Avian Conservation and Management

Utilizing artificial nesting platforms as a management tool: enhancing breeding productivity of Western Flycatchers (*Empidonax difficilis occidentalis*) in southwestern Colorado and southern Arizona, USA

Uso de plataformas de anidamiento artificiales como una herramienta de manejo: aumentando la productividad de reproducción del Mosquero Cordillerano (*Empidonax difficilis occidentalis*) en el suroeste de Colorado y el sur de Arizona, EUA

Charles van Riper III[1,2] , *Harold F. Greeney*[3] , *Abigail J. Darrah*[4,5] , *Andy J. Boyce*[4,6] , *Drew F. van Riper*[7] and *Charles B. Yackulic*[8]

ABSTRACT. Artificial nesting substrates have been added around the world for many cavity-nesting bird species, but this has not been undertaken as extensively for crevice-nesting birds. The Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*) is a migratory, crevice-nesting flycatcher that is nest-site limited, breeding in higher elevation riparian habitats throughout intermountain western North America. We tested the effectiveness of multiple artificial nesting platform types that this flycatcher would accept for nesting, and then utilizing the successful design established an experimental array of platforms in southwestern Colorado and southern Arizona. From 2008 to 2022 we documented Cordilleran Flycatcher breeding and the influence of nesting platforms on productivity of young and adult numbers. Breeding behaviors did not differ significantly between natural nest sites and platform nests, except that the nestling period was an average of 16.73 (+/- 0.98) days on platforms as compared to 15.92 (+/- 0.71) on human structures and 15.67 (+/- 0.48) days in natural locations. Platform nests had lower predation rates and greater rates of successful fledging when compared to natural locations. At both study locations platform nests doubled the number of young fledged each year. In Colorado, where Western Cordilleran Flycatchers were initially absent from areas, adult numbers increased following introduction of platforms, but in Arizona adult flycatcher numbers were not affected. Our findings demonstrate that the addition of artificial nesting platforms can enhance productivity and numbers of Western Cordilleran Flycatchers, and we hope that our findings will prove useful for the conservation of other crevice-nesting bird species.

RESUMEN. Los sustratos de anidamiento artificiales han sido usados alrededor del mundo para muchas especies de aves que anidan en cavidades, pero no se han empleado para aves que anidan en grietas. El Mosquero Cordillerano (*Empidonax difficilis occidentalis*) es un atrapamoscas migratorio que anida en grietas, y que está limitado por sitios de anidamiento, reproduciéndose en hábitats ribereños a mayor elevación a lo largo del oeste inter-montañoso de Norte América. Nosotros evaluamos la efectividad de múltiples tipos de plataformas de anidamiento artificiales que este atrapamoscas podría aceptar para anidar; y luego, utilizando el diseño exitoso, se estableció un arreglo experimental de plataformas en el suroeste de Colorado y el sur de Arizona. Desde 2008 a 2022 documentamos la reproducción del Mosquero Cordillerano y la influencia de las plataformas de anidamiento en la productividad de números de juveniles y adultos. Los comportamientos de reproducción no variaron significativamente entre nidos naturales y nidos en plataformas, excepto que el periodo de anidamiento fue en promedio de 16.73 (+/- 0.98) días en plataformas en comparación con 15.92 (+/- 0.71) días en estructuras humanas y 15.67 (+/- 0.48) días en sitios naturales. Los nidos en plataformas tuvieron tasas de depredación más bajas y mayores tasas de abandono exitoso de nido, en comparación a sitios naturales. En ambos lugares de estudio, los nidos en plataformas duplicaron el número de juveniles que emplumaron y abandonaron el nido cada año. En Colorado, donde los Mosqueros Cordilleranos estaban inicialmente ausentes de algunas áreas, los números de adultos incrementaron después de la introducción de plataformas; pero en Arizona, los números de mosqueros adultos no fueron afectados. Nuestros hallazgos demuestran que la adición de plataformas de anidamiento artificiales pueden aumentar la productividad y los números de Mosqueros Cordilleranos, y esperamos que nuestros hallazgos prueben ser útiles para la conservación de otras especies de aves que anidan en grietas.

Key Words: *Arizona; breeding; Colorado; conservation; crevice nesting; Neotropical migrant; nest site limitation; predation; productivity*

INTRODUCTION

The Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*), an insectivorous Neotropical migrant passerine, breeds throughout the montane regions of western North America (Lowther et al. 2020). Classified as a crevice-nester and considered nest-site limited (Collias and Collias 1984), this flycatcher typically places nests on recessed rock ledges, nooks in stream banks, behind loose bark on trees, or within the roots of wind-thrown trees. The birds also frequently nest on buildings, especially horizontal crossbeams (Boyce et al. 2020, Darrah and

[1]School of Natural Resources and the Environment, University of Arizona, [2]US Geological Survey, Southwest Biological Science Center, Tucson, AZ, [3]Yanayacu Biological Station & Center for Creative Studies, Cosanga, Napo, Ecuador, [4]School of Natural Resources and the Environment, University of Arizona, Tucson, AZ, [5]Audubon Delta, Mississippi Coastal Bird Stewardship Program, Moss Point, MS, [6]Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute, Washington, DC, USA, [7]Manassas, VA, [8]US Geological Survey, Southwest Biological Science Center, Flagstaff, AZ

van Riper 2021). This broad range of nesting substrates has previously been documented for Western Cordilleran Flycatchers in Colorado and Arizona (Corman and Wise-Gervais 2005, Colorado Bird Atlas Partnership 2016).

The addition of 4-sided nest boxes has been shown to increase breeding bird numbers and enhance productivity of numerous hole-nesting birds around the world (Kluijver 1951, Perrins 1979, Brawn and Balda 1988, Fargallo et al. 2001, Sutherland et al. 2004, Mänd et al. 2009, Hepp and Bellrose 2013, Norris et al. 2018, Hannay et al. 2022). In North America, nest boxes for the Wood Duck (*Aix sponsa*) have been erected over much of the continent during the last 50 years, and breeding populations have responded by increasing at an overall continental rate of approximately 6% per year (Hepp and Bellrose 2013). Backhouse (1986) summarized recovery of the Eastern Bluebird (*Sialia sialis*) from the "brink of extinction" to locally common, following placement of nesting boxes throughout Eastern North America. Norris et al. (2018) found that nest boxes increased reproductive output for Tree Swallows (*Tachycineta bicolor*) in central British Columbia, Canada, with pairs nesting in boxes producing over twice the number of young as birds in natural nesting holes. East and Perrins (1988) found in European broadleaf temperate woodland forests that nesting success for species was lower in natural nesting holes than in nest boxes, because of a higher percentage of total nest failures.

