**0.997**
150	0.288	0.699	**0.999**	0.422	**0.812**	**0.999**	0.596	**0.907**	**0.998**
160	0.301	0.725	**1.000**	0.437	**0.831**	**1.000**	0.611	**0.919**	**0.999**
170	0.314	0.749	**1.000**	0.452	**0.849**	**1.000**	0.625	**0.930**	**0.999**
180	0.327	0.771	**1.000**	0.466	**0.865**	**1.000**	0.638	**0.939**	**1.000**
190	0.339	0.791	**1.000**	0.480	**0.880**	**1.000**	0.651	**0.947**	**1.000**
200	0.352	**0.810**	**1.000**	0.493	**0.893**	**1.000**	0.664	**0.954**	**1.000**

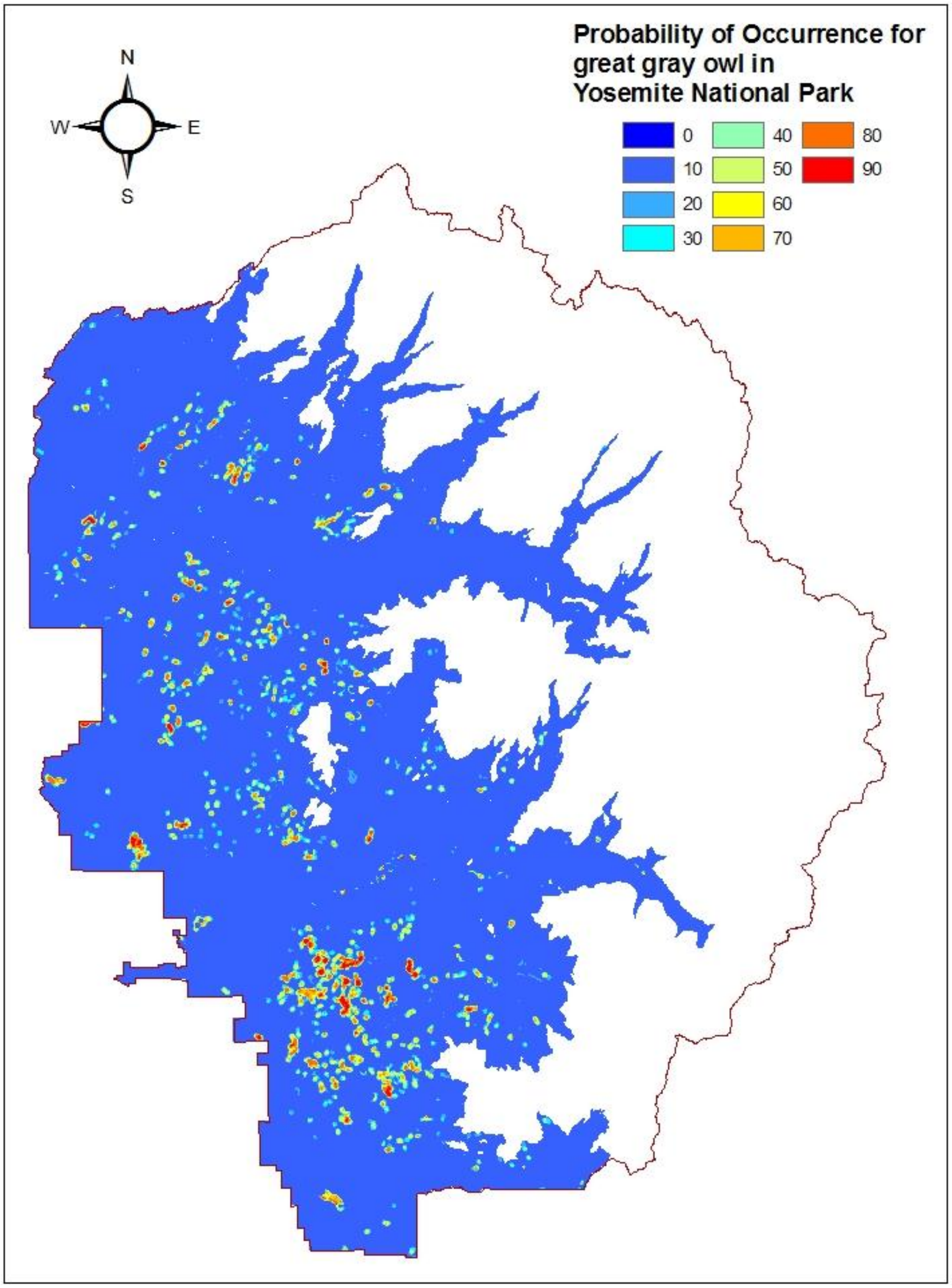
TABLE 4. Predicted distribution of Great Gray Owls in Yosemite National Park by percent probability of occurrence classes in Yosemite National Park based on program Maxent modeling. See text and APPENDIX III for full details on derivation of habitat variables and modeling.

Probability of Occurrence Class	Percent of Total Predicted Distribution Hectares
0-19%	92.9
20-39%	3.2
40-59%	1.7
60-79%	1.4
80-100%	0.8

TABLE 5. Topographic and habitat variables (hectares), and their percent contribution to the model, used in program Maxent to model the probability of occurrence in 10% probability classes for Great Gray Owls in Yosemite National Park. See text and APPENDIX III for full details on derivation of habitat variables and modeling.

