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Feast of skinks for Nankeen Kestrels *Falco cenchroides* breeding on a bird-friendly farm

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Abstract. Nankeen Kestrels *Falco cenchroides* raised three fledglings each year from 2018 to 2020 in nests in hollows of remnant eucalypts on a farm near Deans Marsh in southern Victoria. Observations were made each year of the adults feeding the chicks during foraging sessions, enabling the prey items and estimated feeding and hunting rates to be assessed. Skinks (Scincidae) formed a substantial proportion of the prey items delivered to the chicks. The delivery rate of prey by the male feeding a brood of three—6.0 items/h in 2018 and 2019, and 11.2 items/h in 2020 over 1.2 h—was at the high end of rates previously reported in which vertebrates made up the bulk of the prey. The breeding success of the Kestrels at the study site (three fledglings per nest) was at the high end of results of studies elsewhere in Australia (1–4 fledglings per nest started). Farming practices on this property have been designed to encourage wildlife including skinks, and this might have contributed to the high breeding success of the Kestrels.

Introduction

The Nankeen Kestrel *Falco cenchroides* is a falcon of most open habitats in Australia including farmland with scattered trees and inland shrublands and woodlands (Marchant & Higgins 1993; Debus 2019). Its diet and breeding have been reported in many studies, in various states and territories of Australia (Sharland 1931; Genelly 1978; Olsen *et al*. 1979; Bollen 1991; Paull 1991; Aumann 2001; Starr *et al*. 2004a; Schulz & Lumsden 2009; Leach *et al*. 2015; Tsang *et al.* 2017; Mo 2019; Pryor 2021). The species feeds on a wide range of invertebrate and vertebrate prey. Items of invertebrate prey include spiders (Arachnida), centipedes (Myriapoda), beetles (Coleoptera), crickets and grasshoppers (Orthoptera) (Olsen *et al*. 1979; Bollen 1991; Leach *et al*. 2015; Tsang *et al*. 2017). Vertebrate prey items include skinks (Scincidae) of various species (e.g. Olsen *et al*. 1979; Bollen 1991; Paull 1991; Tsang *et al*. 2017; Pryor 2021), small birds (e.g. Belcher 1914; Oliver 2004; Tsang *et al*. 2017), and such other vertebrates as bats, frogs and rodents (Leach *et al*. 2015; Tsang *et al*. 2017). Carrion is rarely eaten (Olsen *et al*. 1979).

During the incubation and nestling periods, the diet has been found to shift from invertebrates towards vertebrates, mainly skinks, with vertebrates providing most of the biomass during the breeding cycle in the tablelands of New South Wales (Bollen 1991; Paull 1991; Tsang *et al.* 2017). Skinks, though potentially more difficult to catch than most species of invertebrates, are thought to have a higher nutrient value per unit of mass than invertebrates (Paull 1991). Feeding rates, though less studied than diet, have been reported for Nankeen Kestrels, with rates observed to increase as chicks develop and to peak in the morning period of 0800–1000 h (e.g. Bollen 1991; Starr *et al.* 2004a).

On a farm near Deans Marsh in southern Victoria a pair of Nankeen Kestrels was found nesting in hollows in remnant trees every year from 2018 to 2020. Periodic observations were made of their nesting behaviour and prey delivery. These observations are discussed in relation to farming practices that may enhance the value of farming properties for such predatory birds as Nankeen Kestrels.

Study area and methods

Location

The farm of 230 ha is located on the northern foothills of the Otway Ranges in southern Victoria (38°21′S, 143°54′E), 2 km north of the township of Deans Marsh. The observations were made in a 25-ha paddock of improved pasture grazed by sheep at a stocking rate of 140 breeding ewes (15 dry sheep equivalents per hectare). The paddock had scattered trees and stumps of remnant Manna Gum *Eucalyptus viminalis*. The largest living trees, up to 25 m tall, were in decline, and some were in the late stage of senescence, with prominent dead branches within the canopies providing numerous perches for the Kestrels and other bird species.

In 2018, the nest of the Kestrels was in a hollow facing north in a dead tree on an elevated position, 200 m from the nearest public road. The remnant tree was 14 m high and had a diameter of 90 cm measured 1.3 m above the ground. The nest site was 6 m above the ground and several branch stubs above provided convenient perches.