There have been comparatively few studies to determine if crevice-nesting birds would respond to the addition of artificial nesting substrates. In Finland and Lithuania, Kuitunen and Aleknonis (1992) found increased breeding success of the crevice-nesting Common Treecreeper (*Certhia familiaris*) with the addition of nesting boxes. Weeks (1979, 2020) found that the crevice-nesting Eastern Phoebe (*Sayornis phoebe*) realized increased nest productivity when breeding on human structures, compared to natural locations. Kestrels (*Falco* spp.), normally a hole-nesting bird in Europe and North America, have responded to recent efforts to provide them with open 3-sided nesting platforms (Fargallo et al. 2001, Lambrechts et al. 2010).

During a study of Western Cordilleran Flycatcher breeding in southwestern Colorado, we found that nesting birds were absent from portions of riparian habitat along the Dolores River. We hypothesized that this was due to a lack of suitable nesting sites. Beginning in 2010, we tested this hypothesis by adding several types of artificial nesting structures. Although the Western Cordilleran Flycatcher is widespread and not presently a species of concern, we felt that this was an opportunity to test if artificial platforms would help breeding and if so, this could possibly be used as a management tool for crevice-nesting species of concern. After identifying a structure that flycatchers would utilize for nesting, we supplemented the habitat with 2-sided nesting platforms, and from 2012 to 2017 documented how those platforms influenced breeding, adult numbers, reproductive success, and site-level productivity. Then from 2018 to 2022 we tested our platform findings on a breeding Western Cordilleran Flycatcher population at Mt Lemmon in southern Arizona.

We hypothesized that, following the introduction of artificial nesting platforms, Western Cordilleran Flycatcher numbers would increase and that they would utilize artificial platforms where natural nests sites were limited. We also hypothesized that

nest predation by predatory birds and mammals would probably increase because of platform visibility, but in terms of site-level productivity losses to predation might be compensated for by the increased availability of suitable nesting sites. If our nest platform supplementation efforts were successful, we felt that this would enable researchers to have easier access to nests for studying breeding birds (e.g., Katzner et al. 2005), and that this also might encourage similar efforts to increase numbers of crevice-nesting birds of concern at other locations.

METHODS

Study areas
Our study took place from 2008 to 2018 in Dolores County, southwestern Colorado, and then from 2019 to 2022 on Mt Lemmon, in Pima County Arizona USA. In Colorado, study areas were established along the east fork of the Dolores River from 2280 to 2590 m elevation, with a core study site that encompassed 28 ha centered on 37.576234°N, -108.22559°W at 2423 m elevation. We also had a paired 30 ha study site without buildings at Ryman Creek, 20 km up the Dolores River at 2667 m elevation (37.615230°N, -108.045953°W). The Dolores River runs through a glaciated valley bottom and is bounded on either side with riparian cottonwood (*Populus fremontii*) gallery forests. This natural montane riparian habitat is interspersed with patches of open areas created by pasture and residential buildings. The riparian habitat mosaic also includes alder (*Alnus* spp.) and willow (*Salix* spp.) thickets along sections of stream bank, and mixed species stands of spruce (*Picea* spp.), Douglas fir (*Pseudotsuga menziesii*), and aspen (*Populus* spp.) on the more elevated portions of the flood plain. The steep valley walls on either side are dominated by mixtures of mature Ponderosa pine (*Pinus ponderosa*), aspen, and fir (*Abies* spp.) forest.

The Arizona study site encompassed 32 ha, centered on 32.2645° N, -110.4554°W at 2423 m elevation between the town of Summer Haven and the Mt Lemmon summit. In Arizona potential nesting locations are more abundant than in Colorado, and there are greater numbers of breeding Western Cordilleran Flycatchers (*personal observation*). The habitat is composed of mixed fir and spruce stands at moister locations, while ponderosa pine dominates on the drier south facing slopes. Aspen is present, but less abundant than in Colorado, while mountain maple (*Acer grandidentatum*) is more common. Sabino Creek, which is spring fed, runs through the study site and provides moisture to the riparian vegetation. Residential structures are mixed with U.S. Forest Service lands along the riparian corridor.

The bird
The Western Cordilleran Flycatcher is a small (~11 g), migratory aerial insectivore in the suboscine family Tyrannidae, whose breeding is confined to the higher elevation mesic zones of the intermountain west, from southern Canada through the United States and into central Mexico (Greeney et al. 2018, Lowther et al. 2020). Breeding aspects of this species are known from studies of brood provisioning rates and fledgling behavior in Colorado (Darrah and van Riper 2021), nesting studies in northern Arizona (Martin et al. 2015, Boyce et al. 2020), while other life history aspects have largely been extrapolated from the better-studied Western Pacific Slope Flycatcher *Empidonax difficilis* (Davis et al. 1963, Sakai 1988). In Arizona Western Cordilleran Flycatchers

arrive from Mexico in May, but in Colorado during early June. At both locations birds defend Type A territories (Nice 1941, Brown 1969); the average clutch size is four eggs; young fledge between 15 and 17 days; and fall migration begins in August at both locations (*personal observation*).

In Colorado and Arizona, the Western Cordilleran Flycatcher is limited to one complete nesting cycle each breeding season (Kingery 1998, Darrah and van Riper 2021), as are most *Empidonax* flycatchers in North America (Mumford 1964, Walkinshaw 1966, Sogge et al. 2003). An abbreviated nesting season greatly influences annual productivity and population dynamics of small passerine birds (e.g., Kus et al. 2017, Sutton and Freeman 2023), and if a nest fails during late incubation or the nestling stage, it is not possible for the Western Cordilleran Flycatcher to successfully re-nest. Rearing a second successful brood is prohibited by the late initiation of nesting, nesting cycle length (43 days from nest building to fledging), and the species' August departure for the wintering grounds in Mexico.

