5-2023

Trends in Nestling Body Size in a Declining Population of American Kestrels

Kristina M. Ollo

ABSTRACT

American Kestrels (*Falco sparverius*) are small falcons that feed primarily on large insects but also small mammals and birds. During recent decades kestrel populations have been declining in North America, for reasons still unknown. One plausible explanation is that nestlings are becoming malnourished over the years from lack of food resources and are fledging at smaller sizes. Fledging at a smaller size puts kestrel nestlings at greater risk of post-fledging mortality due to starvation or predation. Here we examined long-term trends in the morphological development of American Kestrel nestlings to see if there have been any significant changes over time. We used about thirty years of measurement data from New Jersey and Pennsylvania nest box programs to explore this possibility. In New Jersey, wing length for females increased and wing length for males decreased. Body weight and body condition (wing length/body weight) did not change significantly over time in New Jersey. However, in Pennsylvania nestlings decreased in size, both in wing length and body weight. Moreover, body weight in Pennsylvania decreased disproportionately such that there also was a significant decrease in body condition. Decrease in body weight and body condition possibly could be caused by malnutrition from declines in insect populations, such as grasshoppers. The decrease also may be from exposure to contaminates such as pesticides. Evidence of American Kestrel nestlings decreasing in size could bring us closer to finding out why populations have been declining. Further research will need to be conducted to determine the reason for this change in size.

MONTCLAIR STATE UNIVERSITY

Trends in Nestling Body Size in a Declining Population of American Kestrels

by

Kristina M. Ollo

A Master's Thesis Submitted to the Faculty of

Montclair State University

In Partial Fulfillment of the Requirements

For the Degree of

Master of Biology

May 2023

College of Science and Mathematics

Department of Biology

Thesis Committee

[redacted]

Dr. John A. Smallwood, Thesis Sponsor

[redacted]

Dr. Lisa Hazard, Committee Member

[redacted]

Dr. Matthew Schuler, Committee Member

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ACKNOWLEDGMENTS

I thank my mentor and thesis advisor Dr. John Smallwood for all his help and support during both my undergraduate and graduate program, for teaching me all the ins and outs of handling kestrel nestlings, and for spending endless hours in the field collecting data with me the past two summers. I also thank him for recommending me and giving me the opportunity to collaborate with Hawk Mountain Sanctuary. I also thank Dr. Jean-Francois Therrien, the Graduate Study Director at Hawk Mountain, for help throughout my thesis process and for providing the resources to learn new skills used in the field, especially my favorite, drawing blood from kestrels. I also thank my committee members, Dr. Lisa Hazard, and Dr. Matthew Schuler, for dedicating their time to help me through the thesis process. I also thank Montclair State University for giving me an amazing experience for both my undergraduate and graduate career.

Next, I would like to send a special thanks to my family for all the support they have given me throughout my college career, I would not have been able to do this without them. I also would like to thank all my friends, especially those I have made throughout my graduate program who have helped me through stressful days. Lastly, I would like to thank my wonderful fiancé who has supported me every step of the way and has helped me believe in myself throughout this process.

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INTRODUCTION

The American Kestrel (*Falco sparverius*) is the smallest and most common falcon in North America (Smallwood and Bird 2020). Recently there has been evidence of American Kestrel population declines occurring throughout North America (Smallwood et al. 2009, Farmer and Smith 2009, Hinnebusch et al. 2010). Reasons for this decline are still unknown. Previous studies have suggested it could be from exposure to West Nile Virus. There were cases of kestrels contracting the virus, but they survived and had normal body weights (Medica et al 2007). However, the kestrel decline began before the virus spread to North America (Smallwood et al. 2009). Another suggestion is that increased Cooper's Hawk (*Accipiter cooperii*) populations caused kestrel populations to decline due to predation (Farmer et al. 2008), but evidence of those interactions are scarce (Smallwood et al. 2009). Loss of habitat also could be a cause of population decline, however data for this relationship are limited (Smallwood et al. 2009). A factor that has not yet been widely considered in relation to the decline is the size of American Kestrel nestlings before fledging. Knowing if nestlings are fledging at smaller sizes can narrow down the many possible reasons as to why the kestrel population is declining.

