THE FOODS AND FEEDING OF STARLINGS IN CANTERBURY

J. D. COLEMAN*

Department of Zoology, University of Canterbury, Christchurch

SUMMARY: The feeding ecology of the starling, *Sturnus vulgaris*, was studied in Canterbury from 1968-71.

Starlings fed in flocks which varied seasonally in composition and behaviour. During breeding, parent birds fed in small isolated multispecific flocks which after breeding, coalesced into much larger more regimented monospecific flocks.

Starlings dietary patterns varied seasonally both in diversity and composition, and were influenced by seasonal and local patterns of abundance of food species. Even so, birds occasionally selected certain food species at the expense of other, more common species. The birds selectively foraged on seasonally occurring field forms, especially on cereal stubbles, fields being tilled and well-stocked heavily-grazed pasture.

Numerical dietary evaluations indicated that animals foods constituted 90% of the intake of free-flying starlings, while the remaining 10% consisted largely of cereal and weed seeds. Subsequent caloric estimates of the ingesta altered the numerically established level of importance of some foods, and revealed the insect orders Coleoptera and Lepidoptera to be most important. Notable in these orders were the families Scarabaeidae, Elateridae, Curculionidae, Hepialidae, Pyralidae and Noctuidae. Earthworms, lycosid spiders, Diptera and Hemiptera were less important elements and taken infrequently.

The diet of nestling starlings was similar to the spring diet of free-flying birds, although small nestlings were fed with small soft-bodied foods.

Nestlings averaged about 50 meals/day and when mid-way through their nestling period, consumed approximately 13 Calories/day of metabolizable food.

INTRODUCTION

The starling *Sturnus v. vulgaris* L. is ubiquitous on farmlands of many countries and its foods and feeding habits have been examined in detail in North America (Kalmback and Gabrielson, 1921, Lindsey, 1939, Howard, 1959), Great Britain (Collinge, 1924-7, Dunnet, 1955, 1956), Europe (Kluijver, 1933, Szijj, 1956, Havlin and Folk, 1965, Gromadski, 1969) and Australia (Thomas, 1957). In New Zealand the starling is common on most farmlands, but its feeding ecology is poorly documented. In rural areas of Canterbury the food available to starlings is diverse. The province has extensive grasslands, often infested by high density populations of grass grub—*Costelytra zealandica* White., and is the main cereal growing region of New Zealand. The grass grub, a common food item of the starling (Anon, 1970, East and Pottinger, 1975, Lobb and Wood, 1971), is a serious economic pest. Many farmers believe that starlings may control this invertebrate and have erected nest boxes in attempts to entice and hold starlings on their properties. However, because of their omnivorous feeding habits, it is important that before starlings are used in such biological control programmes, all aspects of their ecology should be fully documented.

This paper describes the foraging movements, selection of feeding sites, and diet of starlings near roosts and breeding sites at West Melton, Canterbury (43° 30′S, 172° 29′E), from 1968-71. The diet of the nestlings is also examined.

The study area selected has a low annual rainfall (58-76 cm), warm summers with occasional hot north west Foehn winds of above 30°C, and cool winters with frequent frosts and occasional snow.

METHODS

Foraging and Feeding Habits

To study flocking behaviour and to determine foraging areas, communal roosts were located by following the evening flight lines of starlings. Foraging ranges were delimited by identifying marked birds at feeding sites. The form of feeding flocks and feeding actions were determined by direct observation, usually from a car.

*Present address: Protection Forestry Division, Forest Research Institute, P.O. Box 31-011, Christchurch.

In the study area of 777 ha (comprising 106 fields), the selection of feeding sites (= field preferences) and the size of feeding flocks were determined once each week, from January 1969 to March 1970 inclusive, by driving over a 21.17 km standardized census route. Each census began at 1000 hr and took approximately 6 hr. Halts were made at 200 m intervals and adjoining fields less than 300 m in depth scanned with 16 x 50 binoculars. Birds feeding in short-grazed pasture were easily counted, while those in rank pasture or in tall crops were "put up" for counting by sounding the car horn.

Starling field preferences were analysed using a technique outlined by Dunnet and Patterson (1970). An index of the utilisation of field types (I.U.) was determined from the ratio between the percentage of all starlings seen on a particular field form and the percentage occurrence of that field form in the area censused. Index values of less than unity showed an avoidance by birds, greater than unity a positive selection, and unity a lack of either.

Food selection by starlings was determined by comparing quantitatively the invertebrate species present in the gizzards of feeding groups of 4-8 birds, with those present in 20 randomly selected soil samples taken in the same field immediately after starling collection. Comparisons were made using Kendall's coefficient of rank correlation (see Seigel, 1956). This selection was then compared with that shown by 41 adult and first year male and female caged starlings fed mixed meals of common foods.

The Diet

The diet of starlings was determined from the gizzard contents of birds shot after more than an hour of feeding on any one field. Approximately 35 birds were collected each month, between 1000 and 1500 hr, throughout the year. In November and December foods were also collected from nestlings with the aid of feeding collars (see Kluijver, 1933). Collars were secured for periods of 1 hr, and food was collected simultaneously from all members of individual broods and from nestlings of all age groups. In all, 199 and 98 nestling samples, each consisting of several "meals", were collected in 1969 and 1970 respectively. A further 80 nestling gizzards were collected in 1971.

Shot birds were immediately given an oesophagael injection of 1 cc of 10% formalin to arrest post-mortem digestion (see Van Koersveld, 1951, Dillery 1965). Subsequently, the contents of each gizzard were searched microscopically for earthworm setae, washed on a 180 micron sieve and sorted under a variable-power stereoscopic microscope. Invertebrate foods were quantitatively recorded using total numbers and percentage occurrence techniques, determined from quantifiable remains such as head capsules, abdomens, paired elytra or wings. The methods were complementary and when used together eliminated much of the bias associated with such numerical methodology (see Hartley, 1948). Cereal remains were estimated volumetrically by spot-count methods as numerical techniques were inadequate for assessing partly digested plant material.

Caloric Determinations

The nutrient value of major foods was determined by calorimetry. Twenty (> 0.01 g dry weight) or 50 (< 0.01 g dry weight) individuals of each species, depending on average size, were dried to constant weight in a vacuum oven at 65°C. Samples were finely ground and heats of combustion obtained for sub-samples of approximately 0.2 g burnt in oxygen in a "Parr" semi-microcalorimeter.

The average amount of chitin present in each species burnt was also determined, as chitin was a common item of starling faeces and indigestible to vertebrates (Stiven, 1961). Methods followed those outlined by Fraenkel and Rudal (1947) and involved the chemical extraction of chitin from a representative sample of the major food species. Caloric values for chitin, determined as 5.69 Cal/g, were then subtracted from calculated heats of combustion and a value for the energy content of "digestible tissues" obtained. Finally, the total caloric value of each major species ingested was calculated by multiplying the value determined for digestible tissues by the number of each species recorded from gizzard or nestling food samples. Such values were, however, slightly high; Stiven (op. cit.) reported that approximately 80% of ingested digestible tissues were absorbed, with the remainder (20%) being lost in gaseous, urinary or faecal wastes. The fraction was approximately constant for most arthropods and correction factors were not used in the present study.

RESULTS

Feeding Activities

1. Daily patterns and feeding ranges

Starlings roosted communally when not breeding. Roosts were deserted each day around sunrise, as birds moved out in flocks to feeding sites. On the way, vacated breeding sites were generally visited where, even in winter, birds spent up to 2 hours in nest site ownership and maintenance activities. Starlings moved back towards roosts approximately 1 hr before sunset. Nest sites were again visited and desultory feeding often occurred nearby. At sunset, birds rapidly entered roosts, although in autumn spectacular pre-roosting aerial displays often occurred.

Winter foraging ranges about West Melton roosts were no greater than 4 km. Foraging ranges during the breeding season were less, with the activity of birds centred about their nest sites, e.g., the mean value of 30 flights each, for four pairs ranged from 108 ± 18.8 (S.E.) m to 216 ± 31.5 m.