Field methods
Each year from 2008 to 2022 we began by listening for males that were singing and exhibiting territorial defense, and then searched each territory until the nest was located. We also checked previously utilized nesting locations, as Western Cordilleran Flycatchers often use the same site for nesting in consecutive years. Nests were also discovered by following adults in the process of nest building or provisioning young. At all locations we checked nests daily, took physical measurements, and at some nests, recorded behavior via a home video system (Diwill 4-port H.264 Digital Wireless). We established 12 permanent mist net sites within each core study area, and at those locations captured and banded birds throughout the breeding season (after Ralph et al. 1998). We also captured unbanded parents at each nest using target mist-netting, but those data were not incorporated into our birds/net hour computations. All birds were banded with a single U.S. Geological Survey numbered aluminum band, and each adult flycatcher received a unique combination of 2-colored plastic leg bands on the opposite leg. We sexed adults by the presence of a brood patch or cloacal protuberance (Pyle et al. 1987, Ralph and Hollinger 2003), which was later corroborated with behavioral evidence (incubation; song). Wing chord was measured to the nearest mm using a wing rule, length of tarsometatarsus to the nearest 0.1 mm with calipers, and mass to the nearest 0.1 g using a digital balance.

At nests we documented hatching success (percentage of eggs laid that hatched), nestling success (percentage of hatchlings fledged), and fledging success (the percentage of eggs laid that fledged). Nest measurements of height, bowl width, depth, and rim thickness were taken with a micrometer, while we used a tape measure for height from ground and substrate measurements. Nest weights were taken on an Ohaus digital scale accurate to 0.01 grams.

Development and use of a 2-sided artificial nesting structure
During 2010 and 2011 breeding seasons, we tested four types of artificial nesting structures: (1) a flat board; (2) a 2-sided platform with roof; (3) a 3-sided platform with roof; and (4) a completely enclosed 4-sided nest box with 4.12 cm (1 5/8 in) diameter entry hole. Five replicates of each structure type were placed

Fig. 1. Locations of 30, 2-sided artificial nesting platforms (on a Google Earth image) from 2012 to 2017 at the Upper Dolores, CO, core study area. Platform placement was in five replicates of a 2 X 2 (building/forest; two adjacent platforms vs single platform) factorial design. Red dots depict paired platform locations while yellow dots are single platform locations.
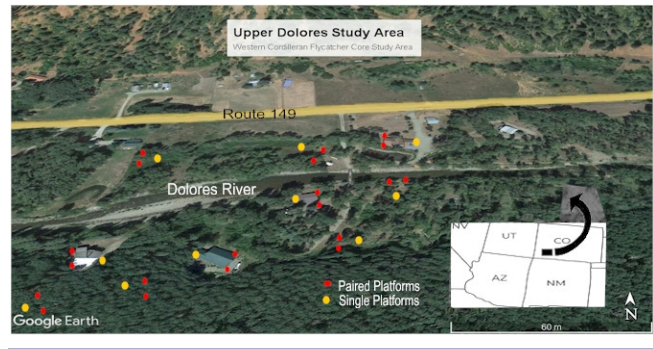
throughout the Colorado study area. During the 2012 breeding season, prior to flycatcher arrival, we placed out 30, 2-sided platforms (Fig. 1). Fifteen platforms were distributed on five cabins, with the remaining 15 placed in groups of three on trees in a natural forest setting. In Arizona, starting in 2019 residents of Mt Lemmon began placing 2-sided nesting platforms on cabins and by 2022 platforms had been placed at 30 residences and at 15 locations in natural forest settings.

Statistical analyses
To determine whether survival from nest to fledgling differed between study sites or among the types of nesting substrates, we fit generalized linear mixed effects model in which the fate of individual eggs was modeled using a binomial distribution and eggs within a nest were given a common random effect. We fit four models: a null model, a model in which survival varied by study site, a model in which survival varied by nest structure, and a model in which effects of study site and nest structure were additive. Models were fit using the lmer package in R and compared using AIC and we based inferences on the best model (which was greater than 10 AIC units better than all models without uninformative parameters sensu Arnold 2010). For inferences regarding parameters, we fit a Bayesian version of the best model using the rstanarm package in R (R Core Team 2017).

Utilizing daily nest checks, we determined incubation stage length (number of days elapsing between laying of the last egg to hatching of all eggs), and nestling stage length (the time from hatching of the last egg to fledging of all young). Annual productivity was calculated as the total number of young fledged per year within study areas. To test if use of platforms affected nesting behavior or success we compared within and between study locations, clutch size, incubation behavior and length, nestling stage length, hatching success, nestling success, fledging success, and total young fledged. We tested among flycatcher pairs using natural nest sites, nests on human-made structures, and those on artificial platforms with ANOVA utilizing SPSS, a 2017 IBM Corp statistical package.

We used a 2-sided t-test and chi-square tests to compare nests on the three types of substrates producing ≥ 1 fledging and the probability of depredation by predatory birds and mammals, during incubation and nestling stages. The proportion of flycatchers captured each year was corrected with a time-series analysis utilizing a damping factor of 0.3. Trends in the time series capture rates were analyzed with a Mann-Kendall trend test.

RESULTS

Acceptability of artificial nesting structures

During our 2010–2011 exploratory testing of four different platform types, Western Cordilleran Flycatchers did not choose to nest on flat boards, 3-sided platforms, or completely enclosed nest boxes with a round entry hole, but did use a 2-sided platform with roof (Appendix 1). In 2012 when we placed 30 2-sided nesting platforms within eight territories, two flycatcher pairs bred on platforms, and from 2013 through 2016 from 3 to 4 pairs used platforms (Table 1). In Arizona, where natural nesting locations were more abundant, Western Cordilleran Flycatchers utilized two nesting platforms in 2019 (11% of all nests), increasing use to eight in 2022 (53% of all nests).