Predictor Variable	Percent Contribution to Model
Elevation (m)	4.1
Slope (degrees)	0.7
Aspect	0.2
Barren	5.8
Grassland	0.5
Meadow	76.3
Aspen	0.2
Shrub	1.3
Lower Montane Forest – High Density (>60% Cover)	0.1
Lower Montane Forest – Medium Density (>=40-60% Cover)	0.2
Lower Montane Forest – Low Cover (<40% Cover)	0.3
Upper Montane Forest – High Density (>60% Cover)	0.4
Upper Montane Forest – Medium Density (>=40-60% Cover)	1.1
Upper Montane Forest – Low Cover (<40% Cover)	1.0
Montane Hardwood	1.9
Riparian	0.6
Subalpine Conifer	1.7
Other	3.5

FIGURE 1. Predicted distribution of Great Gray Owls in Yosemite National Park by 10% probability of occurrence classes, based on program Maxent modeling. Full details of modeling are provided in the text and APPENDIX III.



APPENDIX I. SURVEY FORMS AND BANDING DATA FORMS

Nocturnal Extensive Survey Form SNRC Great Gray Owl

Meadow ________________________________ Date ______/______/_________ Obs1_______ Obs2_______

DD Mon YYYY

Survey Station	Visit #	Start Time	W	P	C	H	T	M	Moon Stage	GGOW Detections						Other Owl Species					Bearing	Distance (meters)	UTM E	UTM N
										#	Pair	Sex	Voc	Time	Heard By	Species	#	Sex	Age	Time				

Wind (W)
0 - calm, smoke rises vertically (0 mph)
1- light air, smoke drifts (1-3 mph)
2 - light breeze, leaves rustle, vanes move (4-7 mph)
3 - gentle breeze, leaves in constant motion (8-12 mph)
4 - moderate breeze, small branches move (13-18 mph)
5 - small trees sway (19-24 mph)

Cloud (C) and Haze (H)
enter cloud and haze cover
to nearest 10% (0, 20, 50, etc)

Precipitation (P)
D - dry
F - fog
M - mist
I - intermittent rain
L - light rain
S - snow

Moon (M)
0 - not visible
1- moon visible

Moon Stage
0 - new moon
1- moon 1/4 full
2 - moon 1/2 full
3 - moon 3/4 full
4 - full moon

Age
A - adult
J - juvenile
U - unknown

Pair
P - pair, M and F
detected <1/10 mile apart
U - unknown
S - single

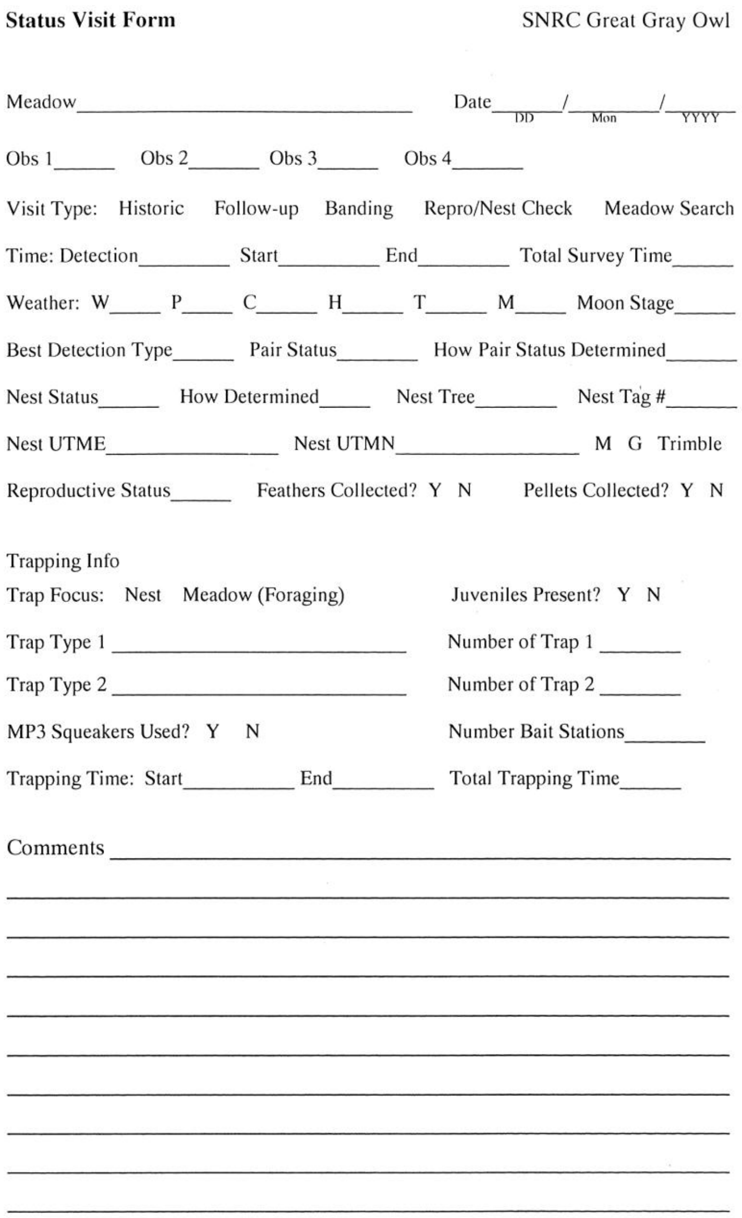
Sex
M - male
F - female
U - unknown
P - pair (non-ggow only)

Vocalization Type
S- series hoot
D - low double hoot
B - barking
F - female begging
W- whoop!
J- juvenile begging
O- other, describe

Other Owl Species
GHOW - great horned owl
NSWO - northern saw-whet owl
NOPO - northern pygmy-owl
SPOW- spotted owl
BDOW- barred owl
SBOH- spotted x barred hybri
STUN- barred or spotted owl
FLOW - flammulated owl
BNOW - barn owl
LEOW - long-eared owl
WESO - western screech-owl