The nest used in 2018 was occupied by a Common Brushtail Possum *Trichosurus vulpecula* in 2019. However, a pair of Kestrels was regularly observed in the locality during 2019 and in October they were found nesting in a cavity of a dead Manna Gum 60 m to the west of the 2018 nest site. Again, the nest was 6 m above the ground (Figure 1). The Kestrels had used this nest site in 2017 and used it again in 2020.

Observations in 2018

Opportunistic observations were made on 15 December of two adult Kestrels feeding a brood of three chicks during

Figure 1. Nest of Nankeen Kestrels in the hollow of a remnant Manna Gum. Photo: Hugh T. L. Stewart

a concentrated feeding session of 2.2 h, from which I determined the prey items and estimated feeding and hunting rates. The nest was observed towards the end of the nestling period when the chicks were ~25 days old. Observations were made from a vehicle that was regularly driven through the paddock during farming activities. The observations were made at a distance of 40 m from the nest site; my experience in the previous 2 years was that at this distance from the vehicle the Kestrels behaved naturally.

Observations were made with the aid of binoculars and photographs, and the time of day, sex of the adults, the direction of foraging bouts, types of prey brought to the nest, and transfers of prey were recorded. Observations were made between 1150 and 1400 h. The 2 days before had been cool and wet, with 17 mm and 20 mm of rainfall on 13 December and 14 December, respectively, recorded at the farm homestead located 2 km south of the nest site. On the morning of 15 December, the site was shrouded in heavy cloud and mist, which persisted until *c*. 1000 h. These brief and opportunistic observations were supplemented with further observations on five occasions during the subsequent 4 weeks, ending on 10 January 2019.

The likely species of skinks observed as prey were identified from photographs taken, reference to species guides, and expert opinion drawing on the known distribution of skinks in the locality (Wilson & Swan 2003; T. Pescott pers. comm.).

Rates of prey delivery by the Kestrels were calculated as the number of prey items delivered per unit time of observation, expressed as an hourly rate (Morley 2020). The proportions of prey items provided by the male and female were calculated. The sex of the adult Kestrels was determined from differences in plumage, notably the male having a pale-grey, dark-streaked crown and long tail with a dark subterminal band, whereas the female was differentiated by her rufous crown and tail with clear darker bands (Menkhorst *et al*. 2017; Debus 2019).

Observations in 2019

On 17 December, I observed a pair of Kestrels feeding a brood of three chicks towards the end of the nestling period. Observations, using the methods of 2018, were made during the period 0600–1115 h. The chicks were estimated to be ~30 days old, given that I believe that I observed the first flight on that day of one of the chicks and that the nestling period of Nankeen Kestrels is 26–35 days (Marchant & Higgins 1993).

Observations in 2020

In 2020, I observed a pair of Kestrels feeding a brood of chicks on 19 and 25 November and on six occasions during December for periods ranging from 2.5 to 4.3 h, using the methods of 2018. When first observed, there were four chicks covered in downy plumage with emerging feathers just visible on the wings. A week later, the primary feathers were several centimetres long. By 3 December, and again on 8 December, the chicks were observed sitting outside the nest on the edge of the cavity of the tree stump. Three days later, only three chicks were seen. By 16 December, three chicks had fledged. Observations

of the adults feeding the fledged Kestrels were made on 20 and 23 December.

Results

Items of prey

In the foraging session observed in 2018, 16 of the 26 deliveries to the nest were skinks (62%) and 10 were small unidentified items, probably arthropods and most likely Wingless Grasshoppers *Phaulacridium vittatum* that were prevalent in the pastures at that time. Skinks were ≤100 mm in length and expert opinion was that there could have been three or four species involved, most likely to be Eastern Three-lined Skink *Acritoscincus duperreyi*, Pale-flecked Garden Sunskink *Lampropholis guichenoti* and Tussock Cool-skink *Pseudemoia entrecasteauxii*. The male delivered 12 of the 16 skinks whereas the female delivered eight of the 10 small items.

In 2019, I observed the male Kestrel deliver 12 skinks to the nest between 0917 and 1115 h. The female, which was observed near the nest earlier in the morning, flew away at 0815 h and was not seen during the feeding session.

