1. **Additional background and context - added in green**

Assessing the demography of a threatened Golden Eagle population in California

The Altamont Pass Wind Resource Area (APWRA) in California is home to one of the densest reported populations of golden eagles in the world. The area, which includes parts of both Contra Costa and Alameda County, also supports large numbers of wind turbines that have altered the landscape and have killed many birds, including golden eagles. Wind energy is a significant resource in California, thus mitigating the impacts it has on wildlife is crucial to support the continued development of sustainable renewable energy.

Golden eagles are of high conservation concern, and a heavily managed species. In the APWRA, the golden eagle population has been a subject of intensive monitoring for several decades. Recent work has included surveying for occupied golden eagle territories, monitoring productivity and reproductive success at nests, and providing estimates of numbers of breeding pairs. For example, the monitored population is ~65-90 territories, of which 55-66% are occupied in any given year (Wiens & Kolar 2021). This information on numbers of territories and occupancy rates already has been important for making informed management decisions to limit disturbances of wind turbines on these eagles.

Despite the extensive monitoring that has occurred recently, two central problems to understanding and managing this eagle population are estimating rates of adult survival and estimating the true size of this population. Golden eagles are long-lived territorial raptors, and have delayed sexual maturity, consequently stable and high rates of adult survival are important for the persistence of their population. In a stable population, survival rates of adult territorial golden eagles should be ~90-95%. However, some golden eagle populations rates may be much lower (Millsap et al., 2022). Calculating longevity and death rates of eagles can be difficult since doing this requires monitoring large numbers of individuals and implementing techniques such as telemetry to track individuals, and because it can be expensive and time consuming. Similarly, reliable estimates of true population size are challenging to generate, especially for species like eagles with a prolonged sub-adult stage. However, estimates of these parameters can provide crucial insight into the stability and resilience of populations and thus can underpin future conservation and management efforts.

The goal of this project is to provide estimates of survival rates of territorial eagles, and to understand the true population size of the eagles in this APWRA population. We will use a non-invasive approach to estimate these parameters. These methods involve first the collection of molted (i.e., naturally shed) feathers at nests, territories, and roosts. Once feather samples are in hand, then we extract DNA from them. We gather this genetic material from the superior umbilicus of the feather - a blood clot found at the junction of the shaft of the feather and the plume (Horvath et al., 2005). We then use that extracted DNA to determine the sex of the individual that dropped the feather and to assign to that individual a genetic ID. Feathers with the same genetic ID will indicate the same individual. These ID's obtained can be compared across territories and years to determine presence or absence of individuals and will form the basis of our demographic analyses. For example, if we collect feathers from a territory in year 1 and identify male A and female B, then we can return to that territory in year 2 and see if those birds are still there. If they are both still shedding feathers, then it means that both survived over the course of the non-breeding season. If one or both has been replaced, it most likely means that one or both did not survive. These approaches rely on the fact that adult eagles return to the same site to breed year after year, and non-breeders tend to congregate in large numbers at certain sites. In both cases, these birds naturally shed feathers which can be used for the foundation of the non-invasive analyses we propose. There have been several recent examples showing that these types of non-invasively collected data can then be used to estimate population size, turnover, and survival of populations.

Over the past 10 years, ~11,000 molted golden eagle feathers have been collected at known nest and roost sites of golden eagles in the APWRA. In Contra Costa County alone, there are approximately 14 golden eagle territories which have been monitored between 3 to 8 years, with an additional >30 territories outside of the county at which feathers have been collected. Our lab and statistical analyses will rely on these feathers. It is not possible or necessary to analyze all 11,000 feathers, so we have implemented a subsampling approach that lets us estimate demography by only analyzing some of these feathers. To estimate turnover and survival rates we will target ~1000 feathers collected from ~40 eagle territories in the two counties that were each visited each year for 5 – 8 consecutive years.

Once feathers are in hand, we will then extract DNA from feathers until both individuals in a breeding pair are genetically identified in several feathers (i.e., we won't analyze all feathers from all territories, just enough feathers to identify the territorial male and female at each territory in each year). These genetic IDs will be compared across years and territories, allowing us to track individuals over time. We can then use a classical mark-recapture analysis to estimate turnover and survival rates. Doing this will also allow us to calculate APWRA-specific metrics unique to this population. As an example, we expect to compare turnover and survival rates at nests that are far from vs. close to wind turbines, to understand if turbines are disproportionately impacting territories that are closer to the wind facility.