Metric Conversion
50 feet= 15 meters
100 feet= 30 meters
100 yds= 100 meters
1/4 mile= 400 meters
1/2 mile= 800 meters
3/4 mi= 1200 meters
1 mile= 1600 meters
at station= 0 meters

APPENDIX I. Continued: SURVEY FORMS AND BANDING DATA FORMS



Status Visit Form SNRC Great Gray Owl

Meadow________________________________ Date______/________/________
DD Mon YYYY

Obs 1______ Obs 2_______ Obs 3______ Obs 4_______

Visit Type: Historic Follow-up Banding Repro/Nest Check Meadow Search

Time: Detection_________ Start_________ End_________ Total Survey Time______

Weather: W_____ P_____ C______ H______ T______ M_____ Moon Stage______

Best Detection Type______ Pair Status________ How Pair Status Determined_______

Nest Status______ How Determined_____ Nest Tree________ Nest Tag #_______

Nest UTME________________ Nest UTMN_________________ M G Trimble

Reproductive Status______ Feathers Collected? Y N Pellets Collected? Y N

Trapping Info

Trap Focus: Nest Meadow (Foraging) Juveniles Present? Y N

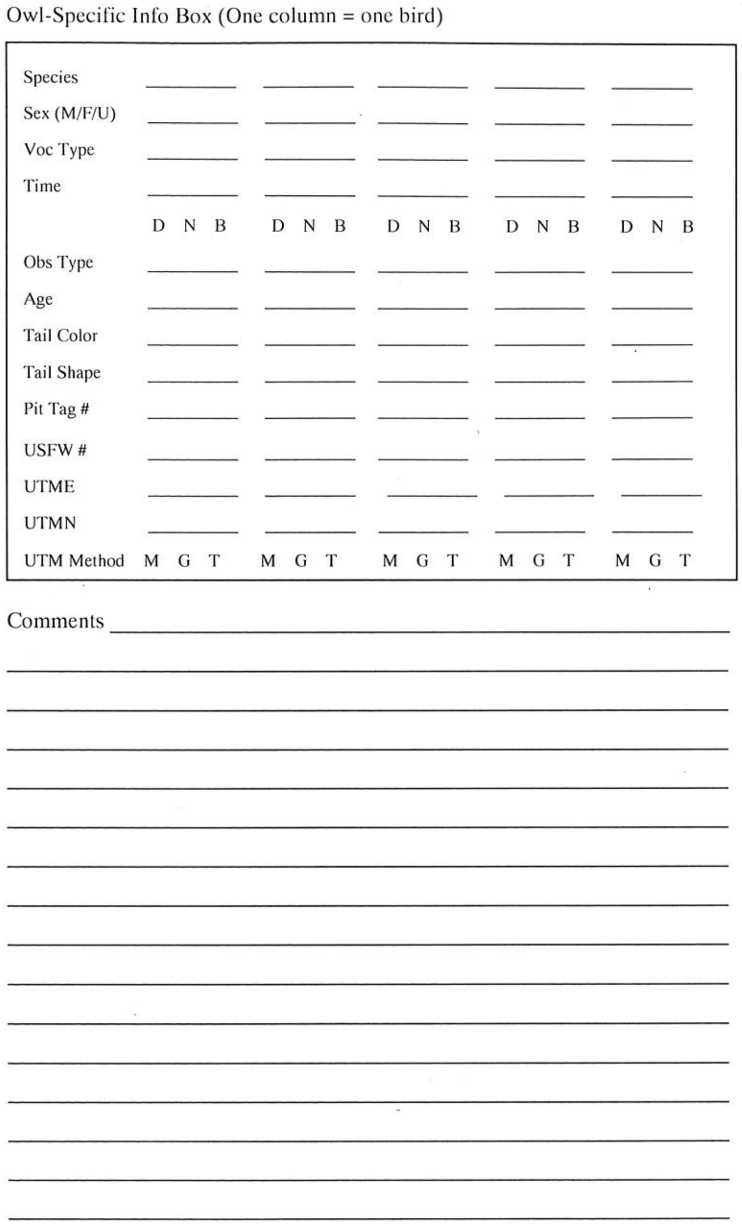
Trap Type 1 ____________________________ Number of Trap 1 ________