2. Flock size and behaviour

Flock sizes varied significantly between breeding and non-breeding seasons ($N = 308$, $t = 5.285$, $p < 0.001$). During breeding, starlings commonly foraged in groups of less than 10 and rarely in numbers greater than 30. At other times, small flocks (<20) predominated but larger ones of 50 to 100 birds occurred frequently, and 100 to 500 occasionally.

Small flocks typically were species-specific but on occasion included house sparrows *(Passer domesticus)* and other small passerines. Such flocks foraged adjacent to occupied or vacated nest sites, where its members fed independently of one another, 1-2 m apart. Small flocks commonly foraged amongst sheep, using their backs as observation posts and taking advantage of insects disturbed by sheep movements.

During late summer, autumn, and winter large monospecific flocks occurred frequently, and members behaved differently from those in smaller flocks. In large flocks, birds became closely integrated with their neighbours and often fed within pecking distance, apparently because mutual attraction overcame spatial adjustments resulting from aggression (Emlen, 1952). Members were noisy, and typically moved rapidly and unidirectionally across fields in "roller feeding" fashion, similar to that described for weavers— *Quelea quelea* (Ward, 1965). Birds with food stopped momentarily and drifted to the rear; they then broke off and flew over the group to drop down in front of advancing birds, thus continually changing the flock leadership.

The Availability of Foods

The availability of pasture dwelling invertebrates commonly taken by starlings at West Melton was inferred from a study of pastoral invertebrates made in a like situation at Harewood, 15 km from West Melton, by Moeed (1970).

The Harewood insect fauna was divisible into a predominantly adult population throughout the warmer months of November to April and a larval one at other times. In summer, Coleoptera were common, and included *Costelytra zealandica* and *Aphodius howitti*, dominants in October/November and January/February respectively, *Hypharpax* spp., *Enneboeus* sp., *Coccinella* spp., and various Elateridae and Curculionidae. Lepidoptera were also common, especially *Crambus* spp., *Aletia* sp., *Persectania* sp., *Agrotis* sp., *Ariathisa comma*, *Wiseana* spp. (in October and November) and *Coleophora* sp. (November to January), as well as Hemiptera such as *Nysius huttoni*, and Diptera, especially *Sarcophaga milleri*, *Sarapogon* sp. and *Anabarrhynchus* sp.

Common winter species included the larvae of most summer forms. Exceptionally, *Wiseana* sp. larvae were abundant in surface layers from December to April, but thereafter were found only at greater depths. Larval Diptera were common about the same time. Other arthropoda such as the Arachnida, particularly the families Lycosidae and Opilionidae, occurred throughout the year, but were most frequent in warmer seasons. Earthworms were common in autumn and in spring.

Field and Food Selectivity

Feeding starlings showed distinct preferences (i.e., I.U. >1) for particular field types (Fig. 1). They generally selected grass pasture in all seasons and largely avoided lucerne; the selection of the latter in mid-winter resulted from its frequent use as a feed-lot for stock. Short-grazed pasture was selected throughout the warmer months, and longer herbage only occasionally. Preferences were influenced by stock, and in their absence both field types were avoided.

Starlings generally avoided cereal, especially fields of sprouted and mature crops although lush cereal used as stock fodder in late winter attracted birds (Fig. 1). Stubbles were selected by birds from mid-summer to early winter, especially when stock were present.

Fields of turnips were selected as feeding sites during autumn, winter and early spring, but were avoided in warmer months. Birds avoided fields of sprouted turnips, but selected those of rank turnips whether stock were present or not.

Starlings rarely fed amongst potatoes, peas or on fallow fields, although along with gulls (*Larus* spp.) and rooks *(Corvus frugilegus)*, they followed the plough during spring tilling.

Starlings selected certain food species and changed their feeding sites and hunting behaviour to accommodate such preferences. Sometimes birds took those foods locally most abundant, but this was not universal. Nevertheless, the major foods taken at West Melton agreed closely with the levels of natural abundance of the same revealed through intensive sampling at Harewood (see Moeed, 1970), and the ease of capture of foods was obviously a decisive factor in starling feeding ecology. Caged

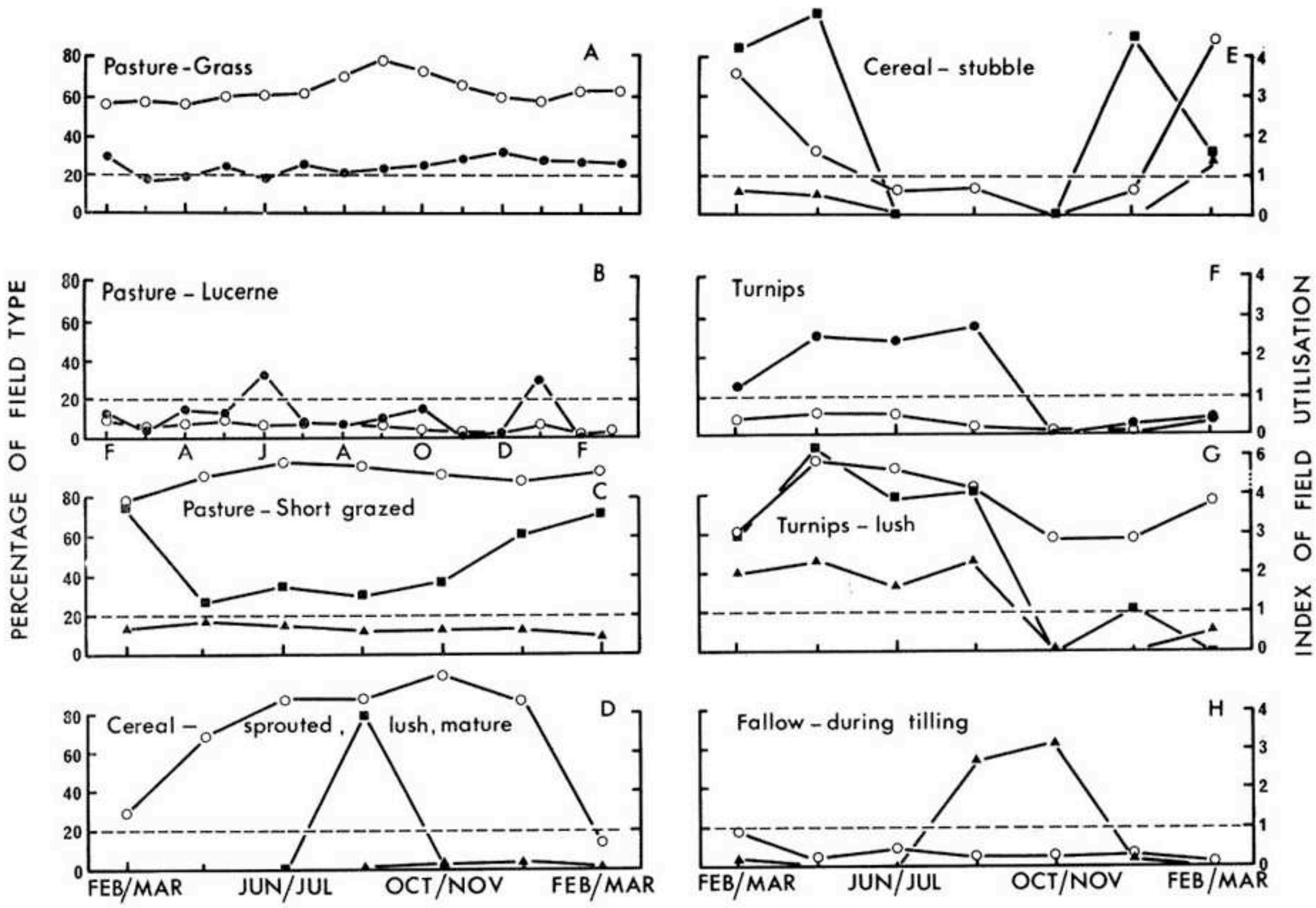

FIGURE 1. *The selection of fields of different types by starlings. Percentages of pasture (A, B) or turnips (F) in the total area surveyed, and of that occupied by different pasture/crop categories (C, D, E, G, H), are indicated by open circles. Overall index of utilisation values and those recorded in the presence and absence of stock are indicated by closed circles, squares and triangles respectively.*

birds also ate selectively, choosing, in decreasing order of preference, soft-bodied insect larvae and spiders, adult beetles and flies, earthworms, Coleoptera spp., cereal and coccinellid beetles (Table 1). A distaste for coccinellid beetles seemed reasonable, as many members of this family were found to be poisonous to invertebrates (see Imms, 1957).

