



Monitoring American Peregrine Falcons in Central Alaska Inventory and Monitoring Network

Data Quality Standards

Natural Resource Report NPS/CAKN/NRR—2018/1749



On the Cover: Three American Peregrine Falcon (*Falco peregrinus anatum*) chicks huddle together in the eyrie during the Central Alaska Network's long-term monitoring program in Yukon-Charley Rivers National Preserve. (NPS/MELANIE FLAMME)

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Joshua H. Schmidt¹ and Melanie J. Flamme²

¹ U.S. National Park Service
Central Alaska Network
4175 Geist Road
Fairbanks, AK 99709

² U.S. National Park Service
Yukon-Charley Rivers National Preserve
Gates of the Central Alaska National Park and Preserve
4175 Geist Road
Fairbanks, AK 99709

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Executive Summary

The purpose of this report is to document the standards used by the National Park Service (NPS) Central Alaska (CAKN) Inventory and Monitoring Network for activities related to the collection, processing, analysis, and publication of American Peregrine Falcon monitoring data as described in American Peregrine Falcon Monitoring Protocol Narrative for the Central Alaska Network (Ambrose *et al.* 2018; <https://irma.nps.gov/DataStore/Reference/Profile/2218300>). This plan also serves as a guide for all CAKN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail. The format and content of this document borrows heavily from Rattenbury and Schmidt (2017) and Ambrose *et al.* 2016.

Acknowledgments

Funding for this project was provided through the National Park Service, Central Alaska Inventory and Monitoring Network (CAKN), Yukon-Charley Rivers National Preserve (YUCH) and U. S. Fish and Wildlife Service (USFWS). The creation of the protocol narrative involved the contributions of numerous individuals.

Introduction

The purpose of this report is to document the standards used by the Central Alaska Network (CAKN) for activities related to the collection, processing, storage, analysis, and publication of monitoring data as described in American Peregrine Falcon Monitoring Protocol for the Central Alaska Network. The policies and procedures documented in this quality-assurance plan for activities follow the quality-assurance plan for other monitoring activities conducted by the CAKN and supplement the National Inventory & Monitoring Division Quality Management Plan. The Standard Operating Procedures provide detailed protocol/program activities associated with American Peregrine Falcon monitoring. This plan serves as a guide for all personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Protocol Overview

This protocol outlines how monitoring data will be collected, managed and reported for the American Peregrine Falcon “Vital Sign”, as part of the NPS Vital Signs Inventory and Monitoring program and as described in the CAKN Monitoring Plan (MacCluskie and Oakely 2005). The study design, data collection methods, and analytical protocols have been peer-reviewed and published in a peer-reviewed journal (Ambrose *et al.* 2016).

Rationale for American Peregrine Falcon Monitoring

The ability to detect and track resource changes over time and to understand the forces driving those changes are fundamental to accomplishing the NPS’s mission of conserving parks unimpaired for future generations. The CAKN developed its monitoring program to encompass several trophic levels of park ecosystems so that the program would be as robust as possible to detecting change wherever it might occur (MacCluskie and Oakley 2005). The CAKN scoping workshop (2002) identified raptors as important vital signs under *Fauna Distribution and Abundance*. American Peregrine Falcons (*Falco peregrinus anatum*) occurring along the upper Yukon River corridor, within and adjacent to YUCH, were selected by the National Park Service (NPS) as an important CAKN vital sign. *Fauna Distribution and Abundance* was identified as one of CAKN’s highest priority vital signs. American Peregrine Falcons (peregrines) were specifically identified because they are long-lived, top trophic level predators that are indicators of persistent bio-accumulative contaminants (Ambrose *et al.* 2000; MacCluskie and Oakley 2005). Additionally, CAKN monitors other raptors, including Golden Eagles in DENA and Bald Eagles in WRST.

American Peregrine Falcons are medium-sized raptors that prey almost entirely on birds. Their breeding range extends from Mexico north to the tree-line in Canada and Alaska. In Alaska, they occur in the forested interior, nesting primarily on cliffs along the major rivers. In the northern parts of its range, the American Peregrine Falcon is highly migratory, wintering as far south as Brazil and Argentina. The upper Yukon River, from the Alaska – Yukon Territory border to Circle, Alaska, provides excellent cliff-nesting habitat for peregrines as well as an abundant variety of prey species. The majority of this habitat lies within YUCH, with peregrine protection being one of the primary reasons for the Preserve’s establishment in 1980 (U. S. Congress). The enabling legislation

establishing YUCH, the Alaska National Interest Lands Conservation Act (U. S. Congress 1980), states:

“the preserve shall be managed for the following purposes... to protect habitat for, and populations of, fish and wildlife, including but not limited to peregrine falcons and other raptorial birds, ...”