During this study, we examined long term data sets from New Jersey and Pennsylvania kestrel nest box programs. The goal of this study was to examine trends in the morphological development of American Kestrel nestlings from 1998-2022 in New Jersey and from 1990-2022 in Pennsylvania to see if there have been any significant changes over recent decades. Morphological traits we focused on were wing length, which is a standard measure of overall body size in birds, and body weight. We then calculated body weight/wing length as an index of nestling body condition (Snyder and Smallwood in press 2023).

METHODS

Study Area. The New Jersey nest box program, established in 1995, currently consists of about 100 American Kestrel nest boxes spread throughout Sussex County and Warren County in northwestern New Jersey. The study area is south and east of the Kittatinny Ridge and the Delaware River. The study area is dominated by agriculture fields, woodland fragments, and residential plots (Smallwood 2016). Nest boxes were placed within suitable grassland habitat for kestrels, with a majority attached to utility poles along roadsides and the rest attached to trees or barns (Smallwood and Wargo 1997). The Pennsylvania nest box program, established in 1990, consists of about 125 kestrel nest boxes dispersed within a 25-mile radius of Hawk Mountain Sanctuary in Berks County, Pennsylvania. Most of the Pennsylvania study area is dominated by agricultural fields. The internal dimensions of the nest boxes were about 33 cm high with a 20 × 23 cm floor, which was covered with a layer of wood chips (Smallwood 2016).

Monitoring Nest Boxes. New Jersey nest boxes were monitored from 1995 to 2022. Pennsylvania nest boxes were monitored from 1990-2022; however no data were available for 1992 and 2011-2014. Monitoring methods were comparable to those described by Smallwood (2016). During each field season, March to July, all nest boxes were opened and checked for breeding attempts every 21 to 28 days. Kestrel sightings at nest boxes were noted, but a nest box was not considered active until at least one egg was present. We checked active nest boxes every few days to determine the completed clutch size. American Kestrel clutches generally are 4 to 5 eggs, with one egg being laid every 2 days. Incubation typically begins upon laying the penultimate egg of a clutch, and hatching occurs about 30 days after the onset incubation. We scheduled additional visits to determine hatching date, which determined the accurate age of nestlings. (Smallwood and Bird 2020).

When nestlings were 20-21 days old, we measured them and banded them with US Geological Survey (USGS) aluminum bands and marked each with a patagial (wing) tag. Some nestlings, mostly from Pennsylvania, were banded as young as 16 days. On banding day, we weighed nestlings in units of grams, measured flattened wing length and the length of the right 7^{th} primary (PR7), in millimeters.

Statistical Analyses. Multiple measurements were taken from each clutch in each nest box. The body weight of kestrel nestlings reaches an asymptote around 19-21 days, while the primary feathers continue to grow linearly until after fledging (Smallwood and Bird 2020). In order to compare nestlings banded younger than 21 days, we standardized age to day 21 using growth curves generated with unpublished data from the New Jersey nest box program in 1998. Those growth curves represent a sample size of 55 nestlings which were measured approximately every two days. We used linear regressions to standardize PR7 to age 21 days (females: $PR7 = 5.564 \times age - 47.841$, $r^2 = 0.865$; males: $PR7 = 4.952 \times age - 39.193$, $r^2 = 0.731$). Standardization to day 21 was calculated by subtracting from the nestling's PR7 length their expected PR7 length for that day according to the model and then adding that difference to the expected PR7 length of a 21-day old nestling. In Pennsylvania the only wing measurement recorded was flattened wing length (FWL) while in New Jersey both FWL and PR7 were measured in 2021 and 2022. Therefore, before standardizing to age 21 days we first converted the Pennsylvania FWL measurements into PR7 measurements, using second-order polynomial regressions based on the dual measurements from New Jersey (females: $PR7 = 0.004 \times FWL^2 + 0.3144 \times FWL - 10.929$, $r^2 = 0.982$; males: $y = 0.004 \times FWL^2 + 0.3398 \times FWL - 10.229$, $r^2 = 0.980$). Hereafter we refer to all standardized PR7 measurements as "wing."

