THE FEEDING ECOLOGY AND BREEDING BIOLOGY OF THE GOLDFINCH (*CARDUELIS CARDUELIS* Linnaeus, 1758) AT HAVELOCK NORTH, NEW ZEALAND.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Zoology at Massey University.

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THE EUROPEAN GOLDFINCH

(CARDUELIS CARDUELIS,Linnaeus,1758)

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CHAPTER I

INTRODUCTION

1.1 AIMS OF THE STUDY

During the past ten years increasing attention has been drawn to damage caused to soft fruits by the European Goldfinch, Carduelis carduelis Linnaeus,1758, * (Dawson 1967, Dawson and Bull 1970, Long 1970). The present study was undertaken in an endeavour to find out more about the food habits of this bird in the district where many of the reports of this damage originated.

The aims of this study were to examine 1) the feeding ecology of the adult Goldfinch; 2) the diet of the nestlings; 3) the extent of crop damage caused by the Goldfinch. Because investigation of nestling diet involved numerous visits to nests, aspects of breeding biology were investigated. Also large numbers of gold-finches were measured during the study and it seemed appropriate to compare data with recent work investigating the subspecific status of the Goldfinch in New Zealand (Niethammer,1971).

A number of smaller points were of interest. Newton (1967a) states that in all the carduelines which feed animal and vegetable matter to their young, the proportion of invertebrates given declines with increasing age of the young. After about the tenth day the young often receive seeds only. This was examined.

* Nomenclature for New Zealand birds follows that laid down in the Annotated Checklist of the Birds of New Zealand (Kinsky,1970). Other bird species are as prescribed in the Handbook of British Birds (Witherby et al, 1943) or in the specific reference works quoted.

It became apparent during the 1969-1970 breeding season that because of differences in surrounding vegetation certain breeding areas had larger amounts of animal protein available to the young. Two breeding blocks were chosen, one being surrounded by a plentiful supply of animal protein and the other, by comparison, with very little. An investigation was carried out to see firstly; whether there was any significant difference in the percentage of animal protein fed to the nestlings in the two blocks and if so did this difference affect growth rates; secondly, if there was a significant difference in growth rates of nestlings from different brood sizes; and thirdly, if there was any significant difference in the diet and growth rates of broods reared at different times of the breeding season.

1.2 THE HISTORY OF THE GOLDFINCH IN NEW ZEALAND

Thomson (1922) records that the Goldfinch was first introduced into New Zealand by the Nelson Acclimatization Society when ten were first imported to Nelson and liberated in 1862. The origin of this stock is unknown but presumably the birds came from Great Britain and would therefore belong to the British race Carduelis carduelis britannica. However, doubt was cast on this conclusion by Moncreiff (1931) who suggested that since the Germans were in the forefront of bird exporters at the time, the birds introduced into New Zealand were more likely to belong to the continental race C.c.carduelis.

In a recent article by Niethammer (1971) he uses wing and tail measurements to prove that the New Zealand Goldfinch stems from British stock. However birds introduced to new areas may undergo morphological changes which subsequently distinguish them from their ancestral race. This is so for the North American House Sparrow, Passer domesticus (Johnston and Selander,1964). In an attempt to verify the origin of the Goldfinch, and to investigate any subsequent morphological change, bill and wing measurements were recorded.

During the 20 years following 1862, the species was liberated in several other places and in the last 100 years it seems to have adapted well to the New Zealand conditions. Oliver (1955) lists it as being found throughout the North and South Islands, Three Kings, Mokohinau, Little Barrier, Kapiti, Stewart and Antipodes Islands and Kinsky (1970), in 'The Annotated Checklist of the Birds of New Zealand', mentions its self-introduction to some of the outlying islands, including Chathams, Kermadecs, Snares and Campbell Islands. The bird distribution mapping scheme carried out by the Ornithological Society of New Zealand (Bull,1970) indicates that the Goldfinch may be more numerous in the northern areas but this is yet to be confirmed.

The Greenfinch Carduelis chloris and the Redpoll Acanthis flammea are the closest relatives to the Goldfinch in New Zealand and with the Chaffinch Fringilla coelebs, inhabit similar areas to the Goldfinch. Differences in size and shape of bills with associated differences in food preferences, enables all four species to coexist.

1.3 STUDY AREA

The study area comprised approximately 417 hectares, about one-third of which was orchards and the remainder

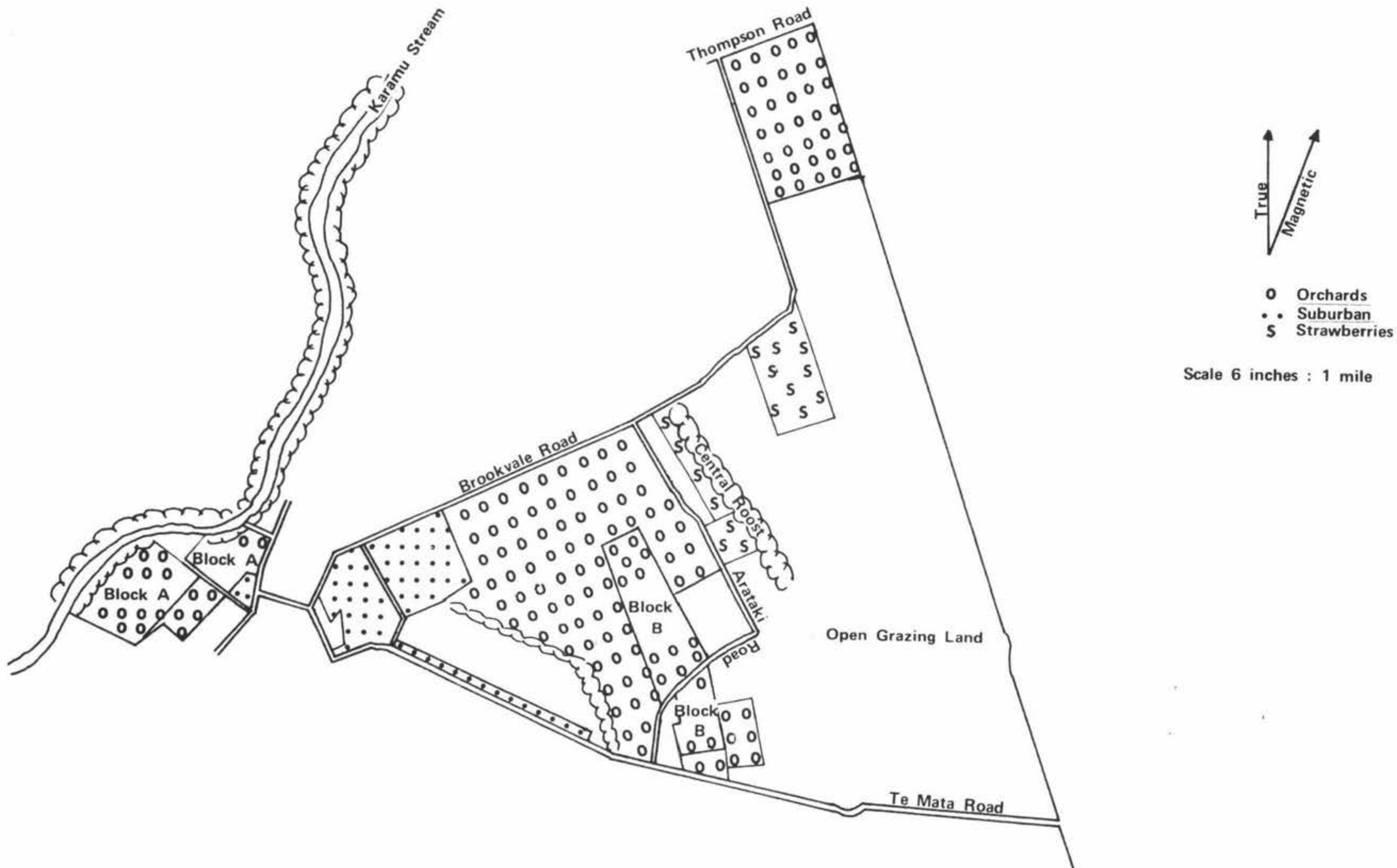


Figure 1 Map of study area, Havelock North.

market gardens, sheep and cattle pasture and housing blocks (Fig.1). The area lay on the north-east boundary of the town of Havelock North.

Two orchards were chosen as study areas during the breeding season; Block A, which was the Department of Scientific and Industrial Research orchard, approximately 10.5 hectares in area and bordered on its western side by a large number of deciduous trees growing on the banks of the Karamu stream. Block B comprised 15 hectares of fruit trees and was bordered by other orchards and open pasture land. Both orchards were within the main study area (see Fig.1). As already stated, because of differences in surrounding vegetation it became apparent during the 1969-1970 breeding season that the food supply to the nestlings in these two orchards would be different in the amount of animal material available to them and this is why these two orchards were chosen.

Many of the goldfinches in the study area utilised a long plantation of trees (Eucalyptus sp.) for roosting at night (Fig.2). This was situated in a fairly central position in the main study area. Weed patches were prevalent, mostly associated with orchards and market gardens.

FIGURE 2. Trees used for roosting at night. (central roost)

CHAPTER II

FEEDING ECOLOGY

A. FEEDING BEHAVIOUR

2.1 METHODS AND RESULTS

i) Food Finding

The Goldfinch primarily eats seeds most of which are from weed species. Consequently most of the areas the birds visited were usually weed patches, either on the floor of the orchard (Fig.3) or in large open uncultivated areas (Fig.4).

Seldom were goldfinches found feeding alone. In the winter months they fed together in large flocks and during the breeding season they were usually observed feeding in pairs or small groups. Most food in the winter months is found by a process known as 'local enhancement', defined by Thorpe (1956) as an "apparent imitation resulting from directing an animals attention to a particular part of the environment". Kear (1962) showed how local enhancement is important in food finding in greenfinches. It involves pointing out the place to act but not what to do. Frequently goldfinches were seen to fly over a weed patch but only settled to feed when other conspecifics were present. However this was not universal. Many foods do appear to be recognised as a food source without the presence of other birds feeding on them. This was especially so during the breeding season when pairs or even single goldfinches would visit a food source without a social stimulus being present.

FIGURE 3. Flock of goldfinches disturbed while feeding on an orchard floor.

FIGURE 4. Flock of goldfinches feeding at a large uncultivated weed patch.

ii) Feeding Positions

The feeding postures of the Goldfinch have been adequately described by both Newton (1967a) and Kear (1962). Newton (1967a) records that greater than 99 percent of feeding time for the wild Goldfinch is spent clinging or perching on vegetation off the ground. This certainly was not the case at Havelock North where a high percentage of the feeding time in the winter was on *Poa annua*,* a low growing winter grass. No estimates of actual time spent in the different feeding positions were made but incidental observations were made.

Feeding positions vary according to the food source. A good example of this is when birds fed on *Amaranthus retroflexus* (Red root). From late summer up to mid-winter most of the *A.retroflexus* seed is retained on the seed heads and the goldfinch feeds from any clinging position on the plant. However, as the winter continues most of the seeds fall to the ground and there was a corresponding move from stem to ground feeding. The Goldfinch appears to favour feeding from the clinging position (Fig.5), but food preferences or food shortage do supersede this tendency.

iii) Flocking

For cardueline finches feeding is usually a social phenomenon. In May 1969 when the study was commenced,

* Nomenclature for weeds found at Havelock North follows that laid down in the 'Standard Common Names for Weeds in New Zealand' (New Zealand Weed and Pest Control Society, 1969). Other weed species are as prescribed in the book 'Weeds of New Zealand and how to eradicate them' (Hilgendorf,1967) or in the specific reference works quoted.

FIGURE 5. Goldfinches feeding from clinging positions.

flocking was well established and continued until the commencement of the breeding season in mid-October. Bird counts for the whole study area during the winter months revealed two main flocks of goldfinches separated by approximately 1.5 miles. Two other smaller flocks were also present. The largest of the flocks contained approximately 600 birds at its peak period just before roosting and the second largest flock reached a maximum of 300 birds. The two smaller flocks contained approximately 40 birds each. Considerable interchange took place between these flocks, disturbed birds frequently flying from one flock to another. Flock sizes at Havelock North were similar with other observations of winter flock sizes throughout New Zealand, apart from some areas in the north of the North Island. Observational notes in Notornis (1963) record a flock size of 15,000 goldfinches in a concentrated area between Warkworth and the Kaipara flats and another flock of over 3000 feeding on four hectares of *A. retroflexus* at Clevedon. However, the record of 15,000 goldfinches in one flock appears most unusual especially if one considers the observation was made at the end of October when most winter flocks have broken up and breeding has commenced.

The presence of only two main flocks within the study area appeared to be the direct result of the available food supply. There was only two large weed patches present throughout the winter and each supported a large flock. As food became scarce in these two areas towards the end of winter, the flocks became much smaller and more numerous. This breakdown of flocks coincided with the onset of sexual display and the formation of breeding pairs.

During the non-breeding period a daily pattern of behaviour was observed. From sunrise until 09.00 hours the flock size increased in the two main feeding areas. After the birds had finished feeding they flew to a nearby tree or fence line where they preened and then either rejoined the main feeding flock or flew to another feeding area. Between 09.00 hours and 14.00 hours the numbers in the flock decreased and the flock lost much of its compactness, i.e. the flock became much easier to disturb and during this time birds would more readily fly to another feeding area. From 14.00 hours until an hour before dusk, the size of the flock started to build up again and displayed its characteristic feeding intensity. In the final hour the flocks slowly broke up as small groups flew to roost. Several roosts were present in the study area; the main one used is shown in Figure 2.

iv) Changes in Flock Behaviour

A marked change takes place in the way in which members of the feeding flock move within the group, as the winter advances. When seeds are plentiful, the flock is a looser unit and individuals hop about in an apparently random way. Later in the winter, however, not only do flocks become bigger, but the method of feeding within the flock changes. When a flock alights on the ground most of the birds face the same way and their movement is generally all in the same direction.

A bird stopping to pick up seeds is by-passed by a number of others and after a few such stops finds itself in the wake of the flock, where less food remains; it then flies over the heads of the birds in front and drops down in advance of the first rank where the chances of finding food are good. Each bird can hold this position for a few moments only. Soon birds fly over, landing in front of it, while others hop by every time a stop for food is made. This type of feeding behaviour produces a continual overhead flow of birds combined with a steady advancement of the flock as a whole. Ward (1965) describes this type of movement in Quelea quelea as "roller feeding". It was particularly evident when goldfinches were feeding on Poa annua and Stellaria media in August, September and early October, probably because both weeds were low growing and presented an evenly distributed food source.

The normal feeding pattern was for the birds to flit from seed head to seed head with a fluttering flight, or to cling to the plants in a tit-like fashion while they stripped the seeds (Fig.5).

Middleton (1965) describes the roller feeding movements of the Goldfinch flock and also mentions the frequent threat displays, described by Conder (1948), observed when individuals approached each other too closely or attempted to feed from the same source. When feeding, all members of the flock twittered softly and threat displays were often accompanied by harsh notes. Fights between individual birds were prevalent towards the end of winter when food in both the two main feeding areas was becoming scarcer. However, some of this aggression could also be due to an increase in sexual fighting at this time.

By mid-October large flocks had all but vanished from the study area, indicating the end of the non-breeding season. Some communal feeding did continue right through the breeding season as did communal roosting. Available food sources concentrated the feeding birds into small groups. These groups, however, lacked the characteristics of the winter flocks as described previously.

Small flocks of juveniles were observed as the breeding season continued. By the end of March 1970 and 1971 most of the adults had rejoined the developing flocks and many of the juveniles had gained their adult plumage. The House Sparrow, Passer domesticus forms flocks several weeks earlier than the Goldfinch and it was not uncommon towards the end of the breeding season to find large numbers of juvenile goldfinches interspersed among them. However, as adult goldfinches finished breeding and formed flocks, the juveniles rejoined their conspecifics.

2.2 DISCUSSION

i) Flocking

Observations on the feeding behaviour of the Goldfinch at Havelock North differ little from those in other countries. Conder (1948) and Bannerman (1953) record winter flocking throughout its European range and Elliot (1969) records the presence of small flocks in North America during the early 1940's. Middleton

(1965) describes the gregarious nature of the Goldfinch in Australia in considerable detail and makes some effort to evaluate the survival value of this behaviour.

Briefly, the possible advantages in flocking, postulated by various authors over the last 100 years, fall into three main groups.

Firstly, that presence in groups conveys a certain amount of protective value to the individuals involved within them. Lack (1954), Tinbergen (1962) and Moynihan (1962) have all suggested that there is a greater protection for the individual from predators when part of a large flock, but observations made in the present study together with those of Beebe (1947) and Morley (1953) would not support this. It was much easier to approach a bird in a flock, than a solitary bird, but this was so only if that particular individual was on the periphery of the flock and the predator was approaching from the perimeter. For individuals enclosed in the group, then the risk of predation would be much less.

Morse (1970) notes that "although flocking birds possess a mechanism that aids in protection from attack, their combined constant group movement also calls attention to their presence, and they also produce a considerable amount of sound 'en masse' ". Observations in my study area support this comment. It was not uncommon to find several domestic cats (Felis domesticus) concealed among the weeds in one of the two main winter feeding areas. As the disturbed flock resettled, the birds, on several occasions, resettled completely surrounding the cat. On three of these occasions birds were killed.

Allee (1938) supported the idea that a certain amount of difficulty is experienced by the predator in singling out an individual because of the confusion effect the flock gives as it moves. This may well apply to flocks of goldfinches but it also seemed clear, because of the number of cats present, that any movement by the flock tended to attract larger numbers of predators, not so likely attracted by an individual's movement.

It seems fair to assume that total alertness would be greater in a flock than for an individual and consequently a greater awareness of predators would exist. However, in the Goldfinch, because of the continual twittering and movement of the flock any advantages gained by increased alertness may have been lost. Due to increased auditory and visual stimuli more predators were attracted and the individuals own alertness appeared to be lowered. Because of the regularity in the Goldfinch feeding pattern, predators, such as the domestic cat, can become more skilful and quite quickly learn more efficient techniques of capture.

An improvement in food gathering is probably a more likely explanation as regards the Goldfinch flocking. Ward (1965) relates flocking to a food shortage in winter where this type of behaviour results in a more efficient method of finding food and a more efficient means of utilizing a limited food supply. The systematic manner in which the flock searches the ground may result in the available food being used more economically. However, there was no apparent food shortage at Havelock North when flocking commenced but nevertheless these advantages could still apply. Lack (1966) suggests that this behaviour type is likely to have evolved for times of food shortage even if these only occur every ten years and therefore the abundant food during the two years of this study would not detract from the theory. It is widely known that a birds metabolism increases in winter (Welty,1964). Energy consumption is greater and there is an increase in efficiency of the food used. Kendeigh (1949) and Davis (1955) showed that in captive English sparrows energy requirements and gross energy intake increased steeply as the temperature decreased. Kear (1962) showed that for the chaffinch consumption and average weight rose as the temperature dropped. Korodi & Nagy (1965-1966) have shown that at 20°C <u>Carduelis carduelis</u> requires 10.7% of its body weight daily as food. At 0°C both the food requirements and the efficiency of its use increased slightly. It is also well known that social facilitation usually affects the quantity of food which the individual takes. The food consumption of social birds may be greater when they are in groups, either because anomalous conditions of isolation produce abnormal behaviour, or because enhancement of the food source occurs (Kear,1962). This type of advantage is probably more closely related to present day conditions for the Goldfinch in New Zealand. Social experience is also important in governing food preferences (Kear,1962); therefore, flocking should increase both the quantity and quality of food which the individual takes.

Lastly, Wynne-Edwards (1962) considers that the primary function of both flocking and communal roosting is to bring the members of the population unit together so, that whenever prevailing conditions demand it, they can hold an epideictic demonstration. In the case of flocking, he suggests that, often the reason for such contact is competition for a common resource such as food. Through this contact individuals become aware of the population density or the scarcity of the resource and their reproductive rate is increased or lowered correspondingly or adjusted through emigration.

However Middleton (1965) doubted that food shortage seriously affects the Goldfinch population in Australia and this also appears to be so in New Zealand. The presence of large quantities of A.retroflexus seed throughout most of the winter does away with any serious food shortage which might result at this time. Middleton (1965) suggests that flock feeding is more economical from an energy point of view. This method concentrates the population in one area and ensures a systematic search by which much food is consumed with a minimum of effort. The individual need only locate the feeding flock in order to find a source of food and by this method (local enhancement) considerable time and energy is saved.