Beginning in the late 1940s, the use of persistent organochlorine pesticides greatly affected peregrines in North America. These pesticides affected mortality and behavior, and caused birds to lay thin-shelled eggs that often failed to hatch (crushed during incubation) and consequently lowered productivity. Peregrines were classified as endangered in 1973 under the Endangered Species Act (U. S. Congress). Peregrines along the upper Yukon River in YUCH have been monitored almost continuously since the listing after exposure to the contaminant, dichlorodiphenyltrichloroethane (DDT), devastated populations. In interior Alaska, peregrines declined to approximately 20 percent of historical levels by the mid-1970s. In 1972, the United States restricted the use of persistent organochlorine pesticides, and since 1978, American Peregrine Falcons in interior Alaska have been increasing.

Recovery efforts, including the banning of DDT, as well as captive breeding and release, resulted in its formal delisting of the species in 1999 (Mesta 1999). Contaminants analyses of peregrine eggs from YUCH suggest that mercury, a persistent compound which bio-accumulates at high trophic levels causing toxic effects (similar to DDT), is approaching levels that may affect reproduction and trends suggest that mercury levels may be increasing (Ambrose *et al.* 2000). High levels of mercury are made biologically available through industrial processes such as mining and waste incineration and will likely increase with global industrialization. Additionally, DDT and other pesticides are still being used in wintering grounds, which may cause continued risk to migratory bird populations. Continued monitoring of contaminants concentrations in peregrine egg shells and nestling and adult feathers allow tracking of these toxic compounds at wintering grounds, along migration routes, and at breeding grounds.

One important aspect of the peregrine population in YUCH is that this population has recovered naturally without interventions from humans. Nest manipulations, captive breeding, releases, and take for harvest have never occurred there. In all other populations in the lower-48 states, there have been influences of these manipulations and captive-breed releases. Hence, the upper Yukon River population is unique for this subspecies as one where the recovery has been completely natural and well-studied.

The peregrine falcon population breeding within YUCH is believed to be one of the densest populations in North America, and the 40+ year dataset is one of the longest and most completely recorded. The peregrine population within YUCH was selected as one of two index study areas for Alaska in the *Peregrine Falcon Recovery Plan, Alaska Population* (USFWS 1982), and more recently in the *National Monitoring Plan for the American Peregrine Falcon* (USFWS 2003).

Though peregrines are still accumulating contaminants, levels are currently low enough for reproduction and subsequent population expansion. Continued monitoring of the increasing peregrine

population in YUCH provides a unique opportunity to contribute data about the recovery and response of a natural population to increased densities. It is critical that the NPS in Alaska takes a leading role in providing such baseline information given the selection of the YUCH study area as an important index area for the state and nation, and our unique NPS mission to manage for intact ecosystems. It is also important to have multiple parameter measurements of a population because various stressors will manifest differently. For example, as the population grows and density increases for a given area, productivity may decline; or high levels of mercury contamination may elicit a rapid decline in adult survivorship.

Due to their near extinction, and subsequent recovery following the ban of DDT throughout their breeding range, peregrines have become a public symbol for recovery and conservation, and specifically for YUCH. Nesting peregrines are one of the top visitor attractions in YUCH and there is strong public support for their protection and the monitoring program. Through the love and interest in peregrine falcons, YUCH and CAKN gain support to protect the entire ecosystem to which they belong. It is important to continue to garner support by sharing the success story of the American Peregrine Falcons' natural recovery to further their conservation.