Trap Type 2 ____________________________ Number of Trap 2 ________

MP3 Squeakers Used? Y N Number Bait Stations________

Trapping Time: Start__________ End_________ Total Trapping Time______

Comments ____

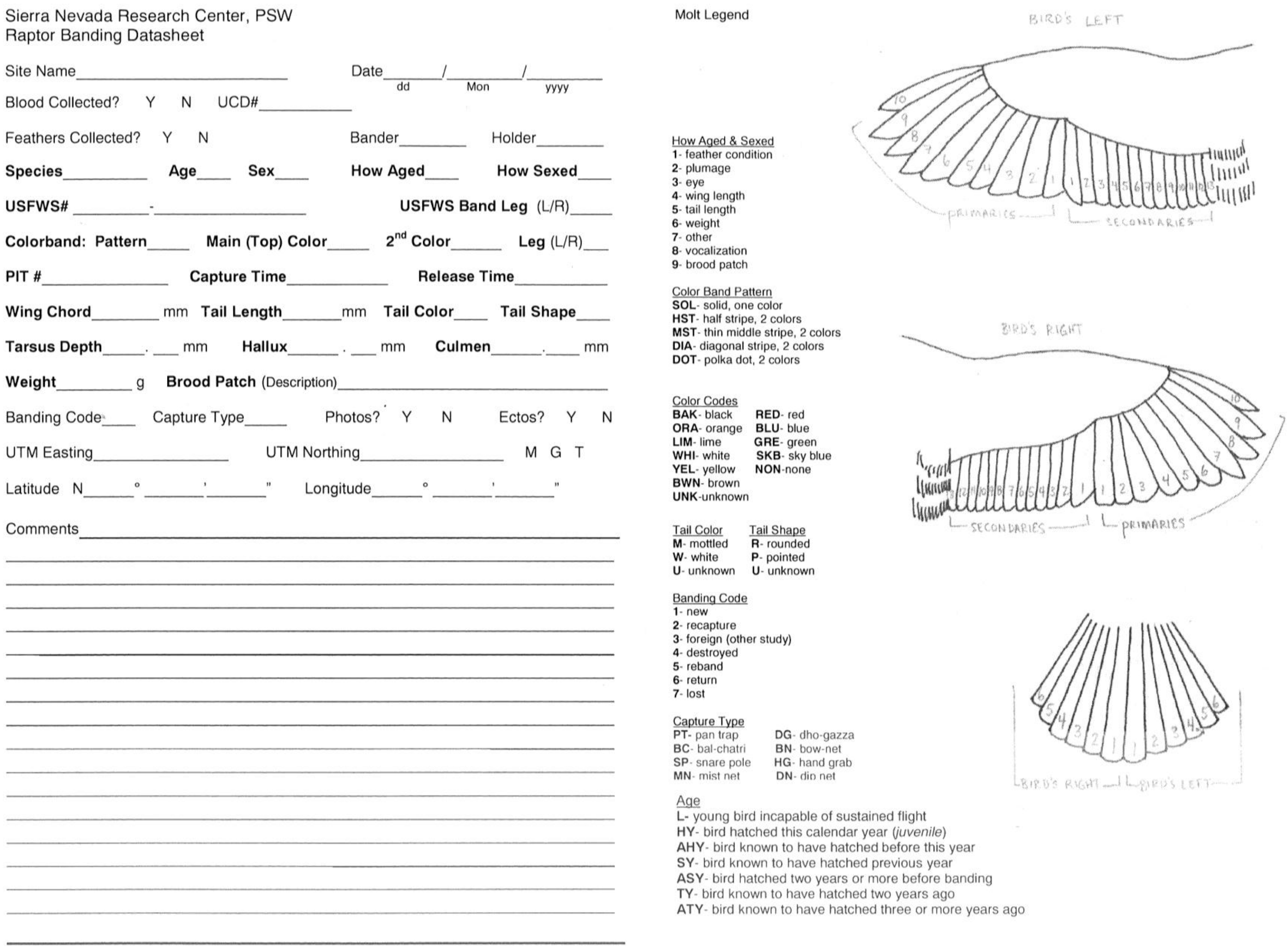


Owl-Specific Info Box (One column = one bird)

Species					
Sex (M/F/U)					
Voc Type					
Time					
	D N B	D N B	D N B	D N B	D N B
Obs Type					
Age					
Tail Color					
Tail Shape					
Pit Tag #					
USFW #					
UTME					
UTMN					
UTM Method	M G T	M G T	M G T	M G T	M G T

Comments ____

APPENDIX I. Continued: SURVEY FORMS AND BANDING DATA FORMS



Sierra Nevada Research Center, PSW
Raptor Banding Datasheet

Site Name____________________ Date______/________/________
dd Mon yyyy

Blood Collected? Y N UCD#__________

Feathers Collected? Y N Bander________ Holder________

Species_________ **Age**____ **Sex**____ **How Aged**____ **How Sexed**____

USFWS# ________-________________ **USFWS Band Leg** (L/R)_____

Colorband: Pattern_____ **Main (Top) Color**_____ **2nd Color**______ **Leg** (L/R)___

PIT #______________ **Capture Time**___________ **Release Time**__________

Wing Chord________ mm **Tail Length**_______mm **Tail Color**____ **Tail Shape**____

Tarsus Depth_____. ___ mm **Hallux**______ . ___ mm **Culmen**______.____ mm

Weight_________ g **Brood Patch** (Description)______________________________

Banding Code____ Capture Type_____ Photos? Y N Ectos? Y N

UTM Easting_______________ UTM Northing_______________ M G T

Latitude N______° _______'_______" Longitude______° _______'_______"

Comments____

Molt Legend

How Aged & Sexed
1- feather condition
2- plumage
3- eye
4- wing length
5- tail length
6- weight
7- other
8- vocalization
9- brood patch

Color Band Pattern
SOL- solid, one color
HST- half stripe, 2 colors
MST- thin middle stripe, 2 colors
DIA- diagonal stripe, 2 colors
DOT- polka dot, 2 colors

Color Codes
BAK- black
ORA- orange
LIM- lime
WHI- white
YEL- yellow
BWN- brown
UNK-unknown
RED- red
BLU- blue
GRE- green
SKB- sky blue
NON-none