In 2020, over four foraging sessions, the adults delivered 60 prey items, of which 55 (92%) were skinks (Table 1). The male delivered 72% of prey items. Some skinks were tailless, presumably because the animal had shed its tail to avoid predation (Palmer 2019). The unidentified prey items were small and probably arthropods.

Feeding rates

In 2018, the combined rate of delivery of prey by the pair of Kestrels to the nest during the 2.2-h feeding period was 11.1 items/h, of which the male provided 6.0 items/h and the female 5.1 items/h. The male transferred two skinks to the female at a perch above the nest site, and the female then delivered these to the chicks. No prey items caught by the female were transferred to the male.

In 2019, the rate of delivery of prey to the nest by the male during the 2-h feeding period was 6.0 items/h. The rate of delivery was 9.0 skinks in the first hour and tapered to 3.0 skinks in the second hour.

In 2020, the combined rate of prey delivery for the pair of Kestrels ranged from 6.0 to 13.8 items/h over four foraging sessions, with a peak early in the nestling period when there were four chicks in the nest (Table 1). The male delivered 11.2 items/h over 1.2 h during the period of peak prey delivery.

Foraging behaviour

In 2018, the male and female Kestrels foraged in different areas of their home range. The female foraged to the north of the nest, the male to the south. To the north was pasture where Wingless Grasshoppers were prevalent, and shelterbelts were established along fence lines. To the south the landscape was more diverse, with undulating terrain and more tree cover and the ephemeral Yan Yan Gurt Creek. Both Kestrels flew out of sight for each foraging bout, so it was not possible to discern whether they foraged by hovering or perch hunting. In 2020, there were few Wingless Grasshoppers in the pastures during my observations, but each adult still foraged in different parts of their home range, concentrating on areas of open country interspersed with woody vegetation.

The adults carried small prey (probably arthropods) inside the bill and disgorged the contents to chicks in the nest. Skinks were carried to the nest in the adult's talons, with both feet used. In some cases, the adult flew directly to the nest and thrust a skink into the mouth of a chick using a foot, but in most cases the adult landed on a perch just above the nest, transferred the skink to the bill (in some cases pinching the skink to make sure that it was dead) and then fed the chick bill to bill. The adults were at the nest for only *c.* 10–15 seconds before retracing their flight path as they continued hunting.

In 2019 and 2020, the Kestrels delivered prey directly to the nest, to the nest after landing on the top of the stump, or to the nest after perching (usually for <1 minute), with prey in the talons, in Manna Gums 30–80 m from the nest.

In 2020, the adults were away from the site early in the morning, then began delivering prey to the chicks at *c.* 0900 h (range 0855–0915 h over 4 days of observation between 25 November and 20 December) on days when the weather was fine (Figure 2). However, wet weather affected prey delivery to the chicks. On 16 December, there was rain during the morning at the nest site and the Kestrels did not start delivering prey until 1217 h. On 8 December, a cloudy day with misty rain following 8 mm of rain in the preceding 24 h, the adults were not seen at the nest site between 0830 and 1230 h, apart from a fleeting visit at 1045 h by the male, which circled the nest site several times and then flew away.

Table 1. Number and type of prey items and prey delivery rates to young for a pair of Nankeen Kestrels at different stages of the breeding cycle in 2020 on a farm near Deans Marsh, southern Victoria.

Date	*Prey items*			*Adult providing prey*		*Foraging period (h)*	*Prey delivery rate (items/h)*
	Total number	*Skinks*	*Other prey*	Male	Female		
19 Nov.	16	14	2	13	3	1.2	13.8
25 Nov.	18	16	2	13	5	1.5	12.0
3 Dec.	12	11	1	9	3	2.0	6.0
11 Dec.	14	14	0	8	6	1.4	10.1
Total	**60**	**55**	**5**	**43**	**17**	**6.1**	**9.8**

Figure 2. Male Nankeen Kestrel feeding skink to chick. Photo: Hugh T. L. Stewart

By 16 December, by which time the three young had fledged, the adults delivered skinks to the fledglings perched on either the top of the nest stump or in a Manna Gum 30 m south of the nest. During a feeding session, the fledglings flew confidently from the nest stump to the Manna Gum and on several occasions flew ~50 m to meet the adult bird flying in with prey. Four days later, the flying prowess of the fledglings had improved markedly, and I observed the three of them on eight occasions flying in unison ≤250 m from the nest site to intercept an adult bringing prey. In some cases, the prey was exchanged in mid air, and the successful fledgling returned to the nest stump with the prey; in other cases, the exchange of prey took place in a Manna Gum or on a power pole near the nest site.

