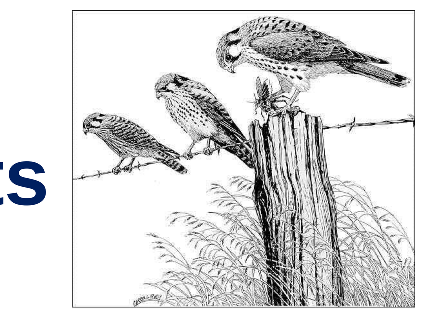
Competition for nesting cavities between American Kestrels *(Falco sparverius)* and European Starlings *(Sturnus vulgaris)* may lead to nesting phenology changes results from a long-term nest box study at the Ridgefield National Wildlife Refuge.



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ABSTRACT

Declines in raptor populations have been well documented based on several measures. These collectively indicate long-term declines of American Kestrel (*Falco sparverius*) populations in numerous regions of North America. We report data from 12 years of nest box monitoring at the Ridgefield National Wildlife Refuge (Clark County) in southwest Washington, USA. Over this period, American Kestrels have occupied the nest boxes 30 times, while European Starlings have attempted to use the nest boxes 90 times. Of the 30 nesting attempts by American Kestrels, 21 were successful (69.6 ±16.1%) over the twelve-year period. Kestrels laid 4.7 ±0.46 eggs per clutch. American Kestrel populations at the Ridgefield National Wildlife Refuge began to decline steadily until 2013 when populations began to incrementally increase, as measured by nest box occupation and productivity. Our data suggests that one reason American Kestrels are declining on the refuge is due to the increase in competition for nesting cavities by European Starlings (*Sturnus vulgaris*). We document a nesting phenology shift for egg laying in American Kestrels of 22.4 ±10.2 days earlier which may suggest a behavior solution, however further research need to support this conclusion.

INTRODUCTION

Declines in raptor populations have been well documented based on several measures (McClure et al. 2017, Goodrich et al. 2012, Bystrak et al. 2012). Data from the US Geological Survey's Breeding Bird Survey, National Audubon Society's Christmas Bird Count, nest box monitoring programs (Smallwood et al. 2009), and Raptor Population Index (migration counts) (Hoffman and Smith 2003), collectively indicate long-term declines of American Kestrel populations in numerous regions of North America (Figure 1). These declines have been noted in western North America including the Pacific Northwest region.

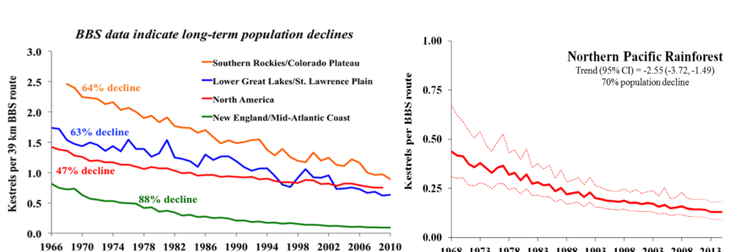


Figure 1. American Kestrel population declines as recorded from USGS banding data reported by region (1996-2010) and from the Northern Pacific Rainforest (1968-2013). (http://kestrel.peregrinefund.org/docs/pdf/American-Kestrel-Partnership)

The American kestrel (*Falco sparverius*) is the smallest of the North American falcons; they are one of the most common raptors. They are secondary cavity nesters, nesting within hollowed out cavities created by other birds or mammals. American Kestrels will also readily use nest boxes due to lack of available cavities. Nest box programs have been used as a management tool for the study of kestrels and also in an effort to increase population sizes (Anderson *et al.* 2016, Strasser and Heath 2013, Katzer *et al*. 2005).

The literature suggests several possible reasons for raptor population declines and American kestrel declines in particular: (1) habitat loss and fragmentation, (2) herbicide and pesticide use, (3)human disturbance (Stupik *et al* 2015, Strasser and Heath 2013), (4) disease, (5) climate change (McClure *et al.* 2017), and in the case of kestrels, (6) changes in their biology (Smith *et al.* 2017), (7) predation (Stupik *et al.* 2015, Smallwood *et al.* 2009) and (8) competition for nest cavities. One of the main competitors for these cavities is the European Starling (*Sturnus vulgaris*) (McClure et al. 2015, Koenig 2003, Bechard and Bechard 1996). Each of these factors may independently contribute to effect on overall population declines.