Table 1. Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*) productivity from 2008 to 2016 within the Upper Dolores, CO, study area, and from 2019 to 2022 on Mt Lemmon, AZ.

Year	Number of natural nests	Total number of young fledged from natural nests	Number of platform nests	Total number of young fledged from platform nests
2008	2	7	-	-
2009	2	6	-	-
2010	2	8	-	-
2011	2	8	-	-
2012	4	3	2	4
2013	4	5	3	5
2014	4	6	2	4
2015	5	7	3	4
2016	4	4	4	8
Colorado total	29	54	14	25
2019	16	9	2	4
2020	26	23	1	4
2021	8	2	2	8
2022	7	4	8	20
Arizona total	57	38	13	36

Nest size and structural integrity

Nest maximum basal width was significantly larger on platform vs naturally placed nests (T-test = -2.208; $df = 16$; $P < 0.05$), but not between nests on platforms and human-made structures (T-test = 1.595; $df = 22$; $P = 0.06$). There was no significant difference between nest cup depth (ANOVA; $df = 2$; $F = 1.74$; $P = 0.20$) or cup width (ANOVA; $df = 2$; $F = 3.67$; $P = 0.07$) when comparing among the three nesting substrates. Because of structural issues of placement locations, nests at natural sites failed more frequently than did those on platforms. Nests placed behind tree bark sometimes failed when the bark sloughed off the tree. At nine locations the nesting crevice was shallow, and nests fell to the ground. We did not observe any eggs or young fall from platform nests.

Differences in breeding behaviors between artificial platforms and other nest sites

When comparing artificial platform nests to natural nests, and those built on human-made structures in Colorado and Arizona there was no significant difference in numbers of eggs among clutches in Colorado (ANOVA, $F = 0.1725$; $df = 2$; $P = 0.84$) or Arizona (ANOVA, $F = 2.575$; $df = 2$; $P = 0.07$; Table 2), and incubation attentive periods were virtually identical between platform and natural nesting locations (T-test = -1.301; $df = 13$; $P = 0.2158$). We also found no significant difference in the incubation periods among natural sites, human-made locations, and artificial platforms in Colorado (ANOVA, $df = 2$; $F = 0.056$; $P < 0.94$) or Arizona (ANOVA, $F = 2.596$; $df = 2$; $P = 0.08$). There was, however, a significant difference in nestling periods among the three nesting substrates as young remained in artificial platform nests significantly longer in Colorado (ANOVA, $df = 2$; $F = 7.609$; $P < 0.01$) and Arizona (ANOVA, $F = 4.584$; $df = 2$; $P = 0.01$; Table 2).

In Colorado platforms fledged an average of 1.65 young/nest, while 1.11 young fledged/nest on human-made structures, and natural substrates averaged 1.41 fledged young/nest (Fig. 2A). There was no significant difference in the number of young fledged/nest among the three nesting substrates ($N = 92$; ANOVA $F = 0.38$; $df = 4$; $P < 0.82$). On Mt Lemmon, AZ, platforms fledged an average of 3.26 young/nest, while 2.44 young fledged/nest on human-made structures and natural substrates averaged 1.49 fledged young/nest (Fig. 2B), and there was a significant difference in the number of young fledged/nest among the three types of nesting substrates ($N = 69$; ANOVA $F = 8.98$; $df = 2$; $P < 0.01$).

Changes in adult Western Cordilleran Flycatcher numbers following artificial platform nest introduction

In Colorado and Arizona standard mist net capture/recapture data provided us with an abundance index of birds/net-hour (after Ralph et al. 1998). In 2007 no Western Cordilleran Flycatchers were captured at our core study site. From 2008 to 2011 the proportion of captured Western Cordilleran Flycatchers was consistently less than 10% of all birds (Fig. 3a). Following platform introduction in 2012, over the next 10 years flycatcher numbers rose to greater than 30–40% of total captured birds, and the increasing trend was significant (Mann-Kendall test; tau = 0.818; $P < 0.01$). In Arizona, there were initially many breeding Western Cordilleran Flycatchers, and the addition of nesting platforms did not increase numbers of adult flycatchers (Mann-Kendall test; tau = 0.429; $P = 0.23$; Fig. 3b).

### Artificial platform nest contributions to productivity

After introduction in 2012 of artificial nesting platforms in Colorado, the total annual number of Western Cordilleran Flycatcher young produced more than doubled in our study area (Table 1). The following year platform nests again doubled the number of fledged young, but in 2014 and 2015 platform nest productivity decreased. In 2016 platform nests again fledged two-times the number of young compared to natural nests. In Arizona, artificial platform nests added at least four young each year from 2019 to 2021, and 20 additional young in 2022, which was over 80% of all young fledged that year (Table 1).

Our top nest survival model included "substrate type" and was 27.2 AIC units better than both the null model and the study site model indicating very strong support for differences in nesting

Table 2. A comparison of Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*) clutch size, incubation period, and nestling periods (+/- SD) among nests locations at natural sites, on human-made structures, and experimental platforms from 2012 to 2016 within our core study area at Upper Dolores, CO and from 2016 to 2022 on Mt Lemmon, AZ. The * signifies a statistically significant difference of P < 0.05 among the three types of nesting substrates.

	Natural nests	Human-made structures	Platform nests
Colorado			
Clutch size (N = 73)	3.72 +/- 0.68 eggs	3.77 +/- 0.42 eggs	3.82 +/- 0.63 eggs
Incubation period (N = 58)	14.73 +/- 0.94 days	14.66 +/- 0.49 days	14.73 +/- 0.90 days
Nestling period (N = 49)	15.67 +/- 0.48 days	15.52 +/- 0.71 days	16.70 +/- 0.98 days*
Arizona			
Clutch size (N = 71)	3.35 +/- 0.57 eggs	3.62 +/- 0.72 eggs	3.47 +/- 0.69 eggs
Incubation period (N = 51)	14.77 +/- 0.44 days	15.00 +/- 0.35 days	15.00 +/- 0.01 days
Nestling period (N = 19)	15.62 +/- 0.81 days	16.38 +/- 0.89 days	16.47 +/- 1.31 days*

Fig. 2. The average number of Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*) young fledged/nest among three types of nesting substrates (natural crevice sites, human-made locations, and nesting platforms) at (a) Upper Dolores, CO and (b) Mt Lemmon, AZ.

