Reproductive Success of American Kestrels Using Nest Boxes in Eastern Pennsylvania, 1992-2005

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Abstract

Since 1987, scientists and volunteers of Hawk Mountain Sanctuary have monitored the reproductive success of American Kestrels (*Falco sparverius*) nesting in boxes near the mountain. Data has been gathered from 1987 onward recording the use and success of nest boxes, as well as assessing the status of the local kestrel population. While kestrel numbers and success rates were somewhat stable between 1992 and 1999, since 2000 box use has declined. For example, in 1995 nest box use was over 50% (N=199 boxes) and fledgling success was over 75%. A decade later, in 2005, nest box use was down to only 23% (N=144 boxes), though success rates remained above 60%. Despite lower nest box use and nestling output, fledgling success in occupied boxes has remained relatively stable throughout the study period (1992-2005).

Introduction

Over the past 50 years the Hawk Mountain Sanctuary and its collaborators have annually collected data pertaining to the nest box use of American Kestrels inhabiting the surrounding area (Nagy 1963; Heintzelman and Nagy 1968; Rohrbaugh and Yahner 1997). This nest-box program has been sustained in part due to the successful growth of kestrel populations in other similar study areas that have shown an increase in breeding pairs (Smallwood and Collopy 1991, 1993; Varland and Loughin 1993; Bortolotti 1994; Dawson and Bortolotti 2000).

The goal of this paper is to update a previous publication (Klucsarits et al. 1997) with our recent data on kestrel productivity from 1995 through 2005, and to compare trends with our past observations of nest-box use and other kestrel population studies. Nest-box use and breeding success are presented, along with records on kestrel egg laying periods. Previous studies have been performed on this site in years past (Rohrbaugh and Yahner 1997, Valdez et al. 2000).

Study Area and Methods

The study area includes 1500 square kilometers of mostly open, slightly wooded farmland in eastern Pennsylvania. The site is located 30 kilometers north of Reading, and 30 kilometers west of Allentown. The study area includes parts of Berks, Lehigh, and Schuylkill counties.

Spread across vast acres of farmland in eastern Pennsylvania surrounding the Mountain, at one time over 200 next boxes were actively checked as part of the study. Sanctuary volunteers routinely check the remaining boxes in mid-April for signs of kestrel nesting. Collected data include numbers of eggs and nestlings, hatch dates, and counts of banded young (assumed to fledge), as well as observations of non-target species using the boxes.

Nest boxes are mounted mainly on trees and utility poles, with a few on barns and other outbuildings. With few exceptions nest boxes are within 50 meters from an accessible road, and most are within half a kilometer apart. Boxes are mounted between 3 to 6 meters above the ground.

The boxes are constructed of rough-cut, untreated lumber (cedar or pine) and measure internally 26 centimeters deep by 24 centimeters wide by 33 centimeters high. Box openings are 7.6 centimeters in diameter and are centered 26 centimeters from the base of the nest box. All boxes are lined with 2 to 5 centimeters of large woodchips (not sawdust) to cushion the eggs and nestlings.

After the breeding season has ended, boxes are checked before winter sets in. Damaged boxes may be replaced or moved, and all boxes are cleaned of old nesting matter and refreshed with clean woodchips. A second check is performed in early to mid-March to prepare the boxes for the coming season and to expel unwanted species, such as Grey Squirrels (*Sciurus carolinensis*), that may deter nesting kestrels.

During the breeding season, boxes are checked at scheduled periods between May and July for evidence of kestrel nesting. When a nest is discovered, the number of eggs or nestlings is recorded, and an estimate of laying and hatching dates can be extrapolated by counting back the nestling's age. Once nestlings have reached approximately 14-17 days, gender can be determined (Griggs and Steenhof 1993) and the nestlings banded. On some occasions, it was possible to trap and band adult kestrels near the nest boxes (typically females) using bal chatri traps or by physically catching them within the box.