Here we report data from 12 years of nest box monitoring at the Ridgefield National Wildlife Refuge (Clark County) in southwest Washington, USA.

STUDY SITE

Our study was conducted at the Ridgefield National Wildlife Refuge located in Ridgefield, Washington. The Ridgefield NWR is an area of marshes, wetlands, grasslands and riparian corridors as well as forests of Douglas fir and Oregon white oak that total 2,084 hectacres, with the elevation ranging between 3 and 30m (Figure 2)(CCP 2010). Ridgefield NWR is made up of five units: the River "S", the Carty, Bachelor Island, Roth, and Ridgeport Dairy. The purpose of the refuge is to provide habitat for wintering waterfowl, except for the Carty and Roth units as they are managed as a natural floodplain. For this study nest boxes where set up in four of the five units of Ridgefield; River "S", Bachelor Island, Roth, and Ridgeport Dairy.

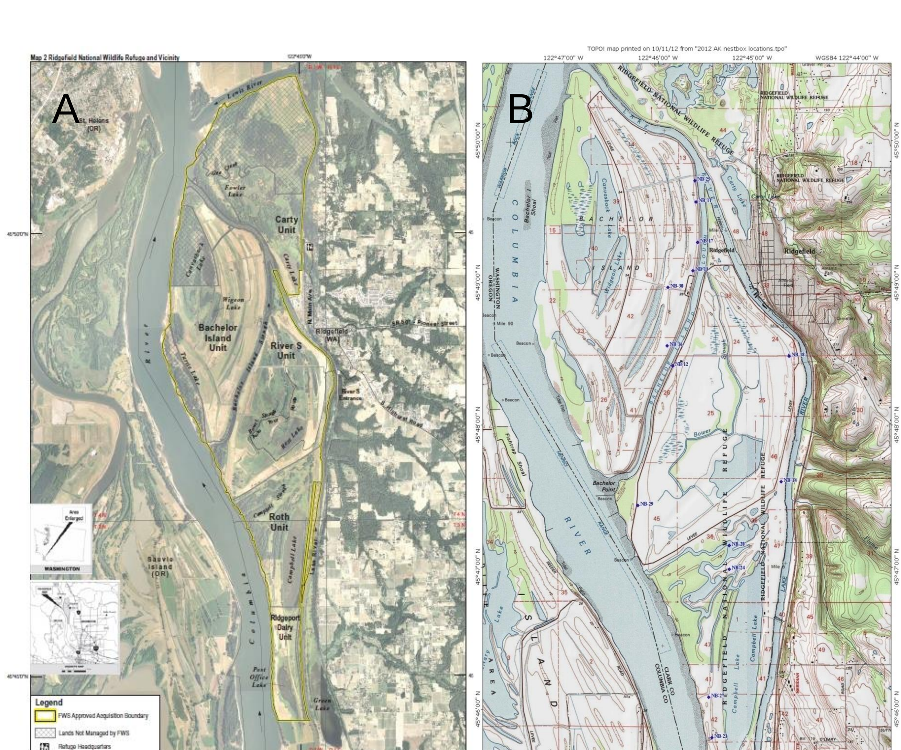


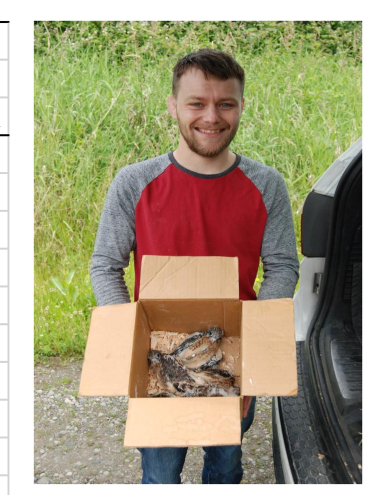
Figure 2. Aerial map(A) of the Ridgefield National Wildlife Refuge (WA) with units identified and 2012 American Kestrel nest box locations (B) identified.

