Nest Occupancy and Breeding Productivity of American Kestrels in Merced, California

Peer-Reviewed Paper

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Researchers have described major declines in breeding populations of American Kestrels (*Falco sparverius*) since the 1960s in the western United States, including parts of California (Hamerstrom et al. 1973, Sauer et al. 1997, Pandolfino 2008, Farmer and Smith 2009, Smallwood et al. 2009). In California, habitat loss and lack of nesting sites are considered the most likely causes of declines (Smallwood et al. 2009). In response, many organizations are working to expand populations by placing nest boxes in suitable areas and monitoring them to determine nesting success (http://kestrel.peregrinefund.org/).

We describe results from 2015 and 2016, the second and third year of a study on American Kestrel breeding productivity at the Merced Vernal Pools and Grassland Reserve near the University of California, Merced (UCM). In the first year, 2014, kestrels occupied six of ten available nest boxes and fledged 15 young (Swarth et al. 2014). In January 2015, we added 20 more nest boxes to the Reserve. Study goals were to assess the population's response to the increase in boxes, measure nest box occupancy and breeding productivity, band nestlings and adults, assess recapture rates of previously banded birds, and provide a hands-on research experience for UCM students.

STUDY AREA

We conducted the study at the University of California's Merced Vernal Pools and Grassland Reserve (Reserve) at 85-177 m (280-580 ft) elevation near Merced, CA. Habitat features and general climate are described by Swarth et al. (2014). The area consists of annual grasslands and vernal pools, with very limited tree cover or other natural or anthropogenic features that supply suitable kestrel nesting sites. The 2,656 ha (6,563 ac) Reserve is moderately grazed by about 1,600 dairy cattle during the green months: December or January through May or June (Swarth et al. 2017). Average annual grass production at the Reserve was estimated at 1,418 kg/ ha (1,266 lbs/ac) and the average annual consumption of grass by cattle was 617 kg/ha (551 lbs/ac) for 2013-2015 (Swarth et al. 2017).

We used annual calendar-year precipitation data taken at the University of California, Merced County Cooperative Extension Office; CDWR station #148 located 7.5 km (4.7 mi) south of our study area at 67 m (204 ft) elevation (http://cemerced.ucanr.edu/about/weather/). Rainfall was 9.6 cm (3.8 in) in 2013, 23.5 cm (9.3 in) in 2014, and 16.2 cm (6.4 in) in 2015. These were three of the driest years on record in Merced. Rainfall increased substantially in 2016 to 43.8 cm (17.3 in). The long term (1899-2016) mean for rainfall there is 31.2 cm (12.3 in).

METHODS

In January 2015, prior to the nesting season, we and student volunteers added 20 nest boxes to the previous 10 boxes (to total 30), placing them along barbed wire fences within the Reserve boundaries and on two utility poles next to the Le Grand irrigation canal adjacent to the UCM campus. All nest boxes along fences were bolted to the top of steel poles approximately 3 m (9 ft) tall. Nest boxes measure about 46 x 20 x 20 cm (18 x 8 x 8 in), and were spaced at least 200 m (650 ft) apart. We placed 4-6 cm (1.5-2.5 in) of wood shavings in boxes to protect eggs from breaking. At the end of each breeding season we cleaned the occupied nest boxes and replenished shavings.

We and student volunteers monitored boxes approximately every 14 days from March through July. To check for nest initiation, we covered the nest box entrance hole with a tight-fitting plug and lifted the box lid momentarily to determine if eggs or an incubating adult kestrel were present. After determining the presence of eggs or an incubating adult in each box, we returned two weeks later to count the number of eggs and to capture and band the adults. We captured adults in the nest box using two techniques. We first plugged the entrance hole, then slowly lifted the lid and captured any adult present. If an adult was not present, we placed a custom-made swing door trap in the box that shut after a bird entered, trapping the bird inside. After the trap was observed to have been triggered, we returned to the nest box and captured the adult for banding.

For summary and analysis, we defined nest initiation as the date when at least one egg had been laid. Nests initiated in May or later were categorized as late-season nests. At late-season nests, we captured females and checked for bands to determine if they were attempting a second clutch. For all nest failures, we identified and documented whether a box was abandoned by the adults before incubation began or if all eggs (a full clutch) remained unhatched despite being incubated by a parent. We also recorded if predation had occurred, based on scratches on nest boxes from raccoon claws, remains of dead adults or nestlings found in nest box, or entire clutches missing. We used student's t-test to compare the average distances-to-water of boxes that were predated and those that were not.