The Foods of Free-flying Starlings

1. Composition of the diet.

The foods collected from free-flying starlings, when assessed volumetrically, consisted of approximately 90% invertebrate and 10% plant remains, and included over 75 invertebrate species, 11 seed species, some plant foliage, grit and one piece of meat (Appendix 1). Of these, over 18 animal species, cereal, and suckling clover *(Trifolium dubium)* occurred in at least 20% of birds collected in one or more seasons, and were labelled major foods; they included various life stages of two species of Hemiptera, two species of Diptera, four species of Lepidoptera, eight species of Coleoptera and unidentified lycosid spiders and lumbricid earthworms. Plant foliage and grit occurred infrequently and probably were ingested accidentally.

Total counts of each food present in gizzards, when ranked showed close agreement with rankings produced by percentage occurrence techniques (Appendix 1). A few large foods were taken infrequently by many birds, e.g., a pentatomid bug *Dictyotus caenosus* and such beetles as *Lacon variabilis, Conoderus exsul* and *Xantholinus* sp. Generally however, high percentage occurrence was indicative of items taken in large numbers, this being especially true of smaller forms, e.g., the "wheat bug"—*Nysius huttoni* (5261 recovered), larval pyralid moths — *Witlesia sabulosella* (3376), muscid fly larvae (787), lycosids (1008), a tenebrionid beetle—*Enneboeus* sp. (3163), a grass weevil— *Irenimus aequalis* (5504) and the Argentine stem weevil—*Hyperodes bonariensis* (2105).

The caloric energies (heats of combustion in Cal/g) of a range of representative foods commonly taken by starlings were similar (Table 2). However, the average caloric value of an individual of each species and of its digestible components varied widely, the latter ranging from 0.513 Cal for *Agrotis ypsilon* larvae (the "Greasy cutworm") to 0.004 Cal for *Nysius huttoni.* Thus, resulting primarily from difference in biomass, one *Agrotis* larvae was equivalent in digestible energy to 2.4 earthworms, 5.6 *Costelytra zealandica*, 11.6 lycosids or 128.3 *Nysis huttoni.*

The relative importance of major food species in the energy budget of free flying birds varied widely

TABLE 1. *Food selectivity of 41 caged starlings*

(L = larvae, A = adult)

Food species		No. of items offered	No. eaten	Selectivity (Items eaten/ items offered)
Tenebrio sp.	L.	82	82	1.000
Costelytra zealandica	L.	82	82	1.000
Muscidae gen. undet.	L.	82	82	1.000
Lycosidae gen. undet.	—	82	82	1.000
Costelytra zealandica	A.	82	76	0.927
Muscidae gen. undet.	A.	82	76	0.927
Tenebrio sp.	A.	82	75	0.915
Apion ulicis	A.	164	132	0.805
Lumbricidae gen. undet.	—	82	47	0.573
Coleophora sp.	L.	164	79	0.482
Coccinella undecimpunctata	A.	10	4	0.400
Cereal grain	—	82	31	0.378

TABLE 2. *Caloric estimates of a range of major foods of free-flying and nestling starlings.*

Food Species	Heat of Combustion of whole animal (Cal/g)	Mean Dry Weight of species (g)	Mean Weight of chitin per animal (g)	Mean caloric value* of digestible components per animal (Cal)
Agrotis ypsilon L.	5.00	0.1080	0.0048	0.513
Nysius huttoni A.	5.30	0.0008	0.0001	0.004
Conoderus exsul L.	5.10	0.0109	0.0019	0.045
Costelytra zealandica A.	4.87	0.0216	0.0024	0.092
Irenimus aequalis A.	5.49	0.0032	0.0007	0.014
Neoitamus sp. A.	4.91	0.0235	0.0019	0.088
Lycosidae gen. undet.	5.37	0.0091	0.0006	0.046
Lumbricidae gen. undet.	5.36	0.0402	—	0.216

* The heat of combustion of an average individual minus the heat of combustion of the chitin present.

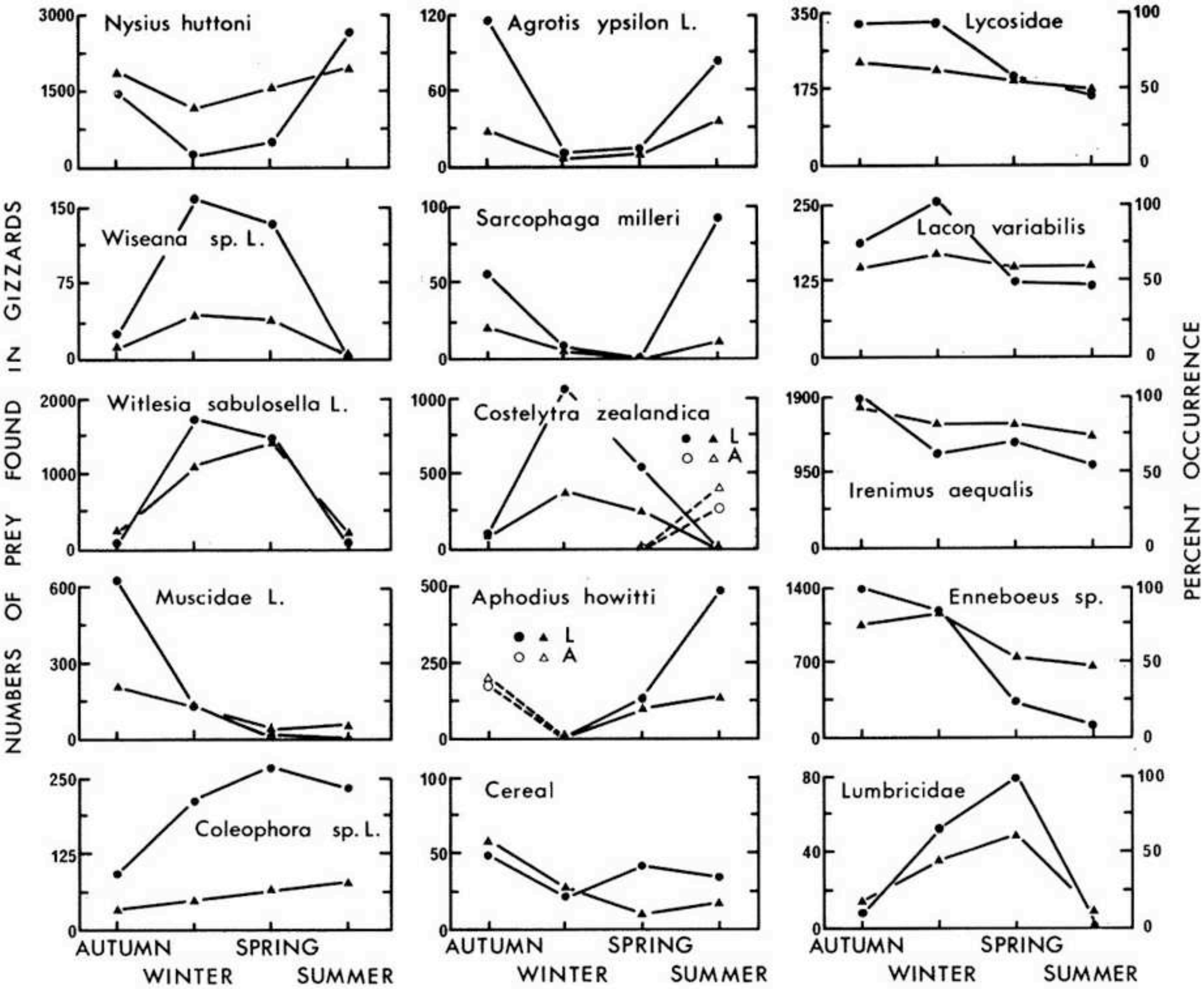

FIGURE 2. *Seasonal variation of selected major foods eaten by free-flying starlings. Note that variations in total numbers of ingested prey (closed circles) generally show similar trends to percentage occurrence analyses (closed triangles), i.e., the percentage of birds taking each prey species.*

(Table 3). Small forms like hemiptera and some beetles were taken frequently but contributed little towards the birds' total sustenance. Conversely, large forms, particularly larval Lepidoptera and Coleoptera, although taken in smaller numbers, contributed greatly.