Boxes were considered used if eggs were found inside. Additionally, record was made of successful egg boxes, nest boxes that produced nestlings that survived to banding age. Note was also taken to boxes where entire clutches or broods disappeared, as well as to boxes with unhatched eggs after observed adult kestrel activity had ceased around the box location.

Kestrel reproductive success percentages were calculated by dividing the number of boxes with banded nestlings by the number of boxes in which eggs were laid. Percentages for egg boxes and nestling boxes were determined by dividing the sample size for a given year by the respective data set (Figure 1).

Results and Discussion

Over the course of the study (1992-2005), kestrel nest box occupancy (boxes with eggs) has ranged from 24% (2005) to 53% (1998). From 1998 onward, box use has begun to decline (Figure 1). Occupancy rates of greater than 50% have been recorded for only four study years during the Mountain's observations: 1987, 1991, 1995, and 1998. In 1998, we observed 101 successful breeding pairs (Figure 2), whereas only five years later in 2003 the number had dropped to approximately half of that total (56 pairs). Continuing declines the past two years have yielded the lowest recorded number of breeding pairs, 34, in 2005. This has resulted in a lower fledgling output of approximately 100 nestlings per season over the past three years (Figure 2).

Reproductive success, the percentage of successful fledglings per boxes with eggs, has varied slightly more, from only 52% (1992) to an 82% success rate in 1994 (Figure 1). Since 1994, success rates declined only to increase again in 1999. A second decline in overall reproductive success, beginning in 2002, continues up to the 2005 breeding season.

The mean clutch size (range: 4.38 to 4.71) over our study interval was 4.57 eggs per kestrel pair (Table 1). Brood size seemed to fluctuate much more than clutch size, with a range of 2.1 nestlings per box (1992) to 3.5 (2000), and a mean brood size of 2.9 nestlings. Referencing the data of our previous publication (1992-1994), the mean brood size has dropped 22%, from a mean of 3.7 nestlings per year during that period. During both intervals, the sex ratio of kestrel nestlings approached unity, despite minor differences in numbers between sexes over a particular year (Table 2, Figure 3).

Kestrel hatch dates vary widely from season to season, from an earliest recorded hatch date of 30 April 1995 to the latest, 1 August 2000. The mean hatch date over all thirteen years was 2 June (Table 3). As Table 3 illustrates, in addition to hatch dates, the kestrel breeding season has varied in length between 1992 and 2005, with a mean season length of 72 days. Hatch dates between first and last clutches in 1996 spanned only 49 days, while in 2000, 94 days separated the earliest from the final hatched clutch.

Perhaps more striking than the variations in hatch date were the overall percentages of clutches hatched in each part of the season. We divided the time between first and last clutches over all the study years into three breeding

periods, and tabulated the total number of clutches for each Early (day 120-150; 30 April-30 May), Middle (day 151-183; 31 May-2 July), and Late (day 184-214; 3 July-2 August) nesting period.

Very few of the overall clutches (and therefore nestlings) resulted from the late nesting period (Figure 4 & 5). It has been documented that female kestrels breeding later yield smaller clutches than those that breed early in the season (Sockman and Schwabl 2001), which supports the lower fledgling counts that we have observed in the Late nesting period. The Early and Middle nesting periods, however, produce over 90% of all clutches and nestlings, with mean percentages of 52% and 42% for the Early and Middle nesting periods, respectively. Figure 4 shows a cyclic pattern of nesting period and fledgling output. Two seasons (1995 and 2002), seven years apart, are dominated by early season nesters. The following season, however, early nesters are replaced by a higher volume of mid-season breeders, which then steadily decline, continuing the cycle. Continued annual observations will be helpful in determining if this behavior is cyclic or simply random variation.