(a) Average number of Cordilleran Flycatcher young fledged/nest Dolores, CO

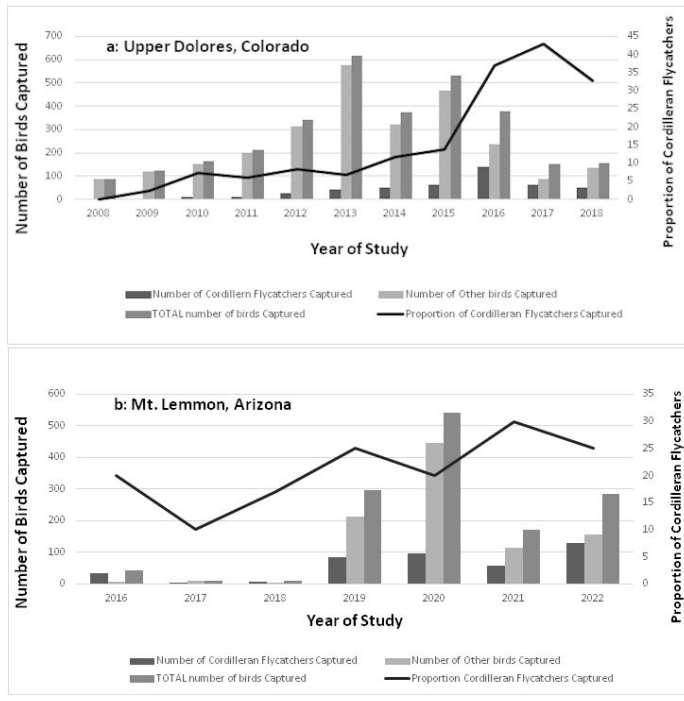(b) Average number of Cordilleran Flycatcher young fledged/nest Mt Lemmon, AZ
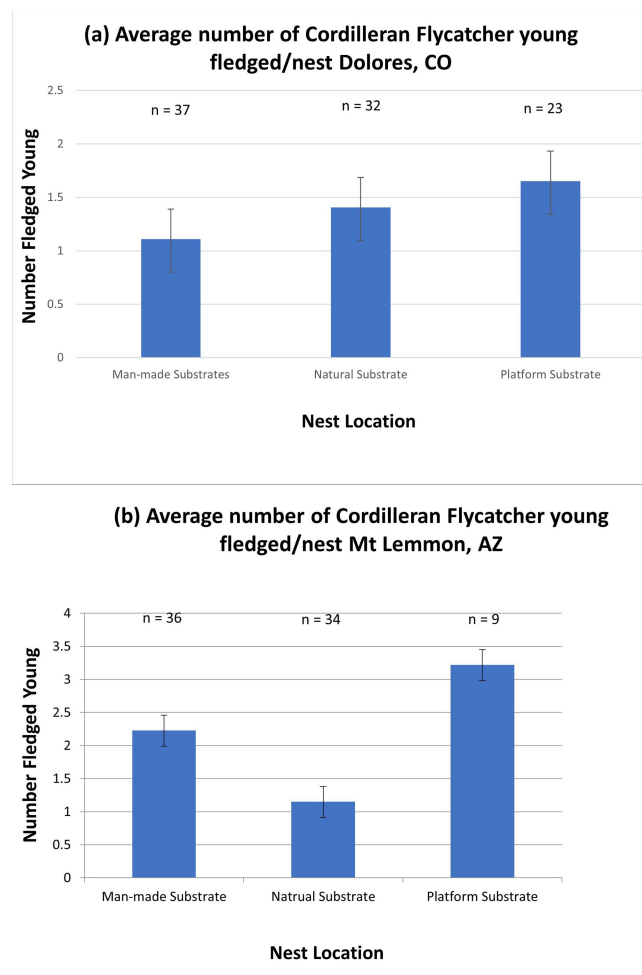
substrate productivity. Parameter estimates from the top model suggested substantial differences among substrate types when individual random effects were set equal to zero (Fig. 4), with nests on platforms experiencing higher survival (mean: 0.85, 95% credible intervals: 0.46–0.99) than nests in human-made structures (mean: 0.39, 95% credible intervals: 0.12–0.74) or nests placed in natural situations (mean: 0.03, 95% credible intervals: 0.01–0.11). Nonetheless, there was substantial unmodeled heterogeneity among nests (i.e., standard deviation of random effect distribution was 6.7) pointing to the high frequency of shared fates among eggs in the same nest (i.e., often all the individuals in a clutch survived to fledglings or no individuals in a clutch survived).

Comparison of predation rates at natural vs artificial platform nests

In Colorado, during the four years prior to introduction of nesting platforms, loss of Western Cordilleran Flycatcher eggs averaged 14.5% annually (n = 115 nests), while nestling predation was 3% of all hatched young. Principal nest predators, as identified from direct and video-recorded nest observations, included the Black-billed Magpie (*Pica hudsonia*) and Steller's Jay (*Cyanocitta stelleri*). We also observed one American Robin (*Turdus migratorius*) involved with egg removal and the American red squirrel (*Tamiascirus hudsonicus*) with young predation. We had hypothesized that predation rates would be higher on nesting platforms, but this was not the case. From 2012 to 2016, 26.3% of eggs at platform nests were depredated, while 17.9% of natural nests and 5.88% of nests on human-made structures were eaten by predators. Even though there was higher egg predation on experimental platforms, there was no significant difference among the three substrates ($X^2 = 1.13$, *df* = 2, N = 159, P = 0.57). Nestling depredation averaged 10.7% on artificial platforms, 25.0% on human-made structures, and 15.6% at natural locations, and there was no significant difference among the three ($X^2 = 1.94$, *df* = 2, N = 69, P = 0.38).