An accurate assessment of the caloric value of the grain ingested was impractical. The wet weight of the total gizzard contents throughout the year averaged 1.60 ± 0.068 g (S.E.), of which 10.4% by volume was grain. Assuming that volumetric and gravimetric ratios of the animal and plant foods present were roughly equivalent, the weight of grain per bird and for all birds sampled was 0.166 and 67.4 g respectively. Starlings ate a mixture of wheat and barley, but as both have caloric values of approximately 3.5 Cal/g (Spector, 1956), no distinction was made between them for the calculation. Thus, the value of grain present in all birds collected equalled 225 Calories and cereal appeared to be a major element in the birds' energy budget.

2. Variations in diet

The major foods collected from starlings varied seasonally (Fig. 2). Species taken most commonly from birds shot during the drier warmer months of November through to April included two species of Hemiptera—*Nysius huttoni* and *Dictyotus caenosus*, a fly—*Sarcophaga milleri*, three beetles—*Aphodius howitti*, *Desiantha maculata* and *Hypharpax abstrusus* and one Lepidopteran larva—*Agrotis ypsilon*. Those taken most frequently from birds shot during the moister, cooler months of May through to October included earthworms, two Lepidoptera larvae *Wiseana* sp. and *Witlesia sabulosella* and three beetles—*Costelytra zealandica* (larva), *Enneboeus* sp. and *Lacon variabilis*. Larval muscid flies were taken most frequently from birds shot in autumn and winter, larval *Coleophora* sp. (Lepidoptera) from winter, spring and summer shot birds, and adult *Costelytra zealandica* and *Coleophora* sp. from summer and autumn ones respectively. Cereal remains were recovered throughout the year, but were taken erratically in spring. Other major foods such as *Hyperodes bonariensis*, *Irenimus aequalis* and lycosids were ubiquitous in all seasons.

The diversity of the starling diet varied seasonally from a 1:1:1:1 ratio ($x^2 = 10.15$, $0.05 > p > 0.01$). Many adult insects, particularly Hemiptera, Hymenoptera and Coleoptera were taken infrequently and only in the warmer months; their immature stages occurred in other seasons and apparently were more secretive.

Many common food species were wide-ranging in habit, but others were specific to a crop or field type. Examples of the latter included *Witlesia howitti* from pasture, *Plutella maculipennis* and muscid fly larvae from turnips, cereal grain from cereal stubble and larval *Wiseana* sp. *Costelytra zealandica* and lumbricids from irrigated fields or those being tilled.

The diversity and composition of the starling's diet were independent of age; all of the 20 adults and recently fledged (within 2 months) birds collected in December and February on pasture, contained a similar range of food species ($x^2 = 0.024$, $0.9 > p > 0.5$). Young starlings clearly recognised food species early in life and did not appear to be more exploratory in their feeding than older birds c.f., young wood pigeons—*Columba palumbus* (Murton, Isaacson and Westwood, 1971).

The number of items present in the gizzards of birds in the above sample was on average greater in adults (123.6) than juveniles (84.6), the difference approaching significance [$Fs = 2.09$, $0.1 > p > 0.05$; $Fs(0.05) = 2.12$]. Compared with recently fledged birds, adults fed more intensively and/or successfully, or possessed a slower rate of digestion.

The Food Brought to the Nest

1. Composition of the nestling diet

The foods collected from nestlings were, with one exception, invertebrates, with arthropods predominant (over 50 spp.), although lumbricids (spp.), arachnids (2 spp.), myriapods (1 sp.) and a gastropod mollusc were also taken (Appendix 2). Cherries were occasionally eaten. Apart from an isopod crustacean, all the Arthropoda eaten were insects with Hemiptera, Lepidoptera, Diptera and Coleoptera predominant; the last three commonly taken as adults and larvae. Major food species (those collected in two or more years in more than 10% of all food samples) were few in number, and in order of percentage occurrence included *Agrotis ypsilon* larvae, lycosid spiders (spp.), *Costelytra zealandica*, *Nysius huttoni*, earthworms (spp.), *Irenimus aequalis*, *Conoderus exsul* larva, and *Neoitamus* sp.

Counts of individuals of food species collected from nestlings generally gave results similar to those obtained by the use of percentage occurrence techniques (Appendix 2).

The caloric value of the digestible components of the major foods of nestlings and their relative importance in the nestlings' energy budget varied widely (Table 4). Thus, of the energy content of major foods present in the food samples collected, 61.6% was derived from *Agrotis* larvae, with *Costelytra zealandica* (15.8%), lumbricids (9.5%) and lycosids (5.2%) of lesser importance. Other species such as *Neoitamus* sp. (3.7%), *Conoderus exsul* (2.3%), and *Nysius huttoni* (1.3%) were taken frequently by many birds but individually were of little consequence.

2. Variations in Diet

The major food species recorded from nestlings in 1969 were generally also important in 1970 and 1971 (Appendix 2). In addition, a further five beetle species were commonly recorded in 1971, viz., adult *Hypharpax antarcticus*, *H. abstrusus*, *Lacon variabilis*, *Coccinella undecimpunctata* and *Metaglymma monolifer*. Their apparent increased dietary importance resulted from the different method of investigation used (gizzard analysis) in that year, which biased diet patterns towards the harder species present (see Coleman, 1974).

The percentage occurrence and total counts of individuals of major food species altered as the breeding season progressed (Fig. 3). Species collected most frequently from later-hatched nestlings included

TABLE 4. *The energetics of the major foods of nestlings.*

Food Species		Mean caloric value of digestible components (Cal) (from Table 2)	Number of animals taken from nestlings	Total energy of digestible tissues taken (Cal)
Agrotis ypsilon	L.	0.513	268	137.40
Nysius huttoni	A.	0.004	800	2.88
Conoderus exsul	L.	0.045	113	5.06
Costelytra zealandica	A.	0.092	385	35.23
Irenimus aequalis	A.	0.014	124	1.69
Neoitamus sp.	A.	0.088	93	8.16
Lycosidae gen. undet.	A.	0.046	255	11.60
Lumbricidae gen. undet.	A.	0.216	98	21.19

Nysius huttoni, Phalangium opilio and lumbricids. Conversely, *Neoitamus* sp. and *Agrotis ypsilon* larvae were taken most frequently from earlier broods, with *Neoitamus* sp. absent from December samples. Other major foods failed to show such obvious trends.