The major potential nest site competitor in our study area has been the European Starling (*Sturnus vulgaris*), inhabiting up to 30% of potential next boxes in a given year (1992, Figure 6) and comprising over 70% of non-target box users (Valdez et al. 2000). Positioning direction of nest boxes, interior color, and the diameter of the box opening are all factors that may determine which species will inhabit which boxes (Balgooyen 1990, Wilmers 1987, Valdez et al. 2000). At most, starlings occupied 29% (1992) of all available kestrel boxes on our study site, observed approximately in 1 of every 5 boxes. While a distinct link between kestrel success and starling abundance is lacking, years with higher numbers of starlings reflect to lower percent success among kestrels (Figure 6). Koenig (2003) showed a definite impact of starling density on kestrel success. Between 2000 and 2005, starling box use within our study site has begun to decline (Figure 6). More observations of the starlings' effects on kestrel success will be needed to determine if a greater link among these two species is present or not.

Summary

Despite the relative breeding success of kestrel populations in some years of the study period (1992-2005), the past three years (2003-2005) have shown reduction in overall kestrel numbers. Despite conservation efforts, the population of northeastern kestrels has begun to decline within the past decade (Bildstein 1996, Illif 1999, National Audubon Society 2005). The underlying mechanisms of this decline may be due to many factors (Sullivan 2005), from habitat loss and prey availability, to an increase in predatory hawks, adverse weather conditions, or perhaps the West Nile virus.

Regardless of the causes, the culminating effect is that the once abundant kestrel in the northeast United States has declined to an alarming level. Though the causes are likely too interrelated to be accurately identified, the reduction may well be dictated by natural forces. The earlier years of our study showed kestrel population numbers in higher density. There are important efforts toward the conservation of American Kestrels living in our ecological community. Continued monitoring and study will certainly be a boon to the kestrels both now and into the future.

Acknowledgements

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Table 1. Annual Mean Kestrel Reproductive Output, 1992-2005

Year	Eggs	Nestlings	Fledglings	Year	Eggs	Nestlings	Fledglings
1992	4.48	2.12	1.91	1999	4.60	3.17	3.02
1993	4.71	3.32	3.21	2000	4.63	3.49	3.21
1994	4.57	3.57	3.35	2001	4.68	3.43	3.34
1995	4.68	3.23	3.12	2002	4.38	2.78	2.63
1996	4.44	2.75	2.57	2003	4.58	2.84	2.36
1997	4.56	2.66	2.35	2004	4.43	2.59	2.41
1998	4.69	2.22	2.04	2005	4.47	3.82	3.65
				Mean All	**4.57**	**2.94**	**2.73**

Table 2. Sex Ratio of American Kestrel Nestlings per Year, 1992-2005

Year	Male	Female	Year	Male	Female
1992	74	90	1999	147	125
1993	148	141	2000	141	103
1994	121	120	2001	122	152
1995	149	166	2002	111	97
1996	123	116	2003	56	76
1997	93	102	2004	60	58
1998	97	109	2005	65	59
			Total	1507	1514

Table 3. American Kestrel Breeding Season Lengths with Respect to Hatching Dates, 1992-2005

Year	Early Hatch	Late Hatch	Season	Mean
1992	133	206	74	153
1993	122	203	82	153
1994	129	199	71	151
1995	120	188	69	154
1996	137	185	49	158
1997	130	208	79	155
1998	124	206	83	148
1999	129	209	81	153
2000	121	214	94	153
2001	131	205	75	154
2002	125	191	67	148
2003	133	199	67	157
2004	135	188	54	155
2005	133	199	67	156
Mean All	**128.71**	**200.00**	**72.29**	**153.43**