Objective

The objectives of CAKN American Peregrine Falcon monitoring project are:

1. To monitor temporal trends in the breeding performance of peregrine falcons along the upper Yukon River from Circle to the Yukon Territory, Canada border. This area includes the entire stretch of the Yukon running through YUCH. This includes annual measures of territory occupancy, nest success and productivity. Monitoring of breeding performance in YUCH will contribute to an assessment of the status of the continental population which is designed to achieve 80% probability ($\beta = 0.20$) of detecting a decline of 12.5 % over 3 years ($\alpha = 0.10$) (U. S. Fish and Wildlife Service 2003).
2. To monitor levels of contaminants in eggs and adult peregrine falcons occupying YUCH:
 - a. This includes repeated analyses of eggs for persistent organic pollutants (e.g., DDT and polychlorinated biphenyls (PCBs)), and heavy metals (e.g., mercury and cadmium). Contaminants found in eggs may reflect contaminants exposure on wintering grounds and migration routes.
 - b. To monitor levels of contaminants accumulated in feathers of nestling and adult peregrine falcons on the breeding grounds within YUCH. This includes repeated analyses of feathers for heavy metals (e.g., mercury and cadmium). Contaminants found in nestling feathers may reflect natal area contaminants exposure.

Sampling Design

Survey methods were derived from the Alaska Plan (USFWS 1982) and USFWS Plan (2003). Additionally, methods were developed specifically for the population in YUCH by CAKN (herein). In 2005, peregrine monitoring was incorporated under the new CAKN Vital Signs monitoring program (MacCluskie and Oakley 2005). The CAKN American Peregrine Falcon protocol herein was designed 1) to align with USFWS post-delisting monitoring requirements 2) to increase survey efficiency and feasibility and 3) to update and improve field data collection and 4) to use new field and analytical methods to improve estimates (Ambrose *et al.* 2016).

Modifications of CAKN methods include:

1. CAKN American Peregrine monitoring utilizes larger field-crew sizes (2-4) to improve peregrine detections. Bluffs can be watched almost continuously as crew members take turns watching for birds while others set up camp, prepare meals, or drive the boat between sites. Crews can be divided into teams to watch two bluffs at once. Effort is increased because more scopes and binoculars are scanning large bluffs for birds simultaneously.
2. CAKN American Peregrine monitoring deviates from the USFWS Plan (2003) by counting chicks in early-late July, when nestlings range from 15-30 days old (nestlings older than 30 days may be prone to jump when the nest is entered). This timeframe was selected because nestlings at different sites along the river may begin to fledge and leave the nest in late July or August.
3. CAKN American Peregrine monitoring deviates from the USFWS Plan (2003) by conducting surveys annually rather than triennially. Annual monitoring meets objectives of both the USFWS Plan (2003) and CAKN protocol, and provides more detailed trend information about the natural recovery of YUCH peregrine populations. Annual monitoring also provides earlier warning of population changes in the event of adverse impacts, e.g., from contaminants or disturbances.
4. CAKN American Peregrine monitoring utilizes both paper nest cards (USFWS 1999) in the field and an Access database that matches the nest card fields (developed by CAKN) to which annual data are appended.
5. CAKN American Peregrine monitoring surveys all historic nesting territories within the study “index” area (length of river) rather than subsamples of territories. Further, newly established territories in the index area are actively searched for and incorporated into the monitoring.
6. CAKN Peregrine monitoring has updated analytical methods to estimate territory occupancy, nest success and productivity. Data analysis procedures are described in detail in SOP 10 and Ambrose *et al.* 2016. CAKN Peregrine monitoring data analysis employs two statistical approaches:
 - a. The first analyzes all data aggregated across territories for all years of observations from different observers. This allows the comparison of annual observations from earlier data sets (Cade *et al.* 1968, 1971, 1976; Enderson *et al.* 1968; Temple *et al.* 1970; Ritchie 1976) based on summary statistics of data aggregated across territories

for each year. A Poisson regression, with robust standard errors for the number of occupied territories each year regressed on year, is used because the dependent variable (number of occupied territories) is a count variable. Nearest-neighbor Distance are regressed on year using Prais–Winsten regression to correct for autocorrelation (Wooldridge 2008). Productivity data and reproductive metrics are analyzed using polynomial regression. The SigmaStat 3.10 Incremental Evaluation tool is used to determine the appropriate order polynomials to use, and then a regression is run using the appropriate polynomials to obtain the final results (Systat Software, Point Richmond, CA). The Kolmogorov–Smirnov is used to check normality, the Spearman’s rank test checks for constant variance, and the Durbin–Watson test checks for serial correlation (α 0.05 for all tests).

- b. The second approach uses mixed models for the period of 1977 onward and territories as the unit of analysis. The data consists of a time series of observations at each nesting territory. A mixed model approach with yearly observations contained within territories is used, which allows the consideration of each observation at each nesting territory across all years the territory was occupied.