Therefore, it appears that the primary function of

Goldfinch flocking is not protection, but is connected with the efficient exploitation of an unevenly distributed food supply. The behavioural mechanism as already mentioned is that termed by Thorpe (1956) "local enhancement", whereby the chance finding of food by a group is of profit to others attracted to the place, the numbers that share the supply increasing until it is exhausted. Here in this case profit can be defined in terms of increases in quantity and quality of food eaten and decreases in time and energy spent in locating the food source. It is probably safest to conclude that there is a subtle combination of all factors mentioned, but feeding efficiency may be the most important.

ii) Communal Roosting

Communal roosting can also be explained in terms of resource acquisition. It has been suggested that the habit serves to keep the members of the roosting community warm but this cannot account for communal roosting in the tropics or in the Goldfinch which maintains an individual distance in the roost.

Another suggestion is that increased awareness of the approach of enemies confers some protection to members of the group but, as Yapp (1970) has recently emphasized, communal roosts can hardly be protection from predators for many predators have learnt that the assembling birds are easy prey.

Hamilton and Gilbert (1969) both consider that starling (Sturnus vulgaris) roosting behaviour can be explained by the fact that dispersing starlings behave to maximise the efficiency and rate of energy gain in feeding. They consider that flocking actions probably make resource evaluation more efficient because the experience of members of a group will provide more reliable information about the values of a resource field than an individuals personal experience. Ward (1965) also put forward a similar explanation to explain roosting behaviour in the black-faced Dioch (Quelea quelea) and it seems quite probable that a similar explanation could apply to Goldfinch winter roosting. However, during the breeding season breeding males returned to their individual nest sites after sunrise, taking no notice of directional flights of other birds.

B. FOOD OF THE ADULT GOLDFINCH

2.3 METHODS

The Goldfinch is primarily granivorous (a seed-eater). A preliminary investigation on several shot birds indicated that digestion is insufficient in the crop and proventriculus to alter seed structure, but in the gizzard most seeds are broken down. It was, therefore, decided to confine the analysis to the contents of crop and proventriculus where a much more accurate assessment could be made of the foods eaten. This decision is supported by Swanson and Bartonek (1970) who clearly showed the bias associated with food analysis in gizzards of blue-winged teal (Anas discors.).

Three months for the assessment of food of a species are open to the investigator. Firstly, repeated field observation can be carried out; secondly, an examination of the crop and stomach contents; and thirdly, an analysis of faecal remains. A combination of the first two was used in this study. Hartley (1948) lists three methods which can be applied in the assessment of data from the stomach analysis; namely, the numerical, gravimetric and volumetric. In this study the numerical and volumetric methods have been used.

Observational Assessment

A qualitative or field observation assessment was carried out between August 1969 and April 1970. Three evenly spaced observation periods were made each month. From September 1969 this assessment was made on the same day as shooting at the roost. The study area was covered partly on foot and partly by car. The food and feeding areas of the goldfinches were noted and Newton's (1967a) arbitrary rule was adopted where one bird, one food = one record. Wherever possible, plants used as a food source were taken back to the laboratory where they were identified, pressed and mounted. Seeds on the plants were used to construct a seed reference key to enable seed identification in the stomach analysis.

Stomach Analysis

Most of the food eaten during the day passed straight through the crop, but before going to roost at night the birds consumed large quantities of food which was stored in the crop. At the commencement of this study birds were sampled at all times during the day and only roosting birds had appreciable amounts of food in their crops. Season and locality may also bias samples taken (Hartley,1948) and so it was decided that shooting at a central roost in the evening was the most suitable sampling method. Observations showed that goldfinches came to this roost from all over the study area.

In May 1969 and from September 1969 until the following April 1970, and November 1970 until April 1971, goldfinches were shot at the roost. Three samples were evenly spread over the month. Number nine orchard shot was used. During June, July and August 1969, birds were mistnetted.

Shot and mistnetted birds were kept in a freezer until analysed. Bill lengths, body weights and gonad measurements were recorded. Contents of the crop and proventriculus were assessed by volume. The aggregate volume method was used for calculating percentage composition (Martin,Gensch and Brown 1946). The different seed and animal species were identified and individual species volumes were estimated in tenths of the total volume. The frequency occurrence of each food species was noted. All seeds were identified by the Grasslands Division of the Department of Scientific and Industrial Research (D.S.I.R.) at Palmerston North and several were rechecked at the Seed Testing Station of the Department of Agriculture, Palmerston North. All insect material was identified by Messrs.J.Esson and J.Dugdale of the Entomology Division of the D.S.I.R.

2.4 RESULTS

Tables 1 and 2 show the percentage frequency of occurrence and percentage composition by volume of the food in the birds examined in the stomach analysis. Results for the months of November to April contain data

TABLE 1

Percentage frequency occurrence of foods in the Goldfinch diet, Havelock North. Stomach analysis. (Foods listed as far as possible in order of their appearance in the diet).

Food: Common name	Food: Specific name	M	J	J	A	S	O	N	D	J	F	M	A
No. of birds		43	37	10	29	29	28	25	20	32	32	22	35
Chickweed	Stellaria media	4.7	8.1	20.0	51.7	34.4	32.1						2.9
Red root	Amaranthus retroflexus	88.4	97.3	100.0	79.3	27.5			5.0	25.0	28.1	81.8	97.1
Winged thistle	Carduus tenuiflorus	23.3					17.8	88.0	95.0	56.3	6.3	13.6	17.1
Fat hen	Chenopodium album	32.6	5.4	40.0	3.4	6.8							
	Puccinellia fasciculata	7.0											
Dandelion	Taraxacum officinale	18.6	2.7				3.5	4.0	60.0	12.5	15.6	13.6	11.4
Scotch thistle (Spear thistle)	Cirsium lanceolatum	16.3	2.7							43.8	87.5	59.1	17.1
Selfheal	Prunella vulgaris	2.3											
Hedge mustard	Sisymbrium officinale	2.3								6.3			2.9
Wild turnip	Brassica campestris	7.0											
Silver hairgrass	Aira caryophyllea	2.3											
Groundsel	Senecio vulgaris	2.3			3.4	20.6	3.5	8.0					
Barnyard grass	Echinochloa crus-galli	7.0		10.0	3.4					9.4		9.1	14.3
Ragwort	Senecio jacobea	2.3											
Annual meadow-grass	Poa annua		2.7	10.0	51.7	89.6	60.7						
Nettle	Urtica urens				6.9	24.1	25.0	20.0					5.7
Storksbill	Erodium cicutarium					10.3	71.5	20.0					31.4
Shepherd's purse	Capsella bursa-pastoris					10.3	17.8	8.0					
Mouse-eared chickweed	Cerastium glomeratum					6.8	67.8	8.0					
Meadow foxtail	Alopecurus pratensis						10.7						
Dovesfoot	Geranium molle						3.5	4.0					
Prickly sowthistle	Sonchus asper							8.0		3.1			
Cocksfoot	Dactylis glomerata								20.0	6.3			
Hawksbeard	Crepis capillaris									9.4			
Vervain	Verbena officinalis											4.5	
	Notodanthus sp.												11.4
	Polygonum sp.												2.9
Unidentified seeds (3 types)		11.6			3.4		3.5	20.0	10.0		12.5	27.3	11.4
Strawberry	Fragaria sp.						3.5						
Green material		2.3			3.4		10.7	4.0	15.0	28.1	37.5		28.6
Tortricids	Fam. Tortricidae	2.3				3.4							
Leaf tiers (larvae)	Tebenna bradleyi	2.3										9.1	
Chironomids	Fam. Chironomidae		2.7										
Aphids	Fam. Aphididae				3.4	13.7	50.0	36.0	5.0	3.1			2.9
Spiders	Order Araneae							4.0	5.0				2.9
Geometrids	Phrissogonus laticostatus									3.1			17.1
Leaf tiers (pupae)	Tebenna bradleyi										9.4	9.1	2.9
Tortricids	Capua semiferana										3.1		
Noctuids	Heliothis armigera											4.5	14.3
Leaf bugs	Order Hemiptera												2.9
Unidentified animals (3 types)		4.7											8.6
Roughage											3.1	2.9	2.9

TABLE 2

Percentage composition by volume of foods in the Goldfinch diet, Havelock North. Stomach analysis. (Food listed as far as possible in order of their appearance in the diet).

+ = food less than o.1 percent by volume

Common name	Specific name	M	J	J	A	S	O	N	D	J	F	M	A
No. of birds		43	37	10	29	29	28	25	20	32	32	22	35
Chickweed	Stellaria media	0.5	+	3.0	13.4	6.8	2.6						0.3
Red root	Amaranthus retroflexus	72.9	92.9	91.0	63.4	4.3			1.0	9.1	13.5	63.8	76.1
Winged thistle	Carduus tenuiflorus	15.4					0.7	64.5	94.2	39.8	0.9	4.6	2.4
Fat hen	Chenopodium album	4.0	6.0	4.0	+	0.1							
	Puccinellia fasciculata	1.0											
Dandelion	Taraxacum officinale	2.7	0.9				0.1	0.4	0.2	2.3	3.3	0.7	0.3
Scotch thistle (Spear thistle)	Cirsium lanceolatum	1.1	+							27.9	76.1	18.7	1.3
Selfheal	Prunella vulgaris	+											
Hedge mustard	Sisymbrium officinale	0.2								0.1			+
Wild turnip	Brassica campestris	0.7											
Silver hairgrass	Aira caryophyllea	+											
Groundsel	Senecio vulgaris	+			0.1	3.1		0.1					
Barnyard grass	Echinochloa crus-galli	0.4		1.0	+					8.1		2.8	3.8
Ragwort	Senecio jacobea	+											
Annual meadow-grass	Poa annua		0.1	1.0	9.7	61.6	26.9						
Nettle	Urtica urens				11.4	3.1	2.7	8.8					2.0
Storksbill	Erodium cicutarium					3.4	33.2	15.6					8.1
Shepherd's purse	Capsella bursa-pastoris					13.1	6.9	1.0					
Mouse-eared chickweed	Cerastium glomeratum					3.2	15.9	0.4					
Meadow foxtail	Alopecurus pratensis						1.0						
Dovesfoot	Geranium molle						0.1	1.4					
Prickly sowthistle	Sonchus asper							0.9		0.1			
Cocksfoot	Dactylis glomerata								1.2	1.9			
Hawksbeard	Crepis capillaris									4.5			
Vervain	Verbena officinalis											+	
	Notodanthus sp.												2.3
	Polygonum sp.												+
Unidentified seeds (3 types)		0.7			0.3		2.9	1.5	0.9		0.5	3.5	1.0
Strawberry	Fragaria sp.						+						
Green material		0.3			1.4		2.1	+	1.6	6.0	5.2	4.4	2.1
Tortricids	Fam. Tortricidae	+				0.1							
Leaf tiers (larvae)	Tebenna bradleyi	+										0.5	
Chironomids	Fam. Chironomidae		+										
Aphids	Fam. Aphididae				0.3	1.2	4.8	5.4	0.6	0.1			+
Spiders	Order Araneae							+	0.2				+
Geometrids	Phrissogonus laticostatus									+			0.2
Leaf tiers (pupae)	Tebenna bradleyi										0.4	0.9	+
Tortricids	Capua semiferana										0.1		
Noctuids	Heliothis armigera											0.1	+
Leaf bugs	Order Hemiptera												+
Unidentified animals (3 types)		+											+
Roughage											+	+	+
Total foods examined (mls)		10.1	1.1	1.0	3.5	8.5	7.2	7.9	6.4	9.2	8.4	9.5	25.7
Total percent veg. matter		99.9	99.9	100.0	99.7	98.7	95.1	94.6	99.1	99.8	99.5	98.5	99.7
Total percent animal matter					0.3	1.3	4.8	5.4	0.8	0.1	0.5	1.5	0.2

from both the 1969-1970 and 1970-1971 periods. There was no noticeable difference in the food types eaten in the different years and because sample numbers were low in the 1969-1970 samples, data from both years were pooled.

The seasonal importance in the diet of the various seeds is illustrated in Figure 6. Altogether 31 different seed types were found and all but three were identified. These three unidentified species formed an insignificant portion of the diet and never reached more than 3.5 percent as an accumulated total by volume for any one month.

Direct observation of the diet in the field did not record as wide range of food types as the stomach analysis (Table 3). However, as a complementary method to the stomach analysis, the observational field method does seem worthwhile as it provides a check on the stomach analysis results and also can provide additional information on any uncommon food source which may be utilized by only one or two birds during the day. Apple of Peru (*Nicandra physaloides*) and Catsear (*Hypochaeris radicata*) are two such food sources not found in the stomach analysis, but observed being eaten by several birds in February and March 1970.

The observational method failed to give any clear indication on animal food eaten but this can probably be explained by the fact that most of the insects taken were either grass or stem feeders. Storksbill (*Erodium cicutarium*) was heavily infested with aphids during October and November and Table 1 indicates that at this

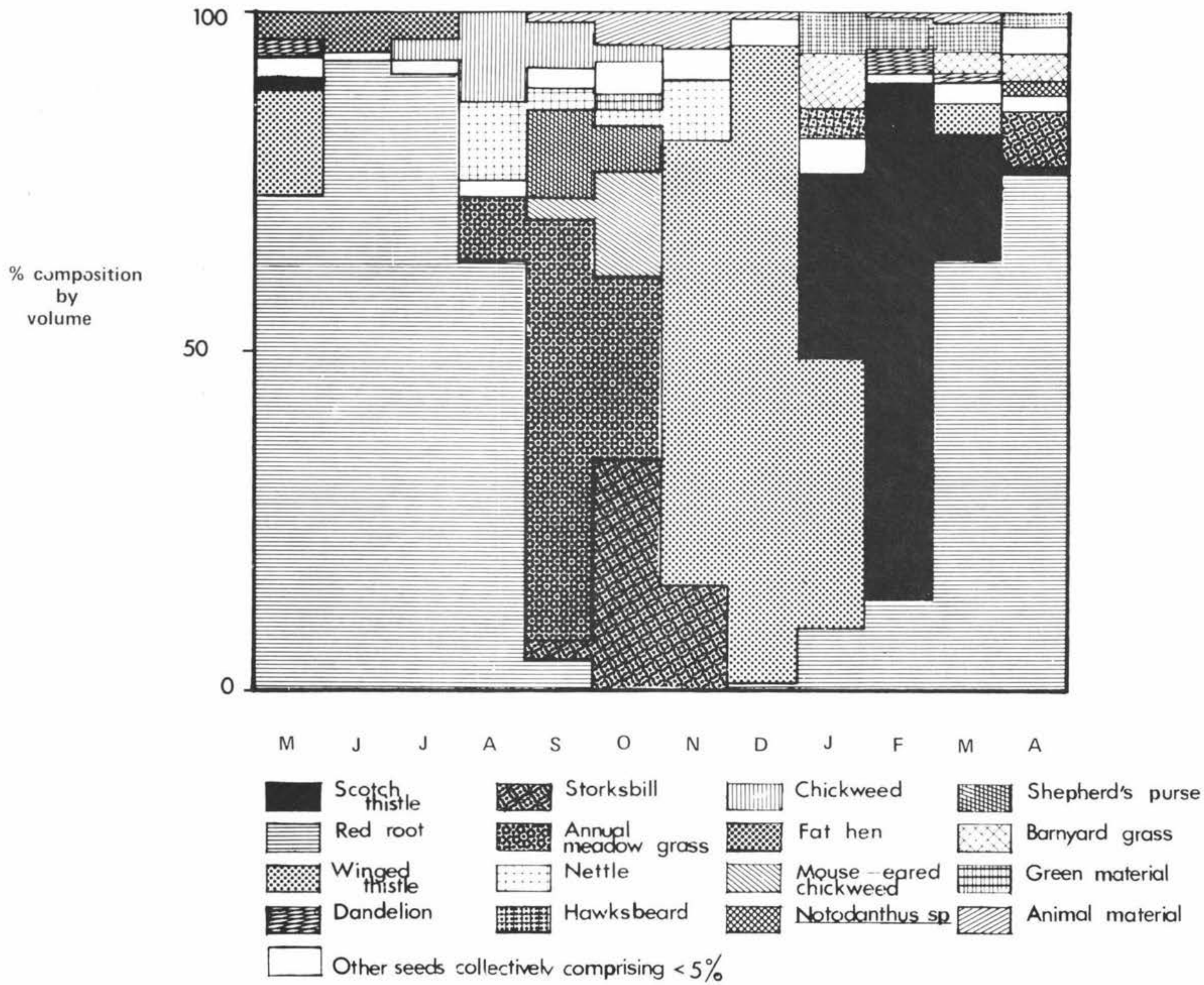


Figure 6 The stomach contents of adult goldfinches

TABLE 3

Percentage frequency of foods seen to be taken in the field by Goldfinches in the Havelock North study area. (Foods listed as far as possible in order of their appearance in the diet).

	A	S	O	N	D	J	F	M	A
No. of records *	1544	1528	864	227	44	256	678	616	710
Food (Common name)									
Annual meadow-grass	57.4	86.1	53.8						
Chickweed	15.0	0.1							
Red root	16.9				4.5	8.2	10.6	48.2	43.5
Fat hen	3.1								3.3
Groundsel	1.0	3.7	0.1						
Nettle	6.6	6.6	9.1	1.8					
Mouse-eared chickweed		0.7	0.2						
Dandelion		2.8	7.3					1.6	4.7
Storksbill			19.9	31.7					
Meadow foxtail			7.8	31.3	4.5				
Winged thistle			1.3	31.7	70.0				
Shepherd's purse			0.3						
Prickly Sowthistle				1.8	9.1	10.9		1.1	
Fog grass				1.3	6.8	1.6			
Cocksfoot					9.1	1.2			
Scotch thistle (Spear thistle)						78.1	89.0	44.8	48.5
Apple of Peru (Nicandra physaloides)							0.4	2.0	
Cats-ear (Hypochaeris radicata)								2.3	
Aphids			0.1	0.4					

*** One bird, one food = one record.**

time the frequency occurrence of these two foods was highest. It seems reasonable to assume that both foods were being taken together, but field observations did not confirm this. Table 3 also indicates aphids in the diet during October and November, but only in insignificant amounts. These figures represent only one sighting, in each of the two months, of a Goldfinch eating aphids off Malva parviflora (Mallow).

Newton (1967a) suggested a difference in feeding habits between male and female goldfinches and this was investigated. Figure 7 compares differences in the diet of the two sexes. In May when Amaranthus retroflexus and Carduus tenuiflorus (Winged Thistle) were both available, males utilised Winged Thistle in much greater quantities than females (22.4 percent and 5.8 percent by volume respectively). In June and July when no thistles were available the difference in diet was negligible. November, February and March showed a similar pattern to May.