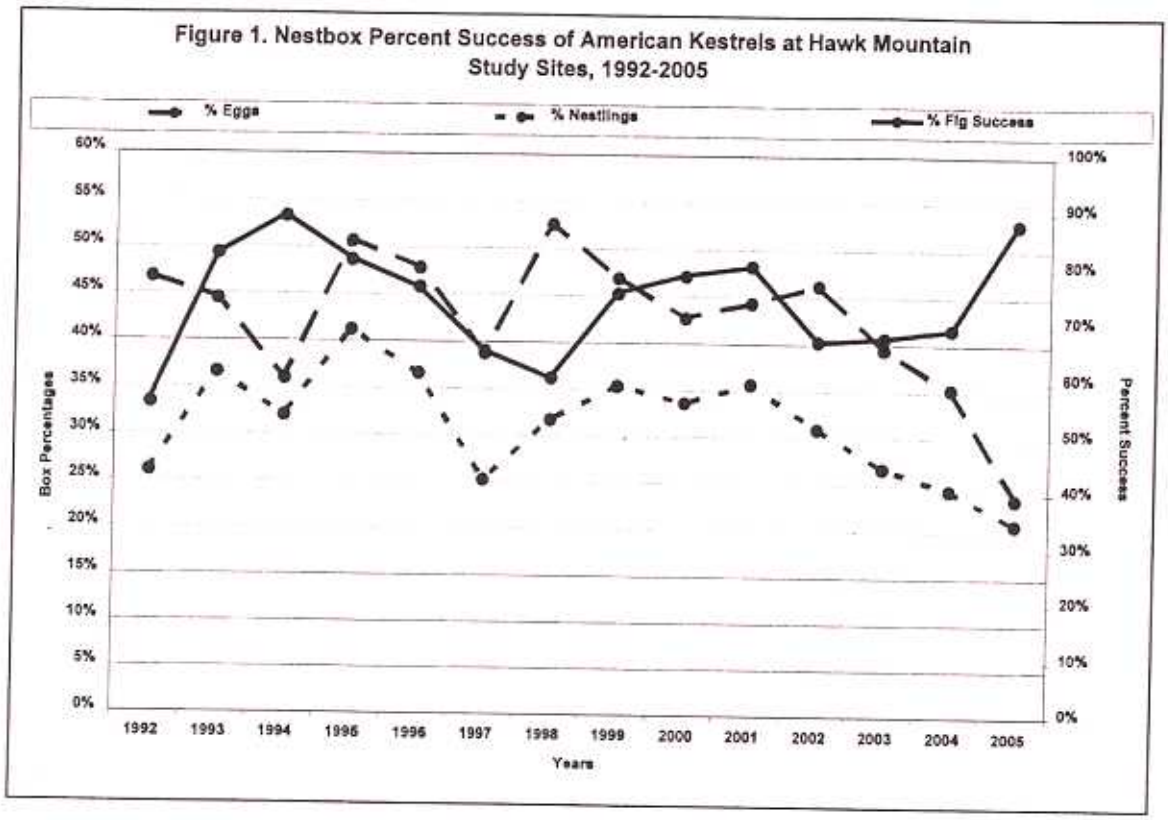

Figure 1. Nestbox Percent Success of American Kestrels at Hawk Mountain Study Sites, 1992-2005