Fledglings

In each year from 2018 to 2020, three Kestrels fledged from the site. I made some observations of the fledglings each year. On 18 December 2018, 3 days after observing the feeding frenzy, two of the young were observed to fledge over several hours. The fledglings spent their first day perched within 60 m of the nest site on a dead tree stump (which became the 2019 and 2020 nest site). The nest was empty 3 days later and all fledglings were flying confidently. Five days later, the male was observed feeding skinks to the fledglings perched on a dead tree (Figure 3). Three weeks after fledging, two of the juveniles were observed foraging on recently disturbed ground and one bird was hovering nearby (Figure 4).

In 2019, on the day when feeding was observed, the first fledgling emerged from inside the nest at 0642 h, the second at 0645 h, and the third at 0700 h. The female was perched high in a Manna Gum 100 m away and left the locality at 0815 h; the male was not seen until delivering the first prey item at 0917 h. At 0915 h, one fledgling climbed to the top of the stump, practised wing-flapping for *c*. 30 minutes, then flew 50 m to a Manna Gum. Ten minutes later it flew back to the nest and was fed soon after. The markings of the fledglings were similar to those described by Paull (1991): a pale-yellow cere, pale blue-grey orbit and yellow feet (Figure 5).

In 2020, one of four chicks disappeared between 8 and 11 December; when last seen, the brood of four was well developed and appeared healthy. I searched the surrounds of the nest site but found no remains of the chick that had perished. One possibility is that the chick was taken by a Wedge-tailed Eagle *Aquila audax*. I have frequently observed a pair in the area. Two Eagles were soaring above the nest site on 8 December and the Kestrel chicks were exposed when perched on the edge of the nest. Of the remaining brood of three chicks, I estimate from my

Figure 3. Male Nankeen Kestrel feeding a skink to a juvenile Nankeen Kestrel 5 days after fledging. Photo: Hugh T. L. Stewart

Figure 4. Nankeen Kestrel hovering 3 weeks after fledging. Photo: Hugh T. L. Stewart

intermittent observations that the nestling period was *c.* 33 days, which sits within the range of 26–35 days reported for the species (Marchant & Higgins 1993). Within a week of fledging, I observed two of the young Kestrels fluttering 4–10 m above the ground, then dropping to the ground to forage.

Discussion

Feeding rates

The delivery rate of prey for the male Kestrel feeding a brood of three during the brief observation periods—6.0 items/h in 2018 and 2019, and up to 11.2 items/h in 2020 over 1.2 h—was at the high end of rates previously reported in which vertebrates made up the bulk of the prey. For example, Starr *et al*. (2004a) found that the rate of prey delivery to the nest by a male over 4 days ranged from 2.9 to 6.1 items/h and small skinks made up the majority of food items. Bollen (1991) found that during the nestling period only the male hunted for the first 2 weeks and he made 0.7 delivery/h to the nest between 0900 and 1900 h and the main prey (by number) was Grass Skink (Pale-flecked Garden Sunskink). A recent study by Pryor (2021) reported an average delivery rate over the entire nestling period, to a single young, of 1 prey item/h.

The combined rate of delivery of prey by the male and female in 2018 (11.1 items/h) and 2020 (6.0–13.8 items/h over four foraging sessions) was high compared with rates

Figure 5. Recently fledged Nankeen Kestrels. Photo: Hugh T. L. Stewart

reported when vertebrates were the main prey. Bollen (1991) observed when chicks were 2 weeks old that both adults hunted and made 0.9 delivery/h. The feeding rate of the chicks changed through the day, peaking at 1.5 deliveries/h from 0800 to 1000 h. When the main food item was invertebrates, Paull (1991) observed a combined feeding rate of a pair of Kestrels during the nestling period of 0.6 delivery/h, whereas Cupper & Cupper (1981) reported a high rate of 22.8 items/h for Kestrels feeding nestlings during a brief morning observation period. The feeding rates that I observed may not be sustained for long periods, but the results show the capability of Kestrels to deliver prey to a brood of chicks under the conditions observed.

