Western Riverside County
Multiple Species Habitat Conservation Plan (MSHCP)
Biological Monitoring Program

Northern Harrier (*Circus cyaneus*)
Breeding Survey Report 2009

23 April 2010

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF APPENDICES

NOTE TO READER:

This report is an account of survey activities conducted by the Biological Monitoring Program for the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). The MSHCP was permitted in June 2004. The Monitoring Program monitors the distribution and status of the 146 Covered Species within the Conservation Area to provide information to Permittees, land managers, the public, and the Wildlife Agencies (i.e., the California Department of Fish and Game and the U.S. Fish and Wildlife Service). Monitoring Program activities are guided by the MSHCP species objectives for each Covered Species, the information needs identified in MSHCP Section 5.3 or elsewhere in the document, and the information needs of the Permittees.

MSHCP reserve assembly is ongoing and it is expected to take 20 or more years to assemble the final Conservation Area. The Conservation Area includes lands acquired for conservation under the terms of the MSHCP and other lands that have conservation value in the Plan Area (called public or quasi-public lands in the MSHCP). In this report, the term "Conservation Area" refers to the Conservation Area as understood by the Monitoring Program at the time the surveys were planned and conducted.

We thank and acknowledge the land managers in the MSHCP Plan Area, who in the interest of conservation and stewardship facilitate Monitoring Program activities on the lands for which they are responsible. A list of the lands where data collection activities were conducted in 2009 is included in Section 7.0 of the Western Riverside County Regional Conservation Authority (RCA) Annual Report to the Wildlife Agencies. Partnering organizations and individuals contributing data to our projects are acknowledged in the text of appropriate reports.

While we have made every effort to accurately represent our data and results, it should be recognized that data management and analysis are ongoing activities. Any reader wishing to make further use of the information or data provided in this report should contact the Monitoring Program to ensure that they have access to the best available or most current data.

The primary preparer of this report was the 2009 Bird Program Lead, Nick Peterson. If there are any questions about the information provided in this report, please contact the Monitoring Program Administrator. If you have questions about the MSHCP, please contact the Executive Director of the RCA. Further information on the MSHCP and the RCA can be found at www.wrc-rca.org.

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INTRODUCTION

The northern harrier (*Circus cyaneus*) is one of 45 bird species covered by the Western Riverside County MSHCP. Five species objectives are identified for this species, of which 3 (objectives 2, 4, and 5) are directed at conserving breeding locations and monitoring nests (Dudek & Associates 2003). Seven known and historic northern harrier (harrier) breeding locations are identified in the MSHCP: Mystic Lake/San Jacinto Wildlife Area, Lake Skinner/Diamond Valley Lake, Chino Hills, Lake Mathews/Estelle Mountain, Lake Elsinore grasslands/Collier Marsh, Vail Lake/Wilson Valley/east Temecula Creek, and Garner Valley. Two additional areas, Potrero and the Prado Basin/Santa Ana River, are also identified as containing suitable breeding habitat (Dudek & Associates 2003). Objective 5 of the species account specifies that the continued use of, and reproduction in, the above Core Areas by northern harriers be documented at least once every 5 years.

The northern harrier is a medium-sized raptor whose breeding range extends south of the Alaskan tundra and throughout Canada, south to southern California, east to southern Texas, and across to northern Virginia (Hands et al. 1989). Outside of the Plan Area in California, breeding harriers occur in the Central Valley, Sierra Nevada Mountains, and northeastern California at elevations ranging from sea level to 1700 m (Garrett and Dunn 1981). Documentation of harriers breeding in western Riverside County is sparse (Garrett and Dunn 1981), though some locations within the Plan Area, including Mystic Lake/San Jacinto Wildlife Area (Garrett and Dunn 1981), Lake Skinner (Bloom 2002, pers. comm. *in* Dudek & Associates 2003), Chino Hills, Lake Mathews/Estelle Mountain, Lake Elsinore grassland/Collier Marsh, Vail Lake/Wilson Valley/east Temecula Creek, and Garner Valley (Cooper 2001) are identified as historical breeding locations. The MSHCP identifies these historical breeding locations as the breeding Core Areas for northern harrier (Dudek & Associates 2003).

Throughout their range, harriers tend to nest on the ground in patches of shrubby or dense vegetation (Brown and Amadon 1968, Toland 1986). Nests are typically constructed near water, but may also be located in agricultural fields or grasslands several miles from water (Call 1978). The nest usually consists of a mound of sticks or grasses when built on wet habitat, or a cup of grasses when constructed on dry sites (Call 1978). Wet nest sites seem to be preferred, due to a decreased risk of predation, and nesting in less optimal habitats such as dry cropland may result in increased nest failure due to predation or human disturbance (MacWhirter and Bildstein 1996).

Data on pair formation and breeding dates for harriers in southern California are sparse, but rangewide, males tend to arrive on breeding grounds 5–10 days before females, sometime between late February and early April (MacWhirter and Bildstein 1996). Nests are built soon thereafter, with construction taking several days to 2 weeks (MacWhirter and Bildstein 1996). Eggs are laid between late March and late June, with the timing correlated with prey abundance (i.e., high vole abundance leads to earlier egg-laying; MacWhirter and Bildstein 1996). Incubation lasts 28–36 days, and nestlings fledge at about 6 weeks (42 days) of age; however, fledglings remain in the vicinity of the nest for an additional 2 weeks (MacWhirter and Bildstein 1996). Overall, the breeding season lasts 120–135 days (MacWhirter and Bildstein 1996).

The goals and objectives for the 2009 northern harrier breeding survey were as follows:

Goals and Objectives

1) Document distribution of northern harrier in the MSHCP-identified Core Areas.
    a. Determine the presence/absence of harrier in the identified Core Areas taking into account individuals present but not detected.
2) Document reproductive status of northern harrier in the MSHCP-identified Core Areas.
    a. Determine the success or failure of any located harrier nests.
3) Characterize northern harrier nest sites.
    a. Quantify habitat characteristics at each harrier nest site located in 2009 as well as at an equal number of unused sites nearby.

METHODS

Protocol Development

We conducted surveys for harriers by making repeat visits to line transects. Survey methods were developed using techniques described in Fuller and Mosher (1981), Andersen et al. (1985), and Rosenstock et al. (2002). The design we used allows for the calculation of transect-level detection probability (*p*) and can also be used to evaluate correlations between covariates (MacKenzie et al. 2006).

We based our techniques for assessing nest-site habitat characteristics on work by several other harrier investigators. Measuring vegetation height and litter depth at set intervals from the nest were suggested by Holt and Melvin (1986), Redpath et al. (1998), and Limiñana et al. (2006) as a way to assess basic habitat characteristics near harrier nest sites. Evrard and Bacon (1998) also assessed nest-site visibility as influenced by the amount of horizontal cover, using a checkerboard technique (Wiens 1969, 1973; Rotenberry and Wiens 1980). In addition to these techniques, we quantified other habitat characteristics, such as distances from nest sites to nearest buildings, roads, etc., as described by James and Shugart (1970).