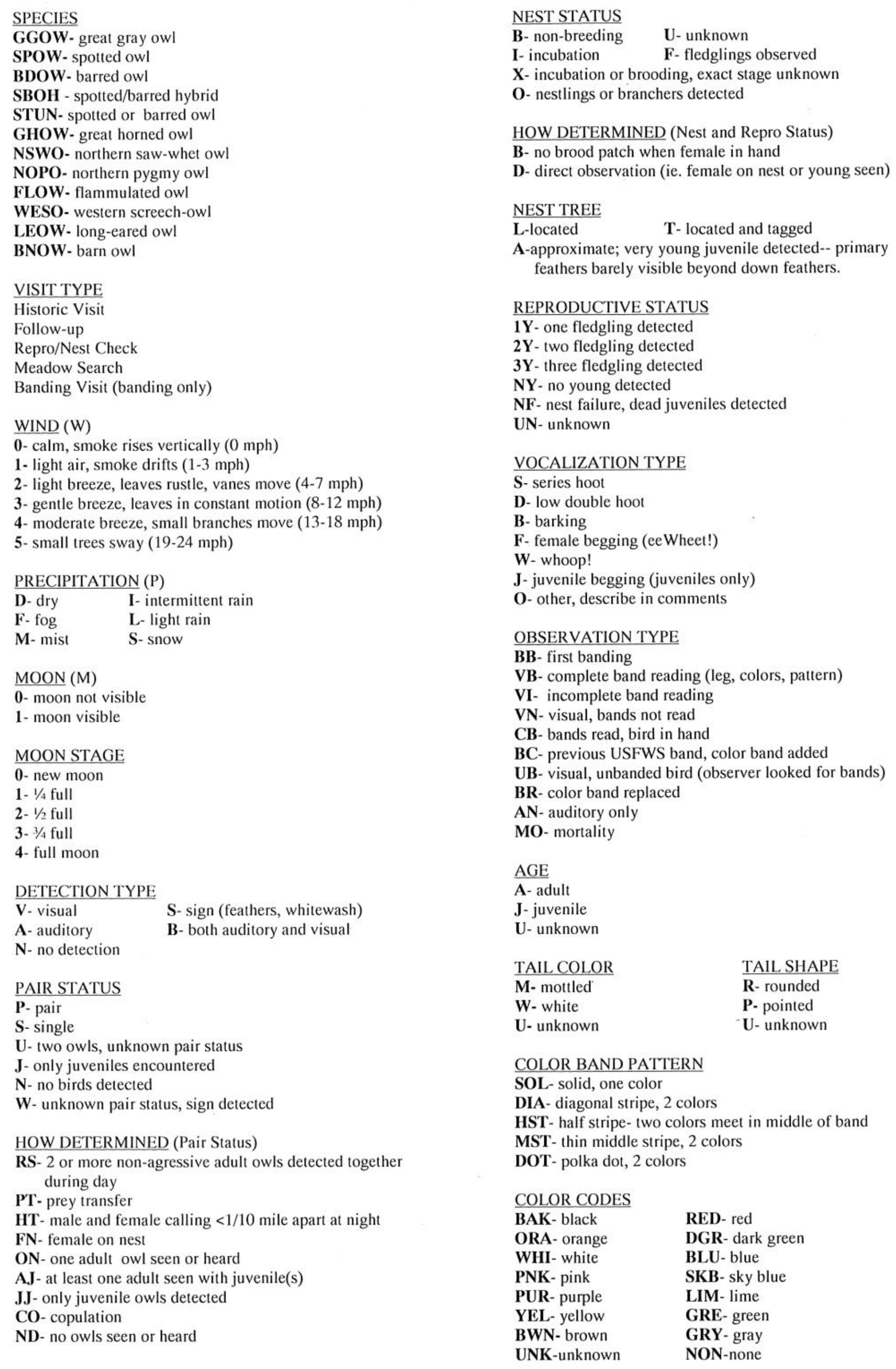
Tail Color
M- mottled
W- white
U- unknown

Tail Shape
R- rounded
P- pointed
U- unknown

Banding Code
1- new
2- recapture
3- foreign (other study)
4- destroyed
5- reband
6- return
7- lost

Capture Type
PT- pan trap
BC- bal-chatri
SP- snare pole
MN- mist net
DG- dho-gazza
BN- bow-net
HG- hand grab
DN- dip net

Age
L- young bird incapable of sustained flight
HY- bird hatched this calendar year (*juvenile*)
AHY- bird known to have hatched before this year
SY- bird known to have hatched previous year
ASY- bird hatched two years or more before banding
TY- bird known to have hatched two years ago
ATY- bird known to have hatched three or more years ago



SPECIES
GGOW- great gray owl
SPOW- spotted owl
BDOW- barred owl
SBOH - spotted/barred hybrid
STUN- spotted or barred owl
GHOW- great horned owl
NSWO- northern saw-whet owl
NOPO- northern pygmy owl
FLOW- flammulated owl
WESO- western screech-owl
LEOW- long-eared owl
BNOW- barn owl

VISIT TYPE
Historic Visit
Follow-up
Repro/Nest Check
Meadow Search
Banding Visit (banding only)

WIND (W)
0- calm, smoke rises vertically (0 mph)
1- light air, smoke drifts (1-3 mph)
2- light breeze, leaves rustle, vanes move (4-7 mph)
3- gentle breeze, leaves in constant motion (8-12 mph)
4- moderate breeze, small branches move (13-18 mph)
5- small trees sway (19-24 mph)

PRECIPITATION (P)
D- dry
F- fog
M- mist
I- intermittent rain
L- light rain
S- snow

MOON (M)
0- moon not visible
1- moon visible

MOON STAGE
0- new moon
1- ¼ full
2- ½ full
3- ¾ full
4- full moon

DETECTION TYPE
V- visual
A- auditory
N- no detection
S- sign (feathers, whitewash)
B- both auditory and visual

PAIR STATUS
P- pair
S- single
U- two owls, unknown pair status
J- only juveniles encountered
N- no birds detected
W- unknown pair status, sign detected

HOW DETERMINED (Pair Status)
RS- 2 or more non-agressive adult owls detected together during day
PT- prey transfer
HT- male and female calling <1/10 mile apart at night
FN- female on nest
ON- one adult owl seen or heard
AJ- at least one adult seen with juvenile(s)
JJ- only juvenile owls detected
CO- copulation
ND- no owls seen or heard

NEST STATUS
B- non-breeding
I- incubation
U- unknown
F- fledglings observed
X- incubation or brooding, exact stage unknown
O- nestlings or branchers detected

HOW DETERMINED (Nest and Repro Status)
B- no brood patch when female in hand
D- direct observation (ie. female on nest or young seen)

NEST TREE
L-located
T- located and tagged
A-approximate; very young juvenile detected-- primary feathers barely visible beyond down feathers.