We also used the 1998 growth curves to standardize weight to day 21. The body weight gain model for females was weight = exp(2.2709874 + 0.38264042 × age – 0.019251953 × age^2 + 0.00033218287 × age^3; r^2 = 0.957, and for males, weight = exp(2.3609669 + 0.34471588 × age – 0.016200524 × age^2 + 0.00025040184 × age^3; r^2 = 0.923. Standardization to age day 21 was calculated as above. Hereafter we refer to standardized weight as simply "weight." We used wing and weight to calculate a standard measure of body condition in birds, wing/weight (e.g., Snyder and Smallwood in press 2023).

We compared the size of 21-day old nestlings over the years of study, using a linear mixed model. We chose the mixed model approach to account for the non-independence of sibling measurements. For this test, brood was considered a random effect and year was the fixed effect. The dependent variables were wing length, body weight, and body condition. Linear mixed model analyses were run separately for New Jersey females, New Jersey males Pennsylvania females, and Pennsylvania males. All statistical analyses were conducted using SAS 9.4 software for Windows operating system (SAS Institute 2013).

RESULTS

We measured a total of 5,090 kestrel nestlings, 2,063 from New Jersey and 3,027 from Pennsylvania. Of the nestlings in New Jersey, 1,061 were female and 1,002 were male; in Pennsylvania, 1,560 were female and 1,467 were male.

In New Jersey, nestling wing length at 21 days of age changed significantly for both females and males from 1996 to 2022 (P = 0.004 and P = 0.025, respectively; Table 1). In this case, female wing length increased while male wing length decreased (Fig. 1). In Pennsylvania, there also was a significant change in wing length from the years 1993 to 2022 for both females and males (both P = <.001; Table 1); both females and males wing length decreased (Fig. 1).

In New Jersey, nestling body weight at 21 days of age did not change significantly for either females or males from 1996 to 2022 ($P = 0.294$ and $P = 0.114$, respectively; Table 1). In Pennsylvania, nestling body weight from the years 1990 to 2022 changed significantly for both females and males (both $P = <.001$; Table 1); both female and male nestlings have decreased in body weight (Fig. 2).

In New Jersey, nestling body condition at 21 days of age did not change significantly for both females and males from 1996 to 2022 ($P = <0.736$ and $P = 0.369$, respectively; Table 1). In Pennsylvania, body condition changed significantly from the years 1990 to 2022 for both female and males (both $P = <.001$; Table 1); both females and males body condition decreased (Fig. 3).

DISCUSSION

We found that New Jersey nestling's body weight and overall body conditions at 21 days old have not changed significantly over the course of our study. However, in both female and male nestlings in Pennsylvania, wing length, body weight, and body condition all decreased significantly over time. With wing length being an indication of size, this means that kestrel fledglings are getting smaller and weighing less, and the decrease in body condition indicates that the weight decreased disproportionately. Body condition index (body weight/wing length) is a good indicator of nestling health before they fledge from the nest. Lower body condition can be caused by malnutrition from not eating enough, or eating a diet that lacks certain nutrients needed for the nestlings to grow and thrive. Insects such as grasshoppers, katydids, and dragonflies are a staple in American Kestrel diets (Sherrod 1978, Smallwood and Bird 2020). A decline in insect populations, including grasshopper populations, has been documented in North America (Welti et al. 2020). It is possible that declines in these populations are making it more difficult for kestrels to find food. American Kestrel parents may require more time to search for insects, which would mean more time between feedings for their offspring, and thus fewer feedings per day. Lacombe and Bird (1994) conducted an experiment on captive American Kestrels where they reduced the amount of food given to three groups of nestlings and compared them to the control group (1994). The experimental groups grew significantly slower than the control group. Mean length of the 9th primary prior to fledging was significantly shorter for nestlings being fed the reduced diet. The experiment groups also fledged with lower body weights compared to the control group (Lacombe and Bird 1994). Pennsylvania kestrel nestlings may not be consuming as much food as they used to, which could explain why their size is decreasing. Alternatively, perhaps they have changed their diet to eating more vertebrates such as small birds rather than invertebrates, possibly resulting in lack of nutrition. In New Jersey, there was a significant trend of increasing wing length for females and decreasing wing length for males. This could possibly be an exaggeration of sexual size dimorphism traits in American Kestrels, in which the females are larger than the males (Smallwood and Bird 2020). Sexual dimorphism is most pronounced in raptor species that feed primarily on other birds (Snyder and Wiley 1976). This could be an indication that kestrels in the New Jersey study area are switching to avian prey.