Personnel and Training

All field personnel demonstrated proficiency at visual identification of adult and juvenile northern harriers prior to conducting surveys. Additionally, all personnel were briefed on the habitats in which harrier nests are commonly found, as well as behavior characteristics commonly observed when harriers are near an active nest. Observers participated in an extensive review of photographs and drawings from both general avian field guides and specialized raptor identification guides (e.g., Dunne et al. 1988, Sibley 2003) as well as conducting at least 20 hours of harrier observation in the field.

All personnel also demonstrated proficiency with survey techniques before field surveys commenced. After surveys started, less experienced personnel continued to train by accompanying more experienced personnel on survey transects. Less experienced personnel did not begin conducting surveys on their own until they had accompanied experienced personnel on a minimum of 15 transects.

Biological Monitoring Program staff are funded either by the Regional Conservation Authority or the California Department of Fish and Game. The following personnel conducted northern harrier surveys in 2009:

- Nicholas Peterson (Biological Monitoring Program, Program Lead)
- Masanori Abe (Biological Monitoring Program)
- Conan Guard (Biological Monitoring Program)
- Lynn Miller (Biological Monitoring Program)
- Ashley Ragsdale (Biological Monitoring Program)
- Nate Zalik (Biological Monitoring Program)

Study Site Selection

We began study site selection by first selecting northern harrier habitats that were identified as primary breeding (i.e., cismontane alkali marsh, freshwater marsh, playas and vernal pools, and grassland) and secondary foraging or wintering habitat (i.e., agricultural land, Riversidean alluvial fan sage scrub, and coastal sage scrub) by the MSHCP (Dudek & Associates 2003) within our ArcGIS (ESRI 2006) vegetation layer (CDFG et al. 2005). Selecting both primary and secondary habitats ensured the best chance of encountering harriers, whether in their breeding or foraging habitat. Next, we eliminated from our study site layer all places in which coastal sage scrub a) exceeded 10% density, or b) was on a slope exceeding 25 degrees. Doing this meant that our personnel would be able to navigate transects while thoroughly scanning for harriers, rather than having to fight through thick vegetation or deal with difficult topography. Furthermore, investigators have suggested that, while harriers may nest near dense shrubs as a defense against predators, nesting in areas of high shrub density may actually have the negative effect of inhibiting take-off and landing for the harriers (Limiñana et al. 2006).

After we identified appropriate harrier habitat in GIS, we clipped that layer to a separate GIS layer consisting of the 8 harrier Core Areas designated by the MSHCP. Next, because the Core Areas and their associated harrier habitat appeared to fall within 2 categories (large and small), we concluded that it would not be possible for us to maintain a constant transect density (# of transects/ha of harrier habitat) throughout the Plan Area given the timeframe of the study and our limited number of personnel (i.e., large Core Areas, of which there were 4, would each have to contain > 100 transects to ensure the smaller Core Areas had an adequate number of transects). Instead, we decided to place transects at a density of 1 transect/95 hectares of habitat in the larger Core Areas (i.e., Lake Mathews, Lake Skinner, Potrero, and San Jacinto Wildlife Area) and 1 transect/8 hectares of habitat in the smaller Core Areas (i.e., Garner Valley, Lake Elsinore, Santa Ana River, and Wilson Valley). This yielded 18–35 transects in the larger cores, and 12–39 in the smaller cores, for a total of 181 harrier survey transects throughout the Plan Area[1].

Next, we used Hawth's Tools (Beyer 2004) to generate 181 randomly-located transect center points (separated from one another by at least 500 m) at our desired densities within the Core Areas. In the larger Core Areas, all transects were oriented in a north-south direction, so northern and southern termini for the 250-m transects were created based on the location of the central point. In the smaller Core Areas, transects were still 250 m long, consisting of one straight line, but we had to orient each transect individually in such a way that ensured the entire length of the transect fit within the Core Area. These transects still consisted of 3 points: 1 central point and 2 termini, each of which was 125 m from the central point.

Survey Methods

Transect surveys commenced no earlier than 0.5 h after sunrise, and each observer attempted to conduct a minimum of 5 transects per day. Surveys were terminated early if the temperature exceeded 35° C or during heavy precipitation or fog. Additionally, we did not conduct surveys for 48 h following significant precipitation events, any time vehicles could leave ruts in roadways, or any time there was significant snow or ice accumulation on the roads being used to access transects. Bildstein (1978) and Wilkinson and Debban (1980) reported that harrier flight activity increased with increased wind speed, so unless wind caused safety concerns for our personnel (e.g., dust/debris storms), we did not terminate surveys due to high wind speeds.

Observers downloaded waypoints for each transect into their GPS units prior to leaving the office and going into the field each day. In addition to a GPS unit, observers carried a thermometer, binoculars, datasheets, an anemometer (if available), and a bird field guide.

At the beginning of the survey (i.e., at one of the termini), observers recorded the transect start time, temperature, and sky conditions. Observers surveyed transects beginning at one of the transect termini and navigating to the central point, and then to the opposite termini of the transect, ensuring that they remained along a straight path during the survey. Observers attempted to walk at a constant speed while surveying for harriers, spending approximately 10 minutes walking the length of the transect. If significantly fewer than 10 minutes were spent on the transect, the observer began walking the transect in the opposite direction (i.e., toward their starting point) until approximately 10 minutes elapsed. For each harrier encountered, observers recorded its age (adult, juvenile, or unknown) and sex.

If a harrier was encountered during a survey, observers spent as much time as necessary to determine whether the harrier had an active nest, while either standing along

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[1] We did not survey within the Chino Hills Core Area because it was not configured in such a way that justified surveys (i.e., it was 650 m long from east to west, and just 10 m wide from north to south).

the transect and observing the harrier, or leaving the transect altogether to follow the harrier. If an observer had to leave the transect to follow a harrier, they recorded the time of departure from the transect and also marked as a waypoint their stopping location along the transect. Then, when the observer finished following/observing the harrier off-transect, they returned to the point along the transect from which they departed, marking the time on their datasheet, and continued the transect. If 10 minutes were already spent surveying the transect before leaving to follow the harrier, observers did not need to continue with the transect. In the event that 10 minutes had not yet elapsed, the observer continued surveying along the transect until the required 10 minutes had been spent surveying on transect.

At the conclusion of the transect, observers recorded the end time, temperature, sky condition, and both average and maximum wind speeds during the survey (recorded in km/h, or the Beaufort scale if an anemometer was unavailable).

When observers found a harrier nest, or a suspected nest location, they practiced caution, because investigators have documented that nesting harriers are easily disturbed by human presence and intrusion (Serrentino 1989). This sensitivity, combined with the protracted nature of harrier breeding attempts, meant that we did not revisit nest sites more frequently than once/week. When a harrier nest fledged young, we continued following to completion any other active nests within that Core Area, but we did not continue searching for additional nests within that Core Area (Appendix A).