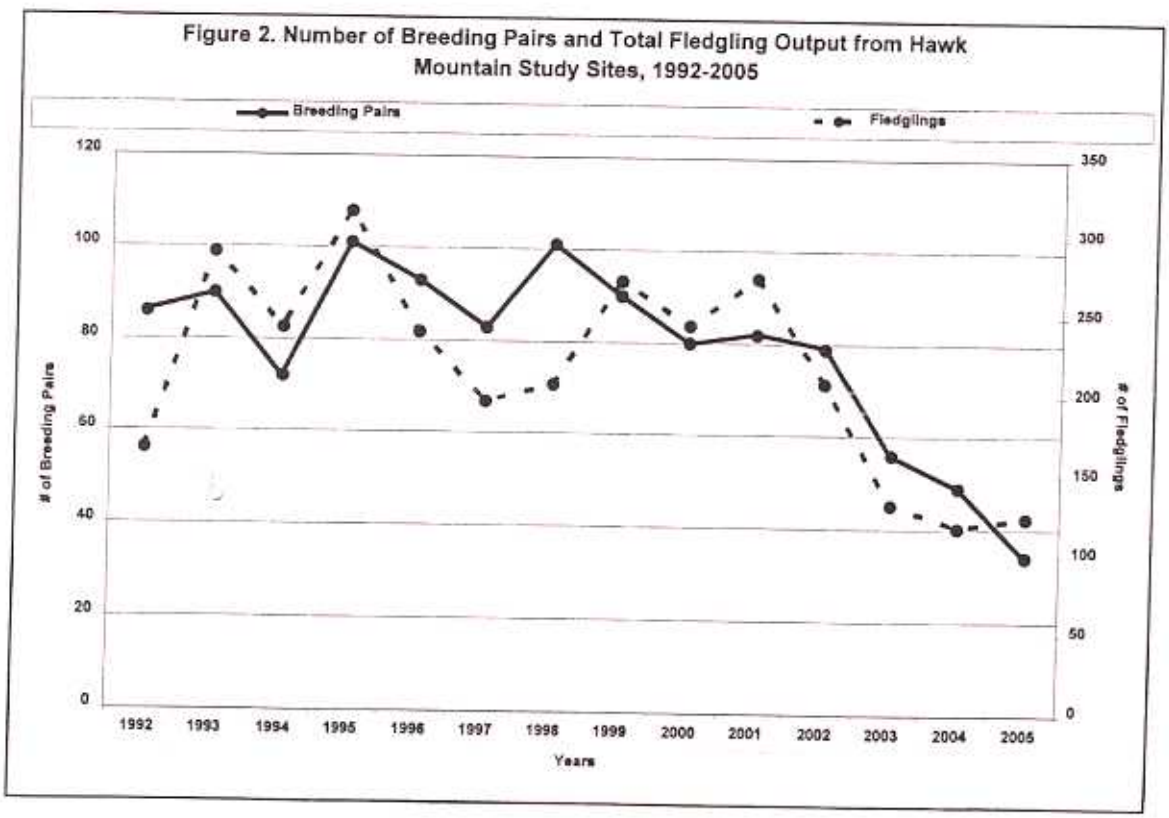

Figure 2. Number of Breeding Pairs and Total Fledgling Output from Hawk Mountain Study Sites, 1992-2005

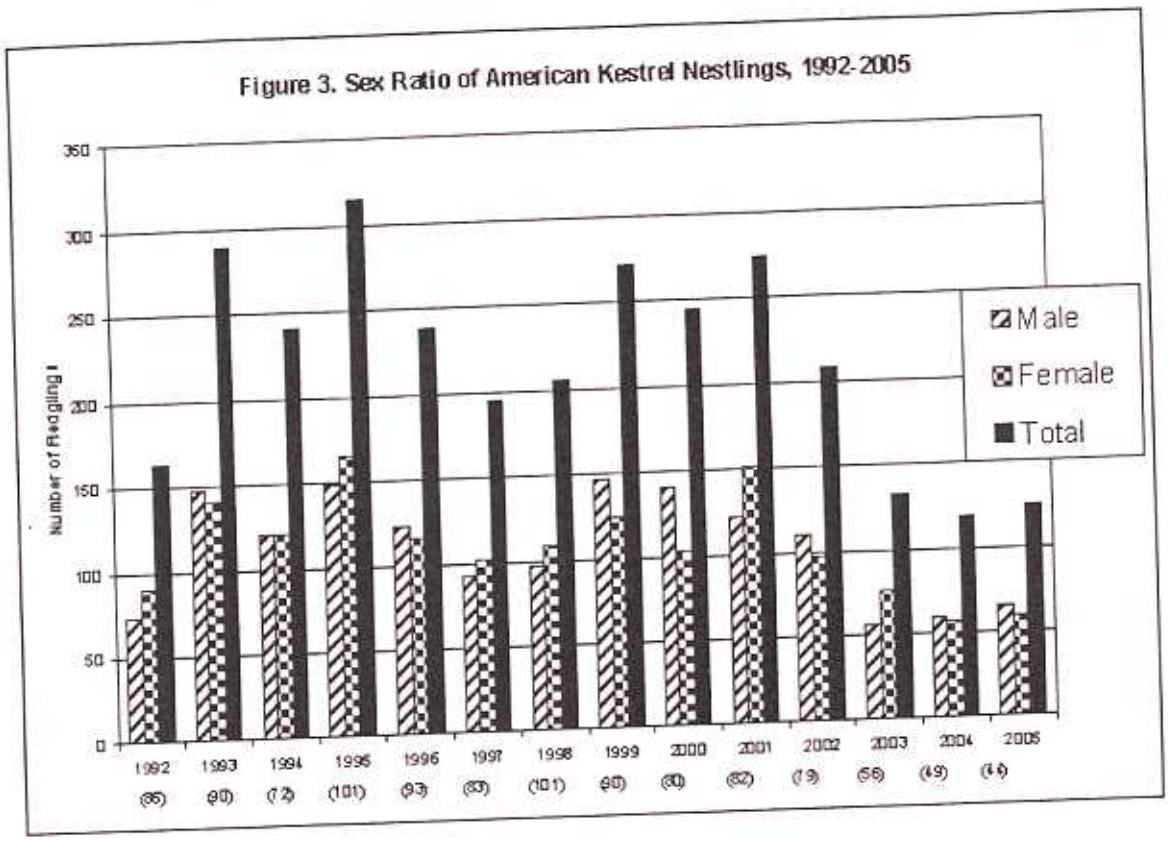
Figure 3. Sex Ratio of American Kestrel Nestlings, 1992-2005
Number of Fledglings
350
300
250
200
150
100
50
0
Male
Female
Total
1992 (86)
1993 (90)
1994 (72)
1995 (101)
1996 (93)
1997 (83)
1998 (101)
1999 (90)
2000 (80)
2001 (82)
2002 (79)
2003 (56)
2004 (49)
2005 (64)