Monthly mean body-weights of all goldfinches analysed are shown in Table 4. Appendix I indicates the significant difference in body-weights of male and females ($p < 0.001$). All birds were weighed before the crop and proventriculus contents were removed and as indicated in Figure 8, in most months, roosting goldfinches on average contained between 0.2 and 0.7 grams of food in these parts. If the average weight of contents for each month is subtracted from

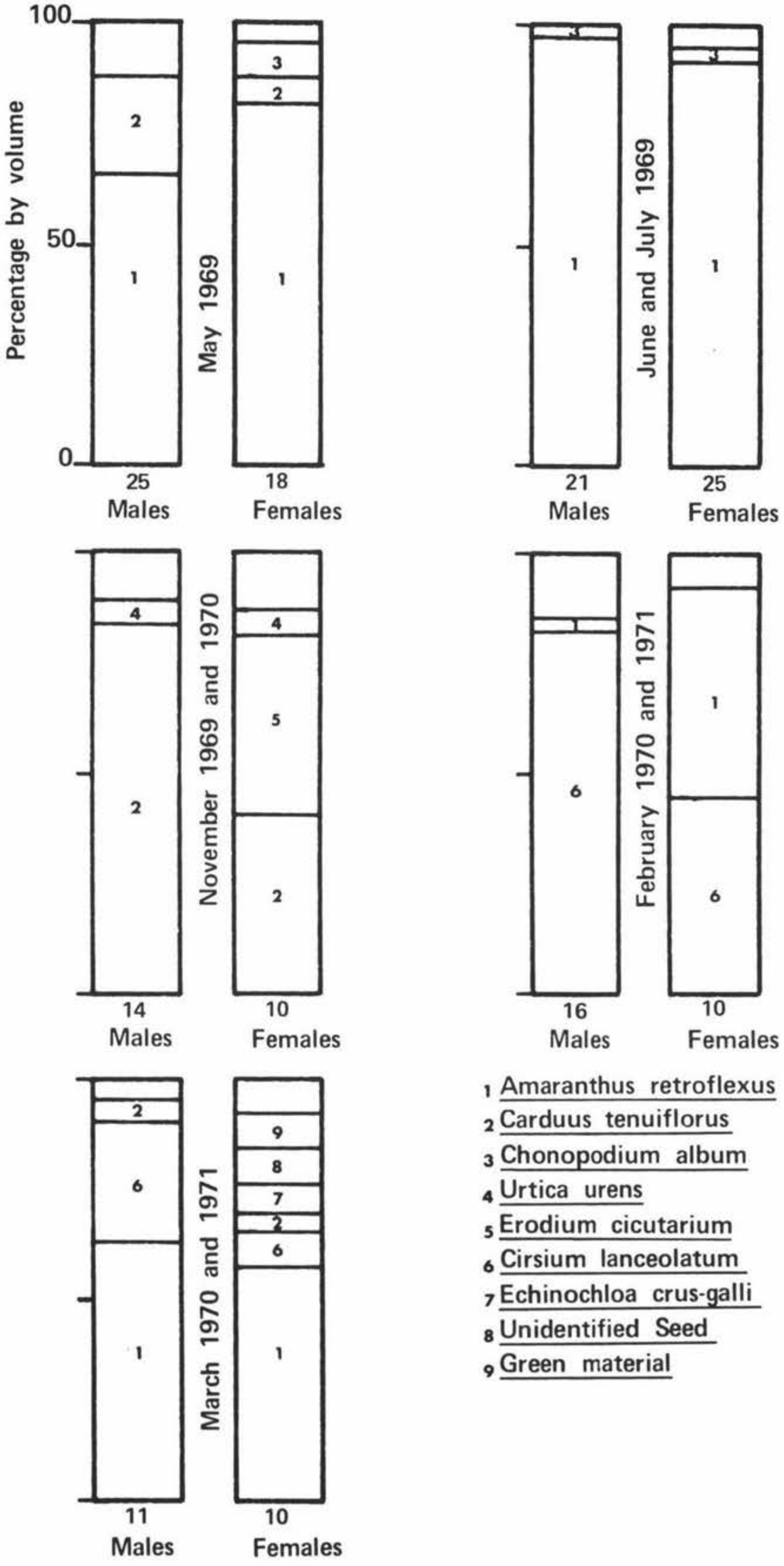


Figure 7 **Comparisons between the average crop contents of male and female goldfinches at different times of the year**

TABLE 4

MONTHLY MEAN BODY-WEIGHTS OF ADULT GOLDFINCHES
(grammes)

Month	No.of Males	Mean Weight	S.D.	No.of Females	Mean Weight	S.D.
May	29	16.34	0.92	21	15.24	0.68
June	24	15.26	0.67	27	14.43	0.68
July	5	16.10	0.42	5	14.80	0.45
Aug.	16	15.73	1.00	13	14.22	1.34
Sept.	13	15.50	0.89	13	14.73	1.17
Oct.	15	15.10	0.97	12	14.71	0.92
Nov.	13	15.48	1.20	10	15.50	1.63
Dec.	13	14.57	1.25	5	15.60	1.52
Jan.	21	15.45	0.93	6	15.18	0.71
Feb.	11	16.04	0.92	8	14.91	0.90
March	7	16.76	0.42	7	15.57	2.37
April	19	16.54	0.92	14	16.08	0.35
TOTAL :	186	15.64	1.57	141	14.89	1.64

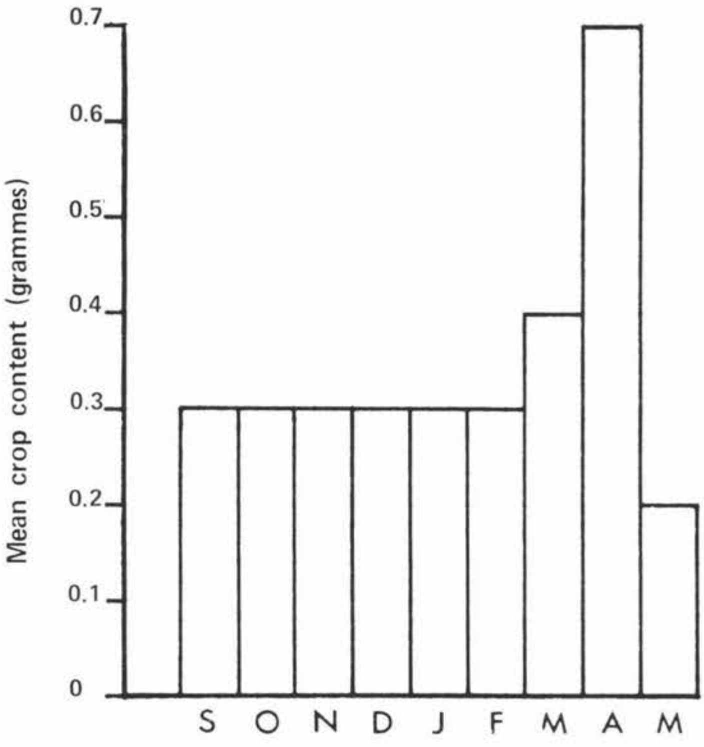


Figure 8 The average crop content weight of roosting goldfinches at Havelock North.

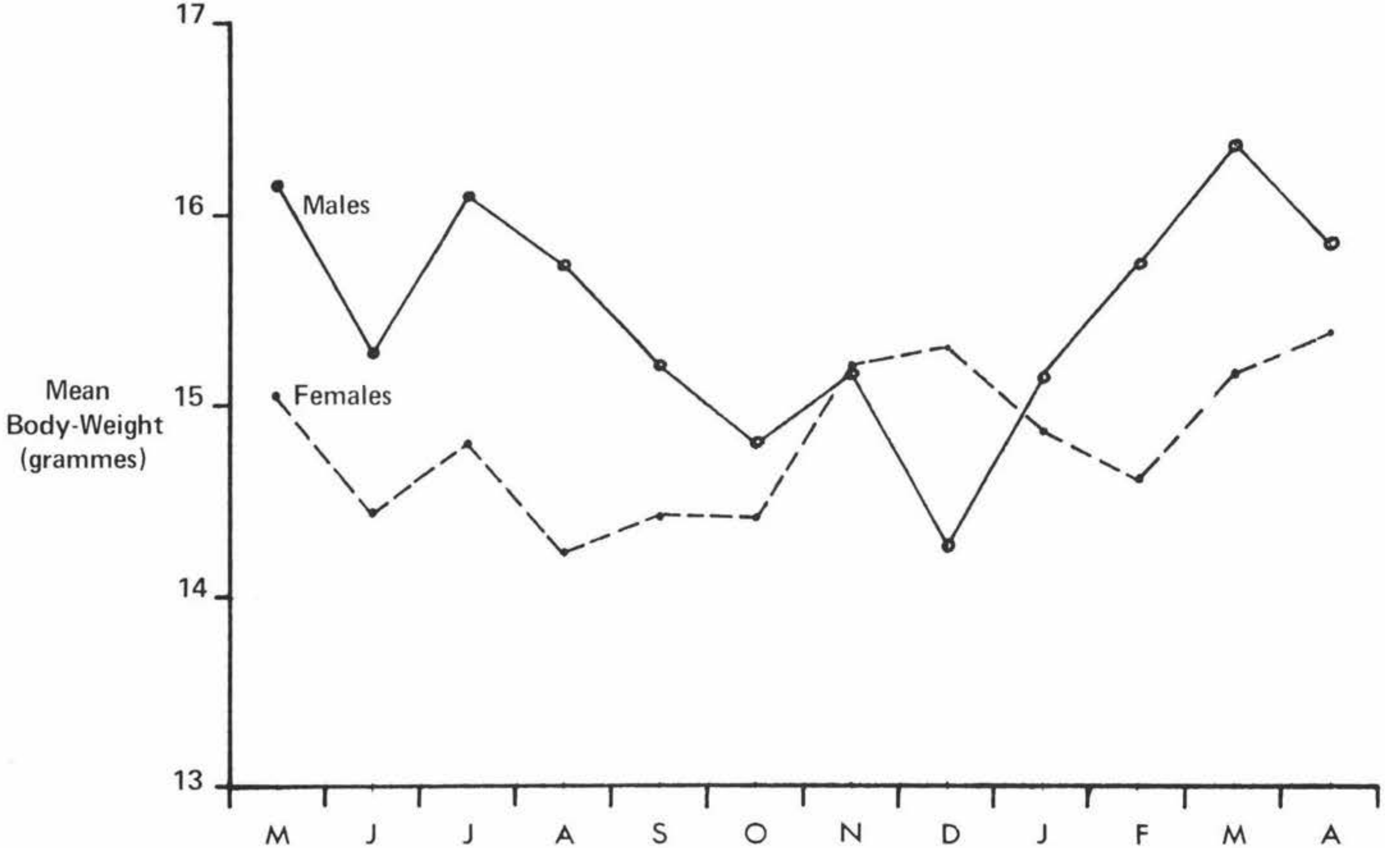


Figure 9 Changes in the mean body-weight of C. carduelis throughout the year (crop and stomach content weights subtracted.)

the mean monthly body-weight (Table 4), a reasonable assessment can be made of the change in body-weight throughout the year (Fig.9).

2.5 DISCUSSION

i) Sample Size.

Although small in some months, the stomach analysis samples are considered adequate to show changes in food habits over a 12-month period. Korschgen (1969) considers a sample size large enough when new samples add no significantly new information to that obtained from previous samples. The large number of observational samples taken in this study permit the conclusion that the analysed sampling results were reasonably close to what was actually being eaten. Also, as already mentioned, the 1970-1971 November to April samples closely resembled results from the previous year in all but one of the months. In April 1970 only three birds were shot and results showed, when compared with the observational data, that this sample was too small to be representative (Campbell,1970). However, in April 1971, 33 birds were shot and when both years' results were combined, the data appeared to be closely representative of the feeding habits evident at that time.

ii) Seasonal Changes in Diet.

The dietary pattern of the Goldfinch at Havelock North can be broadly described as follows. From March until the end of August Amaranthus retroflexus is predominant and then is replaced by Poa annua for all of September. During October Poa annua and Erodium cicutarium form the bulk of the diet, while Carduus tenuiflorus predominates during November and December. Both C.tenuiflorus and Cirsium lanceolatum (Scotch thistle) share dominance in January and then C.lanceolatum dominates during February. A.retroflexus again becomes available in March and so the annual dietary pattern begins once more. Figure 6 illustrates this seasonal variation and shows how the remainder of the diet is filled up by a larger number of food types usually found in smaller quantities.

iii) Animal Material.

Animal material did not form a large percentage by volume of the adult Goldfinch diet. However, aphids did form approximately five percent by volume in October and November. Table 1 indicates that 50 percent of the birds sampled in October contained aphids and 36 percent did in November. This increase during this time can possibly be explained by a number of factors. Firstly, Middleton(1965) suggests that the increase of aphids in the diet that he noted at Monash between September and January was probably related to nesting activity and more in particular, nestling diet. It is widely known that the nestlings of most species require a high protein diet (Welty,1964) but this is unlikely to be the only reason for the Havelock North sample. In both the 1969-1970 and 1970-1971 breeding season no nestlings were present until the beginning of November which means that the increase in frequency and volume of aphids in the diet appeared well before any nestling food was required. It must also be remembered that all adult birds sampled in October and November were shot at an evening roost and so food in the crop at this time was presumably for the survival of the adult through the night and was in no way connected to nestling diet requirements. Also aphids were most abundant in October and November and as already stated were associated with E.cicutarium which was an important plant food. The increase in their availability together with their association with an important food source seems to be a more likely reason for their percentage increase in the diet at this time.

It seems reasonable to assume that most of the animal material was only taken when found in association with a plant food source. For instance there was a definite association of aphids with E.cicutarium and Dugdale (pers.comm.) reports that the host plant of Tebenna bradleyi (Order Lepidoptera) is usually thistles and other hairy leafed compositae. This would account for its largest contribution to the diet during February and March when Scotch thistle was abundant in the study area. This is not the case, however, when adults are collecting the young nestling's food. Results in a later section clearly show that a different process is involved in the selection of food for the young than for the adult. The adult actively seeks animal material for the young nestling but appears to eat animal food itself only when it is associated with a seed food source.

iv) Preferred foods.

Certain foods did appear to be preferred by the Goldfinch and several factors may be responsible for indicating a food of high quality or preference. The most obvious factors are high frequency and high volume of the food. For instance both factors together indicate the importance of A.retroflexus in the Goldfinch diet. Winged thistle and Scotch thistle also fall into this category.

A high frequency value alone may also indicate a food of importance. Cerastium glomeratum (Mouse-eared chickweed) for instance was found in 67.8 percent of all adult goldfinches during October but because of its small size and relative scarcity formed only 15.9 percent of the diet by volume (Tables 1 and 2). For instance, C.glomeratum is a much smaller seed than either E.cicutarium or P.annua; the latter two each forming a similar frequency in the diet but a much larger percentage by volume. This can be explained by the fact that not only did E.cicutarium or P.annua have larger seeds but they were much more abundant as a food supply. Taraxacum officinale (Dandelion) is another example of this. In December, 12 out of the 20 birds sampled contained T.officinale and yet at the same time it comprised only 0.2 percent of the diet by volume. T.officinale was never abundant throughout the study area.

The presence of Dandelion in the diet in all but three of 12 months is another factor which indicates it is a highly preferred food. Apart from A.retroflexus it was found present in more months than any other food type.

However, it is indeed quite possible for a seed to be present in a birds diet almost continuously throughout its seeding period and yet still not be regarded as a preferred food of that bird. Chenopodium album (Fathen), for instance, was present in the diet from May until September and in May was found in 14 of the 43 birds sampled. Yet because it was so prevalent throughout the study area during this time it cannot be classified with T.officinale as a preferred food. T.officinale was scarce in comparison.

The fourth factor which may indicate a food of high quality or preference is when all available supplies of a fairly scarce seed type are fully utilised. Senecio vulgaris (Groundsel) was found in only 6 of the 29 birds sampled in September and formed 3.1 percent by volume of the diet (Tables 1 and 2). However, field observations indicated that all available supplies were taken immediately they became available. This would indicate that if larger amounts of S.vulgaris were present it would probably have formed a much larger proportion of the diet. This latter factor shows the importance of field observations in association with laboratory analyses.

v) Sex differences in Diet.

Sex differences in diet have been demonstrated in a number of birds, namely; in the extinct New Zealand Huia Heteralocha acutirostris (Buller,1888); the Galapogos finch Certhidea olivacea (Lack,1945); the Boat-tailed Grackle Quiscalus quiscula (McIlhenny,1937); the Sparrow-Hawk Accipiter nisus (Tinbergen, 1946); captive zebra-finches Tarniapygia sp. (Morris,1955); the Black-faced

Dioch Quelea quelea (Ward,1965); the Great Tit, Parus major (Hinde,1952); and in the Redstart, Phoenicurus phoenicurus (Buxton,1950).

At Oxford, Newton (1967a) found that beaks of male goldfinches averaged 1mm (9%) larger than those of females and this enabled males to reach Dipsacus fullonum (Teasel) seeds more easily. At Havelock North beaks of males averaged 0.8mm (7.4%) larger than those of females. Newton observed that two captive female goldfinches sometimes fed on teasel heads but before inserting their bills they first had to turn down the surrounding spikes and this meant that, on an average, they obtained only one seed to every four obtained by the larger-billed males. Teasel was not found at Havelock North but presumably if there was any noticeable difference in the feeding habits of male and female goldfinches it would probably be most apparent in those months where thistle seeds formed a large percentage of the diet. Thistle seeds are the only food source utilised which are found deeply hidden in a prickly seed head. To properly demonstrate sexual preferences in the diet, food sources, other than thistle seeds, must be readily available to provide an alternative food supply for the shorter-billed females.

Results in Figure 7 have shown that when the above conditions are present a slight difference in feeding habits does occur. Large seeds provide more food per unit time and it would seem that the male bird may have an advantage over the female in that they are able to utilise the thistle supply more efficiently. In

November, a difference in feeding habits could well be of benefit to both sexes. It is likely that competition between the sexes over E.cicutarium is reduced as the fresh crop of C.tenuiflorus becomes available. Because of this difference in feeding habits between the sexes, the overall dietary pattern shown in Figure 6 could well be affected to a smaller or greater degree depending on the numbers of males or females in the monthly samples. In the four months showing the slight difference in diet (Fig.7), males made up 58% of the sample numbers which means that a small bias towards male food preferences may have been incurred for the months of May, November, February and March.

vi) Quantity of Food Eaten.

It has not been possible to determine the amount of food consumed daily by wild goldfinches. Korodi and Nagy (1965/66)found that at 20°C, Carduelis carduelis required 10.7% of its body-weight daily as food. Throughout most of the year the mean body-weight of goldfinches (both sexes considered) is about 15.2 gm, which means an expected consumption of approximately 1.6 gm of food per day. Odum and Major (1956) found that White-throated Sparrows Zonotrichia albicollis at 20°C took approximately 500 cals./gm. body-weight per day of seed food and if goldfinches metabolise in a similar fashion they would be expected to consume some 7,600 cals.per day. Kendeigh and West (1965) give Amaranthus retroflexus an energy value of 4623 cals.per gm/dry-weight and this again amounts to approximately 1.6 gm of seed required per day. It thus seems probable that goldfinches, at least in the summer season, consume approximately 1.6 gm of food per day and probably increase during the colder winter months. (Korodi and Nagy 1965-1966 mention that at 0°C both the food requirements and efficiency of its use increased slightly in C.carduelis).

The only quantitative estimates of diet were made from the amount of food in the birds' crops when they came into roost. This raises the problem that the sample may not be completely representative of the daily diet. However, there is a noticeable absence (Table 2) of food in the crops of birds shot away from the roost (June, July and August). The emptying of the digestive tract during the night and the subsequently rapid passage of food through the gut during most of the following day would explain this. However, just prior to roosting, most birds were able to fill their crop. Consequently crop analysis tended to reflect food consumed in the latter part of the day only but direct field observation suggested little difference in the diet at different times of the day.

The average crop contents of roosting birds remained fairly constant except during April. This increase cannot easily be explained. There was no sudden increase in the availability of any preferred food and if this increase was connected with the onset of flocking then May crop contents should have also showed a corresponding increase. On the contrary, crop contents in May dropped to average only 0.2 gm (Fig.8).

vii) Changes in Body-Weight.

Throughout most of the year weight differences between the sexes averaged about 0.75 gm except during the breeding season when females weighed approximately the same or even heavier than males. Generally the weights are low at the end of the breeding season, reach their maximum in March, April and early May, and then begin to drop in June and continue to do so until December in the case of males and October in the case of females. Lack (1966) records that this type of cyclic change in body-weight is characteristic of seed eating birds and explains the loss of weight in winter as due to seeds becoming scarce around mid-winter and few fresh supplies of seeds being produced before October. As already mentioned food seeds were present throughout the winter at Havelock North but fresh supplies did not appear until E. cicutarium seeded in early October.

During breeding time the increase in female weight is probably due to one main factor. Most of the females shot in November, December and January were involved in egg laying and contained several eggs at different stages of development. This resulted in a marked increase in weight. On the other hand, the loss of weight suffered by males during this same period was probably due to a greater amount of strain imposed upon them during this period. Feeding of the young and the incubating female together with protection of the nest site is a time consuming task. Nice (1964) found a similar drop in weight in the male Song Sparrow (Melospiza melodia) at this time. Heydweiller (1935) found an even greater loss with the male Tree Sparrow (Spizella a. arborea) in

Manitoba.

It seems fairly safe to conclude that body-weights at Havelock North do bare some reflection on food resources present throughout the year but in the author's opinion food seeds were never scarce at any time. Research involving calculations of body-weight versus time spent feeding would probably produce some interesting results, i.e. it would appear that body-weight increases or decreases according to the time available to the adult to find food for itself.

viii) Comparison with other Goldfinch Food Habit Studies.

A review of previous literature shows that the Goldfinch has adapted to a large number of food sources. Of the important food types in the Havelock North study, Newton (1967a) England, Sokolowski (1962) Poland, and Eber (1956) Germany, make no mention of A.retroflexus. It is known that A.retroflexus is a native of tropical America and is much more abundant in New Zealand than in England or the European continent. Middleton (1965) Australia, observed many goldfinches feeding on Amaranthus sp. on the campus at Monash University but he does not record it being present in the crops and gizzards of the 240 goldfinches he analysed. Harper (1969) Christchurch, New Zealand, observed the diet of the Goldfinch in the south Christchurch region from April to September and it seems interesting that he makes no mention of Amaranthus sp. either in his observations or in the 15 birds he analysed.