Nestlings that leave the nest with a smaller wing length could have a lower post-fledging survival rate. This trend has been documented in other bird species such as the House Sparrow (*Passer domesticus*; Murphy 1978) and Great Tit (*Parus major*; Perrins 1965). Young birds that weigh less are suggested to have lower body fat (Perrins 1965). This is seen in the experiment by Lacombe and Bird (1994): captive kestrel nestlings who were fed reduced diets had less stored fat than nestlings fed a regular diet. Having lower fat reserves could decrease chances of survival in birds who are learning to survive (Perrins 1965). When kestrel nestlings first leave the nest, they still rely on their parents for food. It takes 3 to 4 weeks for them to reach independence; and when they begin to forage on their own, hunting success rate is low (Varland et al. 1991). Grasshopper population declines, as mentioned above, would add to the difficulty of catching prey at this life stage (Welti et al. 2020). If kestrel nestlings already have low body fat when they leave the nest, and they then have difficulty hunting for food independently, they could easily starve to death.

Nestlings leaving the nest with a smaller wing length could also be affecting post-fledging survival. The first week American Kestrel nestlings leave the nest they spend most (~75%) of their time perched and resting and they spend less than 1% of their time flying (Varland et al. 1991). During the first week post-fledging kestrels have not developed their flying skills yet and they continue to lack flying skill up to the third and fourth week post-fledging. This lack of flying skill increases the chance of kestrel nestling mortality due to predation by mammals and other birds (Varland et al. 1993). If Pennsylvania nestlings are leaving the nest with shorter wing lengths, and especially lower body condition, the development of flying skills could become delayed such that they may not be proficient in flying until five weeks post-fledging rather than three or four. This would increase the amount of time they are vulnerable to predators, thus increasing their chances of mortality.

The New Jersey and Pennsylvania study areas are in close proximity, separated by about 60 km, and some individuals banded in one area have bred in the other area. However, decreases in size were seen only in kestrels breeding in Pennsylvania. This could be due to differences in land cover among the two study sites. In the New Jersey study area, there are small forest fragments scattered among the agriculture fields as well as larger forested areas. The Pennsylvania study area has more consistent agricultural cover. These extensive agricultural fields may represent more pesticides used in that area to prevent insects, especially grasshoppers, from eating the crops. Pesticides effectively kill the grasshoppers, thus making it harder for kestrels to find food, as stated above. In addition, pesticides can cause harm to the surrounding environment, to non-target insects, and to other organisms (Dakhel et al. 2020). There have been instances in other raptor species where their populations declined because of pesticide contaminations, e.g., Bald Eagles (*Haliaeetus leucocephalus*; Grier 1982). This could potentially be the case for American Kestrels. Ongoing research begun in 2021 in both the New Jersey and Pennsylvania study areas include taking blood samples from kestrel nestlings to test for contaminants such as these.