Nest Site Characterization

Following fledging or failure of a harrier nest, we quantified nest-site characteristics at both the micro- and macrohabitat scales. First, observers measured the diameter (cm) of the nest at its widest point, followed by the diameter of the nest perpendicular to the widest breadth. If the nest structure appeared disheveled or unkempt, whether as a result of animal activity or general lack of nest maintenance by the harriers, these measurements were skipped, because they would not accurately reflect the actual dimensions of the nest while it was active. Next, observers measured and recorded both vegetation height (cm) and litter depth (cm) 1, 5, and 10 m from the outer edge of the nest in each of the cardinal directions. Care was taken to avoid trampling vegetation along the path of the measuring tape, which could skew measurements. To determine vegetation height at the above intervals, one observer placed a meter stick on the ground, while the second observer (data recorder) determined the maximum height at which vegetation contacted the meter stick. Litter depth was determined by observing the depth of litter atop the solid ground.

Next, we determined effective vegetation height (in.)[2] 10 m from the nest edge using an effective vegetation height checkerboard (Wiens 1969, 1973; Rotenberry and Wiens 1980) consisting of 1 $in.^2$ squares. One observer held the checkerboard on the ground at the mark 10 m from the nest edge while the second observer (data recorder) stood at the nest. The data recorder then determined the maximum height on the

[2] The Standard/English system was used instead of the metric system here because checkerboard squares that are 1 $in.^2$ are more visible in the field than 1 cm^2, which allows for more accurate measurements.

checkerboard at which 90% of the squares at a horizontal level were completely obscured by vegetation, while keeping their eyes at a standardized height of 1 m above ground (which was measured with the meter stick). The checkerboard was constructed with 10 squares at each horizontal level to facilitate this measurement (e.g., if all the squares were obscured at the 1–4-inch levels, 9 of the squares were obscured at the 5-inch level, and 8 were obscured at the 6-inch level, then the effective vegetation height was recorded as 5 inches).

Following collection of the above data, observers recorded data on ground cover within 10 m of the nest. Starting at 0.5 m from the nest edge, and continuing to the 10 m mark, observers recorded ground cover at 0.5-m intervals along a measuring tape using a point-intercept technique. These data were categorical and fell within one of the following categories: grass, forbs, litter, bare ground, rock, shrub, or tree. The data recorder tallied how many of each cover type the observer identified, for a total of 20 tallies when the 10-m mark was reached in each direction. The above processes were repeated at each of the cardinal directions relative to the nest.

After recording the above data within 10 m of the nest, observers indicated on their datasheet whether there were any habitat variables that may not have been captured along the cardinal direction measurements. For example, if a large shrub was located northwest of the nest, the measuring tape, and thus an observer's measurements, may have missed the shrub entirely. This could be an important factor in the nest site selection process by harriers and was noted on the datasheet.

Next, observers collected data on the habitat > 10 m from the nest (i.e., the macrohabitat). Observers began by identifying, relative to the nest, the nearest: building, potential perch site[3], tree, shrub, hydrological feature, paved road, unpaved road, and road of any kind. Observers marked the location of these features on their GPS. Additionally, observers identified and marked the closest outer edge of the habitat in which the nest microhabitat (within 10 m of the nest) was located. For example, if the nest was surrounded exclusively by grassland, the observer would measure the shortest distance from the nest to the point where shrubs or small trees were also mixed in with the grasses (i.e., where the habitat changed from grassland to a shrub-grassland mix). Lastly, observers identified how many buildings were within 50 and 100 m of the nest, as well as the length of the paved and dirt roads within those distances. The number of potential perch sites within 50 m of the nest was also recorded. Upon returning to the office, observers were then able to accurately calculate the distance between the nest and the above nearest features using GPS-collected coordinates and basic trigonometry.

In addition to collecting data at nest sites, we collected similar data in nearby habitat that did not contain a nest. Sampling locations were identified as follows: first, we selected a random bearing (1–360°) in the office. Next, at a distance of 30 m from a nest, and at the random bearing selected, the first unused site was identified. Then, a second unused site was situated 120° in a counterclockwise direction from the first, but this site was 60 m from the nest. Lastly, a third unused site was situated 120° in a

[3] Perch sites were trees, shrubs, snags, fence posts, wires, etc. – anything an observer would reasonably expect to see a harrier using as an above-ground perch site.

counterclockwise direction from the second site, and this site was 90 m from the nest. Thus, the 3 unused points associated with each nest were 120° from one another (relative to nest location) and located at distance of 30, 60, and 90 m from the nest.

Data collection at unused sites followed the same protocol as data collection at nest sites. Two exceptions, however, were that observers did not have nest diameters to measure, and did not radiate the measuring tape from the edge of any nests; rather, such measurements radiated (north, west, etc.) from the random point itself (Appendix B).

Data Analysis

We estimated per visit cumulative detection probability (P^*) for harriers using closed-capture occupancy models (MacKenzie et al. 2006). We considered locations with harrier observations *used* rather than *occupied* because our survey design could not meet the assumption of population closure (i.e., random movement of animals in and out of sample plots across visits). We used Program MARK (White and Burnham 1999) to construct and compare candidate models that examined the full combination of site and visit effects on p. We then ranked candidate models according to Akaike's Information Criterion for small samples (AIC*c*), calculated Akaike weights (w_i), and derived weighted-average estimates for p across the entire candidate set unless a single model showed clear support (i.e., $w_i > 0.9$) (Burnham and Anderson 2002). Cumulative detection probability (P^*) across all visits was calculated using model-averaged estimates of p and the following formula where p_i is the detection probability on a given survey night: $P^* = 1 - \prod_{i=1}^{3} 1 - p_i$. Variances for P^* were calculated using the delta method (MacKenzie et al. 2006, Powell 2007).

RESULTS

We conducted 3 survey rounds for nesting northern harriers in 2009, during which we found 3 active nests: 1 in the Wilson Valley Core Area, 1 in the Mystic Lake Core Area, and 1 just outside of the Mystic Lake Core Area, in an area hereafter referred to as the Badlands (Figure 1). Of the 3 nests, 1 fledged 4 chicks (Mystic Lake nest), 1 was abandoned with 5 eggs still present (Wilson Valley nest), and 1 was abandoned with 4 eggs still present (Badlands nest).

Detection Rates

During Round 1 (3 March–30 March 2009), we surveyed 174 transects and detected harriers on 17 (9.8%) of them. During Round 2 (30 March–16 April 2009), we surveyed 156 transects and detected harriers on 15 (9.6%) of them. Finally, during Round 3 (20 April–15 May 2009), we surveyed 157 transects and detected harriers on 7 (4.5%) of them. Overall, we detected harriers on 8.0% of transects that we surveyed. With the exception of the San Jacinto Wildlife Area (SJWA) Core Area, in which we detected harriers on nearly a quarter (23.5%) of transects, we detected harriers on fewer than 7% of transects within each Core Area (Table 1).

Table 1. Number of transects along which we observed northern harrier in 2009, by Core Area.

Core Area	No. of transects completed during 3 survey rounds	No. of transects with harrier (% of total no. of transects)
Garner Valley	43	0 (0)
Lake Elsinore	19	1 (5.3)
Lake Mathews	38	2 (5.3)
Lake Skinner	60	4 (6.7)
Potrero	51	2 (3.9)
Santa Ana River	114	2 (1.8)
SJWA	102	24 (23.5)
Wilson Valley	60	4 (6.7)
Overall	**487**	**39 (8.0)**

Detection Probability Analysis

Because we surveyed for harriers at 2 different densities (one for large Core Areas and one for small Core Areas), we analyzed data separately for the 2 groups. Within the larger Core Areas (Lake Mathews, Lake Skinner, Potrero, and SJWA), Program MARK identified p(g) as the best-fit model, which carried an AIC_C weight of 0.96. We then used the real function data, provided by MARK, to calculate *P** (cumulative detection probability) and the associated standard error for each Core Area (Table 2).