Of the other important food sources, P.annua appears to be more important in Australia and New Zealand than in either England or the Continent. It appears to have been abundant in all four study areas used.

Thistle seeds are important in all previous studies. E.cicutarium does not appear in the diet either in England, the Continent or Australia and yet forms almost one-third of the diet by volume during October alone at Havelock North. The author also observed large amounts of E.cicutarium taken by goldfinches on the Massey University campus during October and November 1971.

Aphids appear to be the most common animal food source throughout the goldfinches range. Newton (1967) lists them as forming 16 percent of the diet at Oxford during April which corresponds to their peak occurrence during October at Havelock North. (April in the temperate latitudes of the Northern Hemisphere being directly comparable to October in the temperate latitudes of the Southern Hemisphere). Aphids also formed the greatest percentage of the adult insect food in Australia (Middleton,1965).

Middleton (1970) makes mention of the noticeable absence of tree seeds in the diet in Australia. This also appears to be true in New Zealand. European authors report the seeds of Birch Betula, Alder Anus and Pine Pinus as regular items in the diet (Witherby et al 1938; Fitter 1945; Eber 1956; Newton 1967a). In Australia, Middleton suggests that these tree seeds are replaced by seeds of the Compositae which he says are available throughout the year. In New Zealand A.retroflexus and E.cicutarium appear to take their place.

The several points arising from this comparison are worthy of note. Firstly, it appears that certain foods are strongly preferred to others, so that seasonal changes in the diet cannot be attributed wholly to changes in the relative abundance of the different food-plants in the study area. For instance both at Oxford and Havelock North C.album was one of the commonest food-plants in the study area and yet the preferred A.retroflexus (Havelock North), thistle seeds or T.officinale always appeared to be utilised ahead of C.album, even when found in much smaller amounts.

Secondly, this study shows that the feeding habits of the Goldfinch in New Zealand are essentially the same as in its ancestral Europe. Certain differences do exist but most of these can be explained by differences in the availability of the various plant-foods. Perhaps the most significant difference is the change in the food types used in winter; tree seeds together with Dipsacus and Arctium spp. in its ancestral areas have been replaced by A.retroflexus, P.annua and E.cicutarium in New Zealand.

C. FOOD OF THE NESTLING GOLDFINCH

As previously mentioned, the aims of this section of the study were as follows:

(1) To examine the diet of the Goldfinch nestling during the 1970-1971 breeding season.

(2) To investigate Newton's (1967a) statement that "the proportion of invertebrates given declines with increasing age of the young. After about the tenth day the young often receive seeds only".

(3) To investigate the process involved in selection of food for the young.

(4) To determine if there was any significant difference in the percentage animal protein fed to nestlings within two separate breeding blocks. Block A was bordered on one side by large numbers of deciduous trees supporting a plentiful supply of animal protein. Block B was surrounded by other orchards with less animal protein available.

(5) If a significant difference between the two blocks did exist then did this produce any significant difference in growth rates of broods concerned.

(6) To determine if there was any significant difference in the diet of broods reared in early mid and late periods of the breeding season.

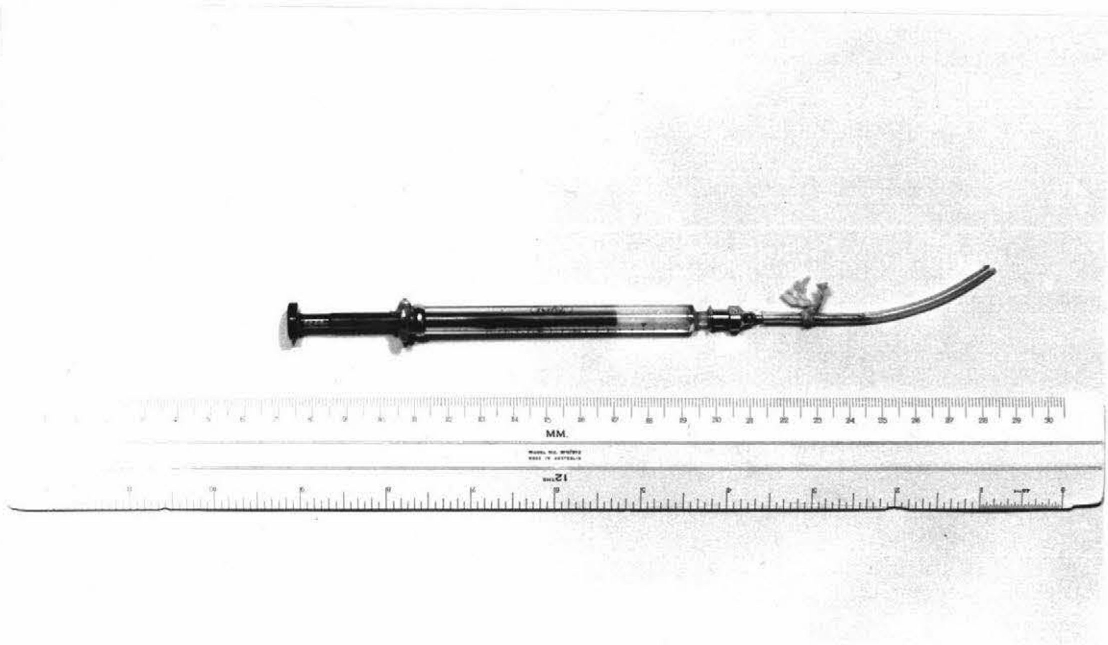
2.6 METHODS

The nestling goldfinches are fed by regurgitation and receive large, but infrequent, meals which they store in their gullet. The food is not digested appreciably beforehand. Food of the nestling was examined through the transparent skin of the neck, without harming the birds, by manipulating the gullet between thumb and finger (after Newton 1967b). Each gullet containing food was scored as ten and its contents as tenths of the whole. Each tenth was considered to be one food unit. Twenty-two nestlings were killed and gullet contents examined thoroughly to check on the accuracy of this observational method. Also when food items of older nestlings were unidentifiable through the skin, a small plastic tube (2 m.m.diameter) attached to a 1 c.c.syringe was inserted into the gullet and the contents withdrawn (Fig.10). There were no observable harmful effects and this was not attempted in any nestlings before their fourth day. Any unidentifiable food in young nestlings was described as accurately as possible and when later found in an older nestling it was withdrawn and identified in the laboratory.

Hatching dates of individual nestlings in each brood were recorded and the daily age of each brood was taken to be the mean age of the nestlings at the time of each recording. Nestlings were visited daily. Day one was considered to be all broods with a mean age between 0 and 24 hours. Day 2, all broods which had entered their second 24 hour period. Most eggs normally hatched within 24 hours of each other which meant that there was little difference in the age of nestlings in any one brood. When a new nest containing nestlings was found, the age of the brood was approximated from an age table based on stage of plumage and mean daily weight increase for each brood size. This was compiled early in the season and needed no alterations as the season progressed. The daily total weight for each brood was measured on a Pesola 100 gm spring scales.

For convenience in analysis, the breeding season was divided into three groups of five 10-day periods. All broods in which the first egg was laid from the start of the season until 26 November are referred to as 'early', those from the 27 November until 15 January

FIGURE 10. Syringe (1 c.c.) and plastic tubing (2 m.m.diameter).



as 'mid',and those from the 16 January onwards as 'late'.

2.7 RESULTS

A total of 4647 nestling diet observations were made and of these 1331 were empty. Tables 5 and 6 record the percentage frequency occurrence and percentage composition by volume of food for each age interval in the diet of nestlings in Block A. Tables 7 and 8 show the same for Block B. Table 9 records the percentage composition by volume of the diet over the whole breeding season. Figure 11 illustrates the occurrence and importance of the main food types. Results of the 22 nestlings analysed in the laboratory are shown in Table 10. Results indicate that the observational method was not accounting for the presence of some of the smaller grass seeds such as Holcus lanatus (Yorkshire fog). Alopecurus pratenis (meadow foxtail) and the small seeds of the compositae, Crepis capillaris (hawksbeard). This means that the frequency of occurrence would be somewhat greater for the smaller sized seeds than that recorded in Tables 5 and 7. The relative volumes changed very little.

Figures 12 and 13 indicate the percentage volume of animal protein for Blocks A and B. In Block A animal protein formed 11.5 percent by volume of the total food consumed and in Block B only 2.2 percent. Appendix II shows this difference to be significant at the 99% probability level. Figure 14 compares nestling development in the two blocks and it is evident that there was no difference in development rates.

The variation in diet between early, mid and late broods was considerable (see Fig.11). Early broods for

TABLE 5

Percentage frequency occurrence of foods in the diet of nestling goldfinches, Block A; Havelock North. 1970–71 breeding season.

Food: Common name	Food: Specific name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nestling age (days)		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
No. of nestlings recorded with some food in gullet		**11**	**57**	**84**	**109**	**104**	**118**	**106**	**92**	**114**	**111**	**96**	**79**	**77**	**52**	**21**	**7**
Winged thistle	Carduus tenuiflorus	54.5	29.8	47.6	38.5	37.5	44.9	50.9	52.1	59.6	63.9	71.8	54.4	74.0	67.3	52.3	85.7
Dandelion	Taraxacum officinale	9.0	38.5	54.7	46.7	47.1	63.5	62.2	42.3	57.0	42.3	56.2	58.2	29.8	48.0	38.0	28.5
Scotch thistle (Spear thistle)	Cirsium lanceolatum	27.2	29.8	20.2	27.5	29.8	31.3	23.5	30.4	21.9	25.2	23.9	18.9	12.9	15.3	23.8	
Cocksfoot	Dactylis glomerata			4.7	1.8		7.6	6.6	4.3	4.3	3.6	7.2	5.0		3.8		
Dovesfoot	Geranium molle				1.8		0.8	1.8	5.4	3.5	3.6	4.1	5.0	1.2			
Storksbill	Erodium cicutarium		3.5			0.9	0.8			0.8							
Hawksbeard	Crepis capillaris			1.1	5.5		5.0		1.0	2.6	3.6	1.0	1.2	1.2			
Nettle	Urtica urens		1.7	1.1	1.8	2.8	1.6					2.0	5.0				
Red root	Amaranthus retroflexus		3.0		4.5	0.9	0.8			9.6	4.5	3.1	2.5	1.2	23.0	9.5	14.2
Barnyard grass	Echinochloa crus-galli							0.9	3.2			1.0					
	Puccinellia fasciculata														5.7		
Wild turnip	Brassica campestris				1.8												
Unidentified seeds (4 types)			1.7	2.3		8.6	4.2	4.7	6.5	6.1	3.6	3.1	7.5	2.5	3.8	4.7	
Green material		18.1	1.7	9.5	16.5	16.3	35.5	31.1	32.6	32.4	32.4	15.6	30.3	24.6	21.1	19.0	42.8
Aphids	Fam. Aphididae	9.0	12.2	22.6	41.2	26.9	16.1	17.9	17.3	14.0	10.8	3.1	3.7	2.5	3.8	14.2	
Willow sawfly (larvae)	Pontania proxima		19.2	15.4	11.0	19.2	23.7	16.9	11.9	7.8	9.9	3.1	1.2				
Cecids (larvae)	Fam. Cecidomyiidae					1.9	4.2	10.3	1.0	2.6	1.8						
Leaf tiers (pupae)	Tebenna bradleyi							0.9									
Long-horned Leaf-miner (larvae)	Fam. Lyonetiidae		1.7		1.8	2.8	2.5	1.8		3.5		1.0					
Noctuids (larvae)	Heliothis armigera			2.3		0.9	0.8	1.8	5.4		0.9	1.0	1.2			4.7	
Unidentified animals (3 types)			3.5									2.0					
Roughage			1.7		7.8	10.5	5.0	12.2	3.2	8.7	5.4	6.2	10.1	7.7	1.9	9.5	
Faecal material				2.3		1.9	1.6										

TABLE 6

Percentage composition by volume of foods in the diet of nestling goldfinches, Block A; Havelock North. 1970–71 breeding season.

+ = food less than 0.1 percent by volume

Food: Common name	Food: Specific name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nestling age (days)		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
No. of nestlings recorded with some food in gullet		**11**	**57**	**84**	**109**	**104**	**118**	**106**	**92**	**114**	**111**	**96**	**79**	**77**	**52**	**21**	**7**
Winged thistle	Carduus tenuiflorus	46.4	23.1	28.6	27.5	21.7	23.2	31.5	37.4	40.8	46.2	49.6	39.4	64.6	57.9	45.2	84.3
Dandelion	Taraxacum officinale	8.1	29.3	35.0	20.5	23.0	26.4	29.3	21.6	29.3	26.1	20.3	26.6	18.7	27.5	28.6	12.9
Scotch thistle (Spear thistle)	Cirsium lanceolatum	27.3	20.2	14.9	15.6	19.0	18.0	14.5	21.1	11.9	11.2	16.8	13.2	9.7	7.5	12.9	
Cocksfoot	Dactylis glomerata			0.8	0.4		0.6	1.2	0.3	0.5	0.4	1.1	1.4		0.8		
Dovesfoot	Geranium molle				0.4		0.1	0.2	0.2	0.5	0.8	0.3	0.2	+			
Storksbill	Erodium cicutarium					+	0.1			0.2							
Hawksbeard	Crepis capillaris		0.4	0.4	1.4		1.5		+	0.4	1.1	0.2	0.3	+			
Nettle	Urtica urens		1.6	0.2	0.4	0.4	0.3					1.2	4.3				
Red root	Amaranthus retroflexus		0.4		0.9	+	+			1.1	0.3	0.9	+	+	1.3	1.0	1.4
Barnyard grass	Echinochloa crus-galli							0.8	1.1			1.0					
	Puccinellia fasciculata														0.8		
Wild turnip	Brassica campestris				0.2												
Unidentified seeds (4 types)			0.3	0.5		5.3	3.7	4.1	5.5	1.3	4.0	1.6	4.1	2.6	0.3	4.2	
Green material		17.3	1.4	1.8	2.5	4.2	7.1	4.5	5.4	5.6	5.7	4.4	8.0	3.7	3.5	2.9	1.4
Aphids	Fam. Aphididae	0.9	7.5	10.1	21.7	13.4	4.6	3.6	2.3	5.1	2.1	1.8	0.6	0.1	+	+	
Willow sawfly (larvae)	Pontania proxima		13.2	6.3	7.1	8.4	12.0	7.4	4.5	2.4	1.6	0.3	0.8				
Cecids (larvae)	Fam. Cecidomyiidae					0.7	0.3	0.6	+	0.2	+						
Leaf tiers (pupae)	Tebenna bradleyi							0.1									
Long-horned Leaf-miner (larvae)	Fam. Lyonetiidae		0.5		0.3	0.7	1.1	0.2		0.3		0.1					
Noctuids (larvae)	Heliothis armigera		1.9									0.2					
Unidentified animals (3 types)				1.3		0.2		0.4	0.3		0.1		0.1			3.3	
Roughage			0.2		1.1	1.1	0.6	1.6	0.3	0.3	0.4	0.1	1.0	0.5	0.4	1.9	
Faecal material				+		1.9	0.3										
Percentage animal food		0.9	23.2	17.7	29.1	23.4	18.0	12.3	7.1	8.0	3.8	2.4	1.5	0.1	+	3.3	
Percentage plant food		99.1	76.8	82.2	70.9	76.6	81.9	87.7	92.9	91.9	96.2	97.5	98.5	99.8	100.0	96.7	100.0
No. of food units recorded		110	570	840	1090	1040	1180	1060	920	1140	1110	960	790	770	520	210	70

TABLE 7

Percentage frequency occurrence of foods in the diet of nestling goldfinches, Block B; Havelock North. 1970–71 breeding season.

Nestling age (days)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
No. of nestlings recorded with some food in gullet		15	61	139	162	189	196	187	183	194	188	153	150	113	98	42	8
Food: Common name	Food: Specific name																
Winged thistle	*Carduus tenuiflorus*	53.3	49.1	55.3	59.8	56.6	52.5	51.3	55.1	58.2	60.1	62.0	66.6	52.2	53.0	59.5	73.7
Dandelion	*Taraxacum officinale*	33.3	31.1	33.0	25.3	38.6	47.4	29.9	40.4	35.0	34.0	24.8	26.0	22.1	14.2	14.2	5.0
Scotch thistle (Spear thistle)	*Cirsium lanceolatum*	13.3	31.1	38.1	40.7	43.9	45.4	48.6	53.5	45.3	43.0	44.4	44.6	47.7	47.9	38.0	21.2
Cocksfoot	*Dactylis glomerata*	6.6	3.2	8.6	1.2	3.7	4.0	2.1	3.2	3.0	4.2	2.6	0.6				
Dovesfoot	*Geranium molle*					0.5	1.0		0.5								
Storksbill	*Erodium cicutarium*		4.9	5.7		0.5	0.5	4.2	1.6								
Hawksbeard	*Crepis capillaris*		1.6		3.0	4.2	5.6	0.5	2.1			0.6	0.6				
Nettle	*Urtica urens*				1.2	0.5											
Red root	*Amaranthus retroflexus*			0.7	1.8	2.6	1.5	2.6	6.5	4.1	4.2	7.8	2.6	7.9	2.0		
Californian thistle	*Cirsium arvense*											1.3					
Mouse-eared chickweed	*Cerastium glomeratum*							0.5									
Unidentified seeds (3 types)				1.4	1.8	0.5	1.0	1.0	0.5	0.5	0.5	2.6		5.3	1.0		
Green material			6.5	7.9	9.2	17.9	38.7	37.9	40.4	38.1	52.6	49.0	40.6	48.6	32.6	40.4	
Aphids	Fam. Aphididae		8.1	5.7	16.6	5.8	7.1	5.3	6.0	1.0	1.0	1.3	2.6		1.0	4.7	
Cecids (larvae)	Fam. Cecidomyiidae		1.6			1.0	1.0		1.0	2.0	0.5			3.5			
Spiders	Order Araneae			1.4			0.5	0.5		0.5		0.6					
Leaf tiers (pupae)	*Tebenna bradleyi*					0.5	2.5	1.0	0.5	1.5	0.5		0.6				
Long-horned Leaf-miner (larvae)	Fam. Lyonetiidae			0.7	1.8	2.6	3.0	0.5	1.0	1.0	0.5		0.6				
Noctuids (larvae)	*Heliothis armigera*				1.2	1.0	2.5	1.6	1.0	1.0	1.0	0.6			1.0		
Unidentified animals (2 types)				4.9	3.0	2.0	1.0	2.6	7.0	3.0	1.5	0.6	1.3	2.6			
Roughage			3.2	2.1	1.2	9.5	7.1	6.4	11.4	8.2	6.9	9.8	6.0	4.4	2.0	11.9	
Faecal material							1.5		1.0								

TABLE 8

Percentage composition by volume of foods in the diet of nestling goldfinches, Block B; Havelock North. 1970–71 breeding season