The CAKN survey protocol will follow those generally used in prior Alaska surveys, which focus on index study areas rather than looking only at territories known to have been used in the past (as recommended for other regions in the USFWS Plan). Index study areas in interior Alaska included a specific section of river (upper Yukon or upper Tanana rivers). All known and potential territories within 1.0 km of the centerline of the river will be surveyed annually within these areas.

The approach of surveying index areas rather than specific territories in CAKN units is favored by NPS for several reasons. By completely re-surveying an established study area annually, new territories will be discovered and this will provide information about the continuing (or lack of) recovery of peregrine falcons (although the species was delisted in 1999, the species was not fully recovered but rather no longer in danger of extinction). Thorough surveys of index study areas do not have this bias in that all potential territories, both good and bad, are surveyed annually. This is important because low quality, seldom-used territories are the ones most likely to be vacated as a result of population decline, thus changes in population parameters may be detected sooner when surveying a given area rather than only known territories. Additionally, pairs which move to a new cliff will more likely be found by a complete survey of a study area than by visits to a historically-used location, thus improving estimates of percent occupancy. Finally, since researchers are able to spend more time in one study area (rather than traveling to several widely dispersed nest territories), they are able to collect more detailed information on the local population in the index area. This sampling design also allows for direct comparisons with the previous 40+ years of monitoring data, and has proven to be monetarily and operationally efficient.

In addition to the valuable information gained by monitoring peregrine falcons within a fixed study area, it is likely that these index areas are consistent with trends observed across interior Alaska. Using “index areas” as representative of a larger area or larger local population was proposed in the *Alaska Peregrine Falcon Recovery Plan* (USFWS 1982) and has proven effective in Alaska based on

analysis of 10 to 15 years of survey data for six rivers in interior Alaska (Payer 2001). Survey data from either of the two index rivers selected (the upper Yukon and upper Tanana rivers) were shown to accurately represent survey data from all of the other rivers. Hence, for this species, the use of index areas to represent a larger area is a viable survey approach which helps to reduce overall survey effort and travel costs.

Site Selection

The study area is located on a section of the Yukon River between the Alaska – Yukon Territory border (64° N, 141° W) and Circle, Alaska (65° N, 144° W), a distance of 265 km (165 miles). The study area is limited to 1.0 km from the banks on either side of the river (Figure 1). The river elevation varies from 260 m (865 ft) above sea level at the Alaska – Yukon Territory border to 170 m (560 ft) at Circle, Alaska. Cliffs, rock outcrops, and dirt banks are common along the river, ranging from 8 m to 600 m above the river. The area's diverse topography, frequent wildfires, discontinuous permafrost, and climate interact to create a complex mosaic of taiga and tundra within the subarctic boreal forest zone (NPS 1993). Spruce/hardwood forest, wet meadows, tussock tundra, shrub thickets, and sparsely vegetated gravel bars dominate. Black spruce (*Picea mariana*) forest occurs in poorly drained areas on north facing slopes, low terraces and floodplains. White spruce (*P. glauca*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and/or balsam poplar (*P. balsamifera*) are common at well drained sites along riparian areas, steep drainages, and south facing slopes.

Most of the vegetation is a mosaic of communities influenced by regular fires. Gallant *et al.* (1995) provides a more detailed description of the study area, a combination of the Interior Forested Lowlands and Uplands Ecoregion at the upriver end of the study area to the Yukon Flats Ecoregion at the downriver end.

The study area overlaps the index area specified in the *Alaska Peregrine Falcon Recovery Plan* (USFWS 1982). The area includes the upper Yukon River in and near YUCH (Figure 1). Surveys are not limited to known nesting territories; rather, all potential nesting territories in the study area will be surveyed as new territories are established. This method incorporates an element of inventory into the monitoring plan in that investigators will search all suitable habitat along the length of the river searching for evidence of occupancy by peregrine falcons.