Table 2. Detection probabilities for northern harrier within the 4 large Core Areas.

Core Area	Estimate (*p*)	*P**	± SE
Potrero	0.06	0.16	0.11
SJWA	0.34	0.71	0.12
Lake Mathews	0.07	0.21	0.14
Lake Skinner	0.09	0.26	0.13

Within the smaller Core Areas (Garner Valley, Wilson Valley, Santa Ana River, and Lake Elsinore), Program MARK identified the p(.) model (with an AIC_C weight of 0.57) and the p(g) model (with an AIC_C weight of 0.36) as the best-fit models. Next, we model-averaged those 2 models to determine detection probabilities [nightly (*p*) and cumulative (*P**)] within each Core Area and the standard error associated with each cumulative detection probability (Table 3).

Table 3. Detection probabilities for northern harrier within the 4 small Core Areas.

Core Area	Estimate (*p*)	*P**	± SE
Garner Valley	0	0	0
Wilson Valley	0.04	0.13	0.08
Santa Ana River	0.03	0.07	0.03
Lake Elsinore	0.04	0.11	0.10

Nesting Dates and Stages

The Wilson Valley nest was the first harrier nest that our observers located in 2009. The first indication of a potentially active nest site occurred on 10 March, when one of our observers was in the area working on a different project and was scolded by a female harrier. On the following day (11 March), a different observer in the area saw 2 adult harriers (1 male and 1 female) engaging in courtship flights, also referred to as sky-dancing (Hamerstrom 1969, Newton 1979), that often correspond with nest site selection (Toland 1986). We revisited the area on 9 April and found a female harrier incubating a nest that contained 5 eggs. On the same day, we also observed an adult male harrier transferring food to the female approximately 200 m from the nest, after which the pair copulated while perched on the ground. On subsequent visits to the nest on 29 April and 29 May, we observed the female continuing to incubate 5 eggs, which were warm to the touch, and vocalizing distress calls in our presence. When we visited the nest on 15 June, the female was still incubating 5 eggs, 2 of which were slightly cracked. We also observed a food transfer from the male to the female on that date. Our final visit to the nest was on 22 June, when we did not observe any harriers in the area. The nest still contained 5 eggs, but they were cold to the touch. When we visited the area on 26 June to collect nest site vegetation data, the nest was empty and in poor structural condition.

We located the nest in the Badlands area on 28 April, at which time the female was inadvertently flushed off the nest by one of our observers, who quickly observed 3 eggs within the nest and then left the area to avoid causing undue stress on the female harrier. On our second visit to the nest (18 May), the nest was abandoned (i.e., no adults were defending the nest) and contained 4 eggs, one of which was destroyed. On our final visit to the nest site to collect vegetation data (29 June), there were no eggs and virtually none of the nest structure remained.

We found the third nest, within the Mystic Lake Core Area, on 18 May and the nest contained 3 nestlings (approx. 5–9 days old). We observed the female carrying food to the nestlings, and at one point she removed excess prey from the nest. On subsequent visits by our observers (21, 22, 28 May, and 5 June), we saw multiple food carries to the nest by the female. The pair fledged 4 young on or before our next visit on 17 June, and on 29 June we observed 3 fledglings perched within 200 m of the nest site. By 2 July, surveyors were unable to locate the fledglings or an adult male, but an adult female was foraging within 200 m of the nest site.

Habitat at Nest Sites and Nearby Unused Sites

There was considerable variation in nest site habitat data among sites, but some variables, such as percentage of shrub cover within 10 m of a nest, and number of buildings within 50 m and 100 m of a nest, were identical or similar among sites (Table 4).

At the Wilson Valley site, vegetation height near the nest was considerably taller than it was at the nearby unused sites. This trend, however, was not evident at the other 2 sites, with vegetation height being similar at nest sites and unused sites.

Table 4. Summary of habitat data for northern harrier nest sites and nearby, unused but potentially suitable nest sites.

Variable	Badlands Site		Mystic Lake Site		Wilson Valley Site	
	Nest site	**Unused sites (*n* = 3)**	**Nest site**	**Unused sites (*n* = 3)**	**Nest site**	**Unused sites (*n* = 3)**
Vegetation ht (cm)	35.8	33.5	20.1	23.3	75.2	36.9
Litter depth (cm)	26	12.7	5.1	7.2	4.6	6.1
Effective veg ht (in)	20.8	13.9	5.8	10.3	35	11.2
Within 10 m of site:						
% grass	0	4.6	8.8	30	0	52.5
% forb	0	7.5	40	37.1	58.8	17.1
% litter	86.3	75.8	50	31.7	38.8	27.9
%bare ground	13.8	11.7	1.3	1.3	2.5	2.5
% shrub	0	0.4	0	0	0	0
Distance (m) to nearest:						
Building	926	927.7	192	193.3	397	396
Potential perch	31	39.7	40	27.2	45	19.5
Tree	405	407.7	172	171	45	28.7
Shrub	31	39.7	112	116.3	45	19.5
Hydrological feature	2700	2677.7	112	108.3	51	64.3
Paved road	264	249.7	88	111.7	814	812
Unpaved road	295	298	65	77.7	393	379
Road (any)	264	248	65	71	393	379
Habitat edge	43.5	94	78	101.7	16.8	16.3
Within 50 m:						
# buildings	0	0	0	0	0	0
Paved road length (m)	0	0	0	0	0	0
Unpaved road length (m)	0	0	0	30.3	0	0
# of potential perch sites	1	1.7	1	4.7	3	13.7
Within 100 m:						
# buildings	0	0	0	0	0	0
Paved road length (m)	0	0	51	48.3	0	0
Unpaved road length (m)	0	0	156	111.7	0	0

At the Badlands site, litter depth was greater near the nest site than it was at the unused sites. As with vegetation height though, we did not observe this trend at the other 2 sites, where litter depth was similar at nest sites and unused sites.

Across all 3 sites, we observed a difference in effective vegetation height between nest sites and unused sites. The trend, however, was not consistent between sites (i.e., effective vegetation height was taller at nest sites than unused sites in the Badlands and Wilson Valley sites, but shorter at the nest site than the unused sites, at the Mystic Lake location).

Another trend that we observed across nest sites was that the number of potential perch sites within 50 m of the nest was less than the number within 50 m of unused sites. The difference between these, however, was not consistent between site locations.