RESULTS

Over 2015 and 2016, 27 (90%) of the 30 nest boxes were used at least once. Seventeen boxes were occupied in 2015, and 22 boxes were occupied in 2016 (Tables 1 and 2). In 2015, 14 pairs made 18 nesting attempts, and in 2016, 20 pairs made 24 nesting attempts (i.e., four pairs nested twice in both years). Thus, compared to the six pairs and nesting attempts in 2014, addition of 20 nest boxes prior to the 2015 season led to a 2.3-fold increase in the American Kestrel nesting population in 2015 and a 2.7-fold increase in 2016. Nesting attempts increased threefold in 2015 and fourfold in 2016 from numbers in 2014 (Table 1). Nest box occupancy averaged 64% over all three years. The highest nest box occupancy (73%) occurred in 2016 (Table 1).

The number of eggs produced increased from 73 in 2015 to 110 in 2016 (Table 2); however, the percent of successfully hatched eggs decreased substantially from 70% in 2015 to 44% in 2016. The average clutch size increased over the three-year period, with an average clutch size for three years of 4.3 eggs per clutch (Table 1).

The average number of nestlings in each occupied box decreased from 2.5 in 2014 to 2.0 in 2016 (Table 1). However, the number of nestlings per successful nest increased from 3.8 in 2014 to 4.2 in 2016 (Table 1). Fledging success of hatched young was 100% in 2014, but dropped in subsequent years to 86% in 2015 and 72% in 2016. The total fledging success over three years was 82% (Table 1).

Thirty adults were banded over the three years of the study. The number of newly banded adults increased from 11 in 2015 to 14 in 2016 (Table 1). Five birds banded as adults were recaptured in 2015 and eight were recaptured in 2016. A total of 97 nestlings were banded and 92 successfully fledged (Table 1). We have yet to document any breeding in subsequent years by birds that were hatched and banded at the Reserve.

In 2015, four boxes were occupied late in the season (eggs laid in May-July), all of which were second nesting attempts by banded females that had nested earlier in the season. No eggs in the four late nests hatched. One box was occupied twice in the same season by different breeding pairs. One late nesting experienced nestling loss; five nestlings were seen in the box, but later only three were banded. The fate of the missing nestlings is unknown.

Four late-season, second clutch attempts occurred in 2016. Two of these attempts resulted in at least one fledged young. In 2016, two boxes were occupied twice; we do not know if, in each case, they were occupied by the same or different breeding pairs (Table 2). Some nestlings in two late 2016 boxes died before fledging. In both boxes, five nestlings were banded, but upon returning to assess fledging success, two dead nestlings were found at one box and three were dead in the other.

Table 1. American Kestrel nest box occupancy, clutch size, hatching and fledging success, reproductive success, and banding results at the University of California's Merced Vernal Pools and Grassland Reserve, 2014-2016.

	2014	2015	2016	All years
Available Boxes	10	30	30	70[a]
Occupied Boxes	6	17	22	45
Percent of Boxes Occupied	60%	56%	73%	64%
Nesting Pairs	6	14	20	40
Nesting Attempts	6	18	24	48
Eggs Laid	22	73	110	205
Eggs Hatched	15	51	46	112
Unhatched or Lost Eggs	7	22	64	93
Mean Clutch Size	3.7	4.1	4.6	4.3
Number of 5 Egg Clutches	2	9	17	28
Successful Nests[b]	4	11	11	26
Nestlings Fledged	15	44	33	92
Hatching Success (eggs hatched/laid)	68%	70%	42%	55%
Fledging Success (fledglings/hatched eggs)	100%	86%	72%	82%
Fledglings/Successful Nest	3.8	4.0	3.0	3.5
Fledglings/Nesting Attempt	2.5	2.4	1.4	1.9
Fledglings/Nesting Pair	2.5	3.1	1.7	2.3
Nestlings Banded	15	44	38	97
Adults Newly Banded	4	11	14	30
Adults Recaptured	3	5	8	16
Total Adult Captures	7	16	22	45

[a] Total is number of box-years (sum of boxes available during 2014-2016)
[b] Nests that fledged at least one young

Four additional clutches failed to hatch in both 2015 and in 2016 (Table 2). The number of abandoned nests doubled from 2015 to 2016. The number of instances of egg and nestling predation also increased, from one in 2015 to five in 2016 (Table 2). The average distance to permanent water sources (irrigation canals or the nearby Lake Yosemite; 1,128 m) was less at boxes where predation occurred to occupied boxes where no predation occurred (2,113 m); this difference was statistically significant ($t = -2.24$, $p = 0.036$).