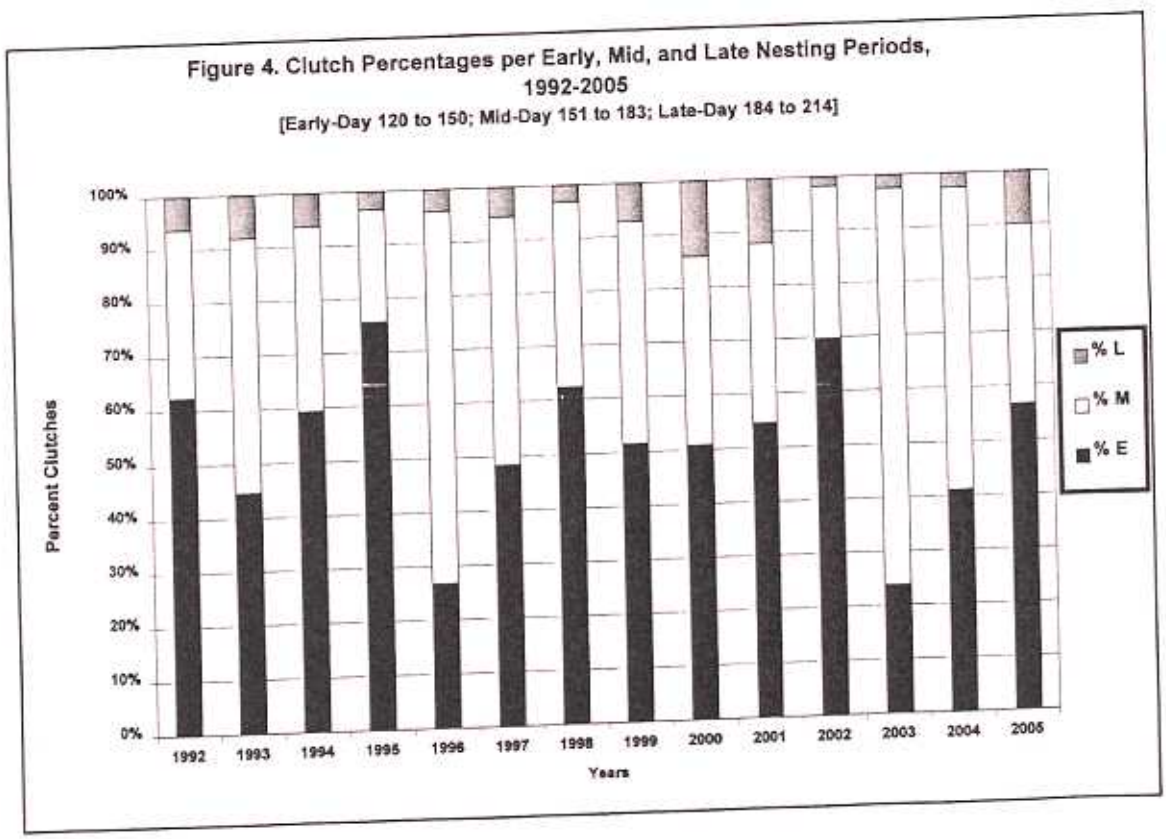
Figure 4. Clutch Percentages per Early, Mid, and Late Nesting Periods, 1992-2005
[Early-Day 120 to 150; Mid-Day 151 to 183; Late-Day 184 to 214]
Percent Clutches
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% L
% M
% E
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Years