DISCUSSION

Detection Rates

Overall, our observers conducted 487 surveys during 3 survey rounds. We were unable to conduct as many surveys in Rounds 2 and 3 as we did in Round 1 due to miscommunication with some Reserve Managers. We did, however, detect harriers at a consistent rate in Rounds 1 and 2 (on 9.8% and 9.6% of transects, respectively). We observed a marked reduction in the detection rate of harriers in Round 3 (on 4.5% of transects), which could have resulted from a couple of potential scenarios. First, Round 3 occurred 20 April–15 May, which is during the peak incubation period for nesting harriers. As a result, nesting female harriers may have been spending most of their time incubating eggs during Round 3, and were thus less likely to be detected by our observers. In this scenario we would expect to see increased foraging activity by male harriers, who would be providing food to incubating females. However, we did not observe any food transfers or hunting attempts by males that did not correspond with one of the 3 active nests that we were monitoring. Additionally, our observers detected subsequently fewer adult male harriers in each survey round, both in actual numbers detected, and as a percentage of all harriers detected.

A second possible explanation for why we detected harriers less frequently in Round 3 was that there were simply fewer harriers to detect. There is no way for us to know whether the individuals we detected in Rounds 1 or 2 were migrants or breeding individuals (except for the 3 nesting pairs). The migration period for harriers peaks from mid-March–early May (Macwhirter et al. 1996), and it is possible that some of the harriers we detected in Rounds 1 and 2 were winter residents that left the area by Round 3 (mid-April–mid-May) for northern breeding grounds. Ideally, for purposes of data analysis, we would be observing a closed population of harriers throughout the course of our study (i.e., only observing those individuals that would remain in the area from early March–mid-May and would thus likely be breeding individuals, rather than migrants). To achieve this, future surveys focusing specifically on the presence of breeding harriers should not begin until early or mid-May, after which it is likely that migrant harriers have left the Plan Area and only breeding or unpaired, non-migrant harriers remain.

We detected few harriers within most Core Areas, with the exceptions being SJWA, where we detected harriers frequently, and Garner Valley, where we did not detect any harriers. According to the northern harrier species account (Dudek & Associates 2003), there is at least 1 historic nest site location in Garner Valley, but this account provides no additional details of when or where this nest occurred. Within the accessible portions of Garner Valley, we surveyed the areas that seemed most suitable to nesting harriers [i.e., the habitat was open, consisting of grasses and shrubs (some of which was grazed by cattle), and did not exceed the 3000-m elevation gradient for nesting harriers identified by Garrett and Dunn (1981)], but did not find evidence of their presence. Furthermore, despite our Program having conducted raptor surveys there during the previous 2 winters (2007–2008 and 2008–2009), we have never detected harriers in Garner Valley. As a result, we cannot conclude that the species uses, let alone breeds in, that Core Area.

At SJWA, we detected harriers during nearly one-quarter (24%) of surveys. This Core Area is unique among harrier cores because it consists entirely of relatively flat, open habitat that is vegetated by grasses and shrubs and dotted with retention ponds used for duck hunting. Not only do these habitats provide adequate foraging and nesting locations for harriers, but the open habitat meant that our observers were able to detect low-flying, foraging harriers from long distances which likely increased the harrier detection probability at SJWA. Additionally, individual harriers could be detected on multiple transects on any given day because the large areas in which they foraged could potentially intersect 2 or more transects. As a result, the higher detection rate of harriers at SJWA may be an artifact of increased numbers of harriers drawn to the preferred nesting and foraging habitat (relative to the other Core Areas), but it could also be a result of our observers being able to detect the same harrier on multiple transects due to the relatively flat and open terrain that is characteristic of SJWA. Indeed, our observers identified a maximum of just 3 harriers at any given time within SJWA, but those 3 individuals were often detected on multiple transects during the day.

Within the remaining harrier Core Areas (excluding SJWA), we detected harriers on just 2–7% of transects. These numbers seem low when compared to SJWA, but could result from multiple factors. First, Core Areas such as Lake Elsinore and the Santa Ana River were relatively flat, but they contained a lot of tall, dense vegetation that made observations of low-flying harriers less likely. For example, N. Peterson observed the only harrier detected at Lake Elsinore from a distance of approximately 300 m, a distance from which we were regularly able to observe harriers for several minutes at a time in SJWA; however, the view of the harrier at Lake Elsinore was quickly obscured by dense stands of tamarisk (*Tamarix* spp.), and we never saw harriers on subsequent visits to Lake Elsinore. Second, several Core Areas, including Lake Mathews, Lake Skinner, Potrero, and Wilson Valley, were less vegetated by tall, dense vegetation, but had more varied topography than the other cores. As a result, low-flying harriers could potentially go undetected if, for example, they were foraging on the other side of a hill below which an observer was surveying. As an example of this, N. Peterson, who recorded 1 of the 2 harrier detections at Potrero, reported that the harrier he observed only briefly appeared, flying above a hill adjacent to a transect, before quickly descending behind the hill and out of view. If N. Peterson’s attention had been directed elsewhere during those few seconds, the harrier may have gone undetected. Although it is impossible to reliably quantify, it is likely that some harriers went undetected due to the effects of these 2 factors. However, while our analyses of detection probabilities did not directly account for the effect of an observer’s view being diminished due to topography or vegetation (which would require gathering data for these variables and using those data as covariates in the occupancy models), calculating independent detection probabilities for each Core Area presumes that there are different factors affecting the harrier detection probability in survey areas and that the detection probabilities vary among survey areas.

Detection Probability Analysis

Within the larger harrier Core Areas, our analysis in Program MARK suggested that detection probabilities varied by group (i.e., Core Area), but not by time (i.e., survey round). This is important for 2 reasons. First, this suggests that our observers remained equally likely to detect harriers throughout the course of the project (i.e., their ability to detect harriers did not improve as the project progressed). If time, or survey round, affected detection probability, especially if detection probability increased over time, we may have had to conclude that some harriers went undetected in the early part of this project. Instead, and possibly due in large part to this project being immediately preceded by our wintering raptor project, our observers were consistently able to detect harriers among survey rounds. Second, these results support our previous theory that the reduction in detection rates of harriers during the third survey round was due to the presence of fewer harriers, rather than our observers missing birds that were actually present.

SJWA had the highest cumulative detection probability (0.71) among the larger Core Areas, which was likely due to the flat topography and short vegetation of the area, as previously discussed. Additionally, SJWA was the only Core Area in which observers detected harriers on specific transects during more than 1 survey round. Such repeatability of detections helps to improve cumulative detection probabilities. The relatively low cumulative detection probabilities at the remaining large Core Areas (0.16–0.26) are likely a result of more varied topography and overall fewer harrier detections within those areas. Furthermore, we should interpret those results with caution, keeping in mind that we did not encounter harriers very often in those cores (3.9–6.7% of transects), and, more importantly with respect to MARK analysis, we never detected a harrier on a transect in these Core Areas during more than 1 survey round. This lack of repeated detections will always result in a low probability of detection, because a major assumption of these analyses was that we were studying a closed population. In other words, we assume that a bird detected during the first survey round is present throughout the study; our failure to detect it on subsequent visits resulted in Program MARK calculating low detection probabilities.