RESULTS

American Kestrels are found year-round on the refuge and in the surrounding area and portions of this population may also be migratory. During the twelve years of study, nest boxes were available for use 155 times. American Kestrels occupied boxes 30 times while European Starlings attempted to use boxes 90 times (Table 1). American Kestrel production was highest in 2019, when 5 pairs fledged 20 chicks (Figure 3). Production was lowest in 2011and 2013 when no chicks were fledged. Two other native species used the nest boxes successfully: Purple Martins (*Progne subis*) and Tree Swallows (*Tachycineta bicolor*). American Kestrels had a total mean percent occupation of 19.2 ±14.6 while European Starlings had a 58.3 ± 16.3 total mean percent occupation over the twelve years of the study; however, year to year occupation varied greatly.

Table 1. Occupation data and American Kestrel (*Falco sparverius*) productivity at the Ridgefield National Wildlife Refuge (WA) from 2009-2020.

Year	Number of Boxes	Number Occupied by Kestrels	Number Occupied by Starlings	Number Occupied by Others	American Kestrel Eggs	American Kestrel Chicks	American Kestrel Fledged	Pairs Successful Fledging	Post Removal Occupation
2009	11	2	6	4	6	5	2	1	0
2010	11	3	3	1	15	8	8	2	0
2011	14	1	7	1	5	0	0	0	1
2012	15	1	7	2	5	4	3	1	0
2013	12	0	10	6	0	0	0	0	0
2014	12	1	9	2	5	5	5	1	0
2015	12	3	8	7	13	9	4	2	1
2016	13	2	10	5	8	4	4	1	1
2017	13	1	9	5	5	2	2	1	0
2018	14	4	8	7	19	13	11	3	0
2019	14	5	7	4	23	21	20	5	2
2020	14	7	6	3	35	18	13	4	0
Total	155	30	90	47	139	89	72	21	5