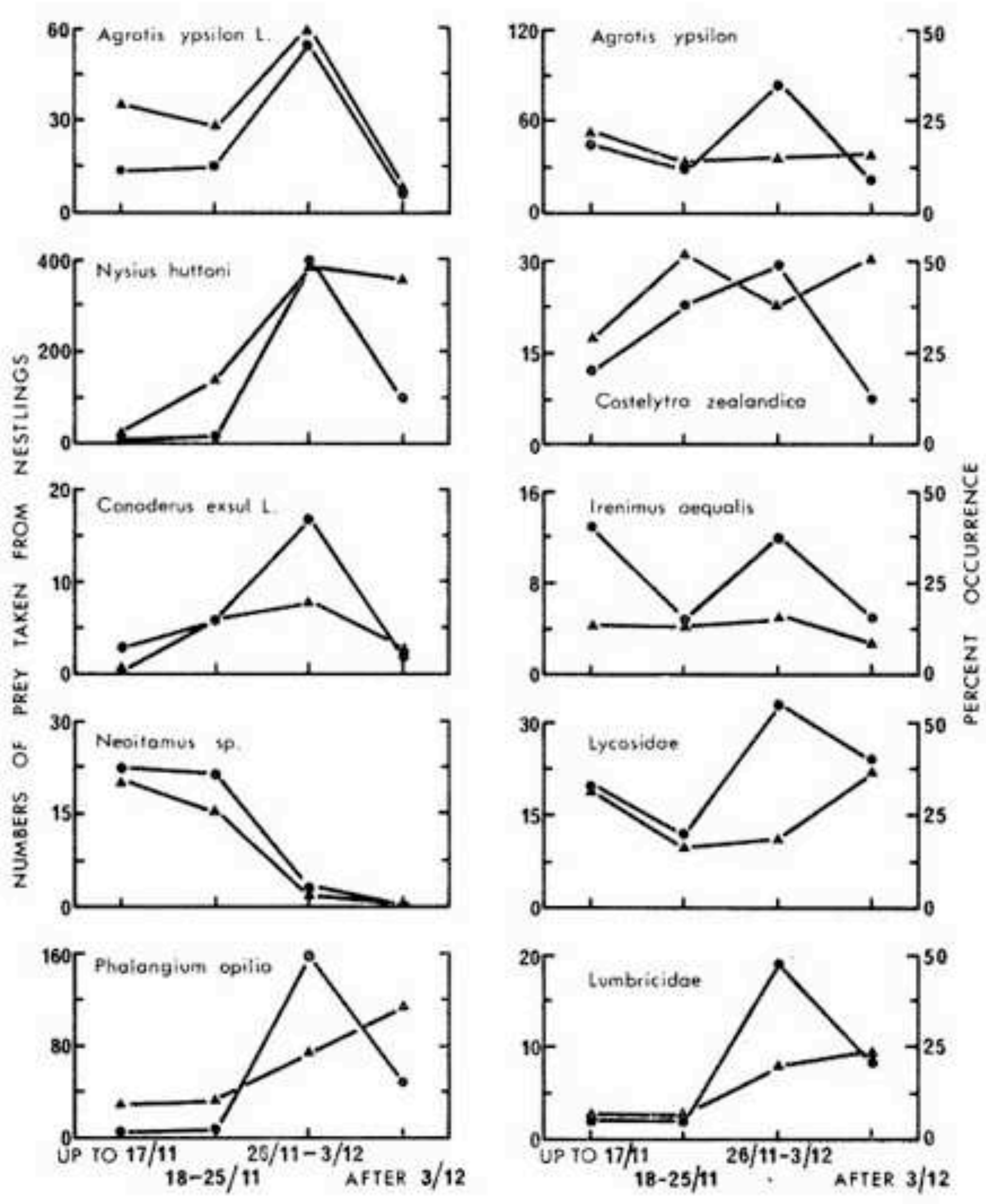

FIGURE 3. *Seasonal variation in total numbers (closed circles) and percent occurrence (closed triangles) of foods dominant in the diet of nestling starlings.*

The numerical frequency of some foods varied with nestling age. Birds aged 0-5 days received fewer individuals of "hard" food species such as adult Coleoptera, than their older conspecifics. Conversely, softer foods, including lycosid spiders, larval and adult Lepidoptera, and Hemiptera, dominated samples taken from the younger nestlings.

3. The size and frequency of meals

Newly-hatched nestlings received small meals, often of single individuals of soft-bodied invertebrates. Older nestlings had larger and more varied meals, and, like adults, ingested prey ranging in size from large noctuid moth larvae 30 mm long (Mean $=0.11$ g dry weight; $N=20$) to nymphal Hemiptera 2 mm long (Mean$=0.001$ g dry weight; $N=50$). Meals consisted of one to 10 items, depending on the size of the components—a single lumbricid or noctuid larva often constituted a meal, but small bugs, weevils or colonial sarcophagid fly larvae were taken several at a time.

Parental feeding visits recorded at four broods over a period of 17 hr 20 min averaged one visit every 6.5 min, with means for individual broods ranging from .37 to 9.1 min (Table 5). Neither brood age nor size appeared to influence the frequency of visits, but the rate was consistently lowest about midday.

The number of nestlings fed at each visit varied with the age of the brood. When 4 days old, two out of four nestlings in a brood of four were fed on 12 of 16 visits, and one on each of the other four occasions. Four days later this pattern had reversed; one nestling received food on 24 of 26 visits, and two nestlings on the remaining visits. When parents arrived, the nestling which begged most vigorously received most food.

4. Feeding Rates as a Measure of Food Intake

Starlings with broods foraged daily from sunrise

TABLE 5. *The frequency of parental feeding visits to starling broods.*

Time of observation	Nestling Age (days)	Brood Size	Total time (min) observed	No. of visits by parents	Visit frequency
1320–1500	9	3	100	12	1/8.3
1310–1355	18	2	45	5	1/9.0
1215–1355	20	2	100	11	1/9.1
1540–1705	7	3	85	19	1/4.5
1445–1625	12	3	100	27	1/3.7
1000–1400	4	4	240	33	1/7.3
0920–1530	8	4	370	52	1/7.1

to sunset. In mid-November, when nestlings were most abundant, there were approximately 14.5 hr of foraging time available each day. Adults averaged 134.6 brood visits daily or, if averaged over the nestling period of 22 days, 48.1 meals/day/nestling for a brood of three (allowing for the feeding of two nestlings per parental visit during the first four days). This compares with 83 meals per day, averaged over the nestling period, of a brood of four starlings in Holland (Kluijver, 1933). As quantitative observations in Canterbury were confined to mid morning and later, thus excluding early morning when feeding was probably most rapid (Kluijver op. cit.; Szijj, 1956), the mean feeding frequency obtained was probably lower than the true value. Even so, it seems unlikely that feeding rates in Canterbury are as high as those reported by Kluijver for Dutch starlings.

If nestlings in broods of 3 and 4 received meals of similar size, at about 8 days of age each would ingest daily approximately 3.4 g dry weight of food [$=48.1 \times 0.07$ g (the mean meal weight recorded for a brood of 4 aged 8 days during the mid-nestling period, N = 24)]. Roughly 10% of the food ingested was non-digestible chitin, and a further 20% of that remaining was lost as metabolic wastes (see methods). Hence, approximately 2.45 g of the daily intake was metabolizable. The daily energy intake of each nestling was 2.46 x 5.2 Cal or approximately 12.82 Cal/day (5.2 Cal equalled the approximate caloric value of the dominant foods eaten).

CONCLUSIONS

Basic dietary patterns established overseas for starlings have usually been similar to one another, although the relative importance of animal and plant species in the diet varies according to local species abundance, land use and methods of analysis.

Starlings in New Zealand eat similar foods to overseas birds. Early workers emphasised the apparent ability of the species to control invertebrate pests, especially Lepidoptera larvae and Coleoptera (Bathgate, 1897), as well as Orthoptera and the ectoparasites of stock (Thomson, 1922). More recently, Dawson and Bull (1970) listed an array of fruits commonly eaten by starlings while Moeed (1970) and Lobb and Wood (1971) identified the pastoral invertebrates taken by starlings in Canterbury. At Winchmore (Lobb and Wood op.cit.) and Harewood (Moeed op. cit.), the birds feed primarily on Coleoptera, especially Curculionidae, Scarabaeidae (predominantly *Costelytra zealandica*) and members of the Elateridae. Other major foods include Hemiptera, especially *Nysius huttoni* and Lepidoptera, particularly *Agrotis ypsilon*, *Wiseana* spp. and *Coleophora* spp. Most staple foods are taken throughout much of the year, with only *Costelytra zealandica* distinctly seasonal.

The diet of free-flying West Melton birds is very similar to that of the neighbouring populations studied. Animal foods constitute 90% of the diet, the remaining 10% consisting largely of cereal, but including a considerable variety of clover (*Trifolium* spp.) and weed seeds. Small seeds may be eaten accidentally; they escape digestion and presumably are disseminated still viable throughout the study area (also recorded by Havlin and Folk, 1965). Fruits are rarely taken.

Caloric evaluations of the diets of Canterbury birds alter the numerically established level of importance of some major foods. Lepidoptera, especially larval forms, predominate. Coleoptera are next in importance, consisting primarily of the Curculionidae, followed by highly seasonal scarabaeids and the more universal carabids, and elaterids. Hemiptera are taken in large numbers throughout the year, but are apparently of little caloric consequence to starlings. Arachnids, lumbricids and cereal are important minor dietary elements.