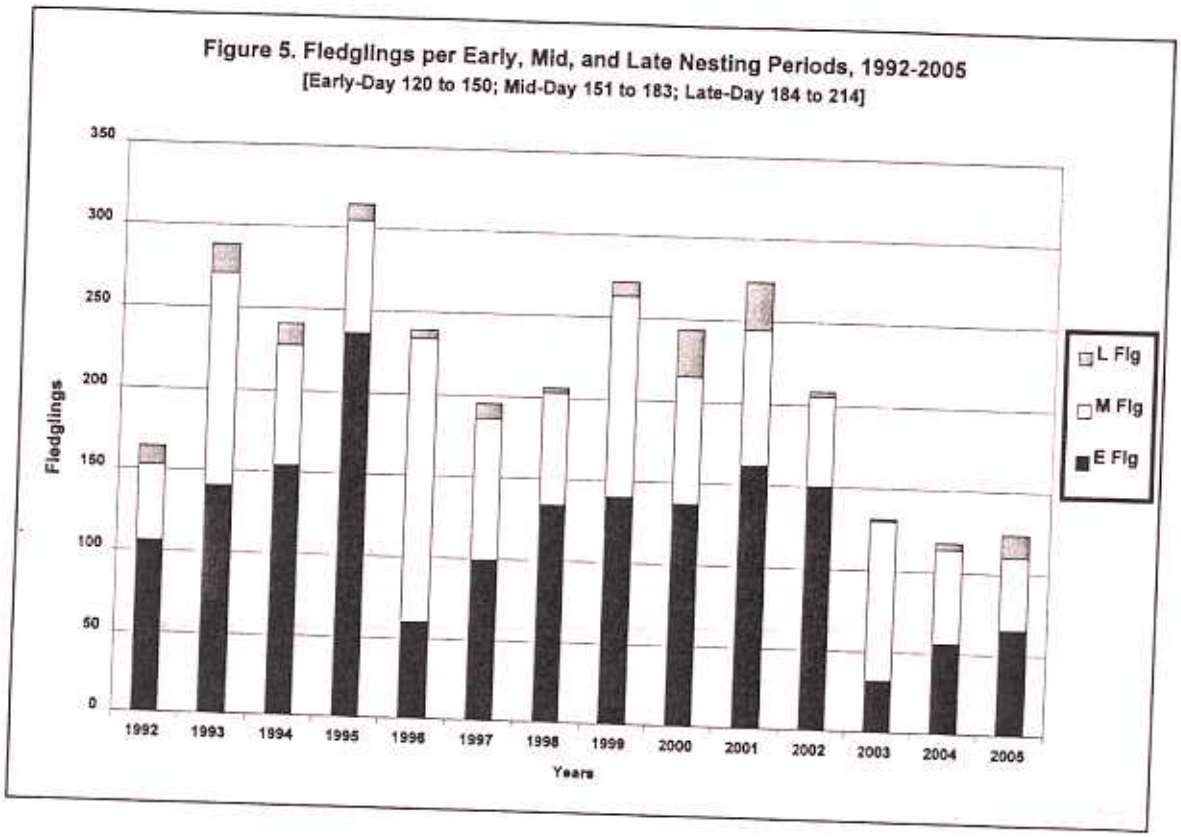
Figure 5. Fledglings per Early, Mid, and Late Nesting Periods, 1992-2005
[Early-Day 120 to 150; Mid-Day 151 to 183; Late-Day 184 to 214]
Fledglings
350
300
250
200
150
100
50
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Years
L Flg
M Flg
E Flg