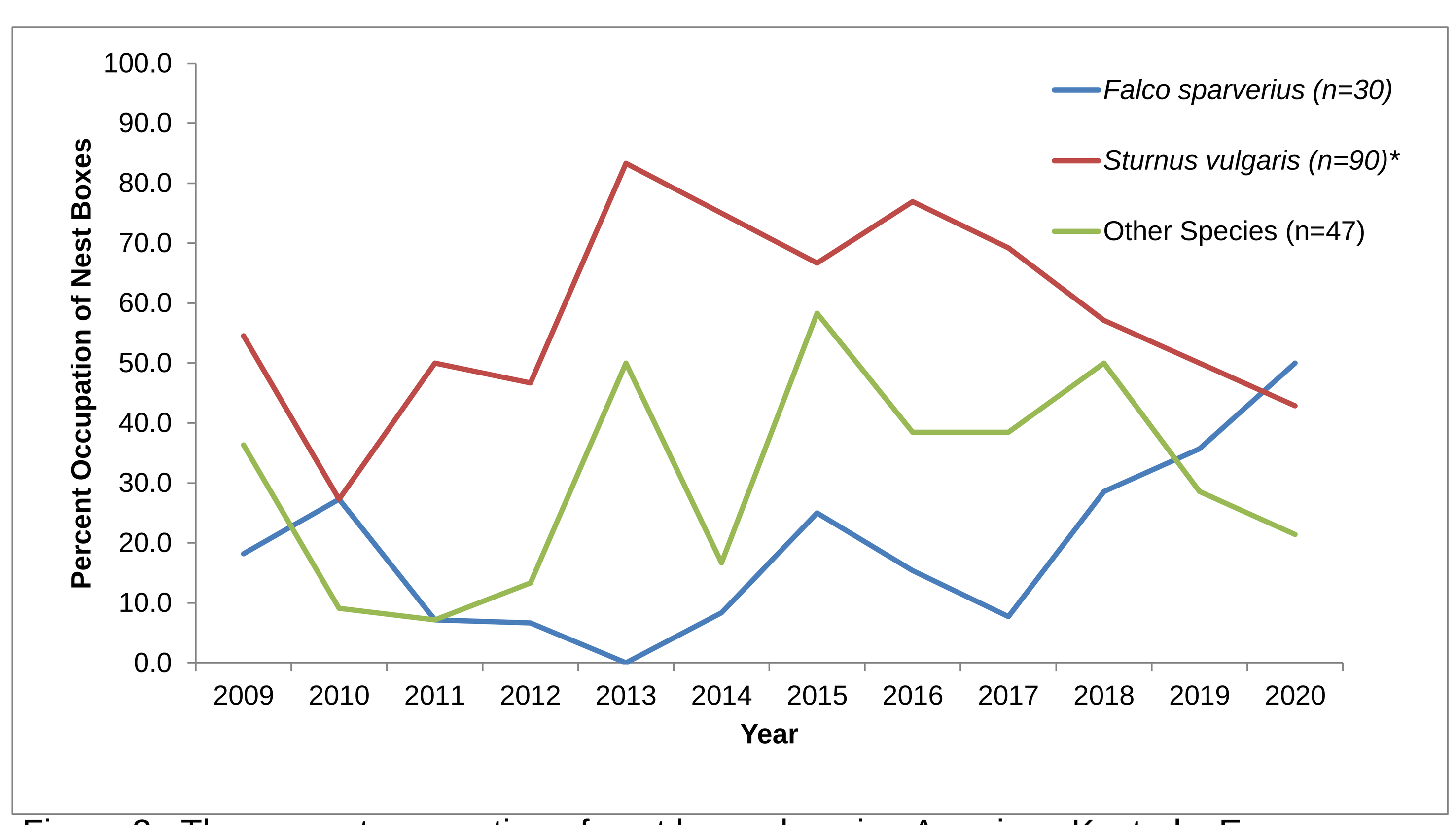


Figure 3. The percent occupation of nest boxes housing American Kestrels, European Starlings and other species at the Ridgefield National Wildlife Refuge (WA) from 2009-2020.

Of the 30 nesting attempts by American Kestrels 21 were successful (69.6 ±16.1%) over the twelve-year period. Kestrels laid 4.7 ±0.46 eggs per clutch (Figure 4). The mean percentage of eggs to fledge young was (46.3 ±14.9%); the conversion rate of chicks to fledglings was (67.0±20.8 %). American Kestrels attempted nesting in boxes 5 times after the removal of starling nests with eggs or nesting material.

From 2009-2019 European starlings laid first eggs 22.6 days earlier than kestrels(Table 2). However in 2020 America kestrels dramatically shifted them mean Julian date of the first egg 24.2 ± 10.2 days earlier to lay on day 102.4.

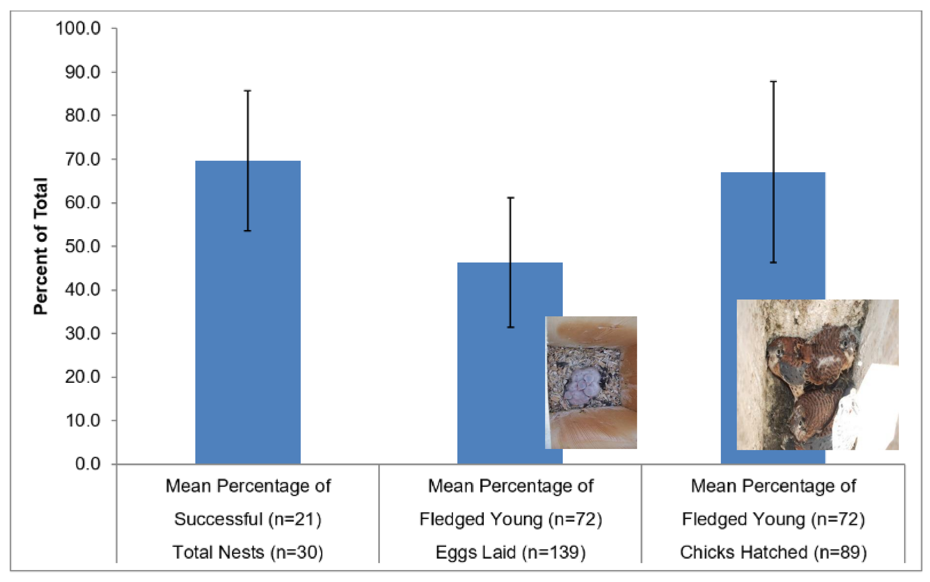


Figure 4. Mean American Kestrel productivity measures of nesting success rate, fledged young to eggs laid, and fledged young to chicks hatched with standard deviation at the Ridgefield National Wildlife Refuge (WA) from 2004-2019.

Table 2. Difference between laying dates of first eggs of American Kestrel and European Starling by Julian laying dates with standard deviation at the Ridgefield National Wildlife Refuge (WA) from 2009-2020.