Evidence of American Kestrel nestlings declining in size can be an important clue as to why populations are declining throughout North America. A decrease in size could indicate an increase in post-fledging mortality. However, the proximate cause of this change in size is a new question to tackle. Future research should investigate these findings.

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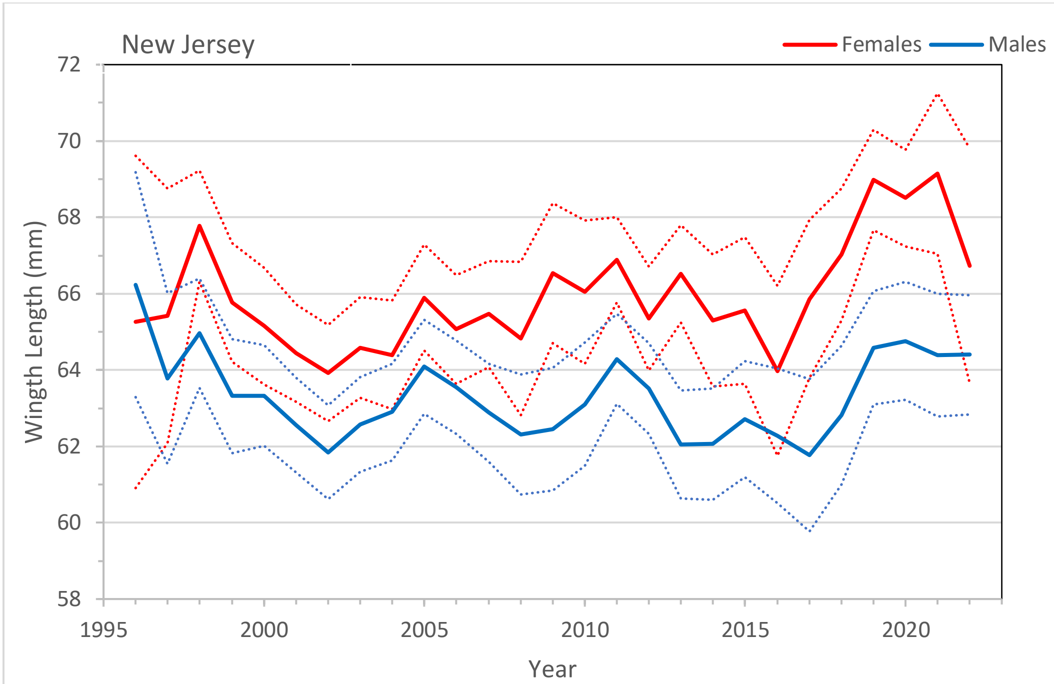
TABLES AND FIGURES

Table 1. Linear mixed model results for body size and body condition in 21-day old American Kestrel nestlings in New Jersey, 1996-2022, and Pennsylvania, 1990-2022. Year was the fixed effect and brood was a random effect. Wing is the length of the right 7th primary feather, and body condition is body weight divided by wing.

	New Jersey						Pennsylvania					
	Females			Males			Females			Males		
	F	*P*	n	*F*	*P*	n	*F*	*P*	n	*F*	*P*	n
Wing	1.92	0.004	1002	1.64	0.025	1061	5.96	<0.001	1418	6.57	<0.001	1513
Body weight	1.14	0.294	1001	1.35	0.114	1059	3.65	<0.001	1404	3.11	<0.001	1489
Body Condition	0.81	0.736	1001	1.07	0.369	1059	6.15	<0.001	1355	4.57	<0.001	1442