During the feeding of the brood in 2018, the male passed prey to the female on a perch near the nest, a common behaviour of the species (Debus 2019; Pryor 2021).

Foraging behaviour

Genelly (1978) found that Nankeen Kestrels normally start foraging about an hour after sunrise, though foraging activity is dependent on the weather, virtually stopping in the middle of the warmest days or during wind-driven rain when shelter is sought. My observations were that in 2018 the pair of Kestrels started to deliver prey to the nest 5 h after sunrise on a day of misty weather, whereas in 2019 and 2020 the Kestrels first delivered prey to the nest 3 h after sunrise on fine days. Bollen (1991) surmised from observations of feeding behaviour that the adult Kestrels fed themselves in the early morning before bringing prey to the nest. I draw the same conclusion from my observations.

I observed in 2018 and 2020 that the male and female hunted in different parts of the pair's territory, though the extent to which they foraged was unknown as the birds flew out of sight after delivering prey to the nest. This behaviour was reported by Genelly (1978), who noted that each adult often foraged up to 1.6 km away.

Common Starlings *Sturnus vulgaris* are a prey item of some Nankeen Kestrels during the nestling period (Olsen *et al*. 1979; Bollen 1991). They were abundant around the observed nesting site in 2018, 2019 and 2020, and even had a nest in a cavity in the dead tree 2 m above the nest of the Kestrels in 2018. However, during the observations reported here and in many other opportunistic observations of the pair of Kestrels, I have not seen any evidence of the Starling being taken as prey.

In the foraging session that I observed in 2018, > 90% of prey items delivered to the nest by the male were skinks whereas only 33% of prey items delivered by the female were skinks. Bollen (1991) likewise found that a male preyed on a much higher proportion of skinks than did the

female during the nestling period. In contrast, in 2020 in the present study, when skinks made up 92% of the prey items delivered, the proportions of prey delivered as skinks by the male and female were similar.

Breeding

The Nankeen Kestrels studied had a brood size of three late in the nestling period in 2018 and 2019 and of four in 2020, which was, on average, slightly higher than the mean brood size of 2.98 (*n* = 122) reported by Olsen & Olsen (1980). However, the breeding success at the study site (three fledglings each year in 2018, 2019 and 2020) was at the high end of other results for the mean number of young fledged per nest started [1.6 in north-western Victoria (Marchant & Higgins 1993) to 1–4 elsewhere in Australia (Starr *et al*. 2004b; Debus 2019)].

Nankeen Kestrels regularly use a variety of nest sites (Olsen & Marples 1993). I observed this behaviour over three consecutive nesting seasons. There was competition for the use of tree hollows by fauna in the immediate vicinity; in 2018–2020, Australian Wood Duck *Chenonetta jubata*, Galah *Eolophus roseicapilla*, Little Corella *Cacatua sanguinea*, Striated Pardalote *Pardalotus striatus*, Tree Martin *Petrochelidon nigricans* and Common Starling were nesting in hollows. In spring 2019, I observed aggression between Galahs and Little Corellas over hollow ownership at the study site. In 2019, a Common Brushtail Possum had taken up residence in the 2018 nest site used by the Kestrels. Other species common in the vicinity were Laughing Kookaburras *Dacelo novaeguineae* and Australian Magpies *Gymnorhina tibicen*. Apart from being aggressive towards a Wedge-tailed Eagle that flew close to the fledgling Kestrels (2 January 2019) and taking evasive action from attacks by a Galah (10 September 2020), the Kestrels were not seen to interact with any other species even though Magpies have been observed to make frequent, hostile advances (Genelly 1978) and Kookaburras take similar food. Paull (1991) noted that Kestrels interacted with few other species, though they did chase Tree Martins in his study.

Assuming an egg-laying interval of 2 days, incubation period of 28 days and fledging at 31–35 days (Olsen & Olsen 1980), the Nankeen Kestrels observed here would have started to lay around the middle of October in 2018–2020. The timing of the start of nesting was within the peak time of September–October for an Australia-wide sample (Olsen & Olsen 1980). My observations over 3 years indicate one brood per year, consistent with the known behaviour of the species (Olsen & Olsen 1980). The sex of the fledglings could not be identified from the observations, given the similarity between the plumage of both male and female first-year birds (Olsen & Olsen 1987).