+ = food less than 0.1 percent by volume

Food: Common name	Food: Specific name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nestling age (days)		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
No. of nestlings recorded with some food in gullet																	
Winged thistle	Carduus tenuiflorus	50.1	41.3	40.5	46.1	39.0	34.6	39.4	34.0	43.7	46.9	49.5	50.7	43.5	51.0	54.8	73.8
Dandelion	Taraxacum officinale	33.3	20.9	16.7	11.7	14.2	19.2	14.9	12.3	14.0	10.1	5.0	4.8	6.8	4.6	5.5	5.0
Scotch thistle (Spear thistle)	Cirsium lanceolatum	13.3	25.3	31.3	30.0	32.3	31.0	35.7	37.4	34.1	31.2	34.3	36.1	36.5	36.4	33.0	21.2
Cocksfoot	Dactylis glomerata	3.3	1.3	3.0	0.1	1.4	0.2	0.2	1.3	0.6	0.2	0.3	+				
Dovesfoot	Geranium molle					0.1	0.1		+								
Storksbill	Erodium cicutarium		3.0	1.0		+	0.1	0.8	0.3								
Hawkesbeard	Crepis capillaris		0.3		0.7	2.4	2.6	0.1	0.2			+	+				
Nettle	Urtica urens				0.2	0.1											
Red root	Amaranthus retroflexus			+	0.6	1.5	0.3	1.0	1.1	0.6	0.9	0.6	0.2	2.1	0.2		
Californian thistle	Cirsium arvense											0.1					
Mouse-eared chickweed	Cerastium glomeratum							+									
Unidentified seeds (3 types)				0.7	1.0	0.1	0.5	0.1	0.1	+	0.1	0.2		0.7	0.8		
Green material			2.8	3.0	1.8	3.3	7.7	5.9	8.6	5.3	9.5	9.2	7.2	10.1	6.5	5.0	
Aphids	Fam. Aphididae		3.3	1.1	6.0	1.2	1.8	1.0	2.0	0.1	0.3	+	0.2		0.1	0.5	
Cecids (larvae)	Fam. Cecidomyiidae		0.2			0.1	+		+	+	+			0.2			
Spiders	Order Araneae			0.1			+	+		+		+					
Leaf tiers (pupae)	Tebenna bradleyi					0.1	0.3	0.1	+	0.7	+		+				
Long-horned Leaf-miner (larvae)	Fam. Lyonetiidae			0.1	1.0	1.0	0.5	0.1	0.3	0.1	0.1		+				
Noctuids (larvae)	Heliothis armigera				0.1	0.3	0.2		0.1	0.2	0.1	+			0.1		
Unidentified animals (2 types)				2.3	0.6	1.3	0.2	0.3	0.9	0.3	0.3	0.1	0.3	+			
Roughage			1.6	0.2	0.1	1.3	0.7	0.3	1.1	0.3	0.3	0.7	0.5	0.1	0.3	1.2	
Faecal material							+		0.3								
Percentage animal food			3.5	3.6	7.7	4.2	3.0	1.6	3.3	1.4	0.8	0.1	0.5	0.2	0.2	0.5	
Percentage plant food		100.0	96.5	96.4	92.3	95.8	97.0	98.4	96.7	98.6	99.2	99.9	99.5	99.8	99.8	99.5	100.0
No. of food units recorded		150	610	1390	1620	1890	1960	1870	1830	1940	1880	1530	1500	1130	980	420	80

TABLE 9

Percentage composition by volume of foods in the diet of nestling goldfinches for early, mid and late broods, 1970–71 breeding season

+ = food less than 0.1 percent by volume

	Block A			Block B		
	Early	Mid	Late	Early	Mid	Late
No. of nestlings recorded with some food in crop	**416**	**613**	**209**	**377**	**1,379**	**322**
Food						
Carduus tenuiflorus	52.0	39.1	1.8	79.1	40.3	12.3
Taraxacum officinale	26.0	25.0	25.2	9.0	12.6	13.6
Cirsium lanceolatum		14.6	46.4		36.7	57.5
Dactylis glomerata	0.6	0.8		0.9	0.7	
Erodium cicutarium	0.1	+		1.1	0.1	
Crepis capillaris	0.5	0.6	+	1.2	0.3	0.8
Urtica urens	1.7			0.1	+	
Echinochloa crus-galli			1.4			
Amaranthus retroflexus		0.6	0.4		0.5	2.6
Puccinellia fasciculata		0.1				
Geranium molle	0.7			0.1		
Cirsium arvense					+	
Brassica sp.			0.1			
Cerastium glomeratum					+	
Unidentified seeds (2 types)	0.5	2.5	8.0	0.2	0.3	0.5
Green material	5.5	4.2	4.7	4.9	6.4	7.4
Fam. Aphididae	7.3	6.1	2.3	2.8	0.8	1.3
Pontania proxima (larvae)	4.1	5.0	6.4			
Fam. Cecidomyiidae (larvae)		0.2	0.3		+	+
Tebenna bradleyi (pupae)			+		0.1	0.3
Heliothis armigera (larvae)		+			0.1	
Fam. Lyonetiidae (larvae)		0.2	1.0		0.1	1.5
Order Araneae				0.1		
Unidentified animal material	0.5	0.1	0.8	0.3	0.4	1.2
Faecal material	+	0.3	0.2	+	+	0.2
Roughage	0.5	0.6	1.0	0.2	0.6	0.8
Percentage animal	11.9	11.6	10.8	3.2	1.5	4.3

TABLE 10

COMPARISON OF GULLET CONTENTS OF NESTLINGS OBSERVED IN THE FIELD AND THEN ANALYSED IN THE LABORATORY.

+ = less than 0.1 percent by volume

No.of Nestlings Food	Observed 22 % Freq.	 % Vol.	Analysed 22 % Freq.	 % Vol.
Erodium cicutarium			4.5	0.1
Cirsium vulgare	36.3	22.2	45.4	22.4
Carduus tenuiflorus	59.0	42.7	59.0	41.5
Taraxacum officinale	36.3	10.0	36.3	8.2
Holcus lanatus			4.5	+
Alopecurus pratensis			4.5	+
Cerastium glomeratum	4.5	0.9	9.0	0.2
Crepis capillaris			13.6	+
Echinochloa crus-galli	9.0	5.4	9.0	6.2
Green material	50.0	5.4	54.5	4.6
Unidentified seed			9.0	0.6
Roughage	13.6	1.8	13.6	1.6
Fam.Aphididae	13.6	2.2	27.2	1.2
Pontania proxima (larvae)	13.6	5.9	18.1	7.8
Fam.Lyonetiidae (larvae)	9.0	1.7	13.6	2.1
Tebenna bradleyi (larvae)	4.5	1.8	4.5	3.1
Tebenna bradleyi (pupae)	4.5	+	9.0	0.4
Unidentified animal material	4.5	+	4.5	+

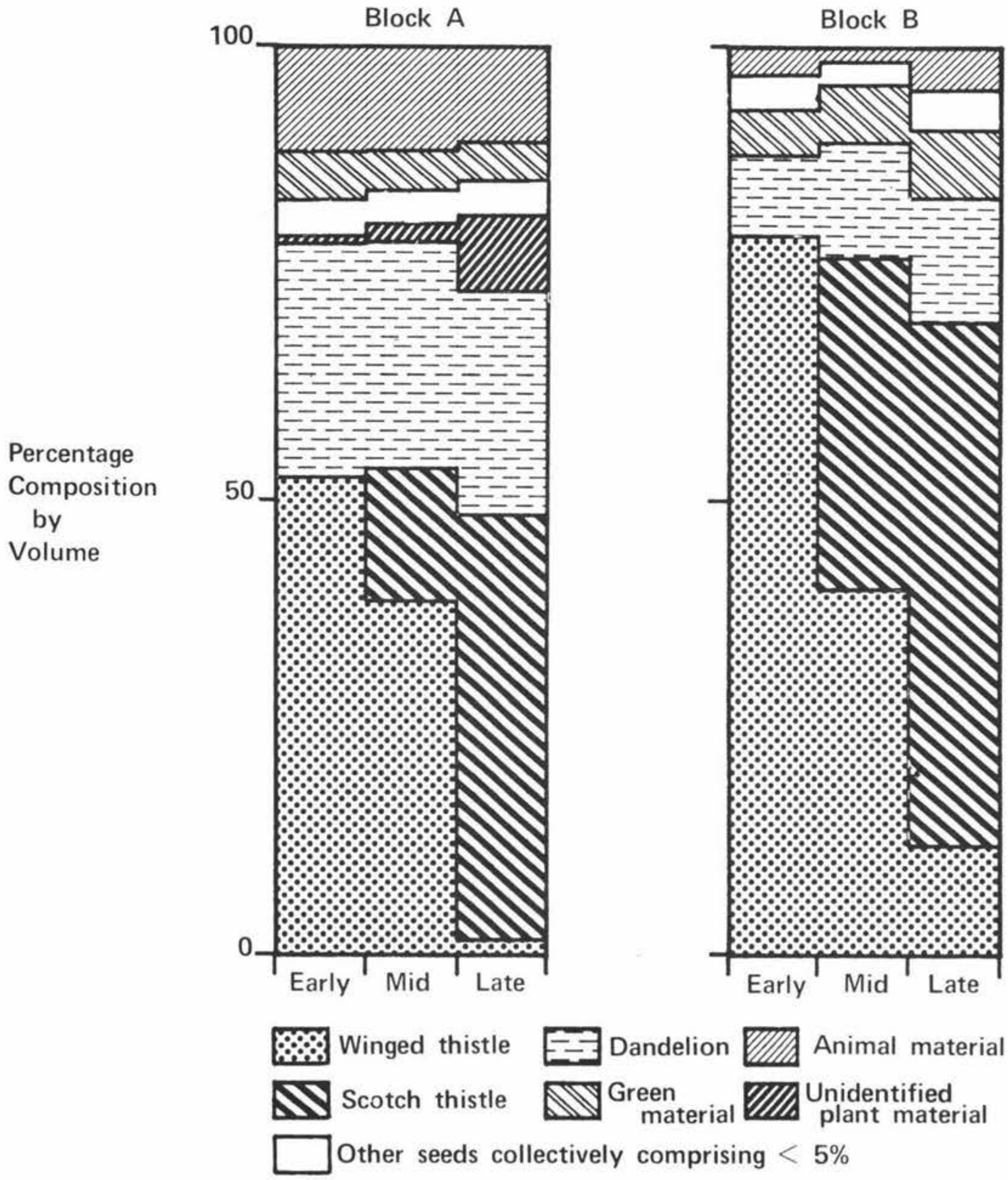


Figure 11 The gullet contents of nestling goldfinches throughout the 1970–71 breeding season.

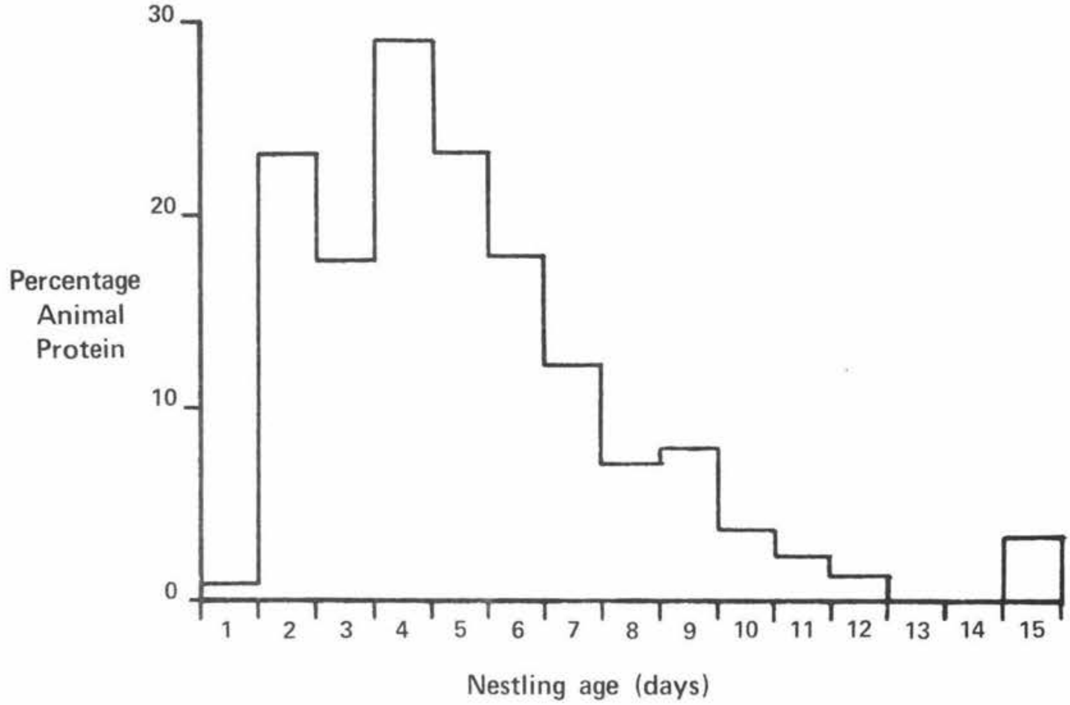


Figure 12 The percentage volume of animal food in the Goldfinch nestling diet, block A, 1970–71 breeding season.

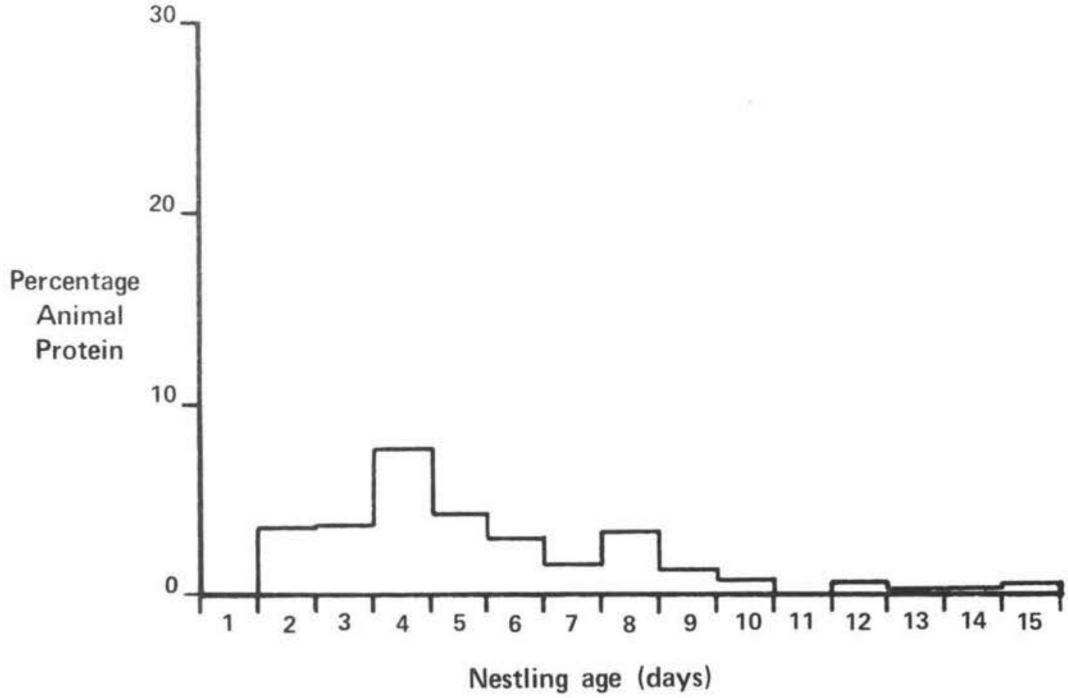


Figure 13 The percentage volume of animal food in the Goldfinch nestling diet, block B, 1970–71 breeding season.

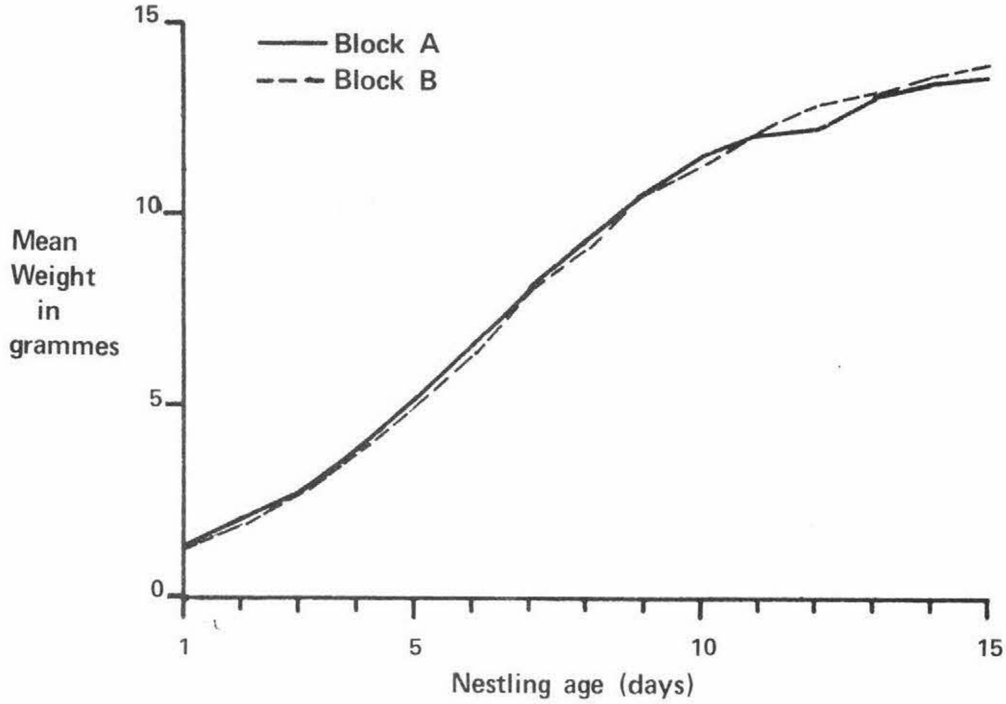


Figure 14 Weight gain of nestling goldfinches.
Results from the whole of the 1970–71 breeding season.

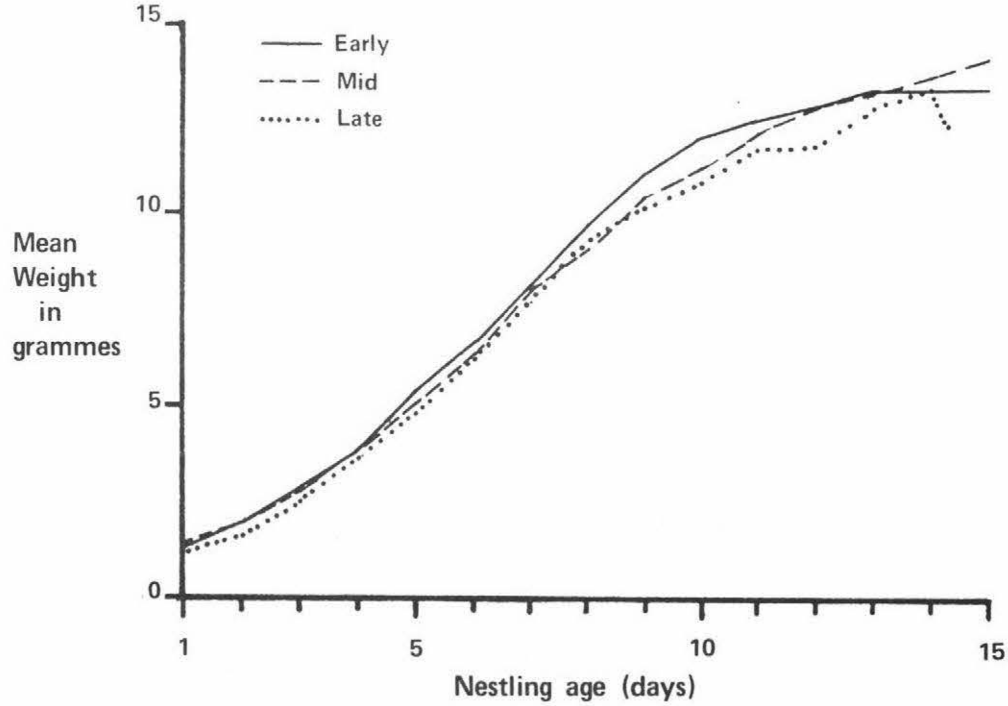


Figure 15 Weight gain of nestling goldfinches over early, mid and late periods of the breeding season.
(Block A and B weights together)

instance were fed large quantities of *Carduus tenuiflorus*, but this almost disappeared from the diet of late broods. *Cirsium lanceolatum* was not available to early broods but constituted approximately 50 percent of the diet of late broods. Both variations can be explained by the limited seeding periods of the two species. However, despite these variations there was little change in nestling growth (Fig.15).

Experimental Work

Experiments were carried out to investigate the process involved in selection of food for the young. Newton (1967a) postulated for those species which give fewer invertebrates to their young as they get older, that this was a direct response to the appearance of the young themselves. He illustrated this by changing two Bullfinch (*Pyrrhula pyrrhula*) broods of three and ten days respectively and the adults of both pairs changed their diets appropriately.

In this study three like experiments were carried out on the Goldfinch. All broods involved the same number of chicks.

Experiment No.1. This involved replacing a 13 day-old brood with one day-old chicks.

The result was the death of both one day-old chicks on the same day of transfer. This was probably due to a failure of the new parents to revert back to a brooding condition so as to maintain the necessary warmth required by both chicks. The 13 day-old chicks left their new nest within 24 hours after being transferred and because of their readiness to leave the nest during

TABLE II

RESULTS OF EXPERIMENT NO.2 INVESTIGATING NESTLING DIET SELECTION.