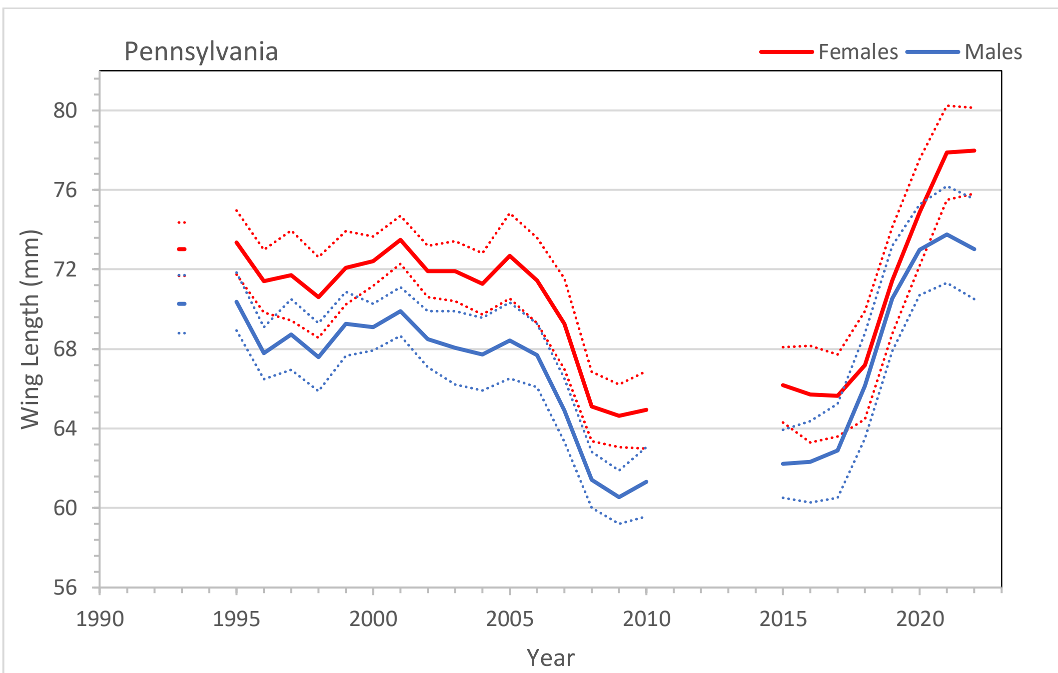
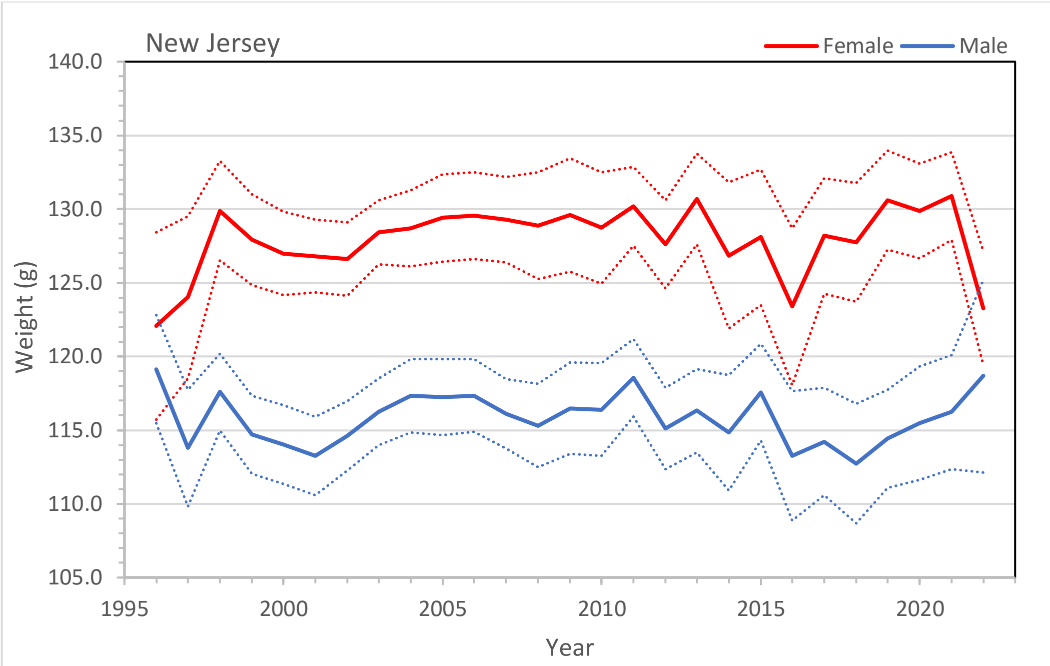


Figure 1. Variability in American Kestrel nestling wing length over the years of study in New Jersey and Pennsylvania. Solid lines are 3-year running means and dotted lines are +/- 1 standard error.