REPRODUCTIVE STATUS
1Y- one fledgling detected
2Y- two fledgling detected
3Y- three fledgling detected
NY- no young detected
NF- nest failure, dead juveniles detected
UN- unknown

VOCALIZATION TYPE
S- series hoot
D- low double hoot
B- barking
F- female begging (eeWheet!)
W- whoop!
J- juvenile begging (juveniles only)
O- other, describe in comments

OBSERVATION TYPE
BB- first banding
VB- complete band reading (leg, colors, pattern)
VI- incomplete band reading
VN- visual, bands not read
CB- bands read, bird in hand
BC- previous USFWS band, color band added
UB- visual, unbanded bird (observer looked for bands)
BR- color band replaced
AN- auditory only
MO- mortality

AGE
A- adult
J- juvenile
U- unknown

TAIL COLOR
M- mottled
W- white
U- unknown

TAIL SHAPE
R- rounded
P- pointed
U- unknown

COLOR BAND PATTERN
SOL- solid, one color
DIA- diagonal stripe, 2 colors
HST- half stripe- two colors meet in middle of band
MST- thin middle stripe, 2 colors
DOT- polka dot, 2 colors

COLOR CODES
BAK- black
ORA- orange
WHI- white
PNK- pink
PUR- purple
YEL- yellow
BWN- brown
UNK-unknown
RED- red
DGR- dark green
BLU- blue
SKB- sky blue
LIM- lime
GRE- green
GRY- gray
NON-none

APPENDIX II. GREAT GRAY OWL CAPTURE AND HANDLING PROTOCOL

Experience of Research Team Members

Given the apparent small population size of GGOWs in the central Sierra Nevada and the high degree of conservation concern for this population we are acutely aware of the high level of experience and professionalism that is required for conducting studies that require capture, handling, sampling and banding GGOWs to meet specific research objectives. Two of our PIs (Dr. John Keane, Dr. Joshua Hull) are certified raptor banding trainers with the North American Banding Council (www.nabanding.net).

Both Dr. Keane and Mr. Hull hold Master Banding Permits from the United States Fish and Wildlife Service (USFWS). All banding is conducted under Dr. Keane's Master banding permit (#22546) with auxiliary marking authorization letter for color-banding, collecting blood samples and telemetry studies, as well as appropriate California Scientific Collecting Permits. Dr. Keane has 25 years of raptor handling and banding experience and closely directs all capture and banding efforts on this study. Additionally, the limited number of experienced researchers on the project conducting the field work are sub-permitted under Dr. Keane's USFWS permit and have multiple years of field experience handling and banding raptors. Eric Jepsen, field project leader for 4 years, and MSc candidate at UCD, has 9 years of raptor banding and handling experience. Joe Medley, our current field project leader and MSc candidate at UC Davis, has 4 years of raptor banding and handling experience. Further, researchers have undergone training on blood sampling and raptor handling at the University of Davis, California through the Veterinary program under the direction of Dr. Lisa Tell.

Capture, Handling and Health Monitoring Protocol

In addition to the high experience levels of our researchers, we also developed a protocol outlining all of the operational and safety procedures we implement during our research efforts to minimize risk to our target GGOWs. These procedures are presented in detail in this section.

<u>Timing and Location of Capture Efforts</u>

Most of our trapping effort is conducted during the breeding period (March-September) with limited operations during the winter season. Sampling during the breeding period presents the best opportunity to catch owls because they are usually wedded to a breeding territory and site, and are generally more territorially defensive and responsive to capture efforts. However, we realize that we want to minimize any potential to negatively affect nesting attempts. We consider the following criteria when formulating our sampling efforts: **timing** of reproductive effort as it associates with male and female GGOW site and nest fidelity, **impact of our presence** in area including cues to predators of GGOW locations, **nestling ability to thermoregulate, stress induced** by trapping process, **handling time**, and our **awareness of signs of stress**.

Timing is an important consideration when determining when to attempt to capture a GGOW. At all territories we attempt to determine pair and reproductive status. If we locate a nest we then observe the nest to determine nesting chronology and time our efforts to minimize any potential negative effects. Specifically, we take special precautions to avoid disturbing or capturing females when they are incubating or brooding small nestlings (2-3 week old chicks).
We time our trapping efforts to **coincide with the development of auto-thermoregulation in nestlings** so that the absence of the female during our trapping effort would not significantly thermally stress the young birds. From the literature, this is 2-3 weeks after hatching (Bull & Duncan, 1993).

Impact of our presence is an important consideration. In all instances, we attempt to maintain sufficient distances from roosting and nesting owls to minimize potential disturbance. This distance is generally a minimum of 50-100 meters based on our experience. While it is vital to our work to get close to the owls for observation and to set up our trapping effort, we make sure to avoid flushing individuals from their roost location at all times. We are also aware of the possibility of giving away the locations of GGOW nests to Common Ravens (*Corvus corax*) and Great Horned Owls (*Bubo virginianus*), both of whom may be present in the area and are potential predators. Thus, if we detect ravens or Great Horned Owls we suspend sampling efforts to eliminate any potential negative effects.