Date	Brood 1		Brood 2	
	Nestling age (days)	Percentage animal food in diet	Nestling age (days)	Percentage animal food in diet
	1	-		
	2	-		
	3	3.3		
	4	-		
	5	70.0		
	6	-		
	7	5.0	1	-
	8	25.0	2	-
	9	-	3	-
	10	-	4	65.0
	11	-	5	90.0
	12	-	6	23.0
31.12.70	13 .... interchange		7	30.0
31.12.70	7	-	13	10.0
	8	40.0	14	5.0
	Nest predated		15	-
			Nestlings flew	

TABLE 12

RESULTS OF EXPERIMENT NO.3 INVESTIGATING NESTLING DIET SELECTION.

Date	Brood 1		Brood 2	
	Nestling age (days)	Percentage animal food in diet	Nestling age (days)	Percentage animal food in diet
	1	-		
	2	-		
	3	84.0		
	4	6.0		
	5	64.0		
	6	18.0		
	7	7.5		
	8	6.6		
	9	-		
	10	-	1	-
	11	-	2	-
	12	-	3	10.0
3.2.71	13	- interchange	4	50.0
3.2.71	4		13	14.0
	Chicks died		14	-
			15	-
			Nestlings flew	

this time no diet observations were made.

Experiment No.2. Two broods of 13 and 7 days respectively were interchanged.

The result was that both sets of parents continued rearing their new broods with no change in diets for the first day. On the second experimental day the parents with the now 8 day-old chicks reverted back to feeding a diet more appropriate to the age of the new chicks. The 13 day-old chicks were fed decreasing amounts of animal material on their first two days and then flew the following day (Table 11).

Experiment No.3. This involved interchanging two broods of three and eleven days respectively.

The adults of the new younger brood failed to feed their chicks and death resulted. After the first experimental day the adults of the 11 day-old brood changed their diet appropriately (Table 12).

These results appear to confirm Newton's ideas. Also it appears that in the Goldfinch at least one day is required from the time of initial stimulus until a change of response occurs. This would probably explain the reason for the lack of observed animal protein in the gullet contents of one day-old chicks (see Table 6 and Table 8).

2.8 DISCUSSION

i) Comparison with adult diet.

Few feeding studies have adequately described the requirements of nestlings in spite of its fundamental importance in the ecology of birds (see Dunnet (1955) on the Starling;Kluyver (1961) on the Black-capped Chickadees Parus atricapillus; Gibb and Betts (1963) on several Parus species; Royama (1966) on nestling Great Tits; Newton (1967b) on the Bullfinch; and Seel (1969) on the House Sparrow).

The nestling stage in the life-history of a bird is a very critical one. Rapid cell multiplication takes place in the growing nestling and if the chick is going to grow quickly and overcome its parental dependency, it will need to be fed the type of food which will best promote rapid growth. It is apparent when comparing the adult Goldfinch diet (Table 2) and the nestling diet (Tables 6 and 8) that certain changes in food selection do occur.

Animal protein, for example, formed a much greater percentage of the young chicks diet and this was not surprising as the nestlings of most species require a high protein diet in their early stages (Welty,1964). Indeed, if the amino acid requirements of a nestling are determined by the composition of its own tissues, then animal rather than vegetable proteins are more likely to meet its needs (Newton,1967a).

Taraxacum officinale also showed a significant increase in the nestling diet. It never formed more than 3.3 percent by volume of the adult diet throughout the year, and yet in the nestling diet comprised approximately 25 percent by volume in Block A and 12 percent in Block B (see Tables 2 and 9). There does not appear to be any obvious explanation for this difference.

The thistle seeds Carduus tenuiflorus and Cirsium lanceolatum also formed a large percentage of the nestlings' diet. Both are large seeds and while this food source is advantageous to the adult in that they provide more food per unit time, the same cannot be said for the young nestling. Gut and faecal examination of nestlings showed that little if any of the thistle seeds were digested in the first five days after hatching. Faecal pellets were eaten by the adults during this early period and this would account for the presence of faecal material in the gullets of some young chicks. Undigested seeds would encourage the parents to eat the faecal pellets but as digestion increased in the growing chick, their food value would drop off. Faeces from older nestlings were either carried away or left on the rim of the nest.

Several of the insect species fed to nestlings never appeared in the adult diet. The most interesting find was the phytophagous hymenopteran larvae Pontania proxima which, in Block A for example, formed 13.2 percent by volume of the two day-old chick diet. This hymenopteran is commonly known as the willow leaf sawfly and causes the plant to produce the prominent galls so common on the leaves of willows (Salix spp.) The larvae feeds inside a hollow gall with a small hole at one end through which excrement is passed (Valentine,1970). Although no actual sightings were made of adults taking the larvae, it appears that in some cases the galls may have been ripped open and the larvae extracted (Fig.16 and 17). Empty galls were examined but it was difficult to determine whether they had been ripped open or were just showing natural deterioration once the larva had emerged. Valentine (pers.comm.) suggested that because

FIGURE 16. Galls of the willow leaf sawfly *Pontania proxima*.

FIGURE 17. Exposed gall showing larva of *Pontania proxima*.

nearly all the specimens taken were mature larvae, the adults may be eating them as they emerge from the galls to pupate on the leaves rather than breaking the galls open. In either case this record seems a most interesting one as an unusual form of biological control.

Cecid larvae (Order Diptera) also appeared in the nestling's diet but never in the adult's. It seems likely that these small red larvae belonged to the species Dasyneura pyri (Pear leaf-curling Midge) but identification was uncertain because the only specimens taken were damaged on transit to the Entomology Division of the D.S.I.R.,Nelson.

ii) The Proportion of Plant and Animal Matter in the Food of Nestlings.

In both breeding blocks the proportion of invertebrates in the food fluctuated from day to day, but in general declined with increasing age of the young. This has also been illustrated in other finches (Newton 1967a); the House Sparrow (Summers-Smith 1963) and the Black-faced Dioch (Ward 1965).

Throughout the nestling period young in Block B received a significantly smaller proportion of animal material than those in Block A. This difference appears to have been a direct consequence of variation in the availability of animal material in and surrounding both breeding orchards. This would indicate (as found also by direct observation) that, although goldfinches do not defend breeding territories, they nevertheless feed mainly near their nests (presumably for reasons of efficiency).

Even with this difference between the blocks, it is of interest that nestlings raised on much smaller proportions of animal material showed little or no difference in their development. It is possible that in Block B nestling growth was maintained by feeding larger quantities of seeds but no comparitive information was obtained.

Since invertebrates were taken in greater proportions in Block A (despite an abundance of seeds there), and in both blocks were digested more efficiently than seeds, goldfinches appear to favour invertebrates in their nestling's diet.

CHAPTER III

CROP DAMAGE REPORTS

As already mentioned in the introductory section, in the past ten years increasing attention has been drawn to Goldfinch damage of soft fruits particularly strawberries and fruit buds on pear trees. Two crop damage reports were carried out to ascertain just how much damage the Goldfinch was responsible for.

A. DAMAGE TO STRAWBERRY CROPS

Goldfinches were held responsible for removing the small brown achenes (commonly called seeds) from the strawberry fruit with the result that the fruit perished and became unsaleable. The crops examined totalled 12 hectares and were situated within the main study area (see Fig.1). Field work commenced on the 15 October 1969 and terminated 16 December 1969. Several aspects were investigated, namely:

(i) To determine whether goldfinches were responsible for any damage.

(ii) To determine what proportion of damage being attributed to goldfinches was being carried out by other species. Several other species were observed to visit the crop in large numbers.

(iii) Netting as a preventative method was examined.

(iv) Monetary loss from bird damaged fruit was estimated.

3.1 METHODS

A stomach analysis was made on 335 birds shot on the strawberry crops between the 20 October and 25 November, 1969. The birds were shot by two men employed by the owners of the properties concerned. All birds observed on the crop were shot at, apart from house sparrows who at that time were thought to be doing no damage. The employer had given orders to both shooters to leave house sparrows undisturbed. The author also gained the impression that both shooters showed a certain bias towards goldfinches. Bird counts were carried out to correct any such bias.

Other foods utilised by goldfinches during this period were assessed from the stomach analysis of adult birds shot at the central roost. Goldfinches were shot at the central roost three times per month and methods used in the analysis of these birds were given in a previous section (p.21). The observational assessment as previously mentioned was also carried out at this time (p.21).

A trial row was set up to estimate the effects of netting as a preventative method. A row 60 metres long was covered with nylon netting from 22 October until berries were picked on the 10 November. Another row the same length and same strawberry variety was sampled and used for a comparison over the same period. The trial row allowed conclusions to be drawn as to the presence or absence of Harpalus rufipes and H.aenus, both strawberry seed beetles present in parts of Europe. This also allowed an estimation of amounts of slug damage.

Monetary loss was estimated from the amount of unsaleable fruit present in the packing shed each day and an attempt was made to determine what percentage of all bird-pecked fruit became unsaleable. Only market prices for the period 17 October to 5 November were recorded.

3.2 RESULTS

Previous analyses of goldfinches sampled while feeding at strawberry patches, failed to find strawberry seeds in the birds (Dawson,1967). During this study the presence of strawberry seeds was determined by identifying the small seed styles present (Fig.18). The style was usually approximately 1-2 mm.long and dark brown. Also fragments of the strawberry seed case were often present in the gizzard.

Table 13 summarises the stomach analyses results for the 335 birds shot on the strawberry crops. Seed-eaters (Class A) were distinguished from fruit-eaters (Class B) by the presence or absence of the placental attachment in the gut (Fig.18). An examination of several strawberries indicated that when the achene only is eaten the placental line becomes detached and remains in the fruit. Many of the fruit-eating species contained seeds with placental attachments but no strawberry fruit pulp, digestion of the pulp probably being more rapid than digestion of the seed. The 35 day period indicated in Table 13 was considered to cover the most important time of damage. Loss being greatest at this time of the season when early berries were bringing a higher price.

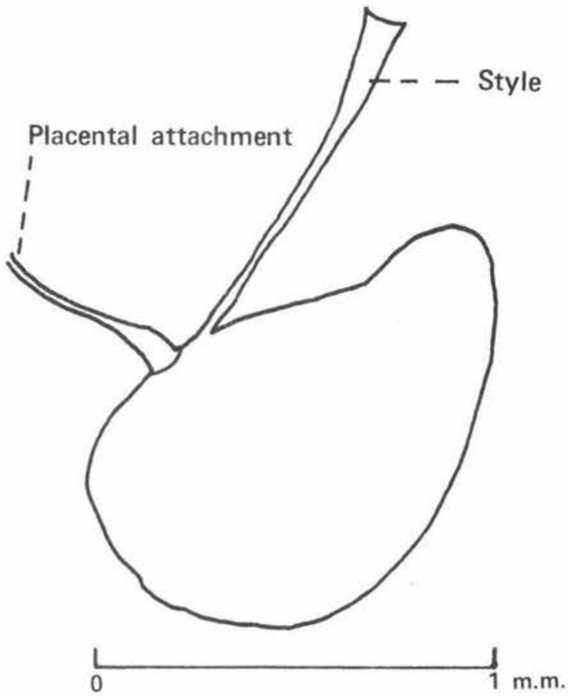


Figure 18 Strawberry seed showing style and placental attachment.

TABLE 13

STOMACH ANALYSIS RESULTS FOR BIRDS SHOT ON STRAWBERRY CROPS BETWEEN THE PERIOD 20/10/69 and 25/11/69.

Bird species	Straw-berry present	Per-cent	Straw-berry absent	Per-cent	Seeds only	Per-cent	Fruit	Per-cent	Total sampled	Percent of Class A.	
Gold-finch	42	36.8	72	63.2	42	100.0	-	-	114	68.2	
Sky-lark	13	35.1	24	64.9	13	100.0	-	-	37	22.1	Seed Eaters Class A
House sparrow	10	62.5	6	37.5	8	80.0	2	20.0	16	9.7	
										Percent of Class B.	
Thrush	46	58.2	33	41.8	5	10.8	41	89.2	79	48.4	
Black-bird	34	62.9	20	37.1	3	8.8	31	91.2	54	33.1	Fruit Eaters Class B
Myna	25	89.2	3	10.8	2	8.0	23	92.0	28	17.3	
Starling	2	100.0	-	-	-	-	2	100.0	2	1.2	
Yellow-hammer	-	-	5	100.0	-	-	-	-	5	-	

Bird scare methods made bird counts very inaccurate and only generalisations could be drawn from these. Observations over the period of shooting indicated that house sparrows were the most numerous species on the crop, being present in large numbers throughout most of the day. Goldfinches visited the patches individually or in pairs and it appeared that most goldfinches were present in the first two hours after dawn. The time of day when each bird was shot was recorded and results are shown in Table 14. Both shooters spent approximately the same time on the crop for each of the four, three-hour intervals listed. Damage was negligible after 18.00 hours.

Foods found in the stomachs of goldfinches shot at the central roost during October and November 1969, are shown in Table 15. The percentage frequency with which various foods were observed taken in the field througout the same period is shown in Table 16.

The netted trial row proved conclusively that the covering of early berries would be to the growers' advantage. Results were as follows:- the netted row yielded 11 lbs., 9 lbs. were sold at 35c./lb.and 2 lbs. at 20c./lb. Unnetted row yielded 11 lbs. all of which were bird damaged, 10 lbs. were sold at the jam fruit price of 15c./lb. and 1 lb. was classified as unsaleable. However the netting material used had a number of drawbacks. The nylon netting tended to constrict after several weeks and tore easily. Also weeds growing up through the netting prevented its removal when berries were ready for harvesting (Fig.19). Slug damage was insignificant and there were no signs of either species

TABLE 14

TIME OF DAY BIRDS SHOT ON CROP.

	06-09 hrs.		09-12.0 hrs.		12.0-15.0 hrs.		15.0-18.0 hrs.	
	No.Sampled	Percent	No.Sampled	Percent	No.Sampled	Percent	No.Sampled	Percent
Goldfinch	81	72.3	4	3.6	-	-	27	24.1
Skylark	20	54.0	7	18.9	4	10.8	6	16.3
House-sparrow	5	33.3	5	33.3	1	6.6	4	26.8
Thrush	45	57.6	6	7.5	9	11.5	18	23.0
Blackbird	29	60.4	5	10.5	4	8.3	10	20.8
Myna	12	42.8	4	14.2	2	7.3	10	35.7
TOTAL	192	60.4	31	9.9	20	6.2	75	23.5

TABLE 15

Percentage frequency occurrence of foods in the diet of Goldfinches shot during October and November, 1969.

	October				November			
Sample Dates	8/10/69	16/10/69	28/10/69	Whole month	7/11/69	17/11/69	24/11/69	Whole month
No. of birds	12	7	9	28	6	5	12	23
Seed Species								
Poa annua	75.0	85.7	22.2	60.7	–	–	–	–
Cerastium glomeratum	75.0	85.7	44.4	67.8	33.3	–	–	8.6
Erodium cicutarium	66.6	71.4	77.7	71.5	83.3	–	–	21.8
Stellaria media	33.3	57.1	11.1	32.1	–	–	–	–
Urtica urens	8.3	71.4	11.1	25.0	33.3	40.0	–	17.3
Capsella bursa-pastoris	25.0	28.5	–	17.8	16.6	20.0	–	8.6
Carduus tenuiflorus	8.3	14.2	33.3	17.8	83.3	60.0	91.6	82.6
Geranium molle	–	14.2	–	3.5	16.6	–	–	4.3
Alopecurus pratensis	–	14.2	22.2	10.7	–	–	–	–
Senecio vulgaris	–	14.2	–	3.5	33.3	–	–	8.0
Taraxacum officinale	–	–	11.1	3.5	16.6	20.0	16.6	4.0
Sonchus asper	–	–	–	–	–	20.0	8.3	8.6
Unidentified seeds	–	–	11.1	3.5	–	–	–	–
Green material	16.6	14.2	–	10.7	–	–	–	–
Fragaria sp.	–	–	11.1	3.5	–	–	–	–
Animal food								
Aphids	41.6	71.4	44.4	50.0	83.3	20.0	16.6	34.7

TABLE 16

PERCENTAGE FREQUENCY OF FOODS SEEN TO BE TAKEN IN THE FIELD BY GOLDFINCHES DURING OCTOBER AND NOVEMBER, 1969.

Sample Dates	OCTOBER 1969 8/10/69	16/10/69	28/10/69	Whole Month	November 1969 7/11/69	17/11/69	24/11/69	Whole Month
Number of Records *	487	160	217	864	140	63	24	227
Seed Species	% Composition of Diet							
<u>Poa annua</u>	80.9	44.2	-	53.8	-	-	-	-
<u>Cerastium glomeratum</u>	-	1.1	-	0.2	-	-	-	-
<u>Erodium cicutarium</u>	10.2	37.4	28.5	19.9	46.4	11.1	-	31.7
<u>Senecio vulgaris</u>	0.2	-	-	0.1	-	-	-	-
<u>Alopecurus pratenis</u>	-	3.6	28.5	7.8	27.1	52.4	-	31.3
<u>Carduus tenuiflorus</u>	-	-	5.0	1.3	20.7	36.5	83.3	31.7
<u>Urtica urens</u>	-	-	36.3	9.1	2.8	-	-	1.8
<u>Taraxacum officinale</u>	8.6	13.0	-	7.3	-	-	-	-
<u>Capsella bursa-pastoris</u>	-	-	1.4	0.3	-	-	-	-
<u>Sonchus asper</u>	-	-	-	-	2.8	-	-	1.8
<u>Holcus lanatus</u>	-	-	-	-	-	-	12.5	1.3
Animal food								
Aphids	-	0.7	-	0.1	-	-	4.2	0.4

* One bird, one food = one record

<u>FIGURE 19</u>. Weeds growing through nylon netting covering strawberry plants.

TABLE 17

Monetary loss for the period 17/10/69 until 5/11/69.

Oct.	Table Fruit Lbs.	$.c.	Total Bird Damage Lbs.	Jam Fruit Lbs.	Loss $.c.	Unsaleable Fruit Lbs.	Loss $.c.	Percent of Fruit bird Damaged	
17	27.0	12.15	34	10	3.10	24	10.80	55.7	1 hectare
20	151.3	68.09	45.7	13.7	4.30	32	14.40	28.2	
22	421.4	189.60	28.6	8.6	2.70	20	9.00	6.3	
24	806.0	362.70	114.0	3.4	10.50	80	36.00	12.3	
26	278.5	125.36	71.5	21.5	6.70	50	22.50	20.4	
27	366.2	164.80	65.8	19.8	6.10	46	20.70	15.2	
28	1,100.0	495.00	1,000.0	300.0	93.00	700	315.00	47.6	7 hectares
29	887.0	399.20	786.0	236.0	73.20	550	247.50	46.9	
30	1,105.0	497.30	957	287.0	89.00	670	301.50	46.4	
31	932.0	419.40	582	175.0	53.60	407	183.15	38.4	
Nov.									
1	1,915.0	861.80	286	86.0	26.70	200	90.00	12.9	
3	1,393.0	626.90	357	107.0	33.20	250	112.50	21.5	2 hectares
4	1,675.0	753.80	500	151.0	46.80	349	157.05	22.9	
5	1,822.0	819.90	300	90.0	27.90	210	94.50	14.1	
		T= 5,796.00			T= 477.7		T= 1,614.60		

Total Loss = Jam fruit at 31c + Unsealeable fruit at 45c

Total Loss = $477.70 + $1,614.60.

Total Loss = $2,092.30.

of strawberry-seed beetle. Results from the packing shed showed that an estimated 70 percent of all bird damaged fruit was unsaleable. Monetary loss from bird damaged fruit, over a 20 day period, is shown in Table 17.

3.3 DISCUSSION

That the Goldfinch is responsible for strawberry damage is correct. Results show that almost 37 percent of all goldfinches shot on the strawberry crop contained pieces of strawberry seed. However, to assume that the Goldfinch is solely or even mostly responsible for seed-pecked damage would be an incorrect assumption. Results have thrown new light onto this problem. Species causing damage can be divided into three groups : those feeding only on strawberry seeds, namely goldfinches and skylarks (*Alauda arvensis*); those feeding mainly on strawberry seeds, namely house sparrows; and those feeding only on berries, namely thrushes (*Turdus philomelos*), blackbirds (*Turdus merula*), mynas (*Acridotheres tristis*) and starlings (*Sturnus vulgaris*).