Reproductive success (young per nesting attempt) averaged 2.4 in 2015 and 1.4 in 2016 (Table 1). Reproductive success in 2015 and 2016 was higher for the 40 early-season nesting attempts (2.0 young/nesting attempt) than for the eight late nesting attempts (0.62 young /nesting attempt). Given that all late season nesting attempts were believed to be second attempts by pairs that had nested previously in the study area, average annual productivity per nesting pair was 3.1 in 2015 and 1.7 in 2016 (Table 1).

DISCUSSION

The substantial increase in the nesting population of the American Kestrel on the Reserve, where natural nest sites were very limited, demonstrates the value of nest boxes as a conservation tool for this species in this grassland region. Our results strongly suggest that the size of the regional kestrel population was constrained by lack of nest sites. Placement of boxes resulted in rapid adoption and population increase. Our results amplify similar preliminary conclusions by Swarth et al. (2014) for the study area, and by other kestrel nest box studies (Smallwood and Collopy 2009, Steenhof and Peterson 2009).

Nest box occupancy rates reported elsewhere for American Kestrels varied from 45% to 75% (Varland and Loughin 1993, Breen and Parrish 1997, Smallwood and Collopy 2009). The average Reserve nest box occupancy rate of 67% over three years is above the mid-point of the reported range. Annual occupancy rates may fluctuate due to climatic variation, changes in prey availability, and distance between nest boxes (Toland and Elder 1987, Varland and Loughin 1993, Breen and Parrish 1997, Dawson and Bortolotti 2000). We discuss potential contributions of these factors to occupancy at the Reserve.

We did not analyze effects of climate or weather on nest occupancy. Although the highest breeding population occurred in 2016, the only year of above-average precipitation, this outcome also could have resulted independently from gradual demographic response to the increased availability of nest boxes. Climate effects on occupancy could be evaluated over a longer period of years if nest box availability is held steady.

Table 2. American Kestrel nest box occupancy, clutch size and banding results for 2015 and 2016. Three nest boxes were occupied twice in a season (*). Boxes 11, 19, and 27 were not occupied in either year. A=Abandoned; P=Predated; U=Unhatched.

	2015		2016	
Nest Box	Clutch Size	Nestlings Banded	Clutch Size	Nestlings Banded
1			3	0 (A)
2*	5 and 3	5 and 0 (U)	6	2
3	2	0 (U)	5	3
4	5	0 (P)	5	0 (U)
5			5	5
6			5	5
7	5	5	5	2
8			5	0 (P)
9			4	0 (P)
10	5	5		
12*	5	5	2 and 5	0 (A) and 3
13	4	0 (U)		
14			5	5
15	5	5		
16	4	4	5	0 (P)
17			4	0 (U)
18			5	0 (U)
20	5	3	5	0 (P)
21	4	4	5	0 (U)
22	1	0 (A)		
23	4	0 (U)		
24*	5	3	2 and 5	0 (A) and 5
25	4	4	5	0 (A)
26	2	0 (A)	5	5
28			5	2
29	5	1	4	1
30			5	0 (P)
Totals	73	44	110	38

Although we did not investigate prey abundance, we do not suspect that nest box occupancy was influenced by food limitation, based on the rapid increase in the box occupancy. Anecdotally, we observed abundant grasshoppers and small bird species in all study years. Important prey items for kestrels nesting on the Reserve have been identified as grasshoppers (Caelifera), Horned Larks (*Eremophila alpestris*), Cliff Swallows (*Petrochelidon pyrrhonota*), and wolf spiders (Lycosidae) (McDermot 2016).