Capture Methods

We use two techniques for capturing GGOWs. First, we use collapsible dho-gaza nets and either a robotic mount of a study skin or live, non-releasable Great Horned Owl (GHOW) to capture adult GGOWs near active nest sites. This is a common, safe, and reliable method for capturing breeding raptors. The GHOW is placed in a safe, clear opening near an active nest which takes advantage of the GGOWs aggressive, territorial response to a potential predator. The breeding GGOWs swoop toward the lure and are captured in the nets. Our researchers are hidden under a camouflaged tent cover within 10-20 meters of the GHOW and then retrieve the captured GGOW. This is a proven safe technique that has been effectively deployed to capture thousands of raptors (Bloom 1987). The GHOW with dho-gaza nets method will be used exclusively within the immediate area of nesting GGOWs during the late-nestling or early fledgling dependency periods of the breeding cycle. These periods correspond to when young GGOWs are able to thermo-regulate on their own.

Our second capture method uses a noose-plate trap (NPT) to capture birds that are foraging for small mammals. NPTs are useful throughout the year. We will use NPTs opportunistically to target GGOWs that we discover throughout the study area. NPTs are placed in areas of high GGOW use based on proximity to activity center (based on GGOW sightings, whitewash, and feathers) as well as visibility from many perches. NPTs are a simple spring-loaded snare which is baited with a live mouse. They are a safe, reliable, and effective method specifically effective on GGOWs, as well as several other raptor species (Bloom 1987). NPTs are placed underneath potential or known perches. A digital broadcasting device, which plays occasional mouse squeaks is also placed near the NPTs to increase owl attraction to the area.

NPTs are outfitted with a radio-telemetry units that trigger a doubling of frequency rate when an owl lands on the plate, signaling our crew that the plate is sprung. Researchers wait within 100-200 meters of the deployed traps and monitor the radios on the plates with a receiver. The radio-telemetry units provide an excellent safety feature as the researchers are monitoring each NPT 100% of the time and are immediately aware when an owl activates a NPT.

Handling and Health Monitoring

Our team consists of researchers with extensive experience in trapping and handling raptors to complete this work. In addition, all of our crewmembers have undergone training in blood sampling techniques through the UC Davis School of Veterinary Medicine, under the direction of Dr. Lisa Tell or at the Lindsay Wildlife Museum in Walnut Creek with Dr. Nancy Anderson, depending on availability. We implement a standard process for banding, measuring, describing molt patterns, and collecting blood and feather samples from GGOWs based on standard protocols that have been developed over 25 years of field research and the safe processing of thousands of raptors. A series of standardized morphological measurements is collected from each GGOW. A 2-3 ml blood sample and 4 small body feathers are collected for genetic and disease research. Molt patterns are documented with photographs and then birds are released. We band each GGOW with a standard United States Fish and Wildlife aluminum numbered band and a unique color-band with a tiny PIT tag glued to the band. Banding is required to identify individual birds in the future without necessarily having to recapture them. The total process requires about 20 minutes. The health of each bird is closely monitored during the entire process as described in detail in the following paragraphs.

We are particularly cognizant for any signs of stress-induced response. Issues that are of particular importance to us are stress induced by the capture event, the length of handling time, awareness of signs of stress, and proper handling techniques. The first signs of stress include gular fluttering, hot legs, prolonged “bill-clacking” followed by excess drool, squinting/closing of eyes, limp head, and defecation while in the hand. In the event that a bird exhibits any of these symptoms, their condition will be immediately assessed and if necessary, released immediately, irrespective of whether data has been collected. If a bird is discovered to be injured or exhibiting signs of disease during the capture and handling process we will immediately transport the bird to the University of California Davis Raptor Center, or to a local wildlife rehabilitation center if we determine that the bird is in need of immediate treatment.

We implement every possible precaution to minimize the potential for stress. This begins with covering the head of the owl with a cloth or hood to reduce visual stimuli. This is a common, effective, preventive technique for calming raptors. We handle owls with our bare hands to better monitor their heat levels and body condition. Using gloves reduces a researcher's ability to closely monitor the physical condition of a raptor. We hold an ice-pack against the owl during handling process to reduce any threat of overheating. We also make every effort to process the birds as smoothly, quickly, and efficiently as possible. Smooth, confident handling of raptors is critical for keeping them calm. The use of hoods, ice packs, close monitoring of behavior and efficient handling and sampling are all techniques that have proven highly effective and safe over 20 years of research for safely handling spotted owls (*Strix occidentalis*), close congeneric relatives of GGOWs, and other raptors. We have observed that GGOWs are very sensitive and responsive to noise generated by banders during the banding process. Thus, we take precautions to minimize noise, especially talking and movements that produce noise, during the banding process.

The following outlines the specific sequence of handling and processing steps that are followed during each capture event. Our standard raptor banding data sheet is attached and provides full details on the data we collect from each individual GGOW.

1. The GGOW is captured quickly and gently brought under hand control, and hooded using a cotton cloth to cover the bird's eyes and head that helps to calm the bird.

2. The GGOW is fitted with a standard, aluminum, uniquely-numbered band from the USFWS and a gray color-band with PIT tag that allows for each bird to be re-identified in the future without the need for further capture or handling.

3. Blood (2-3 ml) and feather samples (4 small body feathers) are collected following standard veterinary sampling procedures that we adhere to based on training at the UC Davis Veterinary School or Lindsay Museum.

4. A series of standard morphological measurements is collected. In case of stress we will only record weight and wing chord. Morphological measurements are necessary for accurately determining the sex of each bird.

5. The wings and tail of each bird are photographed to measure molt patterns. A few complete body pictures are taken to document each bird.