When compared to Colorado, in Arizona Western Cordilleran Flycatchers experienced higher egg and nestling predation rates. Of 257 flycatcher eggs monitored in Arizona, 34.25% were lost to predation. Nestling predation averaged 21% in Arizona when compared to 9.9% in Colorado. Magpies are absent in Arizona, but mist net capture rates of Steller's Jay and Common Raven

Fig. 3. The influence of artificial nesting platforms on Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*) adult numbers at our (a) Dolores River, CO (platforms introduced in 2012) and (b) Mt. Lemmon, AZ (platforms introduced in 2019) study areas. Captured flycatcher numbers (line in graphs) are time-series transformed.

Fig. 4. The probability of Western Cordilleran Flycatcher (*Empidonax difficilis occidentalis*) nests surviving from egg to fledgling varies according to the type of nesting substrate, at the Dolores, CO and Mt Lemmon, AZ study sites. The highest rates of survival occurred on platform structures. Dots indicate the mean estimate for structure type and whiskers span the 95% credible intervals (both calculated assuming the nest random effect was zero).

(*Corvus corax*), two major egg predators, were higher in Arizona. Nest-video playback substantiated that jays and ravens contributed to the higher Arizona egg and nestling predation rates.

DISCUSSION

Nest platform types and influence on adult numbers
We found three platform structures that were not utilized by Western Cordilleran Flycatchers (completely flat, 3-sided, and closed 4-sided with entry hole), and only the 2-sided structure with roof was used for nesting (Appendix 1). By installing 2-sided nesting platforms, we found that at locations where flycatcher breeding numbers were low, adult numbers could be increased. But in an area that contains more suitable natural nesting sites and higher adult populations, like Mt Lemmon, AZ, the addition of nesting platforms did not increase breeding bird numbers. The increase in adult Western Cordilleran Flycatcher numbers that we documented in Colorado is like what has been found when nest boxes have been added to hole-nesting bird species (Mänd et al. 2009, Hannay et al. 2022).

Nest platform influence on breeding behaviors
There were no significant differences in clutch size, incubation period, or four adult breeding behaviors (nest building, attentiveness, feeding, and brooding rates) between platform nests and nests at other locations. But the nestling period at platform nests was approximately 1 day longer than on other substrates, and this difference was statistically significant. Platform nests had higher fledging rates than

did nests on other substrates. We have demonstrated that, with the addition of nesting platforms, the number of fledged young can be more than doubled per unit area of habitat. A contribution to this success was likely the more secure nest-basal area that platforms provided for nesting. Nests that were placed on narrow ledges or small crevices sometime failed because of structural constraints.

Nest platform influences on productivity
Western Cordilleran Flycatchers are nest-site limited in many areas of the intermountain west (Martin et al. 2015), and our results demonstrate that artificial nesting structures can enhance productivity. This would be especially true when platforms were placed at locations where there are not initially large numbers of breeding Western Cordilleran Flycatchers. Following introduction of nesting platforms in Colorado, production of fledged young in our core study site doubled, while in Arizona artificial platforms added annually from 16% to 80% additional fledged young.

Predation at artificial nest platforms
Our initial hypothesis was that there would be higher predation rates on platform nests, as predators might develop a "search image" for the structure. This was, however, not the case and in fact we found predation lower on platform nests when compared to nests at natural locations and on human-made substrates. This may be because the platform roof hides nests from aerial predators, while natural nest locations are closer to the ground and eggs are more visible, as Chiavacci et al. (2015) demonstrated in grassland birds. It may be that over time predators will develop a search image for the platforms and focus on them as a potential food resource, but during the 15 years of our study this did not occur.

Conservation

As demonstrated in this study and found in other areas of the world (Kuitunen and Aleknonis 1992, Weeks 1979, 2020, Warakai et al. 2013), crevice nesting birds will readily utilize artificial platforms. This should also hold true for other regions where crevice-nesting birds occur. For example, Warakai et al. (2013) found in New Guinea that crevice nesting birds will readily utilize artificial platforms. In Hawaii, utilizing nesting platforms might prove beneficial for enhancing populations of crevice-nesting birds like the endangered Akepa (*Loxops coccineus*). Freed et al. (1987) found that Akepa will not accept nest boxes, but this endangered species might possibly benefit from the addition of nesting platforms. A slightly larger platform could also be used for the declining Hawaiian Thrush (*Myadestes obscurus*) as, like the Western Cordilleran Flycatcher, this endemic thrush utilizes bark crevices for nesting (van Riper and Scott 1979, Wakelee and Fancy 2020). Even for non-endangered species, like the Western Pacific Slope Flycatcher and Black Phoebe (*Sayornis nigricans*), placement of nesting platforms could provide a buffer by adding additional young each year to those populations. Our study clearly demonstrates that artificial platforms can be utilized to increase numbers and to enhance productivity of the crevice-nesting Western Cordilleran Flycatcher. We hope that the addition of artificial nesting platforms as a management tool will prove useful for scientists who wish to take advantage of more readily accessible bird nesting locations and for the conservation of crevice-nesting bird species of concern.

Author Contributions:

CvR III designed study, collected data, analyzed, and wrote all drafts; HFG helped with design and collected field data; AJD helped with design, collected field data. DFVR helped with data collection, data entry, and editing manuscript. AJB helped with data collection. CBY assisted with data analyses.

LITERATURE CITED

Arnold, T. W. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. Journal of Wildlife Management 74:1175-1178. https://doi.org/10.2193/2009-367

Backhouse, F. 1986. Bluebird revival. A heart-warming comeback from the brink of extinction. Canadian Geographic 106:33-39.

Boyce, A. J., J. C. Mouton, P. Lloyd, B. O. Wolf, and T. E. Martin. 2020. Metabolic rate is negatively linked to adult survival but does not explain latitudinal differences in songbirds. Ecology Letters 23:642-652. https://doi.org/10.1111/ele.13464

Brawn, J. D., and R. P. Balda. 1988. Population biology of cavity nesters in northern Arizona: do nest sites limit breeding densities? Condor 90:61-71. https://doi.org/10.2307/1368434

Brown, J. L. 1969. Territorial behavior and population regulation in birds. Wilson Bulletin 81:293-329.