Within the smaller harrier Core Areas, Program MARK identified both the p(.) and p(g) models as the best fit models. As we discussed with respect to the larger cores, we can assume from these results that the ability of our observers to detect harriers did not change over the course of this project. Additionally, we can conclude that the drop in the detection rate of harriers during the third survey round was not a result of our observers being less able to detect harriers. Unlike the analysis of the larger Core Areas, though, the p(.) model was one of the best-fit models for smaller cores. This could potentially be a result of us detecting few harriers within the smaller cores as a whole (as opposed to the larger cores, which included harrier-abundant SJWA). Too few data could result in Program MARK assigning a lower AIC_C weight to the p(g) model (0.36 in this case), with the p(.) model making up much of the difference (AIC_C weight of 0.57 in our study).

As with the larger Core Areas (excluding SJWA), we should be cautious when interpreting the detection probability data for the smaller cores. As previously mentioned, we detected harriers rarely during surveys in the small cores (0–6.7% of transects), and we never detected them on any transect more than once. Without repeatability of detections, we must either conclude that the population of harriers was not closed, or that our probability of detecting birds that were present was extremely low (7–13% of the time, excluding Garner Valley).

Overall, we can conclude that our ability to detect harriers depended largely on the habitat in which we were surveying. We were clearly able to detect harriers when they were present in large, flat, open habitats such as SJWA. Because foraging harriers tended to fly low, any dense vegetation or varied topography made detecting them difficult. Furthermore, we cannot determine whether birds we were seeing during the early part of this study remained in the area throughout, or whether they were migrants that departed or arrived during our study. In all likelihood, at least some of the individuals that we detected were migrants that left or arrived during the course of this project, thereby violating the assumption of population closure. Fortunately, our observers appeared to remain consistently able to detect harriers throughout the project, suggesting that the decrease in harrier detections during Round 3 did not result from a change in our observers' abilities, but may have instead resulted from a decreased presence of detectable (i.e., flying) harriers. Such a decrease could have stemmed from an actual decrease in the number of harriers in the Core Areas, or it could have resulted from breeding female harriers spending less time foraging and more time on the ground in the vicinity of a nest. As discussed earlier, though, we detected progressively fewer adult male harriers as the project progressed; if females were nesting during the later stages of our project, we would have expected to see relatively more males (compared to females), who would have been providing food to incubating females and nestlings. Thus, we conclude that the decrease in detections during the third survey round likely resulted from fewer detectable harriers being in our survey areas, and this was not necessarily due to increased nesting activity during the final survey round.

Nesting Dates and Stages

The dates during which we observed nesting behavior at our 3 harrier nests were within the ranges presented by Macwhirter et al. (1996): egg-laying and incubation occur from early April–July, with fledging occurring as late as mid-September. We found the first active harrier nest (Wilson Valley) on 9 April, containing 5 eggs, and the only successful nest in our study (Mystic Lake) fledged young on or before 17 June.

Of particular interest is the Wilson Valley nest, which a female continued to incubate from approximately 9 April–15 June. First, we have no way of confirming that the 5 eggs we initially detected on 9 April were the same ones we saw on 22 June, by which point the nest was abandoned. Ideally, we would have assessed the age of the eggs, by weighing and measuring them, which would have enabled us to conclude whether the female had ever laid a new clutch, or replacement eggs, in the same nest. However, we were reluctant to disturb the nest or its contents, because harriers are notoriously sensitive to nest disturbances (Serrentino 1989). While it is common for harriers to incubate eggs beyond the usual 31-day period (R. Simmons, pers. comm.), it is virtually unheard of for harriers to continue incubating more than 2 weeks beyond the expected hatch date. For example, B. Massey (pers. comm.) indicated that, during their study on Nantucket Island

(Massey et al. 2008), they assumed any harrier nest that was incubated 2 weeks past the expected hatching date was failed. This assumption seemed valid: none of those nests ever produced young. This leaves open the possibility that the Wilson Valley female laid either replacement eggs or an entire replacement clutch in the same nest after the initial clutch failed and was either eaten by a predator or disposed of by the adult harriers. Usually, following the failure of a nest during its early stages (i.e., egg-laying or incubation), harriers will re-nest within 1–2 days and within 200 m of the initial nest (Simmons 1984), but almost never in the same nest that failed (R. Simmons, pers. comm.). Ultimately, we know that this nest failed, though such an observation of a female continuing to incubate so long beyond the expected hatch date is not reported in the literature.

We are unsure why the Badlands nest failed, though it appears that abandonment was involved. We did not observe adult harriers in the area on 18 May, though the nest still contained 3 cold eggs and 1 broken egg. This nest was not far from the nest that ultimately succeeded (approximately 950 m), so it seems unlikely that environmental factors (e.g., extreme temperatures or precipitation) caused the adults to abandon this nest while the other nest remained protected. Both nests were in large fields that theoretically provided abundant mammalian prey, and there was also a large cattle lot and sod farm nearby that likely provided additional foraging opportunities in the form of mice and rats. Indeed, during one visit to the Mystic Lake nest, which eventually succeeded, one of our observers noted that the nestlings appeared to have full crops, and the adult female was actually removing excess prey items from the nest, likely because the nestlings were satiated. Thus, it is difficult for us to conclude why the Badlands nest failed, though we have circumstantial evidence against low prey availability or environmental factors as causes.

Habitat at Nest Sites and Nearby Unused Sites

Mean vegetation heights surrounding our 3 nests were highly variable (20.1–75.2 cm), which is a trend that is echoed in the harrier literature. Redpath et al. (1998) reported a mean vegetation height of 46 cm at harrier nests in Scotland, while Evrard and Bacon (1998) and Terraube et al. (2009) reported mean vegetations heights of 106 cm surrounding northern harrier nests in Wisconsin and pallid harrier (*Circus macrourus*) nests in Kazakhstan, respectively. Redpath et al. (1998) reported that harriers in Scotland nest in taller vegetation than would be expected by chance; however, Limiñana et al. (2006) reported that Montagu's harriers (*Circus pygargus*) in Spain tended to select nesting sites with short vegetation, and hypothesized that tall vegetation, which would be effective in concealing the nests from terrestrial predators, would make landing and taking off difficult for adult harriers. Simmons and Smith (1985) came to a similar conclusion after determining that the most concealed harrier nests (i.e., those surrounded by tall, dense vegetation) were the least successful, though not significantly so. They proposed that harriers indeed select nest sites in part based on predator deterrence, with the focus on deterring terrestrial, rather than aerial, predators (they found that harriers are very successful at deterring aerial predators). To this end, harrier nests tend to be most successful when they are constructed on "wet" or "very wet" ground, which deters terrestrial predators from approaching. With only 3 harrier nests in our sample size, it is difficult to draw any substantial conclusions with respect to habitat variables and their influence on nest success, but our only successful harrier nest was indeed surrounded by shorter vegetation than was found elsewhere in the vicinity of the nest. At the remaining 2 nest sites, both of which failed, vegetation tended to be taller at the nest site than it was 30, 60, or 90 m from the nest.

Previous investigators have come to different conclusions regarding the role of certain habitat variables on nesting success. For example, Redpath et al. (1998) reported that harrier nesting success in Scotland was not influenced by any habitat variables they measured. However, Simmons and Smith (1985) reported that nest site ground moisture positively influenced nest success, as did the degree of nest concealment (negatively, though not significantly so). Dechant et al. (2003) suggest that management for harriers should include modification of the habitat, including periodic mowing, burning, or grazing in an effort to maintain 2–5-year-old accumulations of residual vegetation that is preferred by nesting harriers. This management approach would also improve habitat for the small mammals that make up the majority of a harrier's diet. Increasing the number of prey has been shown to not only increase harrier fecundity, but also cause otherwise monogamous male harriers to become polygynous (Hamerstrom et al. 1985).