6. An oral swab is used to collect a sample from the mouth of each bird to be used for Trichomoniasis testing.

7. The bird is then given time (20-30 seconds) to adjust to darkness, if the processing occurs at night, and then the bird is released.

Abbreviated Handling and Processing Protocol

Given recent concern over possible acute disease effects on the health of individual owls during the handling and banding process we recognize the need for an abbreviated processing protocol to be used in situations where the researchers determine that an owl may be at risk for high stress or is exhibiting signs of poor or failing health during the capture or handling process. Based on monitoring of the basic health indicators described above, if the researchers determine that an owl appears compromised or is exhibiting signs of failing health they may, upon the discretion of the researcher, release the bird immediately or use the following abbreviated handling and processing protocol to collect a subset of basic information and quickly release the owl to minimize any chance of mortality or further stress. This abbreviated protocol should only require 5-10 minutes of handling time per owl. The abbreviated protocol consists of 4 steps as described below:

1. The GGOW is captured, quickly and gently brought under hand control, and hooded using a cotton cloth to cover the bird’s eyes and head that helps to calm the bird.

2. The GGOW is fitted with a standard, aluminum, uniquely-numbered band from the USFWS and a unique color-band with PIT tag that allows for each bird to be re-identified in the future without the need for further capture or handling.

3. Feather samples (4 small body feathers) are quickly collected following standard veterinary sampling procedures that we adhere to based on training at the UC Davis Veterinary School. Feathers are required for the population genetic analysis.

4. The bird is then given time (20-30 seconds) to adjust to darkness, if the processing occurs at night, and then the bird is released.

APPENDIX III. METHODS FOR PROGRAM MAXENT MODELING OF GREAT GRAY OWL DISTRIBUTION AND PROBABILITY OF OCCURRENCE IN YOSEMITE NATIONAL PARK

Introduction: This appendix provides additional information on the methods used to model great gray owl (GGOW) distribution and probability of occurrence using program Maxent. This information augments the material provided in the main text of the report.

Study Area: The model was created for the areas below an elevation of 8500 feet within the borders of Yosemite National Park, California, USA.

Observations: Both results of broadcast surveys and end-of-season meadow searches were compiled for the 2008-2009 breeding seasons. GGOWs were detected at 51 sites. A single random location from each of the 51 sites was selected and used in the Maxent modeling exercise.

Habitat Data: Within the program ArcMap (version 9.3), habitat variables were sampled at a 30-meter resolution and within a 200-meter moving-window buffer. Within the 200-meter buffer, topographic variables were averaged, and vegetation variables were totaled. This step was done to assess the contribution of neighboring habitat variables to owl observations and to incorporate potential location error in the estimated location of the owl detection.

To incorporate topographic variables we used 7.5 minute United States Geological Survey (USGS) Digital Elevation Models (DEM) of the study area, which were available through the California Environmental Resource Evaluation System (CERES 2008). We used the ArcMap Spatial Analyst Toolbox to convert the DEMs into the topographic variables elevation, slope, and aspect.

The vegetation layer *yose_97veg_final_poly.shp* furnished by Yosemite staff is based on a detailed classification of YNP vegetation types. To reduce the number of vegetation types for our modeling purposes, we grouped vegetation types into broader classes following the California Wildlife Habitat Relationship System (WHR) and Kuchler (1977) definitions of vegetation and forest types. This resulted in 11 categories used for our modeling: barren, grassland, meadow, aspen, shrub, lower montane conifer, upper montane conifer, other, montane hardwood, riparian, and sub alpine conifer (Table 3.A.1). To further refine our analysis, we further classified upper and lower montane conifer types into high (>60%), medium (40-60%) and low (<40%) density categories.

Vegetation types created for Maxent modeling of great gray owl distribution and probability of occurrence in Yosemite National Park are shown in the table below.

Vegetation Type	Definition
Barren	alpine talus, exposed rock, etc.
Grassland	annual grassland, sedge, herbaceous
Meadow	wet meadows, upland herbaceous
Aspen	quaking aspen and associates
Shrub	chaparral, sage, chamise, manzanita
Lower Montane Conifer	Douglas-fir, ponderosa pine, white fir, incense cedar, giant sequoia and associates
Upper Montane Conifer	Jeffrey pine, lodgepole pine, red fir and associates
Other	urban, water
Montane Hardwood	canyon live oak, interior live oak, black oak, blue oak, foothill pine, knobcone pine, and associates
Riparian	black cottonwood, fresh emergent wetland, mountain alder, willow, white alder, big leaf maple, and associates
Sub Alpine Conifer	single leaf pinyon pine, Sierra juniper, western white pine, whitebark pine, limber pine, mountain hemlock, and associates

Within ArcMap 9.3 we created raster maps of each vegetation habitat variable from the original shapefile, and sampled them as described above. All raster maps of the sampled variables were then converted into ascii text files for Maxent analysis.

Maxent Modeling: The program Maxent (version 3.3.3) was used to analyze owl location data in relation to topographic and vegetation variables. A total of 18 variables were used in the Maxent model (Table 16 of this report). We ran program Maxent in standard mode using 10 replicates and using 10% of the data to test the models. The final model and results are the calculated averages from these replicates. We created response curves and conducted jackknife analyses of variable importance. This gave us the ability to analyze the positive or negative contributions of each habitat variable in the context of GGOW probability of occurrence.

The output spatial probability distribution was converted from ascii format to a raster file and analyzed within ArcMap. To provide clarity and assist with interpretation, we classified the probability distribution into 10% probability categories. We then tallied the number of cells within each category, and calculated their percent cover to assess availability of suitable GGOW habitat by suitability classes.