As already stated house sparrows were the most numerous of the species on the crops throughout the whole day and 62.5 percent of all house sparrows sampled showed some presence of strawberry. Fewer goldfinches and sky-larks showed any signs of strawberry. Therefore in terms of bird numbers, time spent on the crop and percentage of birds sampled containing strawberry seeds, house sparrows probably accounted for the largest proportion of all seed-pecking damage in this study. According to the October edition of the Commercial Grower (1969), house sparrows are now considered to be the biggest problem to the

English strawberry growers (p.313).

Tables 15 and 16 indicated the change from one main food type to another during October and November. *Poa annua* formed almost 81 percent of the goldfinches diet at the beginning of October and then dropped rapidly in importance as the month progressed. At the end of October *Carduus tenuiflorus* formed only five percent of the diet but increased to 83.3 percent by the end of November. Both *P.annua* and *C.tenuiflorus* are available as a food source in excess of two months and it is in this period of ending and beginning of two important food supplies that the greatest amount of bird damage occurred.

Another observation is of interest. It was observed during the early morning that goldfinches were often reluctant to feed on weed or grass seed foods because of a heavy dew covering. The strawberry fruit was free from dew and this may have been a reason why they were utilised at this time. Goldfinch damage appeared heaviest during the first three hours after daybreak.

B. DAMAGE TO FRUIT BUDS ON PEAR TREES

Complaints from several orchardists within the Hawkes Bay area specified that goldfinches in large flocks were responsible for heavy pear bud damage. Long (1970) reported that in Eastern Australia some damage had been recorded to the buds of apricot trees.

3.4 METHODS

Forty-two goldfinches were shot from a large flock in an orchard where heavy pear bud damage was occurring.

Contents of the crop, proventriculus and gizzard were analysed in the laboratory.

3.5 RESULTS

No sign of fruit buds were found in any of the birds. Table 18 indicates the stomach contents of the birds analysed.

TABLE 18

CROP AND STOMACH CONTENTS OF GOLDFINCHES SHOT IN A HAVELOCK NORTH ORCHARD. + = less than 0.1%.

No. of Birds 42	Percent Frequency	Percent Composition by volume
Poa annua	100.0	88.6
Stellaria media	61.9	7.3
Amaranthus retroflexus	28.5	2.1
Chenopodium album	2.3	+
Unidentified seed	14.2	1.0
Aphids	61.9	1.0
Volume sampled (mls)		16.6 mls.

3.6 DISCUSSION

It appears that little, if any bud damage, can be attributed to goldfinches. The presence of large flocks in several orchards appeared to be a direct result of the large areas of *Poa annua* and *Stellaria media* that were available. No sign of fruit buds was found in any of the goldfinches sampled at the central roost.

The orchard sightings can be explained by the feeding behaviour of the species. Goldfinches feeding on weed seed in an orchard will often, when disturbed, fly up into neighbouring fruit trees and scrape their bill on the branch they land on. Dawson and Bull (1970) in a questionnaire survey of bird damage to fruit crops in New Zealand record that the main birds causing damage to fruit buds were redpolls, house sparrows, chaffinches, silvereyes (*Zosterops lateralis*) and greenfinches. In this study the numerous House Sparrow was probably responsible for most bud damage.

CHAPTER IV

BREEDING BIOLOGY

4.1 METHODS

Breeding data were obtained from the same blocks used in the nestling diet study (Fig.1). Both areas were orchard farms and contained a mixture of Apple (Malus sp.), Pear (Pyrus sp.), Peach (Prunus sp.) and Plum (Prunus sp.) trees. From the onset of breeding, these areas were visited daily.

Data on clutch size, incubation and nestling periods, nestling weights, as well as nesting and territorial behaviour were collected at each visit. Also every fourth day the orchards were systematically searched for new nests. Every nest tree was marked and each nest numbered. To aid nest observation a mirror mounted on a five foot pole and a small ladder were used.

4.2 RESULTS AND DISCUSSION

i) Breeding season

The start of the breeding season was marked by the break-up of winter flocks. By mid-October 1969 and 1970, most of the winter feeding grounds were deserted and the birds formed small groups feeding mainly on Storksbill, and the fresh supplies of Winged thistle which became available in early November. Birds were often seen in twos and as early as mid-September twos were exploring the areas which would soon provide nesting cover.

The timing of the breeding season is reflected in changes in gonad size and Figure 20 illustrates the growth and regression of the gonads throughout the year.

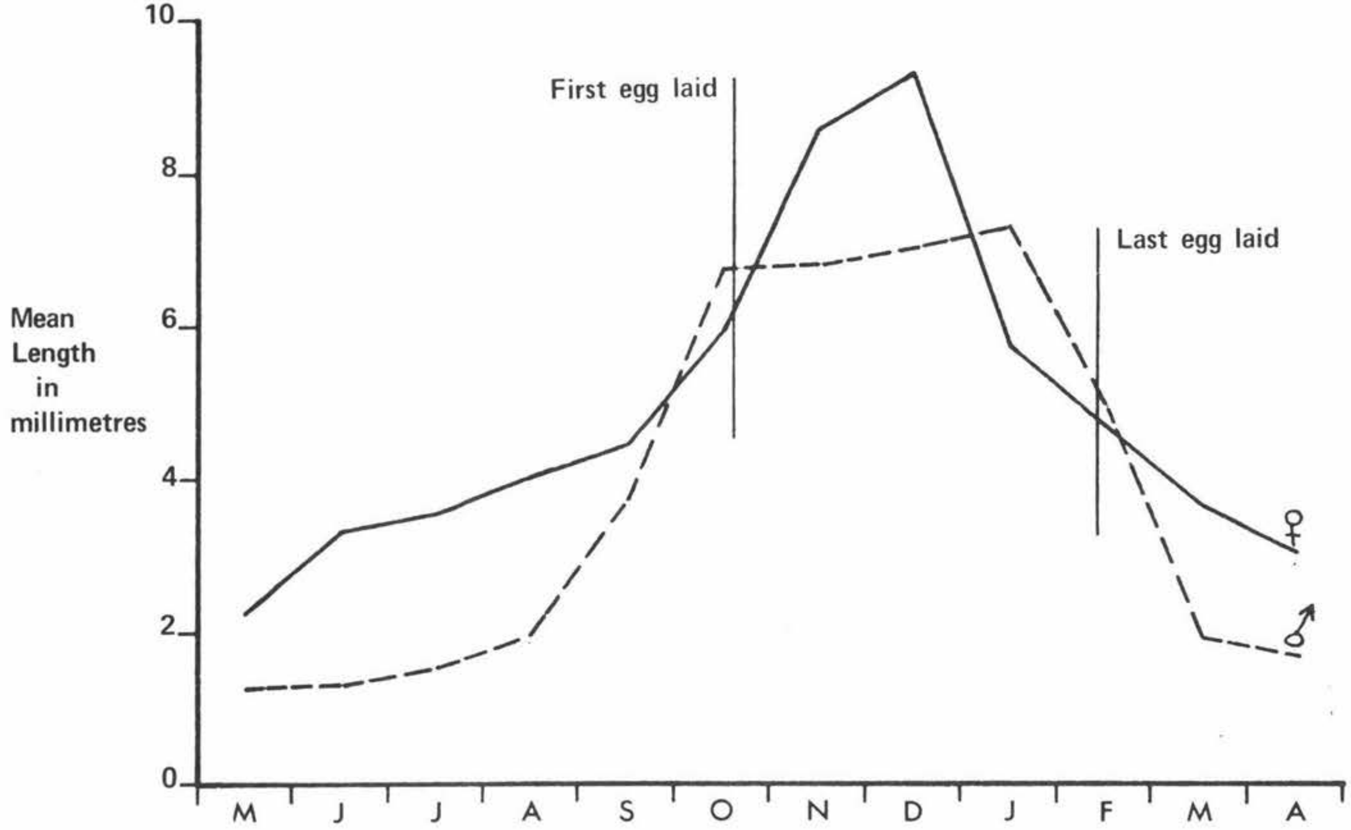


Figure 20 Seasonal variation in gonad measurements of the Goldfinch, Havelock North.

Recrudescence appeared to begin earlier in the male, growth being rapid in late September, several weeks ahead of the female. Maturation of gonads in the male before the female could be adaptive in that it would allow early breeding females to lay fertilised eggs and so prevent any wastage of female gametes at the beginning of the breeding season.

ii) Sexual Dimorphism

Recognising the sexes in the field was not easy. Middleton (1965) and Newton (1967a) found that on average males were bigger than females and measurements from this study confirmed this (see Table 4). At the nest the sexes could be separated behaviourally. In general the male bird appeared to have brighter facial colouring and while collecting specimens for stomach analysis, sex was estimated before the gonads were examined. In most cases the diagnosis was correct. Elliott (1969) suggests that during courtship the female is much duller than the male but this is probably because the male carries out most of his display by flashing his bright yellow wing patches.

Witherby *et al* (1938), Bannerman (1953) and Peterson *et al* (1954) all state that the sexes are morphologically similar and in this study, as with previous ones, no reliable criteria could be established for separating the sexes.

iii) Pair Formation

Recognising the timing of pair formation was difficult because birds were not banded and could not be externally sexed in the field. However, it seems that pair formation took place, at least for the early breeding birds, within the winter flock. In early September goldfinches were regularly seen in twos during the middle part of the day. In the early morning and before roosting at night they would gather with the main flock to feed. Also in September, if a flock was disturbed, many birds would fly off in twos, but during the earlier winter months the disturbed flock remained together. Middleton (1965) supports this idea and both Lack (1940) and Conder (1948) suggest pairs are formed within the flock.

iv) Territory

Nest site selection took place before territorial claims were made. Conder (1948) observed that the territory was limited to a mating and nesting station only and both Middleton (1965) and Elliott (1969) agree with this. Observations in this study generally confirmed that the Goldfinch was territorial around the nest site but in several instances copulation was observed outside of the territorial boundaries.

The size of the territory appeared to correlate with individual sexuality and the stage of the breeding cycle. During nest building the territory was approximately 50 metres square around the nesting site but was reduced to the nesting tree once the eggs were laid. This reduction in the size of the territory once the eggs are laid can be explained by the nesting behaviour of the Goldfinch.

During incubation the male was responsible for feeding the sitting female and therefore spent most of his time absent from the territory searching for food. As a result, song was infrequent and, intruders could easily enter the nest area. The female was less eager to leave the nest and defend the territory as incubation progressed and as a result intruders penetrated more deeply into the territory which became increasingly smaller. Middleton (1965) postulates a similar explanation.

Newton (1967a) mentions that most cardueline finches nest either in loose colonies or solitarily. During the 1969-1970 breeding season one loose colony was observed and two more in the following season. According to Newton (1967a) group nesting is quite common in the Linnet (Carduelis cannabina) and the Lesser Redpoll (Carduelis flammea) but less frequent in the Greenfinch, Goldfinch,Siskin (Carduelis spinus) and Hawfinch (Coccothraustes coccothraustes) and very rare in the Bullfinch. Conder (1948) also reports loose colonies in the Continental Goldfinch and Nice (1939) found a social tendency in the Eastern Goldfinch (Spinus tristis).

There were no definite boundaries to these colonies but the breeding density per number of trees was much higher than in surrounding areas. Typically each colony involved approximately 30 trees and had about 10 nests, the ratio of the numbers of trees per nest being approximately 60:1 for the rest of the orchard. In one colony pairs nested simultaneously in the same tree. In that instance, however, the female in one nest was brooding young before the other nest was built. It appears that in group nesting, breeding pairs dispense with a certain amount of territorial defence so as to achieve a clumped type of dispersion pattern which may have more advantages than solitary pairs.

The most widely accepted hypothesis about the origin and advantages of colonial breeding, supposes that it confers increased protection partly from increased awareness of the approach of predators and partly from the subsequent mobbing attack on the predator. However, the amount of increased protection can be questioned on the basis that an increase in concentration of nests usually increases the predators awareness to these breeding areas. Observations in this study supported both ideas. Mobbing attacks were often shown when nests in the loose colonies were visited. Parents from surrounding nests would join with the disturbed parents and both sexes would pivot back and forth uttering sharp shrills. On one occasion this same behaviour pattern was shown to a domestic cat wandering beneath the colony. The following morning most of the nests were found on the ground with several chicks in a mauled condition. It seemed obvious that the mobbing behaviour shown to the cat had possibly alerted its attention to their presence. However, on several other occasions mobbing appeared to be effective in deterring other predators such as the Magpie (Gymorhina tibicen) and the Kingfisher (Halcyon sancta).

An alternative suggestion proposed by Crook (1965) links colonial breeding with flock formation for foraging purposes. It appears that breeding birds in a loose colony may be more able to exploit an uneven food supply than those nesting separately (ibid). Horn (1968) has shown this to be true in the colonial nesting Brewer's blackbird (*Euphagus cyanocephalus*). Goldfinches often foraged communally during the breeding season (although in much smaller groups than in the winter) but with a food supply which was plentiful and evenly scattered it seems unlikely that colonial nesters possessed any foraging advantages. Presumably at some stage in the evolution of the Goldfinch colonial nesting was more advantageous than solitary breeding but whether these advantages still exist today, in new environments, is questionable.

v) Nesting

Nest building usually began as soon as a nest site was selected. Within the study area breeding activity appeared to be mainly centred in the orchards and so nest sites in Blocks A and B were probably typical of most of the nest sites throughout the area (Table 19). The high proportion of nests found in the fruit trees is probably a reflection of their sheltered location as well as their association with readily available food supplies from weeds growing at the orchard boundaries and on the orchard floor. Fruit trees are commonly reported nest sites for goldfinches throughout New Zealand as taken from the Ornithological Society of New Zealand (O.S.N.Z.) nest record cards (Table 20). However, these records show that the Goldfinch has adapted well to the available nest cover and it is interesting to find quite a number of endemic species used as nest sites. The high proportion of nests recorded in fruit trees may, however,

TABLE 19

SITE AND HEIGHT OF GOLDFINCH NESTS FOUND DURING 1969-70 AND 1970-71, HAVELOCK NORTH.

Common Name	Specific Name	No.of Nests	Mean height above ground(m)	Range (m)
Plum sp.	Prunus sp.	24	3.0	1.5 - 6.0
Apple sp.	Malus sp.	82	2.2	0.9 - 4.8
Pear sp.	Pyrus sp.	66	2.6	1.3 - 5.1
Peach sp.	Prunus sp.	39	2.7	1.3 - 4.2
Maple	Acer sp.	2	1.6	1.5 - 1.8
Macrocarpa	Cupressus macrocarpa	2	3.3	3.0 - 3.6
Hazel nut	Corylus avellana	2	3.3	2.7 - 3.9
Nectarine sp.	Prunus sp.	2	2.8	1.9 - 3.6
Phebalium	Phebalium sp.	1		4.5
Lawsoniana	Chamaecyparis lawsoniana	1		4.5
Cypress sp.	Taxodium disticum	1		6.0
Oak	Quercus robur	1		6.0
Barberry	Berberis sp.	1		1.8
Elm	Ulmus procera	1		2.4
Total		225	2.6	0.9 - 6.0

TABLE 20
Site and height of Goldfinch nests
(From New Zealand Ornithological nest record cards: 1948 – 1969).

Common name	Specific name	No. of nests	Percentage of total	Mean height above ground (m)	Max. and min. height above ground (m)
Peach	Prunus sp.	81	25.9	2.5	1.5 – 4.5
Gorse	Ulex europaeus	29	9.3	2.0	0.9 – 3.6
Apple	Malus sp.	27	8.6	2.0	0.9 – 3.0
Plum	Prunus sp.	26	8.3	2.5	1.5 – 4.5
Pine	Pinus sp.	19	6.1	2.2	1.5 – 4.5
Poplar	Populus sp.	12	3.8	2.1	0.9 – 3.6
Hawthorn	Crataegus laevigata	12	3.8	3.8	2.1 – 9.1
Broom	Cytisus sp.	9	2.9	1.7	1.2 – 3.3
Willow	Salix sp.	9	2.9	2.6	1.8 – 4.5
Macrocarpa	Cupressus macrocarpa	8	2.6	3.0	0.9 – 6.1
Lawsoniana	Chaemaecyparis lawsoniana	6	1.9	2.0	1.2 – 2.7
Lupin	Lupinus sp.	6	1.9	1.1	0.9 – 1.2
Spruce	Picea sp.	6	1.9	2.0	0.9 – 3.0
Apricot	Prunus sp.	5	1.6	2.1	1.8 – 2.7
Totara	Podocarpus totara	4	1.3	2.2	1.8 – 1.5
Oak	Quercus robur	3	1.0	3.6	1.9 – 6.1
Matagourie	Discaria toumatou	3	1.0	1.9	1.8 – 2.1
Alderberry	Sambucus sp.	3	1.0	2.4	1.6 – 3.6
Maple	Acer sp.	3	1.0	2.2	1.8 – 2.6
Douglas Fir	Pseudotsuga taxifolia	3	1.0	2.0	1.5 – 2.4
Kanuka	Leptospermum ericoides	3	1.0	2.8	2.7 – 3.0
Hazelnut	Corylus avellana	3	1.0	2.4	2.1 – 3.0
Lemon	Citrus sp.	3	1.0	3.1	3.0 – 3.6
Boxthorn	Lycium sp.	2	0.6	2.1	1.8 – 2.4
Elm	Ulmus procera	2	0.6	2.6	1.6 – 3.6
Gum sp.	Eucalytus sp.	2	0.6	2.9	2.1 – 3.6
Mapou	Suttonia australis	2	0.6	3.8	3.3 – 3.6
Kohekohe	Dysoxylum spectabile	2	0.6	4.3	3.6 – 4.8
Cypress	Taxodium disticum	2	0.6	1.2	1.0 – 1.3
Ivy	Hendera helix	1	0.3		3.3
Blackberry	Rubus fruticosus	1	0.3		1.0
Wattle	Acacia sp.	1	0.3		1.9
Rewarewa	Knightia excelsa	1	0.3		2.4
Nectarine	Prunus sp.	1	0.3		1.8
Matipo	Myrsine australis	1	0.3		2.8
Mahoe	Melicytus ramiflorus	1	0.3		3.3
Whau	Entelea arborescens	1	0.3		6.4
Sycamore maple	Acer pseudoplatanus	1	0.3		2.1
Kohuhu	Pittosporum tenuifolium	1	0.3		2.4
Orange	Citrus sp.	1	0.3		3.0
Mamangi	Coprosma arborea	1	0.3		2.1
Putaputaweta	Carpodetus serratus	1	0.3		1.8
Barberry	Berberis sp.	1	0.3		1.0
Kaikomako	Pennantia corymbosa	1	0.3		2.1
Rimu	Dacrydium cupressinum	1	0.3		1.8
Rose bush	Rosa sp.	1	0.3		1.8

be due to observer bias as most of the records came from orcharding areas.

Nest heights ranged between 0.9 and 6.1 metres (Table 19) and most nests were built in the forks of branches in the outer extremities of the tree. This provided good concealment from predators and as most orchards were well sheltered did not contribute to any nest instability.

First egg dates were calculated in the following ways. Firstly, first egg dates were recorded in the field for 80 of the nests. Secondly, when a full clutch was found and incubation had already begun, the date of laying was calculated using a mean incubation period of 14½ days from first egg laid to first egg hatched. (Where no eggs hatched, no estimate could be made). Thirdly, when nestlings were found in the nest, the age of the oldest chick was determined, 14½ days added and this total figure subtracted from the date of observation.

Observations in Block A and B over the 1970-1971 season indicated the first egg was laid on the 18th October and the last egg on the 16th February. The O.S.N.Z. nest record cards give similar dates (Table 21).

Breeding activity at Havelock North (Fig.21) reached an early peak in mid-November and then fell off slightly only to again increase and reach a mid-season peak during late December. Activity then declined through until the middle of January and then increased to reach a late-season peak at the end of January. This was followed by a rapid decline in egg laying which terminated with the laying of the last clutch in mid-February.