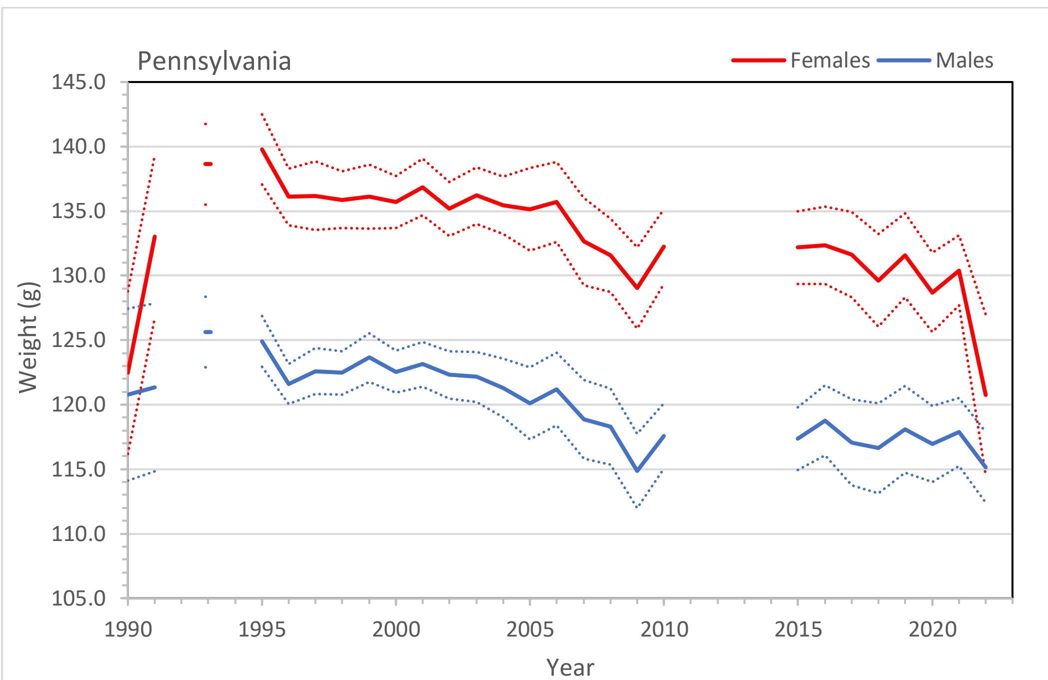
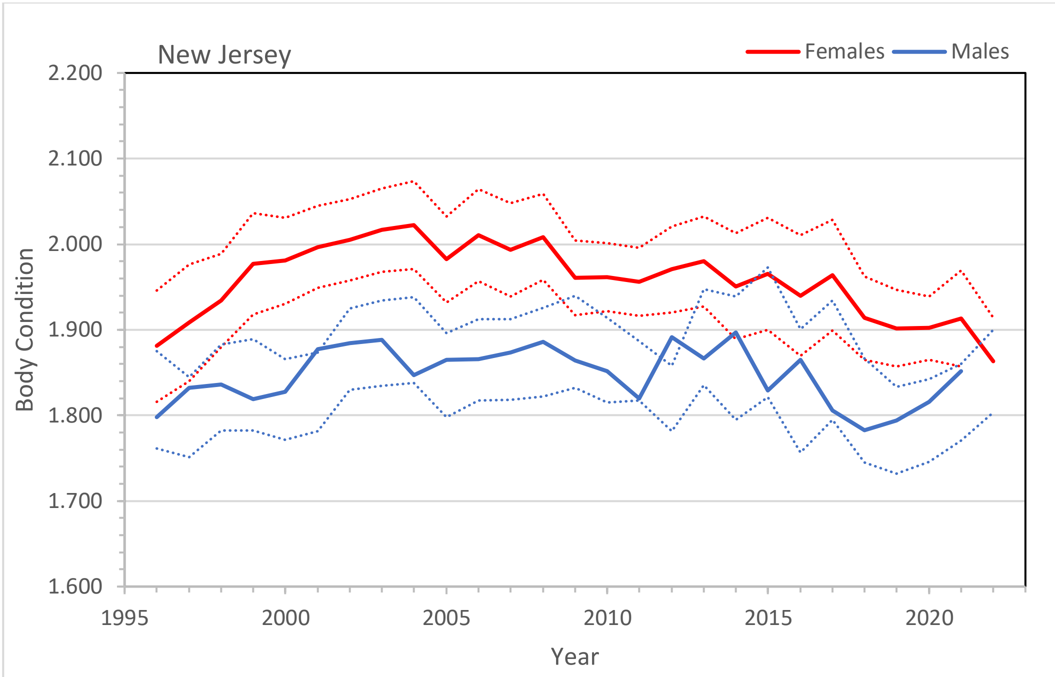