Our data suggest that the way we spaced nest boxes did not influence occupancy because many adjacent nest boxes were occupied.

Average clutch size in both natural sites and nest boxes varied from 4.0 to 5.0 (Smallwood and Bird 2002). The average clutch sizes in our study in 2015 (4.1) and in 2016 (4.6) were comparable with the average clutch size of 4.3 in Lassen County, California (Bloom and Hawks 1983). Nests with larger clutches tend to be more successful (i.e., produce at least one fledgling) than nests with smaller clutches (Smallwood and Bird 2002).

The average hatching rate (55%) from 2014-2016 on the Reserve is lower than that found in other studies conducted in North America, which ranged from 62% to 89% (Varland and Loughlin 1993, Smallwood and Bird 2002, Smallwood and Collopy 2009). Hatching success may be influenced by the age and size of the female. Smaller females may not be capable of fully covering their clutches during incubation, resulting in a lower hatching success (Bortolotti and Wiebe 1993). Future examination of size and age in adult females on the Reserve may provide more insight on hatching success. The average fledging rate (82%) for the three years of our study was slightly lower than rates reported in other studies, which ranged from 85% to 98% (Varland and Loughin 1993, Smallwood et al. 2009). Additionally, fledglings per nest attempt also were considerably lower in our study (mean = 1.9) than in other studies (range = 2.9 to 4.5; Bloom and Hawks 1983, Tolland and Elder 1987, Varland and Loughin 1993).

The somewhat low hatching and fledging rate in 2015 is attributable mostly to the four (22% of clutches) unsuccessful late-season, second nesting attempts. Late nesting attempts typically fail to produce young in our region (S. Simmons, unpubl data). Low nesting success in 2016 primarily resulted from a high predation rate (21% of clutches) on eggs and nestlings. Nest boxes that experienced predation were, on average, closer to water sources. Raccoons (*Procyon lotor*) are suspected to be a likely predator as they prefer to travel along water. Gopher snakes (*Pituophis catenifer*) are also a possible predator. It is not uncommon for predation of eggs and young in nest boxes to increase over time as predators learn to identify and enter artificial nest boxes in search of prey (Robertson and Rendell 1990, Miller 2002). For example, Tree Swallows (*Tachycineta bicolor*) in artificial nest boxes experienced a reduction in nesting success over time due to increases in predation by both raccoons and snakes (Robertson and Rendell 1990). Identifying and applying methods to prevent egg and nestling predation in nest boxes would likely help increase kestrel nesting success on the Reserve.

Breeding productivity at the Reserve varied by 44% (from 1.4 to 2.5 young per nesting attempt) over the three study years. As with occupancy, variation in kestrel productivity is also thought to be influenced by climate and prey availability (Dawson and Bortolotti 2000). Breeding productivity was lowest in 2016 due to increased incidence of predation and nest abandonment. The greater nesting success during drier 2014 and 2015 suggests that drought did not depress breeding productivity. The relationship between rainfall and nesting success, however, cannot be conclusively determined based on a three-year study.

The increased number of nest boxes on the Reserve has made it possible for us to band more young and adults. A larger population of banded, known-age individuals will help us gain a better understanding in the future of age-related breeding, movements, and possibly survival. The percentage of adults returning to breed on the Reserve (35%) is higher than that of other studies, which range from 9.7 to 22.6% (Bowman et al. 1987). A higher rate of returning adults may indicate a lack of nesting sites in other locations. To date, the reserve has not recaptured a breeding adult that was hatched and banded on the Reserve as a nestling. However, two females were recaptured on the Reserve in 2015 that had been banded as nestlings in 2013 from the same brood at the nearby Flying M Ranch, indicating that adults will nest in the same general area where they hatched. Female kestrels in Florida moved on average about 8.6 km (5.2 mi) from their natal site (Miller and Smallwood 1997), which is about the distance from the Flying M Ranch to the Reserve.

In summary, the results of our nest box occupancy and productivity study are similar to those of other studies carried out in a variety of regions across the United States. Results show that American Kestrels will occupy and successfully nest in nest boxes within a range of landscapes, thereby leading to an increase in breeding populations. Our study also documents the potential for American Kestrel population resiliency during a drought period. Finally, this study continues to be an excellent way to introduce undergraduate students to field ecology and wildlife conservation.

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