Recommendations for Future Surveys

The importance of ground-truthing transects prior to project commencement should not be underestimated. We spent time during Round 1 driving to transects that were ultimately unsuitable for surveying, even though GIS-based maps prepared in the office suggested otherwise. Such transects had to be moved, revisited, and reassessed. In the future, we should devote 2–3 weeks to ground-truthing the transects before commencing surveys. This will hopefully maintain a relatively equal time period during which each survey round lasts.

Our results suggested that we may not have been observing a closed population of harriers, especially during the initial rounds of our survey, thereby violating a major assumption of our detection probability analysis. To minimize this effect, or eliminate it altogether, future surveys focusing specifically on the presence of breeding harriers should not begin until early or mid-May, after which it is likely that migrant harriers have left the Plan Area and only breeding or un-paired, non-migrant harriers remain.

Additional GIS work during the pre-fieldwork phase should aim to construct, or model, a surveyable area of inference (e.g., eliminating small patches of habitat that cannot support an entire transect, accounting for accessible slope, vegetation density, etc.). With this goal in mind, our Program has started constructing a GIS-based model of accessibility that eliminates slopes greater than 25 degrees and chaparral densities exceeding 60% from areas that will be surveyed. Continuing to adjust the model in the office, followed by ground-truthing areas before surveys start, should increase efficiency in future survey projects.

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Appendix A. Western Riverside County MSHCP Biological Monitoring Program Protocol for Northern Harrier Breeding Surveys, February 2009

Goals: Document the distribution and breeding status of the Northern Harrier (*Circus cyaneus*; "NOHA") within Western Riverside County. Examine potential seasonal habitat covariates for the occurrence of this covered species. Determine detection probabilities and available habitat use for breeding harriers in the Conservation Area. Demonstrate at least 75% of 9 Core Area as having a successful NOHA nest, defined as at least one young of host species fledged.

Timing: Surveys will be conducted to coincide with a known breeding period of March–August for southern California (Davis and Niemela 2008). In February, in Riverside County, the NOHA population is comprised of residents and northern migrants. Therefore, observers will be on the ground late-Feb/early Mar. to document how the NOHA populations in the Core Areas change during migration and to identify breeding territories of resident breeders as early as possible.

Survey Locations: Surveys will be conducted within identified Core Areas for NOHA within the Conservation Area (see attached map). Appropriate habitat will consist of primary and secondary habitat types identified in the MSHCP species accounts for the target species, including all open country (grasslands, agriculture, and bare ground), wetland or marsh as well as sage scrub. Potential breeding habitats will be identified by using CDFG et al. (2005). Excluded from the appropriate habitat layer were any areas containing more than a 10% density of coastal sage scrub, as well as any coastal sage scrub habitat located on a slope of more than 25 degrees.

Methods: Transects will be sampled on foot. Survey methods are based on techniques described in Fuller and Mosher (1981).

Sampling Design: Approximately 150 randomly-located transects, each 250 m long, were placed throughout accessible lands using Hawth's Tools (Beyer 2004). The transects were located in appropriate breeding habitat within the Conservation Area. Center points of transects were ≥ 500 m from one another, and the entire length of each transect was within appropriate habitat. This will enable us to survey a greater amount of land within potential breeding habitats.

Eight Core Areas were divided into two groups. The first group, including the San Jacinto Wildlife Area, Lake Skinner, Lake Mathews, and Potrero Cores, contained one transect/95 hectares of appropriate habitat. The second group, including the Santa Ana River, Wilson Valley, Garner Valley, and Lake Elsinore Cores, contained one transect/8 hectares of appropriate habitat. This division in transect density served two purposes. First, it gave us a manageable sample size of transects in the larger Core Areas while at the same time providing us with a reasonable number of transects given the number of personnel working on the project. Second, surveying at a higher density within the smaller Core Areas allowed for a more adequate sample size than would have been attained if we had used the same transect density as in the larger Core Areas. All transects within the larger Core Areas were oriented in a north-south direction and include GPS coordinates for the southernmost, central, and northernmost points. Transects within the smaller Core Areas were oriented in random directions that kept the entire transect within appropriate habitat; these also included one central and two terminal sets of coordinates. The Chino Hills Core was excluded from our study design because it contained just 0.05 hectares (500 m^2) of appropriate habitat.

Survey Techniques: All sites will be surveyed beginning 0.5 h after sunrise and each observer will attempt a minimum of 5 transects per day. Surveys will be terminated early if the temperature exceeds 35 degrees C or during precipitation or heavy fog. Additionally, no surveys will be conducted for 48 h following a significant precipitation event, any time vehicles leave significant ruts in the roads, and any time there is significant snow or ice accumulation on the roads being used to access transects. Bildstein (1978) and Wilkinson and Debban (1980) showed that as wind speed and temperature increased, so did harrier flight activity. Therefore, unless wind causes safety concerns (dust/debris storms), it is not necessary to stop a survey for high winds. Waypoints and routes for each transect will be downloaded into a GPS unit prior to the beginning of the survey. At the beginning of each transect, observers will record the transect start time, temperature, wind speed (estimated on the Beaufort scale if no wind gauge is available), and weather conditions on provided datasheets.

Observers will survey the transect beginning at either the southernmost or northernmost point, and navigating to the opposite end of the transect. While surveying for harriers, observers should attempt to walk at a constant speed, spending approximately 10 minutes walking from one end of the transect to the other. If significantly less than 10 minutes have been spent walking a transect, the observer will turn around and begin walking the transect again until approximately 10 minutes have elapsed. If no NOHA are observed, transects should last no longer than 20 minutes.

If NOHA are observed, strict timing of the transect may cease as this is a breeding survey and observers will need to spend time with NOHA to at least determine the breeding status of individuals encountered and attempt to locate nests.

If NOHA are seen, and the observer has to leave the transect to follow the bird, the time of transect departure will be recorded, and the observer should also mark as a waypoint their stopping point along the transect. When finished following/observing the NOHA, the observer should return to the point along the transect from which they departed, and continue the transect; however, if more than 10 minutes were already spent on the transect before observing a NOHA, there is no need to finish the transect. When continuing a transect after following a NOHA, the observer will add to the time already spent on the transect.

When a NOHA nest, or suspected nest location, has been found, observers must practice caution, as harriers have shown to be easily disturbed by human presence and intrusion (Serrentino 1989). Certain data may necessitate visual inspection of the nest; however, at present, searches will not require an approach of closer than 20 m to determine if a nest is active, and if so, the approximate stage of nest. Due to the protracted nature of each NOHA breeding attempt, nests will not be revisited more frequently than once a week. As each breeding attempt progresses and adults are less likely to abandon their nest, it may become necessary to visually inspect the nest to age nestlings for accurate forecasting of fledging dates. If visual inspection of nest is required and a fledging date is forecast, revisit to the nest to determine if nest fledged will occur no less than 6 days before forecast date. When a nest in any Core Area successfully fledges any NOHA young, all other active nests within the same Core Area will be followed to completion but new nests will not be searched for.