Figure 2. Variability in American Kestrel nestling body weight over the years of study, in New Jersey and Pennsylvania. Solid lines are 3-year running means and dotted lines are +/- 1 standard error.



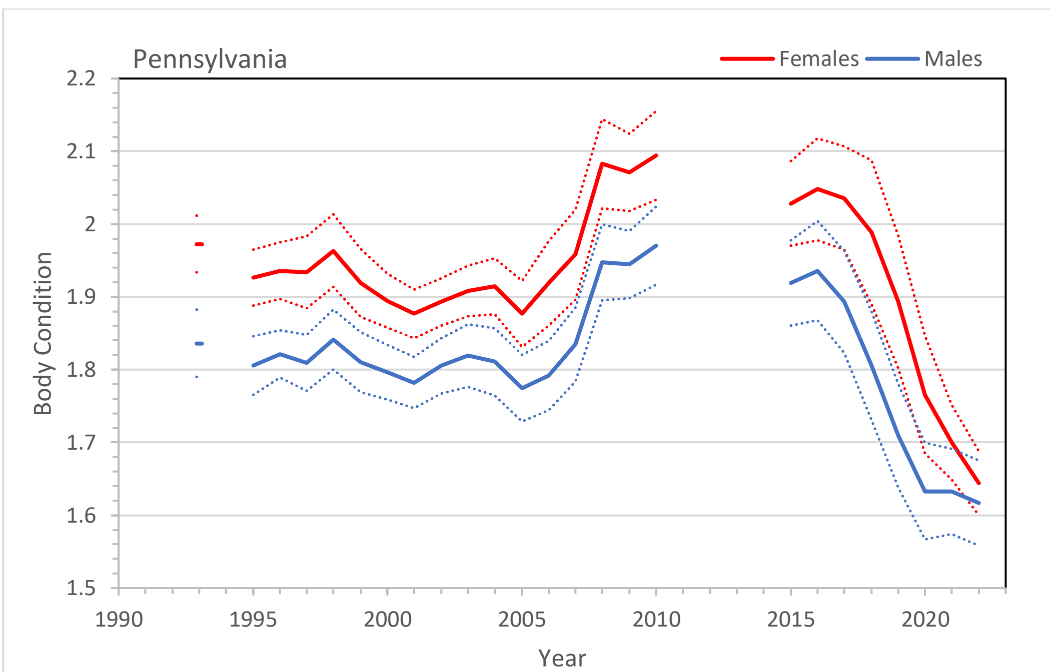


Figure 3. Variability in American Kestrel nestling body condition over the years of study, in New Jersey and Pennsylvania. Solid lines are 3-year running means and dotted lines are +/- 1 standard error.

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