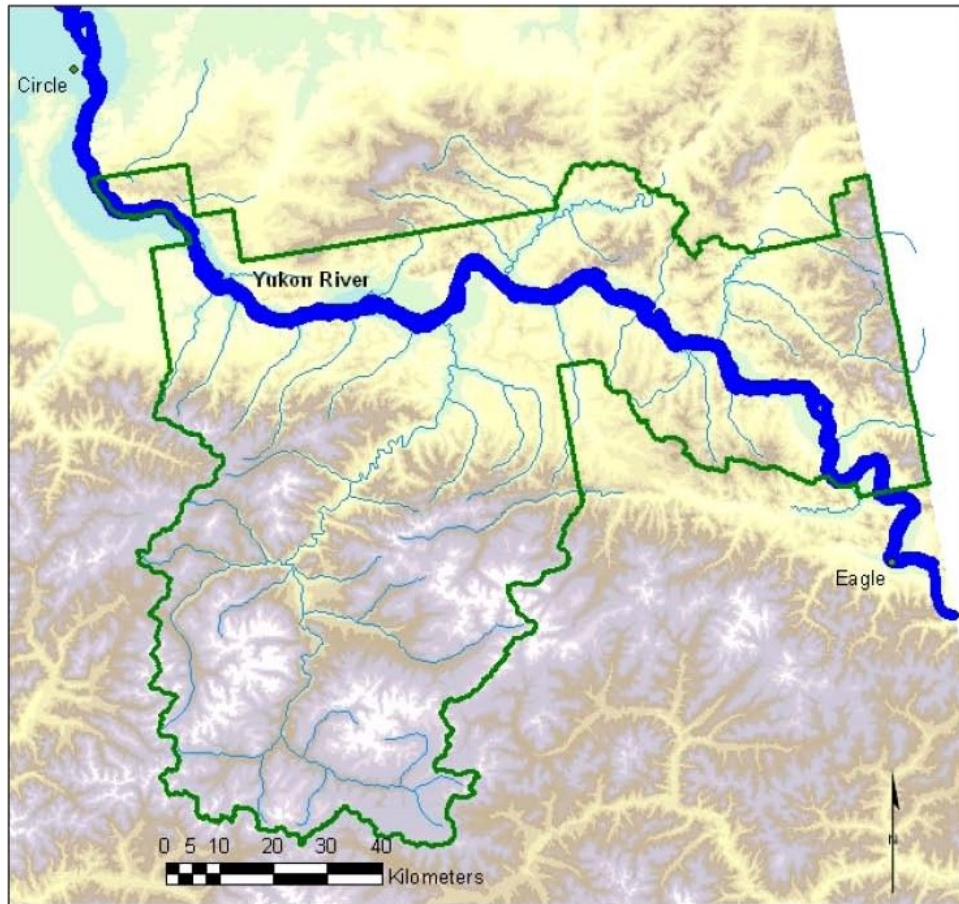


Figure 1. The Upper Yukon study area includes all available habitat within 1.0 km of from bank of the section of the upper Yukon River between Circle, Alaska and the Yukon Territory border. The area was also designated as a “Yukon River Peregrine Falcon Index Area” under the *Monitoring Plan for the American Peregrine Falcon* (2003). Yukon-Charley Rivers National Preserve, Alaska, is outlined in green.

Sampling Methods

Before beginning the field season, observers review this entire protocol, including all of the SOPs, Alaska Plan (USFWS 1982), USFWS Plan (2003, Appendix A), and Colorado Division of Wildlife Field Protocol (see Appendix 4 of Craig and Enderson 2004). Preparation and training for observers is described in SOP 1 “Before the Field Season” and SOP 2 “Training Observers.” Equipment and supplies listed in SOP 1 are organized and made ready for the field season, and copies of the Alaska Raptor Nest Card (nest cards) in SOP 5 “Conducting the Peregrine Falcon Survey” are printed (on acid-free, water-proof paper).

General sampling times and logistics are organized prior to the start of each field season. However, flexibility is required in scheduling sampling trips because of unpredictable weather and break up (river thaw).

Surveys involve two visits to potential habitat or known territories during the breeding season to ascertain territory status (occupancy) and determine productivity of active nests. Potential territories

include cliffs >350 m to steep dirt banks <5 m. Each visit may require up to four hours of observation to determine status of the territory. In most cases, activity such as a nest exchange, feeding, hunting, or flight will occur during a four-hour period. No loud, explosive devices shall be used to flush birds from nests or perches; recorded vocalizations may be used to elicit responses from territorial birds. Surveys are conducted in appropriate weather such that accurate survey data can be obtained (wind or rain may hamper survey efforts).