Equipment

Handheld GPS Unit
Thermometer
Binoculars
Spotting Scope
Data Sheets
Camera
Anemometer
Rangefinder
Compass
Field Guide
Spotting scope w/tripod

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Appendix B. Protocol for Quantifying Habitat At and Around Northern Harrier (*Circus cyaneus*) Nests, 2009

Data collection at the nest (Microhabitat)

To begin, observers should make sure they have filled out the top portion of the data sheet: date, observer(s) initials, and Point ID. Nest sites will have two-letter location-specific abbreviations, followed by the word “Nest,” then “09” for 2009, and lastly a two-digit code for the nest number (e.g., “WV Nest 09-01” for a nest in Wilson Valley).

After arriving at the nest, the width (cm) at the nest’s widest point should be measured and recorded, followed by the width of the nest perpendicular to the widest breadth. In the event that the nest structure appears disheveled and unkempt, whether as a result of animal activity or general lack of nest maintenance by the harriers, this measurement can be skipped, because it will not accurately reflect the actual dimensions of the nest while it was active.

Next, observers will measure and record both vegetation height (cm) and litter depth (cm) 1, 5, and 10 m from the edge of the nest in each of the cardinal directions. Observers may find it useful to hold the measuring tape in place with a survey pin. Begin by stretching the measuring tape 10 m north of the northern edge of the nest. Care should be taken to avoid trampling vegetation along the path of the measuring tape, which could result in skewed vegetation height measurements. To determine vegetation height at the above intervals, one observer will place a meter stick on the ground, while the second observer (data recorder) determines the maximum height at which vegetation contacts the meter stick. Litter depth (cm) will be determined by observing depth of litter[4] atop the solid ground.

Effective vegetation height (in.[5]) will be determined at 10 m from the nest edge using an effective vegetation height checkerboard consisting of 1 square inch squares. One observer will hold the checkerboard on the ground at the 10-m mark while the second observer (data recorder) is at the nest. With their eyes 1 m above the ground, which can be measured with the meter stick, the data recorder will determine the maximum height on the checkerboard at which 90% of the squares at a given horizontal value are completely obscured by vegetation. This is made easier by the fact that the checkerboard has 10 squares at each horizontal level. For example, if all of the squares are obscured at the 1–4-inch levels, 9 of the squares are obscured at the 5-inch level, and 8 are obscured at the 6-inch level, the effective vegetation height should be recorded as 5 inches.

Following the collection of effective vegetation height and litter depth data, observers will record data on ground cover within 10 m of the nest. Starting at 0.5 m from the nest edge, and continuing to the 10 m mark, observers will record ground cover at 0.5-m intervals along the tape using a point-intercept technique. These data are categorical, and

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[4] Litter is defined as dead organic vegetation that is positioned 45 degrees or less relative to the ground.
[5] These data will be converted to cm for analyses. Checkerboard squares that are 1 square inch are more visible in the field than 1 square cm, which will allow for more accurate measurements.

should fall within one of the following categories: grass, forbs[6], litter, bare ground[7], rock[8], shrub[9], or tree[10]. The data recorder will tally how many of each cover type the observer identifies, and there should be a total of 20 tallies when the 10-m mark is reached in each cardinal direction. One of the simplest methods in identifying ground cover is to simply lower the pointed end of a survey pin toward the ground at the 0.5-m intervals and identify the type of ground cover it first contacts. The above processes (i.e., vegetation height, litter depth, etc.) will then be repeated at each of the cardinal directions (i.e., west, south, and east) relative to the nest.

After making the above measurements within 10 m of the nest or unused point (see **Data collection at unused sites near nest sites** section below), indicate in the Notes section of the datasheet whether there were any habitat variables that may not have been captured along the cardinal direction measurements. For example, if a large shrub was located northwest of the nest, the measuring tape, and thus an observer's measurements, may have missed the shrub entirely; this could be an important factor in the nest site selection process by harriers and should be briefly noted on the datasheet.

Data collection in the vicinity of the nest (Macrohabitat)

After collecting data at and around the nest, observers will need to identify the distance from the nest to the nearest: building, potential perch site[11], tree, shrub, hydrological feature[12], paved road, unpaved road, and road of any kind. Additionally, observers will need to identify the closest outer edge of the habitat in which the nest microhabitat[13] is located, and calculate that distance as well. Lastly, observers will identify how many buildings are within 50 and 100 m of the nest, as well as the length of paved and dirt roads within those distances. The number of potential perch sites within 50 m of the nest should also be counted and recorded.

As noted on the data sheet, some or all of the distances mentioned in the above paragraph can be calculated at the office, but that will require observers to either mark on their GPS the coordinates of the features in the field, or identify them on an aerial photo of the area. With that information, distances between the nest and the features can easily be calculated in the office.

Data collection at unused sites near nest sites

Unused site locations will be identified as follows: first, a random bearing (1–360°) will be selected in the office to ensure that points are within appropriate harrier habitat. Next,

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[6] Forbs will be defined as herbaceous plants that are not graminoids (which are grasses, sedges, and rushes). Some examples of forbs would be clover, sunflower, and milkweed.
[7] Bare ground can include dirt or grains of sand up to 2 mm in diameter.
[8] Rock is defined as consolidated mineral material more than 2 mm in diameter.
[9] Shrubs are defined here as woody perennials, usually with several main stems, and < 7 m tall.
[10] Trees are defined here as woody perennials with (usually) a solitary trunk or main stem, > 7 m tall.
[11] Perch sites can be trees, shrubs, snags, fence posts or wires, etc. – anything you, as an experienced harrier observer, would reasonably expect to see a harrier using as an above-ground perch site.
[12] Lake, stream, river, etc. We may choose to identify the nearest hydrological feature as noted on a topographical map, which has been done by previous investigators.
[13] Within 10 m of the nest

at a distance of 30 m from the nest, and at the random bearing selected, the first unused site will be identified. Then, a second unused site will be situated 120° in a counterclockwise direction from the first, but this site will be 60 m from the nest. Lastly, a third unused site will be situated 120° in a counterclockwise direction from the second site, and this third site will be located 90 m from the nest. Thus, the three unused points will be 120° from one another and located at distances of 30, 60, and 90 m from the nest. These points will be labeled with the same two letters identifying the nearby nest, followed by "09" and the nest number, then 30, 60, or 90, for points 30, 60, and 90 m from the nest, respectively (e.g., "WV-09-01-30" for the unused point 30 m from the Wilson Valley nest).

Data collection at unused sites will follow the same protocol as data collection at nest sites. Of course, observers will not have nest diameters to measure, and will not be radiating the measuring tape from the edge of any nests; rather, such measurements will radiate (north, west, etc.) from the random point. Otherwise, collection of effective vegetation height, litter depth, and ground cover data will be the same as described above. Additionally, measurements of the distance to the nearest features will proceed as described above.

Materials Needed

50-m measuring tape, GPS, compass, effective vegetation height board, and survey pins.