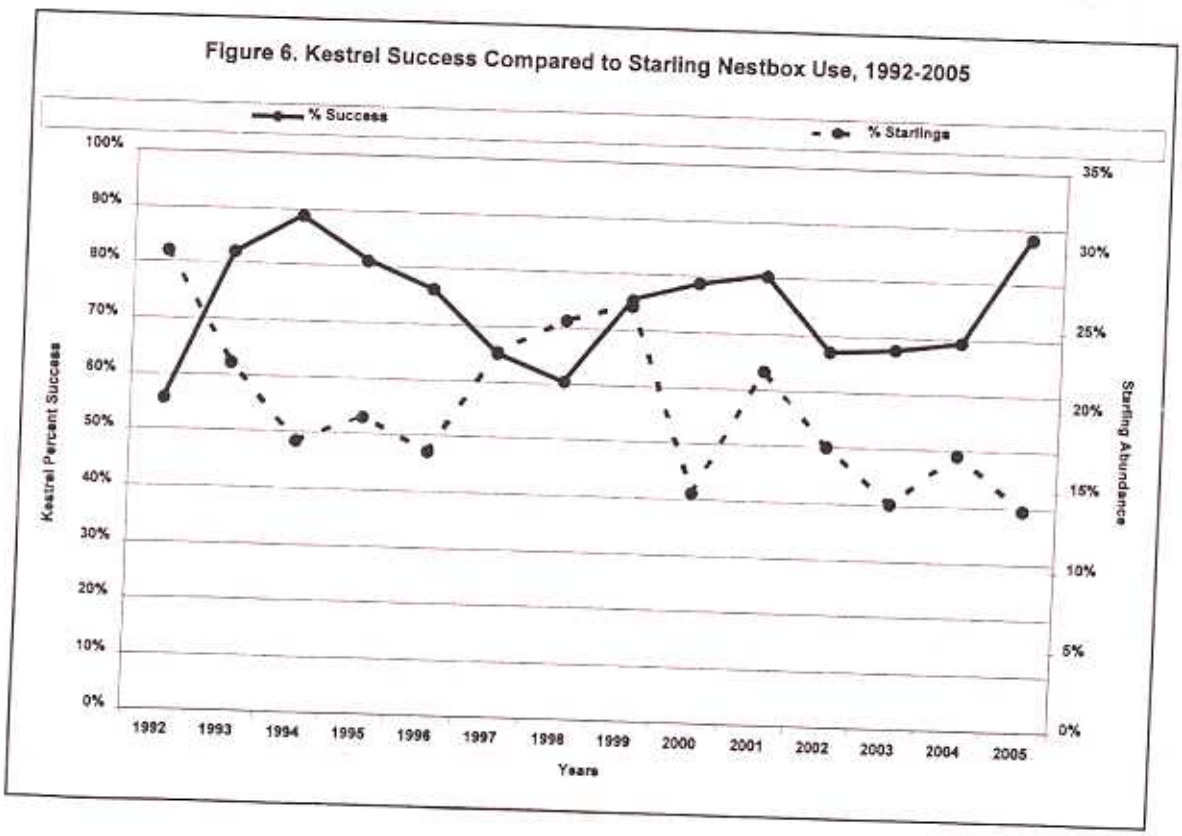
Figure 6. Kestrel Success Compared to Starling Nestbox Use, 1992-2005
% Success
% Starlings
Kestrel Percent Success
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Starling Abundance
35%
30%
25%
20%
15%
10%
5%
0%
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Years