Caloric evaluations based on numerical analyses

TABLE 6. *A re-analysis of the energetics of the major foods of free-flying starlings (from Table 3).*

Food form		No. of items taken from gizzards	Total energy of digestible tissue in gizzard (Cal)	Correction factor for each food group (from Coleman 1974)	Relative total energies of tissues eaten (Cal)
Hemiptera	A.	5,328	27.55	3.5	96.43
Lepidoptera	L.	4,720	542.79	1.5	814.19
Diptera	A.	168	4.75	3.5	16.63
Curculionidae/ Tenebrionidae	A.	11,046	95.42	3.4	324.43
Carabidae/Scarabaeidae/ Elateridae	A.	1,379	105.71	2.5	264.28
Scarabaeidae/Elateridae	L.	2,383	237.42	1.5	356.13
Lycosidae	A.	1,008	46.37	4.5	208.67
Lumbricidae	A.	141	30.46	22.2	676.21
Cereal	—	—	225.00	1.0	225.00

of gizzard contents bias dietary patterns towards harder foods present. Realistic patterns may be obtained through the use of factors which correct for differential digestion rates (Coleman, 1974). Caloric estimates of each major food group then assume new proportions relative to one another (Table 6), with soft-bodied foods forming a bigger proportion of the annual diet. With revaluation, Lepidoptera larvae remain predominant; Lumbricid earthworms supersede all remaining forms; lycosid spiders, Hemiptera and Curculionidae increase markedly; but cereal grain decreases in importance. Overall, the caloric value of major foods consists of 82.9% animal and 17.1% plant tissues before the inclusion of factors correcting for differential digestion, but subsequently of 92.5% animal and 7.5% plant tissues.

Nestlings at West Melton eat similar foods to free-flying birds although very young nestlings are fed a more restricted diet. Nestling diets are also similar to, but broader than, those of nestlings in other countries, e.g., in Scotland—Diptera larvae 80%, earthworms 16% (Dunnet, 1955); in the USSR—Lepidopteran larvae 82% (Korol'kova, 1963); in Poland—Coleoptera 53%, Diptera 23%, earthworms 15% (Gromadzki, 1969).

Caloric evaluations of Canterbury nestling diets also follow patterns established for local adults. Small forms ingested in large numbers, such as Hemiptera and Curculionidae, contribute minimally towards the nestlings' sustenance, while common larger forms, especially Lepidopteran larvae and scarabaeid beetles, form the bulk of the ingested energy.

Overall, nestling foods are similar each year but the abundance of major foods varies seasonally; diets become more diverse with the December emergence of adult Coleoptera and Diptera and the accompanying loss of some larval forms.

The diet of West Melton birds varies seasonally in content and diversity, and generally follows trends in abundance established for soil invertebrates at nearby Harewood (Moeed, 1970). There, adults are taken more commonly in the warmer drier months, and larval forms, arachnids and earthworms at other times.

Dietary variations also result from changes of feeding sites. Although some foods are apparently ubiquitous and others specific to particular field types, still others are available only during specific farming operations.

Selection of individual field types as feeding sites varies seasonally, apparently due to phenological differences in pasture and crop maturity and in associated insect populations. For example, in Canterbury, in spring, summer and autumn, starlings select pasture fields, especially well-grazed grass. Supplementary foods are obtained in spring from fields being tilled, and in summer and autumn from cereal stubbles. In winter, starlings select fields of turnips and other fodder crops and also occasionally take cereal from stock feed lots.

The use or avoidance of all fields is markedly affected by stock; in particular, birds in small flocks select fields with stock and use them as "beaters". Overall, the bulk of Canterbury starlings feed on pasture. Selections favouring less frequent field types generally involve only a small percentage of all birds censused, e.g., 5% follow the plough in spring and 2% feed amongst lush cereal in winter. Conversely, winter pasture, though selected against, still contains approximately 36% of all birds.

Starlings have frequently been termed "generalistic" feeders as their diet often reflects the natural abundance of their foods, e.g., Kluijver (1933), Dunnett (1955), Korol'kova (1963), Davis (1967), Gromadzki (1969). However, recent studies have shown that many bird species often feed selectively (see Tinbergen, 1960, Croze, 1970, Royama, 1970) and utilize such factors as prey palatability, nutritive value, abundance and prey size and hardness.

Canterbury starlings show distinct dietary preferences. During the nestling period, parents select food of a size and hardness suitable for nestlings, and apparently ignore common, large, "hard" bodied beetles and similar foods. Preferences appear to extend outside of breeding; caged adults and first year birds prefer soft-bodied larvae and spiders to harder forms.

The diets of juvenile and adult starlings are similar in content and diversity, and preferences are apparently established in the first post-fledging month. However, adults feed more successfully, presumably due to experience (shown for wood pigeons, Murton, Isaacson and Westwood, 1971, and cattle egrets—*Ardeola ibis,* Siegfried, 1972). Throughout most of the year overall dietary patterns agree closely with the natural abundance of favoured food species, and starlings appear to follow Lack's (1970) tenet that animals select food not only in relation to their physiological needs but also with regard to the ease with which foods are captured.

ACKNOWLEDGEMENTS

I am grateful to J. Orwin of the Forest Research Institute, and M. C. Crawley of the Department of Zoology, University of Canterbury, for assistance with the manuscript. The programme used in the analysis of field utilisation by starlings was written by S. Robson, late of the Department of Zoology. Financial assistance was provided by Ecology Division, DSIR.

REFERENCES

ANON., 1970. Starlings help control pasture pests. *N.Z. Farmer* 91 (17): 21, 23-4.

BATHGATE, A. 1897. Notes on acclimatization in New Zealand. *Transactions of the N.Z. Institute* 30: 266-79.

COLEMAN, J. D. 1974. Breakdown rates of foods ingested by starlings. *Journal of Wildlife Management* 38 (4): 910-12.

COLLINGE, W. E. 1924-27. *The food of some British wild birds.* York.

CROZE, H. 1970. *Searching image in carrion crows. Hunting strategy in a predator and some anti-predator devices in camouflaged prey.* Paul Payre, Berlin and Hamburg.

DAVIS, B. N. K. 1967. Bird feeding preferences among different crops in an area near Huntingdon. *Bird Study* 14(4): 227-37.

DAWSON, D. G.; Bull, P. C. 1970. A questionnaire survey of bird damage to fruit. *N.Z. Journal of Agricultural Research* 13(2): 362-371.

DILLERY, D. G. 1965. Post-mortem digestion of stomach contents in the savannah sparrow. *Auk* 82(2): 281.

DUNNET, G. M. 1955. The breeding of the starling *Sturnus vulgaris* in relation to its food supply. *Ibis* 97(4): 619-62.

DUNNET, G. M. 1956. The autumn and winter mortality of starlings *Sturnus vulgaris,* in relation to their food supply. *Ibis* 98(2): 220-30.

DUNNET, G. M.; Patterson, I. J. 1968. The rook problem in North-East Scotland, Pp. 119-39. In Murton, R. K. and Wright, E. N. (Eds), *The problems of birds as pests.* Academic Press, London and New York.

EAST, R.; Pottinger, R. P. 1975. Starling (*Sturnus vulgaris L.*) predation on grass grub [*Costelytra zealandica* (White), Melolonthinae] populations in Canterbury. *N.Z. Journal of Agricultural Research* 18: 417-52.

EMLEN, J. T. 1952. Flocking behaviour in birds. *Auk* 69: 160-70.

FRAENKEL, G.; RUDALL, K. M. 1947. The structure of insect cuticles. *Proceedings of the Royal Society* (B) 134: 111-43.

GROMADSKI, M. 1969. Composition of food of the starling, *Sturnus vulgaris* L., in agrocenoses. *Ekologia polska Ser.* A 17(16): 287-311.

HARTLEY, P. H. T. 1948. The assessment of the food of birds. *Ibis* 90(3): 361-81.

HAVLIN, J.; Folk, C. 1965. Food and economic importance of the starling, *Sturnus vulgaris* L. *Zoologicke Listy* 14(3): 193-208. (In Czechoslovakian).

HOWARD, W. E. 1959. The European starling in California. *Bulletin of the California Department of Agriculture* 48: 171-9.