To estimate the size of the non-breeding portion of the population, we will use a similar approach. Feathers have been collected at shared roost sites, areas occupied by non-breeding individuals, in the APWRA. We implemented feather collection at one of these roost sites each quarter across a one year. We will extract DNA from ~700 feathers that were collected at this site and identify (genetically) individuals present. We will then use another mark-recapture analysis to estimate detection rates across these visits and use these data to estimate the total size of this group. Specifically, we plan to use a Cormack-Jolly Seber (CJS) open-population model approach (Lukacs and Burnham, 2005) with program RMARK to estimate population size at this roost.

Estimates of survival rates of breeding eagles and population size estimates of non-breeding eagles will provide additional understanding as to the stability of this unique eagle population in the face of the numerous fatalities that occur at wind turbines in the APWRA. Knowing which breeding pairs or territories are affected by fatalities and knowing the total size of the population are key pieces of information that can be used to improve future management for this at-risk population.

Referenced Literature:

Horváth, M. B., Martínez-Cruz, B., Negro, J. J., Kalmár, L., & Godoy, J. A. (2005). An overlooked DNA source for non-invasive genetic analysis in birds. *Journal of Avian Biology*, *36*(1), 84–88.

Lukacs, P. M., & Burnham, K. P. (2005). Review of capture-recapture methods applicable to noninvasive genetic sampling. *Molecular ecology, 14*(13), 3909-3919.

Millsap, B. A., Zimmerman, G. S., Kendall, W. L., Barnes, J. G., Braham, M. A., Bedrosian, B. E., et al. (2022). Age-specific survival rates, causes of death, and allowable take of golden eagles in the western U nited S tates. *Ecological Applications*, *32*(3), e2544.

Wiens, J.D. and Kolar, P.S. (2021). Golden eagle population surveys in the vicinity of the Altamont Pass Wind Resource Area, California, 2014–21. *U.S. Geological Survey Open-file Report No. 2021-1107.*

2. An explanation of the benefits in Contra Costa County and how the data could be used in the future.

This project will directly support management and conservation of raptors in Contra Costa County. The data will provide additional and critical information to understand the impact of wind turbines on population demographics of golden eagles in the APWRA and the broader region, including the large proportion of breeding eagles that reside in Contra Costa County. The molecular techniques employed in this project will provide information on the demographics of these eagles, including survival estimates of adults, which are critical estimates for understanding and managing populations. An understanding of how and to what extent these populations are impacted by wind turbines will benefit not only golden eagles but raptors who may disturbed similarly, while simultaneously supporting the goals of sustainable renewable energy and future wind projects.

As an example, typical annual survival rates of adult golden eagles are between 90 and 95%, meaning that in any given year, between 90 and 95% of birds should survive to see the next year. Eagles also show nest-site fidelity, meaning that if they survive from one year to the next, they should continuously occupy the same territory and nest sites. Thus, if this population is stable, then we expect turnover rates at territories to be at or below 10% (i.e., more than 90% of birds we identify at a territory should have also been there the year before). If we discover that turnover rates are higher, this would indicate to Contra Costa County that the mortality from wind turbines is not sustainable and that if the County wishes the eagle population to persist in the future, mitigative action may be required.

3. Can the data be shared?

The genetic results of this project can be shared. At the completion of this project, a final project report, including results of this project will be shared with Contra Costa County Fish and Wildlife as per the requirement of this grant. We also expect these data to be uploaded to a public database in conjunction with publication of our results in a peer-reviewed scientific journal.

4. Can the project proceed without funding indirect costs?

The project cannot proceed without indirect costs because they represent real expenses that universities incur to support sponsored projects. Without these costs being covered, universities would be subsidizing sponsored activities, which is unsustainable. Sponsors paying indirect costs ensures that universities are fairly reimbursed for the resources they provide to collaborate with external entities, and this ensures that sponsored projects can be conducted effectively, compliantly, and with proper oversight. Indirect cost recovery helps universities maintain and improve their infrastructure, which benefits all activities, including those sponsored by external organizations.