Chiavacci, S. J., M. P. Ward, and T. J. Benson. 2015. Why fledge early in the day? Examining the role of predation risk in explaining fledging behavior. Behavioral Ecology 26:593-600. https://doi.org/10.1093/beheco/aru236

Collias, N. E., and E. C. Collias. 1984. Nest building and bird behavior. Princeton University Press, Princeton, New Jersey, USA. https://doi.org/10.1515/9781400853625

Colorado Bird Atlas Partnership. 2016. The second Colorado breeding bird atlas online database. Colorado Bird Atlas Partnership, Denver, Colorado, USA.

Corman, T. E., and C. Wise-Gervais, editors. 2005. Arizona breeding bird atlas. University of New Mexico Press, Albuquerque, New Mexico, USA.

Darrah, A. J., and C. van Riper, III. 2021. Brood provisioning rates and fledgling behavior of Cordilleran Flycatchers in southwestern Colorado. Journal of Field Ornithology 92:30-42. https://doi.org/10.1111/jofo.12361

Davis, J., G. F. Fisler, and B. S. Davis. 1963. The breeding biology of the Western Flycatcher. Condor 65:337-382. https://doi.org/10.2307/1365143

East, M. L., and C. M. Perrins. 1988. The effect of nestboxes on breeding populations of birds in broadleaved temperate woodlands. Ibis 130:393-401. https://doi.org/10.1111/j.1474-919X.1988.tb08814.x

Fargallo, J. A., G. Blanco, J. Potti, and J. Viñuela. 2001. Nestbox provisioning in a rural population of Eurasian Kestrels: breeding performance, nest predation and parasitism. Bird Study 48:236-244. https://doi.org/10.1080/00063650109461223

Freed, L. A., T. M. Telecky, W. A. Tyler, III, and M. A. Kjargaard. 1987. Nest-site variability in the Akepa and other cavity-nesting forest birds on the island of Hawaii. Elepaio 47:79-81.

Greeney, H. F., M. J. Miller, and C. van Riper, III. 2018. A review of current knowledge concerning the breeding and summer distribution of the Cordilleran Flycatcher (*Empidonax occidentalis*) in Mexico. Occasional Papers of the Museum of Natural Science, Louisiana State University 89:1. https://doi.org/10.31390/opmns.089

Hannay, M. B., M. E. Shave, O. J. Utley, A. Groendyk, and C. A. Lindell. 2022. Nest boxes increased presence of American Kestrels in a blueberry production region despite low box occupancy. Journal of Raptor Research 57:12-21. https://doi.org/10.3356/JRR-21-80

Hepp, G. R., and F. C. Bellrose. 2013. Wood Duck (*Aix sponsa*). In A. F. Poole, editor. The birds of North America, version 2.0. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.169

IBM Corp. 2017. IBM SPSS Statistics for Windows. IBM Corp, Armonk, New York, USA.

Katzner, T., S. Robertson, B. Robertson, J. Klucsarits, K. McCarty, and K. Bildstein. 2005. Results from a long-term nest-box program for American Kestrels: implications for improved population monitoring and conservation. Journal of Field Ornithology 76:217-226. https://doi.org/10.1648/0273-8570-76.3.217

Kingery, H. E., editor. 1998. Colorado breeding bird atlas. Colorado Bird Atlas Partnership, Denver, Colorado, USA.

Kluijver, H. N. 1951. The population ecology of the Great Tit, Parus m. major L. Ardea. Brill, Leiden, The Netherlands.

Kuitunen, M., and A. Aleknonis. 1992. Nest predation and breeding success in common Treecreepers nesting in boxes and natural cavities. Ornis. Fennica 69:7-12.

Kus, B. E., S. L. Howell, and D. A. Wood. 2017. Female-biased sex ratio, polygyny, and persistence in the endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Condor 119:17-25. https://doi.org/10.1650/CONDOR-16-119.1

Lambrechts, M. M., F. Adriaensen, D. R. Ardia, A. V. Artemyev, F. Atiénzar, J. Bańbura, E. Barba, J.-C. Bouvier, J. Camprodon, C. B. Cooper, R. D. Dawson, M. Eens, T. Eeva, B. Faivre, L. Z. Garamszegi, A. E. Goodenough, A. G. Gosler, A. Grégoire, S. C. Griffith, L. Gustafsson, L. S. Johnson, W. Kania, O. Keišs, P. E. Llambias, M. C. Mainwaring, R. Mänd, B. Massa, T. D. Mazgajski, A. P. Møller, J. Moreno, B. Naef-Daenzer, J.-Å. Nilsson, A. C. Norte, M. Orell, K. A. Otter, C. R. Park, C. M. Perrins, J. Pinowski, J. Porkert, J. Potti, V. Remes, H. Richner, S. Rytkönen, M.-T. Shiao, B. Silverin, T. Slagsvold, H. G. Smith, A. Sorace, M. J. Stenning, I. Stewart, C. F. Thompson, P. Tryjanowski, J. Török, A. J. van Noordwijk, D. W. Winkler, and N. Ziane. 2010. The design of artificial nestboxes for the study of secondary hole-nesting birds: a review of methodological inconsistencies and potential biases. Acta Ornithologica 45:1-26 https://doi.org/10.3161/000164510X516047

Lowther, P. E., P. Pyle, and M. A. Patten. 2020. Cordilleran Flycatcher (*Empidonax occidentalis*), version 1.0. In P. G.

Rodewald, editor. Birds of the world. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.corfly.01

Mänd, R., A. Leivits, M. Leivits, and N. L. Rodenhouse. 2009. Provision of nestboxes raises the breeding density of Great Tits *Parus major* equally in coniferous and deciduous woodland. Ibis 151:487-492. https://doi.org/10.1111/j.1474-919X.2009.00929.x

Martin, T. E., J. C. Oteyza, A. J. Boyce, P. Lloyd, and R. Ton. 2015. Adult mortality probability and nest predation rates explain parental effort in warming eggs with consequences for embryonic development time. American Naturalist 186:223-236. https://doi.org/10.1086/681986

Mumford, R. E. 1964. The breeding biology of the Acadian Flycatcher. Miscellaneous publications, No. 125:1-50. Museum of Zoology, University of Michigan, Ann Arbor, Michigan, USA.