IMMS, A. D. 1951. *A general textbook of entomology including the anatomy, physiology, development and classification of insects.* Methuen and Co., London 8th Edn.

KALMBACH, E. R.; Gabrielson, I. N. 1921. Economic value of the starling in the United States. *U.S. Department of Agriculture. Bulletin No.* 868.

KLUIJVER, H. N. 1933. Bijdrage tot de biologie en de ecologie van den spreeuw (*Sturnus vulgaris vulgaris* L.) gedurende zijn voortplantingstijd. *Versl. en Med. van het Plantziekt. Dienst te Wageningen* 69: 1-145.

KOERSVELD, E. Van. 1951. Difficulties in stomach analysis. *Proceedings of the Xth International Ornithological Congress*: 592-4.

KOROL'KOVA, G. E. 1963. Vliyanie pjtits na chislennost' vrednkh nasekomykh (po issledovaniyam v) esostepnykh dubravakh. *Akadamiia Nauk SSSR.*

LACK, D. 1970. Introduction, Pp XIII-XX In Watson, A. (Ed.). *Animal populations in relation to their food resources.* Blackwell scientific publications, Oxford and Edinburgh.

LINSEY, A. A. 1939. Food of the starling in Central New York State. *Wilson Bulletin* 51(3): 176-82.

LOBB, W. R.; Wood, J. 1971. Insects in the food supply of starlings in Mid-Canterbury. *The N.Z. Entomologist* 5(1): 17-24.

MOEED, A. 1970. (Unpublished) *Ecological aspects of the bird hazard problem at Christchurch International Airport.* Ph.D. Thesis, Univ. Canterbury.

MURTON, R. K.; ISAACSON, A. J.; WESTWOOD, N. J. 1971. The significance of gregarious feeding behaviour and adrenal stress in a population of Wood-pigeons *Columba palumbus. Journal of Zoology* 165(1): 53-84.

ROYAMA, T. 1970. Factors governing the hunting behaviour and selection of food by the great tit (*Paris major* L.). *Journal of Animal Ecology* 39(3): 619-668.

SIEGEL, S. 1956. *Nonparametric statistics for the behavioural sciences.* McCraw-Hill Book Co., New York, Toronto and London.

SIEGFRIED, W. R. 1972. Aspects of the feeding ecology of cattle egrets (*Ardeola ibis*) in South Africa. *Journal of Animal Ecology* 41(1): 71-8.

SPECTOR, W. S. (Ed) 1956. *Handbook of biological data.* W. B. Saunders Company. Philadelphia and London.

STIVEN, A. E. 1961. Food energy available for and required by the blue grouse chick. *Ecology* 42(3): 547-53.

SZIJJ, J. 1957. A seregely taplalkozasbiologiaja es mezogazdasagi jelentosege. *Aquila* 63: 71-101.

THOMAS, H. F. 1957. The starling in the Sunraysia district, Victoria. Pt. 3. General habits when attacking fruit. *Emu* 57: 157-80.

THOMSON, G. M. 1922. *The naturalisation of animals and plants in New Zealand.* Cambridge University Press, London.

TINBERGEN, L. 1960. The natural control of insects in pinewoods. I. Factors influencing the intensity of predation by songbirds. *Archives neerlandaises de zoologie* 13: 265-343.

WARD, P. 1965. Feeding ecology of the black-faced dioch *Quelea quelea* in Nigeria. *Ibis* 107(2): 173-214.

TABLE 3. *The energetics of the major animal foods of free-flying starlings.*

Food Species		Heat of* combustion of entire animal (Cal/g)	Mean dry weight of species (g)	Mean weight of chitin per animal (Cal)	Caloric value of digestible components per animal (Cal)	No. of items taken from gizzards	Total energy of digestible tissue eaten (Cal)	Total energy ingested for each animal group (Cal)
Nysius huttoni	A.	5.30	0.0008	0.0001	0.004	5261	21.04	
Dictyotus caenosus	A.	—	0.0084	0.0011	0.039	167	6.51	27.55
Agrotis ypsilon	L.	5.00	0.1080	0.0048	0.513	231	118.50	
Coleophora sp.	L.	—	0.0005	—+	0.003	816	2.45	
Witlesia sabulosella	L.	—	0.0123	0.0005	0.059	3376	199.18	
Wiseana sp.	L.	—	0.1510	0.0061	0.725	307	222.57	542.79
Neoitamus sp.	A.	4.91	0.0235	0.0019	0.088	10	0.80	
Sarcophaga milleri	A.	—	0.0055	0.0005	0.025	158	3.95	4.75
Irenimus aequalis	A.	5.49	0.0032	0.0007	0.014	5504	77.06	
Hyperodes bonariensis	A.	—	0.0005	0.0001	0.002	2105	4.21	
Desiantha maculata	A.	—	0.0040	0.0009	0.017	274	4.66	
Enneboeus sp.	A.	—	0.0008	0.0002	0.003	3163	9.49	95.42
Costelytra zealandica	A.	4.87	0.0216	0.0024	0.092	291	26.77	
Aphodius howitti	A.	—	0.0200	0.0022	0.087	170	14.79	
Lacon variabilis	A.	—	0.0163	0.0018	0.071	687	48.78	
Hypharpax abstrusus	A.	—	0.0040	0.0005	0.017	231	3.93	105.71
Conoderus exsul	L.	5.10	0.0109	0.0019	0.045	32	1.44	
Aphodius howitti	L.	—	0.0220	0.0038	0.093	617	57.38	
Costelytra zealandica	L.	—	0.0243	0.0042	0.103	1734	178.60	237.42
Lycosidae gen. undet.	A.	5.37	0.0091	0.0006	0.046	1008	46.37	46.37
Lumbricidae gen. undet.	A.	5.36	0.0402	—+	0.216	141	30.46	30.46

* The calculated heats of combustion and percent chitin content of the first species in each group were considered representative of related forms.
+ The chitin present in lumbricids and *Coleophora* sp. was ignored, being within the limits of the equipment used.

APPENDIX 1. *The foods identified from the gizzards of 406 free-flying starlings (major foods are in bold type; items recorded on 10 or fewer occasions have been omitted.)*

Food Species	Animal Foods Insecta		FMA		MJJ		ASO		NDJ	
			N^+	$\%F^+$	N	%F	N	%F	N	%F
ORTHOPTERA										
Gryllidae	*Nemobius* sp.		16	10.7	2	1.7				
DERMAPTERA										
Forficulidiae	*Forficula auricularia*		8	1.8	6	1.7	16	10.7	5	3.0
HEMIPTERA										
Cicadellidae	*Deltocephalus taedius*		13	8.9	2	1.7			16	9.1
Lygaeidae	*Nysius huttoni*		1454	**61.6**	444	**38.8**	713	**51.8**	2650	**62.1**
	Nysius sp.		58	8.0	4	0.9	4	1.8	2	1.5
Cydnidae	*Philapodemus australis*				77	0.9			1	1.5
	Chaerocydnus nigrosignatus				64	0.9			5	1.5
Pentatomidae	*Dictyotus caenosus*		25	8.0	22	12.9	17	10.7	103	**37.9**
Reduviidae	*Onecocephalus* sp.		33	17.0	89	15.5	1	0.9	3	4.5
LEPIDOPTERA										
Hepialidae	*Wiseana* sp.	L.	25	7.1	158	**29.5**	124	**25.9**		
Coleophoridae	*Coleophora* sp.		62	10.7						
	Coleophora sp.	L.	101	13.4	211	17.2	270	**25.0**	234	**31.8**
Pyralidae	*Witlesia sabulosella*	L.	80	11.6	1728	**56.6**	1484	**71.4**	84	12.1
Pieridae	*Pieris rapae*	L.	31	8.0						
Noctuidae	*Ariathisa comma*	L.	74	7.1	9	3.4	3	0.9		
	Agrotis ypsilon	L.	115	**24.1**	12	6.9	18	9.8	86	**31.8**
	Aletia temenaula	L.	13	4.5	8	3.4	2	0.9	20	7.6
	A. moderata	L.	1	0.9	6	3.4	4	2.7	6	1.5
	gen. undet.	L.	28	7.1	25	6.3	16	4.5	2	3.0
Hyponomeutidae	*Plutella maculipennis*				57	3.4				
	Plutella maculipennis	L.	945	13.4	87	1.7			2	3.0
DIPTERA										
Muscidae	gen. undet.		9	4.5			1	0.9	2	1.5
	gen. undet.	L.	639	**33.0**	130	**22.4**	12	8.0	6	9.1
	Sarcophaga milleri		56	**21.4**	8	6.0			94	12.1
Calliphoridae	gen. undet.	L.	395	8.9	24	2.6			109	7.6
HYMENOPTERA										
Ichneumonidae	gen. undet.		4	3.6	75	13.8	12	8.9	1	1.5
Braconidae	*Apanteles* sp.		21	4.5						
COLEOPTERA										
Carabidae	*Metaglymma monolifer*		2	1.8	1	0.9	6	4.5	10	9.1
	Hypharpax antarcticus		30	9.8	19	5.2	6	3.6	12	9.9
	H. abstrusus		53	11.6	51	9.5	37	11.6	90	**27.3**
	Mecyclothorax rotundicollis		21	2.7	11	5.2	1	0.9		
Staphylinidae	*Xantholinus* sp.		28	17.0	10	8.6	44	18.8	20	18.2
Scarabaeidae	*Costelytra zealandica*						8	1.8	283	**40.9**
	Costelytra zealandica	L.	102	9.8	1073	**37.1**	559	**26.8**		
	Aphodius howitti		170	**38.4**						
	Aphodius howitti	L.					132	17.9	485	*25.8*
	Pyronota setosa						29	0.9		