The Kestrels were unmarked so there is no certainty that the adults observed each season were the same birds, but only one pair was observed each season despite there being suitable tree hollows elsewhere on the farm. After breeding, pairs of adults continue to occupy and defend fixed territories (Genelly 1978). Nankeen Kestrels are resident year-round in many parts of Australia, particularly in the south (Olsen & Olsen 1987). My observations indicate that Kestrels were resident on the property, as I saw them every month in the period 2017–2020 though not every month in each year. Family oral and written records indicate that Nankeen Kestrels have been resident in the vicinity of the observed nesting sites for decades. Observations elsewhere in the study region indicate that Kestrels have been in residence in a particular area for >60 years (Pescott 1996).

Farm management

My family has farmed the property since 1905. A wildlife conservation ethos has been practised for decades. A farm plan was implemented in 1992, driven by a goal to sustainably produce timber and livestock products by integrating commercial trees and habitat trees into the farming system of sheep grazing on perennial pastures. This has been achieved by adopting principles from agroforestry, and has led to substantial improvement in the aesthetics and biodiversity of the property, in addition to the new enterprises of forest products and tourism. Core elements of the farm plan were fencing of the property into five land-classes for better rotational grazing of livestock, and strategic planting of a wide range of trees in various configurations along drainage lines and land-class boundaries (Stewart *et al.* 2011). The plan has increased the tree cover (planted trees and remnant vegetation) from 3.5% of the property in 1992 to 18.0% by 2020. Species of birds on the farm have been monitored in accordance with the 20-minute search method (Loyn 1986); by 2021, 120 species had been recorded.

The Nankeen Kestrel, together with the Peregrine Falcon *Falco peregrinus*, are the only diurnal raptors that habitually use tree hollows for nests where available (Debus 2019; Mo 2019). Growing and conserving hollow-bearing tree species is therefore an important means of supporting populations of these species in rural landscapes. This is particularly so given that Nankeen Kestrels appear to be scarce in agricultural areas in Australia compared with resident kestrel species in other parts of the world such as the Common Kestrel *F. tinnunculus* in Europe (R. Loyn pers. comm.).

I have pondered the question of the age of the remnant dead trees in which the Kestrels nested in 2018. Taking into account that ages of *c*. 500 years are thought to be the upper bound of longevity for eucalypts (Prior & Bowman 2014), the time for hollows suitable for faunal use to form in eucalypts in natural forests is in the range of 100–200 years (Koch *et al.* 2008; Loyn *et al.* 2008), the growth rate of eucalypts in temperate forests with similar climate to that of the study site is in the order of 0.2–0.4 cm/year in tree diameter (Bowman *et al*. 2014), the size of the tree that housed the nest (90 cm, measured at 1.3 m above ground), and the long family oral history about the property (115 years), I conservatively estimate that the tree would have been at least 200 years of age before it died, and that perhaps another 100 years or more would have elapsed as the tree disintegrated to its current state. The point is, stand-alone remnant eucalypts with hollows and cavities, no matter what their condition, potentially provide valuable habitat for Kestrels and a wide range of other species of fauna for long periods and should be preserved in the landscape.

Retention and protection of remnant, hollow-bearing trees has been an integral part of our farm management. Suitable tree hollows for nesting can be scarce in farming areas (Mo 2019). In recognition of this, we have started to plant Manna Gums as single trees or clusters of trees as the next generation of habitat for fauna dependent on hollows. This takes a very long-term outlook, though Loyn *et al.* (2008) observed that plantations aged 60–80 years can provide abundant hollows and coarse woody debris, as found in stands of Sugar Gum *Eucalyptus cladocalyx* in western Victoria.

Our management also includes retention of down wood (fallen branches) across the farm to provide habitat for reptiles. The high proportion of skinks in the prey captured by the Kestrels that I observed suggests an abundance of these species on the farm. Small diurnal skinks commonly bask in open situations, predisposing them to predation by Kestrels (Schulz & Lumsden 2009). We are also using this knowledge in designing revegetation areas on the farm.

Starr *et al*. (2004b) concluded that sustainable farming practices at a 1600-ha site in New South Wales were not detrimental to number of raptors, including Nankeen Kestrels, over four consecutive years of observations. My observations support this finding on our family farm, and we will continue to modify our farming practices for the benefit of biodiversity and sustainability as we learn more about the complex interactions at play.

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