Nice, M. M. 1941. The role of territory in bird life. American Midland Naturalist 26:441-487. https://doi.org/10.2307/2420732

Norris, A. R., K. E. H. Aitken, K. Martin, and S. Pokorny. 2018. Nest boxes increase reproductive output for Tree Swallows in a forest grassland matrix in central British Columbia. PLoS ONE 13:e0204226. https://doi.org/10.1371/journal.pone.0204226

Perrins, C. 1979. British Tits (Collins New Naturalist Library, Book 62). Collins UK, London, UK.

Pyle, P., S. Howell, R. P. Yunick, and D. DeSanto. 1987. Identification guide to North American passerines. Slate Creek Press, Bolinas, California, USA.

R Core Team. 2017. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1998. Handbook of field methods for monitoring landbirds. U. S. Forest Service, General Technical Report PSW-GTR-144. Pacific Southwest Research Station, Albany, California, USA. https://doi.org/10.2737/PSW-GTR-144

Ralph, C. J., and K. Hollinger. 2003. The sStatus of the Willow and Pacific-slope Flycatchers in northwestern California and southern Oregon. Studies in Avian Biology 26:104-117.

Sakai, H. F. 1988. Breeding biology and behavior of Hammond's and Western Flycatchers in northwestern California. Western Birds 19(2):49-60.

Sogge, M. K., B. E. Kus, S. J. Sferra, and M. J. Whitfield. 2003. Ecology and conservation of the Willow Flycatcher. Studies in Avian Biology 26:1-210.

Sutherland, W. J., I. Newton, and R. Green. 2004. Bird ecology and conservation: a handbook of techniques. Oxford University Press, Oxford, UK. https://doi.org/10.1093/acprof:oso/9780198520863.001.0001

Sutton, A. O., and N. E. Freeman. 2023. The biotic and abiotic drivers of timing of breeding and the consequences of breeding early in a changing world. Ornithology 140:ukad017. https://doi.org/10.1093/ornithology/ukad017

van Riper, III, C., and J. M. Scott. 1979. Observations on distribution, diet, and breeding of the Hawaiian Thrush. Condor 81:65-71. https://doi.org/10.2307/1367858

Wakelee, K. M., and S. G. Fancy. 2020. Omao (*Myadestes obscurus*), version 1.0. In A. F. Poole, editor. Birds of the world. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.omao.01

Walkinshaw, L. H. 1966. Summer biology of Traill's Flycatcher. Wilson Bulletin 78:31-46.

Warakai, D., D. S. Okena, P. Igag, M. Opiang, and A. L. Mack. 2013. Tree cavity-using wildlife and the potential of artificial nest boxes for wildlife management in New Guinea. Tropical Conservation Science 6:711-733. https://doi.org/10.1177/194008-291300600602

Weeks Jr., H. P. 1979. Nesting ecology of the Eastern Phoebe in Southern Indiana. Wilson Bulletin 91:441-454.

Weeks Jr., H. P. 2020. Eastern Phoebe (*Sayornis phoebe*), version 1.0. In A. F. Poole, editor. Birds of the world. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bow.easpho.01

Appendix I

Appendix I – Plans for the construction of a Western Cordilleran Flycatcher

(*Empidonax difficilis occidentalis*) nesting platform.
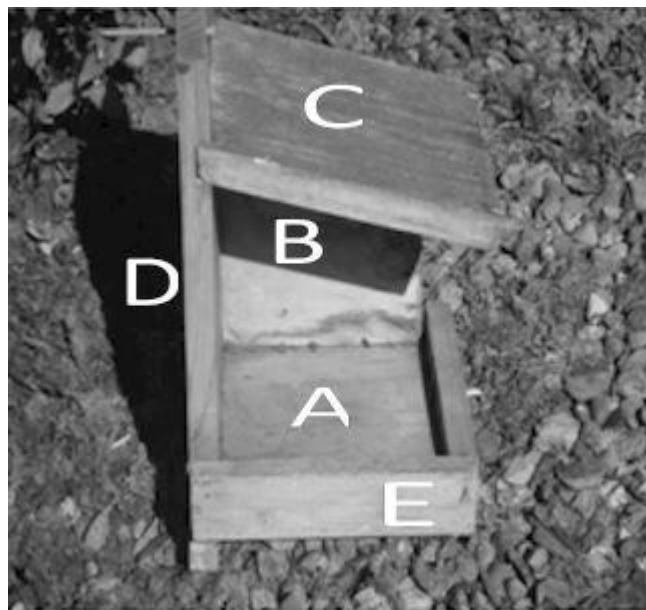
Materials required for the construction of a Cordilleran Flycatcher nest platform*:

One 3-foot (0.91 m) length of 1" (2.54 cm) x 6" (15.24 cm) board and a dozen 8 p

finishing nails (or 2" [5 cm] wood screws). A smaller opening can be made by using a

1" x 4" (2.54X10.16 cm) board.

Measurements for the Western Cordilleran Flycatcher nest platform pieces*:

A = Bottom --5 ½" (13.97 cm) X 6" (15.24 cm). Note that the front is ½" (1.27 cm)

longer so that it will hold the "E" pieces on the two open sides.

B = Side -- 5 ½" (13.97 cm) X 4" (10.16 cm) high in front and 5" (12.7 cm) high in back.

C = Top -- 5 ½" ½" (13.97 cm) wide X 8" ½" (20.32 cm) long (back edge angled @ ~10 degrees to fit slope angle

D = Back -- 5 ½" (13.97 cm) X 10" (25.4 cm) long and can be routed out to better hold piece "C," or piece "E" can be placed underneath to better hold the top in place.

E = Borders for bottom 1½" (3.81 cm) wide, with one bottom border piece 5 ½" (13.97 cm) the other 6 ½" (16.51 cm) long.

*(letters A-E correspond to letters on the diagram; the standard 1X6" (2.54 X 15.24 cm) board width is actually 5 ½" (13.97 cm) long.