APPENDIX 1—*continued.*

Food Species			FMA		MJJ		ASO		NDJ	
ANIMAL FOODS			N^+	$\%F^+$	N	%F	N	%F	N	%F
INSECTA										
Elateridae	*Lacon variabilis*		183	**58.0**	259	**68.1**	124	**58.9**	119	**60.0**
	Lacon variabilis	L.	17	7.1	29	10.3	35	7.1	23	12.1
	Conoderus exsul				42	5.2	85	13.4	27	15.2
	Conoderus exsul	L.	2	1.8	1	0.9	26	16.1	3	4.5
Coccinellidae	*Coccinella leonina*		3	0.9	11	8.6	1	0.9	16	6.0
	C. undecimpunctata		1	0.9	6	5.2	3	2.7	3	3.0
Chrysomelidae	*Atrichatus aeneicollis*						1	0.9	14	3.0
Curculionidae	*Gonipterus scutellatus*		14	4.5			4	1.8	4	1.5
	Hyperodes bonariensis		429	**78.6**	497	**58.6**	726	**77.7**	453	**65.2**
	Irenimus aequalis		1905	**92.2**	1191	**81.0**	1351	**82.1**	1057	**74.2**
	Desiantha maculata		152	**49.1**	37	**23.2**	33	10.7	52	**25.8**
	Listroderes delaigue		26	11.6	49	14.7	9	5.4	90	18.2
	Otiorhynchus sulcatus		7	3.6	20	7.8	10	6.3	27	18.2
	Epitimetes grisealis				6	1.7	82	17.0	42	9.1
Tenebrionidae	*Enneboeus* sp.		1393	**75.0**	1295	**84.5**	349	**53.6**	126	**47.0**
	Enneboeus sp.	L.	16	3.6						
ARACHNIDA										
ARANEIDA										
Lycosidae	gen. undet.		321	**67.0**	324	**62.9**	208	**57.1**	155	**47.0**
PHALANGIDA										
Phalangiidae	*Phalangium opilio*		9	6.3			1	0.9	6	6.1
CRUSTACEA										
ISOPODA										
	Porcellio scaber		10	3.6	12	7.8	1	0.9		
OLIGOCHAETA										
TERRICOLAE										
Lumbricidae	gen. undet.		8	17.0	52	**45.7**	80	**62.5**	1	12.1
MYRIAPODA										
CHILOPODA										
Gonibregmatidae	gen. undet.		15	7.1	6	4.3	4	3.6		
Henicopidae	gen. undet.								1	1.5
OTHERS										
PLANT FOODS (N lists percentage of stomach contents by volume)										
Gramineae	*Triticum* sp./*Hordeum* sp.		48.4	**58.0**	20.5	**25.8**	41.7	8.0	34.5	16.7
Solanaceae	*Solanum nigram*		25	0.9						
Papilionaceae	*Trifolium dubium*				114	**24.1**	37	10.7		
Chenopodiacae	*Chenopodium album*		3	2.7	14	3.4	1	0.9	9	6.1
OTHER ITEMS										
Small stones					5.0	0.9			20.0	1.5
Grass/Plant material			40.0	2.7	40.0	3.0	6.0	6.3	5.0	1.5
SAMPLE SIZE			112		116		112		66	

NOTE: N^+ = Number identified $\%F^+$ = Percent frequency L = larvae.

APPENDIX 2. *The foods of nestling starlings (major foods are underlined, items recorded on 10 or fewer occasions have been omitted).*

	Food Species		1969		1970		1971	
			N	%F	N	%F	N	%F
DERMAPTERA								
Forficulidae	*Forficula auricularis*		3	1.0	1	1.1	10	4.4
HEMIPTERA								
Cicadidae	*Melampsalta* sp.		6	2.6	1	1.1	7	6.6
Lygaeidae	*Nysius huttoni*		609	**33.8**	20	7.9	171	**28.6**
Pentatomidae	*Dictyotus caenosus*		7	3.6	4	2.2	24	15.4
LEPIDOPTERA								
Hepialidae	*Wiseana* sp.		28	2.6				
	Wiseana sp.	L.	10	3.1	1	1.1		
Coleophoridae	*Coleophora* sp.		25	2.6	8	1.1	128	4.4
Pyralidae	*Witlesia sabulosella*		18	5.6	16	3.4		
Crambidae	*Crambus* sp.	L.	16	5.6	2	1.1	4	2.2
Noctuidae	*Agrotis ypsilon*		43	**15.4**				
	Agrotis ypsilon	L.	83	**32.8**	21	15.7	164	**61.5**
	Ariathisa comma	L.	12	4.1				
	Persectania aversa	L.	10	2.6			14	8.8
DIPTERA								
Asilidae	*Saropogon* sp.		11	3.1			1	1.1
	Neoitamus sp.		46	**12.8**	32	**20.2**	15	8.8
Muscidae	spp.		35	6.2	4	4.5	23	**13.2**
	spp.	L.			10	3.4	36	3.3
Calliphoridae	*Calliphora laemica*	L.	15	0.5	9	4.5		
COLEOPTERA								
Carabidae	*Metaglymma monolifer*		11	4.6			44	**23.3**
	Hypharpax antarcticus		13	5.6	5	5.6	175	**22.0**
	H. abstrusus		32	6.7	5	4.5	151	**28.6**
Scarabaeidae	*Costelytra zealandica*		292	**42.1**	15	**14.6**	82	**29.7**
	Aphodius howitti		15	2.1			11	4.4
Elateridae	*Lacon variabilis*		13	5.1	3	3.4	79	**28.6**
	Conoderus exsul		7	3.6			15	12.1
	Conoderus exsul	L.	28	**12.3**			85	**35.2**
Coccinellidae	*Coccinella undecimpunctata*		22	4.6			19	**11.0**
Curculionidae	*Irenimus aequalis*		38	**12.8**	20	**10.1**	66	**22.0**
	Hyperodes bonariensis		9	2.1			2	1.1
	Listroderes delaigue		16	1.5				
ARACHNIDA								
ARANEIDA	Lycosidae spp.		88	**24.1**	31	**29.2**	136	**41.8**
PHALANGIDA	Phalangiidae—*Phalangium opilio*		236	**19.5**	14	5.6	8	5.5
CRUSTACEA								
ISOPODA	*Porcellio scaber*		21	5.1	1	1.1	26	6.6
ANNELIDA								
OLIGOCHAETA	Lumbricidae spp.		31	**15.4**	37	**33.7**	30	**17.6**
PLANT FOODS								
ROSACEAE	*Prunus avium*		30	0.5				