Species-date	n	Mean Date Julian	Standard Deviation	Julian Range
American Kestrel (2009-2019)	23	126.7	9.5	100-145
European Starling (2009-2020)	43	104.1	7.8	96-143
American Kestrel (2020)	7	102.4	10.2	90-117

METHODS

Nest boxes suitable for American Kestrels were placed at the Ridgefield National Wildlife Refuge (WA) in 2004; during subsequent years' additional nest boxes were added and others repaired and occasionally relocated (Fig 2 current locations). The number of boxes ranged from 7 to 15 with a mean of 10.6. Nest boxes were cleaned, and 5-7 cm of new wood shavings added each March. All nest boxes were monitored weekly for occupation in the spring of each year. Kestrel pairs were observed during the breeding season; records of nesting chronology and occupation of other species were recorded. European Starling nesting material and eggs, if present, were removed while native species were not otherwise disturbed. In 2016, we attached RFID chips to the leg bands of nesting adults. Adult birds were trapped via a *bal-chatri* trap or within the nest box; nestlings were sampled prior to fledging. The presence of eggs were recorded and converted to Julian days for both species. All subjects were banded with USGS aluminum bands to allow for the identification of individual birds and standard morphometric data was collected for all individuals including age, sex, tarsus length, beak length and weight. All samples were collected in accordance with *Guidelines to the use of wild birds in research* (Fair 2010). We report productivity measures and reproductive output following Smallwood, 2009 and Katzner *et al.* 2005. All data are reported to USGS Bird banding laboratory and the American Kestrel Partnership.

DISCUSSION/CONCLUSION

American Kestrel populations at the Ridgefield National Wildlife Refuge have declined steadily since 2005 as measured by nest box occupation and productivity. This decline mirrors data reported in the literature (Anderson *et al.* 2016, Strasser and Heath 2013, Goodrich *et al.* 2012, Bystrak *et al*. 2012, Smallwood 2009 and Katzner *et al.* 2005). Our measures of productivity are also similar to those reported by other studies. Smallwood 2009 postulates several reasons for declines. American Kestrels are found year-round both on the refuge and in the surrounding areas; it is unlikely that the predominant portion of the population is migratory as in other parts of their range. Migration mortality is probably not a cause of decline in our study area. However, first year mortality is probably similar as reported by Stupik *et al.* (2015). Predation by Cooper's Hawks could lead to population declines. Within in our study site Cooper's Hawks occur; however, we found no evidence of predation by Cooper' Hawks but Great Horned Owls (*Bubo virginianus*) were commonly observed, and they are known to hunt kestrels. One nest in 2015 had predation of 4 of the 5 chicks but a specific predator was not identified.

Habitat loss and fragmentation are often cited as possible causes. The area surrounding the refuge has been transformed from mainly rural to semi- suburban with several large housing subdivisions and smaller housing developments during the study. This may have affected the quality of wintering areas adjacent to the refuge. Additionally, the increased traffic may result in more automobile mortality of first year birds. Smallwood (2016) indicates that researcher disturbance is low and not likely a cause for population declines of kestrels. The refuge size and habitat management have remained consistent; haying and grazing have even been increased. This should have provided more suitable habitat for kestrels, however, the increase in short grass areas and the presence of cattle may have increased the prevalence of European Starlings.

Our data suggests that one reason American Kestrels are declining on the refuge is due to the increase in competition for nesting cavities by European Starlings. We disagree with Koenig (2003) in that starlings are a major competitor for nest cavities. Starlings can be aggressive (McClure et al. 2015), and we witnessed kestrels being mobbed by starlings on several occasions often in near proximity to nest boxes. We actively tried to evict starlings from nest boxes by removing nesting material and eggs. Five kestrel pairs nested in boxes from which starlings had been repeatedly evicted. We have observed startling's at boxes occupied by kestrels. Starlings may have a direct effect via nest box competition by earlier nesting but an indirect effect via repeated stress (Mobbing, landing at the nest box entrance, perhaps competition for food resources) however we did not directly measure these effects). Management implications indicate that eviction of starlings can increase American kestrel nesting attempts. However removal frequency may be a prohibitive factor. More research needs to be conducted to determine if European Starlings competition for nest boxes is a major contributing factor to American Kestrel population declines at other locations. Further, American Kestrels may me compensating for by nesting earlier. We document a nesting phenology shift of 22.4 ±10.2 days which may suggest a behavior solution, however further research need to support this conclusion.

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