Peregrine falcon surveys can be accomplished with either two observers or more observers. Two observers or more are recommended, as observers can follow different birds, one of which might go to the eyrie. All observers shall review appropriate literature on peregrine falcons, their behavior during the nesting season, and survey techniques.

Field notes and data forms are used during each visit to record falcon activity, which results in a season summary of the status of the territory. In addition, photographs or sketches of the nest ledge are collected, coordinates of the territory are determined, and maps are used to mark the location of important features of the site. Refer to SOP 5, “Conducting the Peregrine Falcon Survey” for detailed instructions on conducting the survey.

Surveys are conducted using a 21-ft motorized river boat launched from Circle. The crew travels upriver from Circle to the Alaska – Yukon Territory, Canada border, and back again. During the occupancy survey (late May to early June), all potential nesting territories along the river are observed from shoreline or islands using binoculars and spotting scopes. Observations are conducted for a up to four hours at each potential nesting territory (historic or potential), unless occupancy is determined sooner. When possible, campsites are chosen for their proximity to potential nesting territories to extend observation periods. The productivity survey (early to late July) is conducted similarly, all occupied territories are observed using binoculars and spotting scopes to determine the number and age of nestlings. Additionally, eyries that are difficult to see from shore may be entered using standard rock climbing techniques to confirm the number of young. Samples such as prey remains, unhatched (addled) eggs, and nestling and adult feather may be collected for contaminants and other analyses.

Nestlings ages is estimated from using photographs of known age nestling prairie falcons (*Falco mexicanus*) (Moritsch 1983) and nestling peregrine falcons (Cade *et al.* 1996). The age of the oldest nestling was used for all chicks in each nest.

Nesting territories are noted on U.S. Geological Survey topographic maps (1:63,360) and latitude and longitude from GPS units and iPads with the Park Observer application are used for navigation and to mark waypoints of all territories. Nest occupancy data and nest site characteristics are entered into the Alaska Raptor Observation Cards (nest cards; USFWS 1989).

Narrative descriptions of behavior, nest site locations and other observations are kept in field notebooks. Terminology and definitions follow those described in the National Wildlife Federation’s Raptor Management Techniques Manual (1986). The following data are collected:

The following information was collected:

1. Number of nesting territories occupied by a pair;
2. Number of nesting territories occupied by a single adult;
3. Number of pairs attempting to breed;
4. Number of pairs with nestlings;
5. Number of nestlings reaching 2 to 4 weeks of age; and
6. Estimated Age of nestlings at time of nest visit.

Nesting phenology is calculated based on 7 days for clutch completion, 33 days for incubation (with incubation beginning after the third egg, 6 days after the first egg was laid), and 40 days from hatching to first flight (Cade *et al.* 1996). Ages of nestlings are estimated during nest visits using photographs of known-age nestlings (Cade *et al.* 1996).

The following nest site information is collected for each new occupied eyrie and/or territory (previously used sites are documented in past years):

1. Cliff height (primary rock surface area, m);
2. Cliff height above river (talus slope or forested area below cliff, m);
3. Cliff length (km);
4. Nest height on cliff (relative to rock surface area, m); and
5. Nest height above river (m).

During the productivity survey, the number of successful pairs and the number of nestlings at successful nests are determined. Nestlings are most often counted from the shore using spotting scopes but are also counted by climbing to the nest.

Terminology follows Steenhoff (1987) with slight modifications for productivity and successful breeding:

- Fledged Young: For survey purposes, young falcons that could fly or had reached 80% or more of their respective fledging age (32 days old for peregrine falcons) were considered fledged.
- Nest Site: The actual site of the nest (or scrape) on the cliff. More than one nest site may be present within the nesting territory of a pair of birds.
- Nesting Territory: An area that contains, or historically contained, one or more nest sites within the breeding territory of a pair of peregrines, and where no more than one pair has ever bred in any one year. The size of nest territories can change as the population size changes. For example, in a depressed population, one pair may use a large nest territory which includes several nest sites. However, if the population expands and a second pair moves into this “territory,” the size of the original nest territory contracts and the larger area becomes two separate nest territories.
- Nestling: Young of the year between hatching and fledging.

- **Occupied Nesting Territory:** A nesting territory where one or two birds show an affinity for the territory and defend the territory against other falcons.
- **Productivity:** Reproductive output, measured as the number of nestlings raised by a pair. This is expressed both as number of nestlings per total pair and number of nestlings per successful pair. It is important to note that these values are not the number of young fledged, but the number of nestlings generally 10-30 days old.
- **Successful breeding:** Having one or more nestling.

Nest territory occupancy is defined as regular (occupied 80 percent or more for all 34 years), irregular (occupied 20 to 80 percent of 34 years), and occasional (occupied less than 20 percent of 34 years).

Alaska Raptor Observation Record Card (front) and Alaska Raptor Eyrie Record Card (back) are both printed on opposite sides of the same “nest card” (USFWS 1989). All nest card data are entered into the CAKN Peregrine Access database (CAKN_PEFA.accdb). The database has fields that match the revised Alaska Raptor Observation/Eyrie Record Card. All digital historical data (including Access database, photos, nest cards, field notes, maps of territories and eyries information) are scanned and archived on the CAKN network drive and in the IRMA Data Store (Miller 2017): <https://irma.nps.gov/DataStore/Reference/Profile/2218300>

Monitoring Schedule

The CAKN American Peregrine Falcon Monitoring occurs annually in perpetuity. Peregrine surveys in YUCH have occurred nearly annually from 1973-2016. Occupancy surveys to identify nesting territories occur from mid-May to early June as soon as the ice melts and the river is accessible (approximately three weeks). Timing of the occupancy survey is dictated by the date of ice breakup on the Yukon River, which generally occurred by mid-May. Peregrine Falcons in this area have usually completed their clutches by this date. Productivity surveys to count nestlings occur after hatch but before fledging from early-late July (approximately three weeks) (Table 1).

Table 1. Annual field survey schedule for American Peregrine Falcon monitoring in YUCH.

Survey Type	May	June	July
Occupancy*	X	X	–
Productivity**	–	–	X

* ~May 20-June 10

** ~July 6-26

Data Quality Objectives

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate and transferable information.

Representativeness and Data Comparability

Analytical methods are based on those from Ambrose *et al.* 2016. The general statistical approach analyzes aggregated occupancy data across all territories for all years. It allows comparisons to annual observations to, and in combination with, earlier data for 1966–1975 (Cade *et al.* 1968, 1971, 1976; Enderson *et al.* 1968; Temple *et al.* 1970; Ritchie 1976). Combining all observations provides annual data for 1966–2015. Because site-specific information was not available for earlier years analysis of the 1966–2015 period is not based on summary statistics of data aggregated across territories for each year. A Poisson regression with robust standard errors for the number of occupied territories each year regressed on year was used because the dependent variable (number of occupied territories) is a count variable. NND was regressed on year using Prais–Winsten regression to correct for autocorrelation (Wooldridge 2008).

Productivity data and reproductive metrics are analyzed using polynomial regression. The SigmaStat 3.10 Incremental Evaluation tool is used to determine the appropriate order polynomials to use, and then a regression is run using the appropriate polynomials to obtain the final results (Systat Software, Point Richmond, CA). The Kolmogorov–Smirnov is used to check normality, the Spearman’s rank tests to check for constant variance, and the Durbin–Watson tests to check for serial correlation ($\alpha = 0.05$ for all tests).

The once annual sampling rotation targeting the end of the summer is sufficient to detect trends local density and abundance patterns. Preliminary results suggest estimator precision will be sufficient to meet study objectives (see Ambrose *et al.* 2016).

Completeness

If surveys are unable to be completed in a scheduled year due to funding or logistical issues, they will be attempted in the next year if possible to provide density and abundance information. Although completing surveys of all territories is desirable, it is not required. Due to the flexibility of the analytical framework, valid estimates can still be produced if some territories are not surveyed. That said, at some point, incomplete coverage becomes a problem. Consultation with a biometrician is considered necessary if >25% of territories remain uncompleted at the end of the survey period. The biometrician must use expert judgement to determine proper inference when surveys are incomplete.

Measurement Quality Objectives and Performance Standards

See Table 2.

Table 2. Quality Objective table for field observations for the American Peregrine Falcon monitoring protocol.

Measure / Quality Indicator	Quality Objective
Location accuracy	+/- 50m (horizontal) for territory, no standards for vertical accuracy
Species ID	Observers must mutually agree on the species, sex, behaviors, eyrie site
Occupancy	Poisson regression with robust standard errors (SOP 8, Ambrose <i>et al.</i> 2016)
Productivity	Polynomial regression (SOP 8, Ambrose <i>et al.</i> 2016)

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1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525