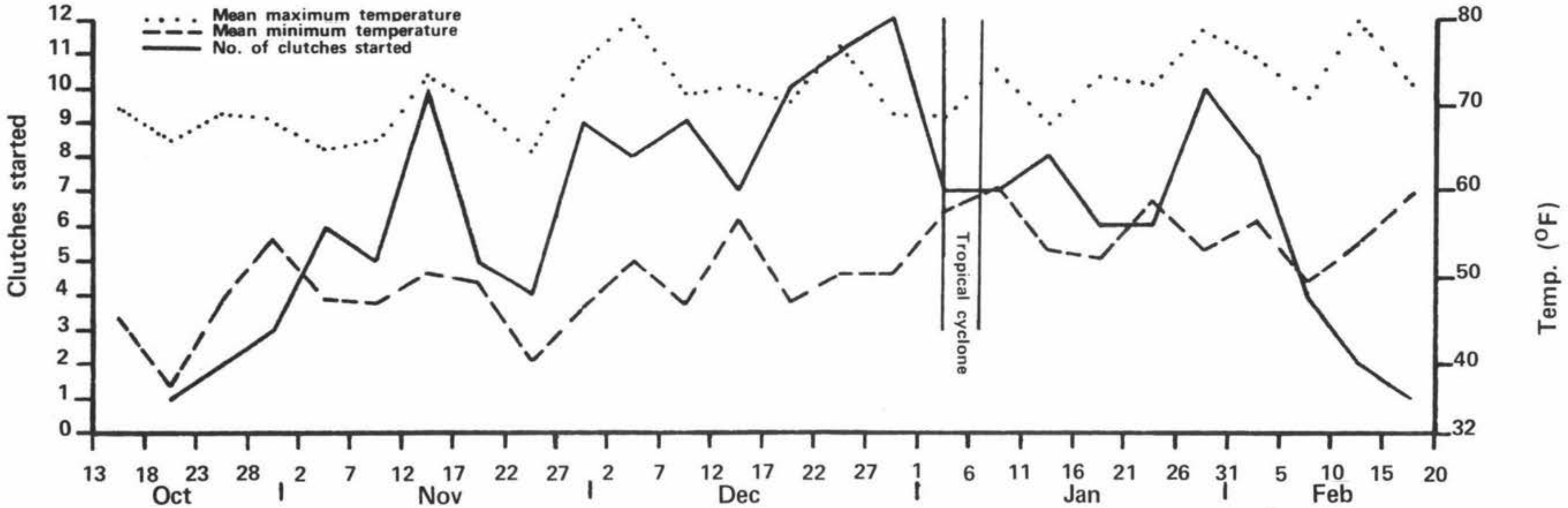


Figure 21 The interrelationship of nesting activity and temperature

TABLE 21

RECORDED BREEDING DATES FOR
THE NEW ZEALAND GOLDFINCH
(O.S.N.Z. nest records).

Locality	First Egg	Last Egg	Season
Pakowhai	21 October	6 February	1957-58
Gisborne	20 October	5 February	1964-65
Wanganui	20 October		1969
Queenstown		28 February	1957
Ashburton	22 October	10 February	1960-61
South Canterbury	26 October	12 February	1968-69

According to several authors (Lack 1954, Haukioja 1970), older breeding passerines usually lay before the first year breeding birds and this would probably account for the early breeding peak in mid-November. The peak in late December can be explained by a commencement of first clutches together with repeat clutches of early birds who were unsuccessful. The late peak was probably due to repeat clutches plus attempts at second clutches by parents of successful first clutches. Because no birds were banded, no evidence can be given on the incidence of second clutches.

On several occasions inclement weather appeared to interrupt the commencement of new clutches once breeding had begun and to check this mean temperature was plotted against first eggs laid (Fig.21). Weather data was provided by the Department of Scientific and Industrial Research meteorological station situated in Block A.

Kessel (1957) made an extensive analysis of the relationship between egg-laying dates and environmental temperatures in the European Starling, concluding that annual variations in breeding dates are largely a result of temperature difference. Newton (1964) showed that temperature controls the onset of breeding in the Chaffinch (Fringilla coelebs). This was also probably true for the Goldfinch at Havelock North and Figure 21 suggests there may have been some relationship between the minor temperature peaks and minor laying peaks throughout most of the breeding season. It appeared that nesting and territorial behaviour increased on warm sunny days but this may have been only an increase in the breeding behaviour of birds already nesting rather than a recruitment of new breeders. However, Figure 21 shows that some correlation did exist between the weather and laying peaks but weather is obviously not the only factor affecting laying of first eggs.

Nest building usually took place in four distinct stages. Firstly a foundation was made and held to the fork by spider silk. On top of this a cup was built, usually of coarse material, and then lined with soft material on its inside. Finally most nests were decorated either with moss, small leaves or spider silk.

All nests still remaining at the end of the breeding season were collected. Nests were measured and nesting materials identified from 151 nests. The mean length and breadth of nests still compact was 66 mm and 55 mm respectively (inner rim measurements). The average depth of cup was 27 mm. (Table 22 gives a list of nesting materials used).

As Conder (1948), Middleton (1965) and Elliott (1969) have suggested, building materials were influenced to

TABLE 22

Major nest materials (results from 151 nests arranged in descending order of importance for each stage)

Nesting materials	Specific name	Use in nest
Spider silk	–	Foundation, cup and decoration
Yorkshire fog grass	Holcus lanatus	Foundation, cup and decoration
Sheep wool	–	Foundation, cup, and lining
Moss	Camptochaete aciphylla	Foundation, cup and decoration
Currant twigs	Ribes sp.	Foundation and cup
Rootlets	–	Foundation, cup and lining
Cleavers	Galium aparine	Foundation, cup and decoration
Lotus twigs	Lotus sp.	Foundation, cup and decoration
Nettle	Urtica urens	Foundation, cup and decoration
Wattle leaves	Acacia sp.	Foundation, cup and decoration
Annual meadow-grass	Poa annua	Foundation, cup and decoration
Thistle down	Carduus and Cirsium sp.	Foundation, cup, lining and decoration
Pine needles	Pinus sp.	Foundation and cup
Elm leaves	Ulmus sp.	Foundation
Catchfly twigs	Silene gallica	Foundation and cup
Grass stems	–	Cup
Hoary stock	Matthiola incana	Cup
Twiglets	–	Cup
Forget-me-not	Myosotis arvensis	Cup and decoration
Sowthistle down	Sonchus oleraceus	Lining
Dandelion down	Taraxacum officinale	Lining
Horse hair	–	Lining
Oxtongue down	Picris echioides	Lining
Goldfinch feathers	Carduelis carduelis	Lining
Hawkbit down	Leontodon taraxacoides	Lining
Clematis down	Clematis sp.	Lining
Woolly mullein leaves	Verbascum thapsus	Lining
Mouse-eared chickweed stalks	Cerastium glomeratum	Decoration
String	–	Decoration
Shivery grass	Briza minor	Decoration
Storksbill stems	Erodium cicutarium	Decoration
Hawkbit leaves	Leontodon taraxacoides	Decoration

some extent by their availability during the breeding season and no two nests were identical, each having its own characteristics (Fig.22). Also the appearance of any nest changed during occupancy. Before the nestlings hatched nests were clean and compact but as the nestlings developed the nest became soiled and broken and often by the end of the nestling period the nest had become an irregular platform (Fig.23).

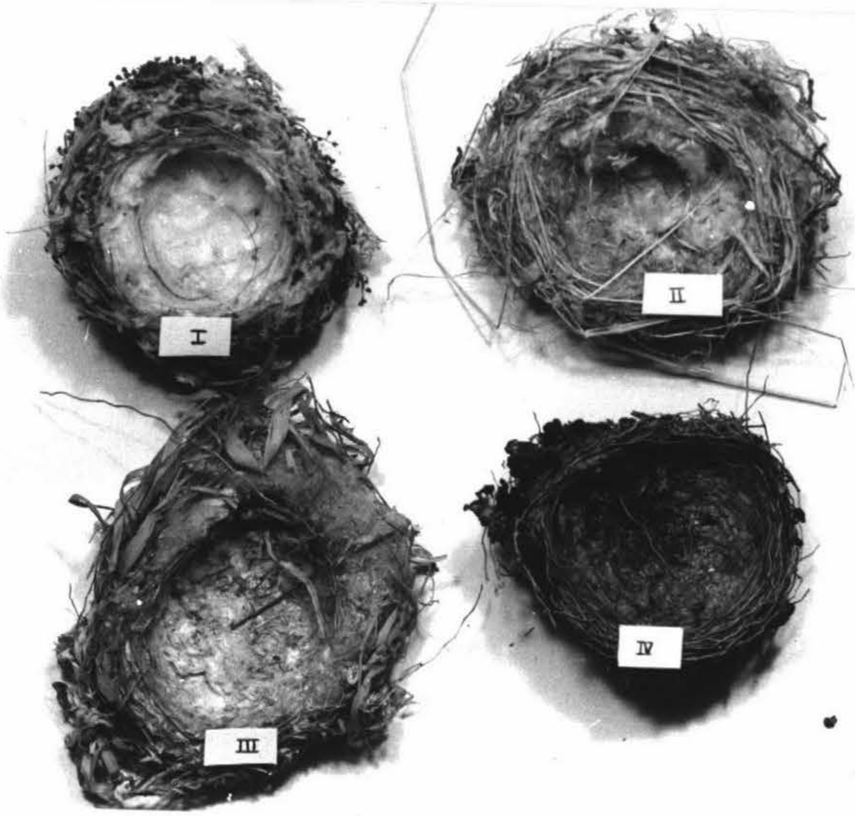
No nests used in the 1969-1970 breeding season were used in the following season. Nests either rotted away during the winter, were removed by orchardists or were partially destroyed by infestations of beetles. Of the 151 nests measured and analysed in the laboratory, 31 contained populations of the dermestid larvae Anthrenocerus australis (order Coleoptera) identified by Dr R.Milne,Massey University. Britton (1970) records that dermestid larvae often feed on dry animal material of high protein content and live naturally in the debris of birds nests. Most of the nests infested were old nests built during the early part of the season and had probably been infested after the nestlings had flown. No larvae were seen during daily nest observations. Several nest sites used during 1969-1970 were used again in the 1970-1971 season. Breeding pairs were not marked and so it was impossible to tell whether the birds were the same breeding pair from the previous year.

vi) Egg Laying

Eggs were laid at one-day intervals until the clutch was completed, but there were several exceptions.

FIGURE 22. Goldfinch nests showing individual variation in appearance.

FIGURE 23. Change in nest appearance during its occupancy.


I
II
III
IV


I
II
III
IV

In one clutch the female stopped laying after the fifth egg and then produced another egg three days later. Another two nests had a two-day interval between the last two eggs. The earliest nest observations were made at 08.00 hours each morning and on all but two occasions eggs appeared to be laid either during the night or in the early morning. Conder (1948) and Middleton (1965) stated that Goldfinch eggs are laid shortly after sunrise and Welty (1964) indicates that eggs are laid by many species early in the morning. In most cases the first egg was laid the day following completion of the nest.

vii) Clutch size

In this study a clutch was considered complete if at least one of the following two conditions was satisfied:-

a) The number of eggs had not increased between two visits when the interval was not less than one day. Only on three occasions, as already mentioned, were the intervals between the laying of each egg more than one day.

b) If young were found in the nest after a shorter period than the minimum incubation period. In such cases it is probable that incubation had already begun when the nest was inspected for the first time and the clutch wasthen full.

In both above conditions it is assumed that single eggs are not normally lost either during the laying or incubating period but this is not always the case.

Single eggs did disappear from nests during the study but in most cases the nests were deserted before any of the remaining eggs hatched. At Havelock North nests were visited daily and so the chances of missing an egg were slight. Clutch size at Havelock North is shown in Table 23. Results from the O.S.N.Z. nest record cards have been calculated using the same conditions above (Table 24).

TABLE 23

CLUTCH SIZE FOR THE HAVELOCK NORTH STUDY AREA, 1970/71 BREEDING SEASON.

Time of Season	Clutch size 3	4	5	6	Total No. Nests	Total No. Eggs	Average Clutch Size
Early (Oct.18-Nov.26)	0	4	19	3	26	129	4.96
Mid (Nov.27-Jan.15)	5	8	50	11	74	363	4.91
Late (Jan.16-Feb.16)	6	18	8	2	34	142	4.18
Whole season	11	30	77	16	134	634	4.73

TABLE 24

CLUTCH SIZE FOR OTHER NEW ZEALAND AREAS. (Results from the O.S.N.Z. nest record cards).

Site	No. of Clutches	Average Clutch Size	Standard Deviation	Range
Pakowhai	64	4.55	0.50	4-5
D.S.I.R. orchard (Havelock North)	27	4.67	0.62	3-5
Gisborne	27	4.60	0.64	3-5
North Island	131	4.60	0.56	3-5
South Canterbury	32	4.72	0.53	4-6
Timaru	12	4.67	0.66	4-6
South Island	80	4.74	0.62	3-6
New Zealand	211	4.65	0.59	3-6

The mean clutch size at Havelock North was 4.73. This value, however, means very little because of the variation in the size throughout the season. The mean clutch size in ten-day periods is given in Figure 24. Throughout the early and middle parts of the breeding season the mean clutch size remained fairly constant at approximately 4.9, but then dropped to 4.1 during the last breeding month. This decrease was significant ($p < 0.001$).

The change in average clutch size within the season is often distinct within a population and has been shown for a number of passerine species (Snow 1955, Newton 1964, Haukioja 1970). Haukioja (1970) lists a number of possibilities in explaining the reason for this decrease as the season progresses. Firstly in the Reed Bunting he showed there was less animal protein available at the end of the season and so a smaller clutch would be adaptive. In this study results in Table 9 showed there was little difference in the amount of animal protein fed to the nestlings throughout the entire season, and field observations indicated there was little difference in animal protein availability over that time.

Secondly, differences in the clutch sizes of age groups could be the reason for this seasonal trend. Kluyver (1951), Lack (1954) and Haukioja (1970) have all found a lower clutch size for first year breeding birds and a decline in the mean clutch size would occur if young females laid their smaller clutches at later stages of the breeding season. However in the Reed Bunting, Haukioja (1970) found that late clutches are

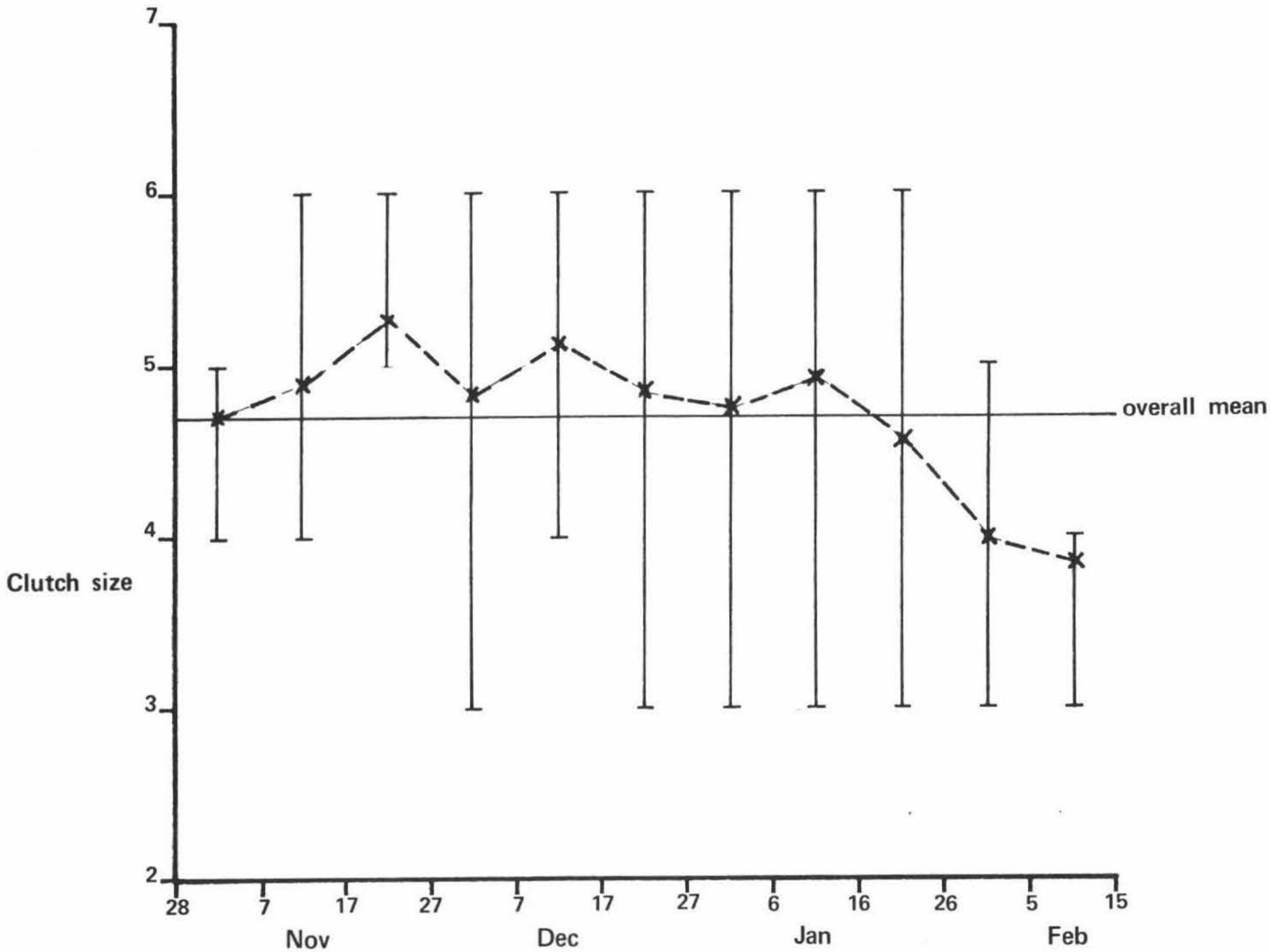


Figure 24 Mean clutch size and range throughout the breeding season.

practically all laid by old females.

Thirdly, in order for the female to survive it may be important for her not to produce so many eggs just before moulting. Haukioja (1969) again found in the Reed Bunting that weights of females feeding late broods are rather low and suggested that this could be an indication of stress at this period. Other authors have paid little attention to this possibility. Weights of female goldfinches at Havelock North were low during February (see Fig.9) and there would be an even greater stress on the late breeding bird if moulting had already begun. Middleton (1965) quite clearly shows an overlap between moult and breeding in the Goldfinch in Australia. Field observations confirmed this for the Goldfinch in this study. Several late breeding females when disturbed from their nest had already started to moult with most of the colour from their head and chin feathers missing. Also moult was well underway in several of the females, feeding recently fledged young juveniles, which were shot at the central roost during February. Middleton (1965) suggests that the simultaneous occurrence of both breeding and moulting may be more widespread than realised at present and this being so the onset of moult may well be the real reason for a decrease in clutch size as the breeding season comes to an end.

In addition to the seasonal variation in the clutch size of any one population there also appears to be some differences between different populations. Not only is there a variation in the average clutch size of populations in different countries but there may be fairly significant differences within any one country. For instance, there is a significant difference ($p < 0.10$) in the mean clutch size for the North and South Islands of New Zealand (see Table 24).

A tendency for increase in clutch size with increasing latitude is apparent in many birds (Lack, 1947) and Lack reasons that longer daylight hours enable the parents to feed more young and so raise a larger brood. Frith (1957) reported a clutch size of 3.7 for the Goldfinch at Griffith, New South Wales, and together with New Zealands' 4.65, and 4.83 for England (Niethammer,1970), these results would lend support to Lack's view. However, after much more accurate observations by Middleton (1965), the clutch size for the Goldfinch population at Monash, calculated over three seasons, was 4.8. The New Zealand clutch size is slightly less than this figure and so in this instance Lack's theory is rejected.

Therefore, no one factor appears responsible for controlling clutch size. Not only do clutch sizes vary with the age of the individual within a season and from area to area, but also vary annually. As Haukioja (1970) has pointed out there is a need to consider all environmental factors before any direct conclusions can be drawn.

viii) <u>Incubation</u>

The incubation period of a species is difficult to measure accurately. Even when a bird sits on eggs heat may not be applied to them and so incubation in its strict sense may not have yet begun. In all clutches it appeared that incubation began before the last clutch was laid. Eggs were tested for warmth by placing on the lips of the observer, a recognised procedure among many ornithologists. Records from 51 nests suggest that incubation could have started with the first egg in 11, with the second egg in 21, with the third egg 13, with the fourth egg 4, and the fifth egg in 2 of the nests. Conder (1948) and Middleton (1965) observed similar variability but Conder noticed that incubation was higher than average on the day the fourth egg was laid. Elliott (1969) observed that incubation usually began with the laying of the second egg in the Massapequa colony, United States.

Considerable error is possible when measuring incubation period and it seems that quite a number of differences in the incubation period of a species may be superficial. Van Tyne and Berger (1959) define incubation period as "the elapsed time between the laying of the last egg in a clutch and the hatching of that egg when all the eggs hatch". However, most previous studies on the Goldfinch (Walkinshaw 1938, Conder 1948, Elliott 1969) have failed to state what definition they used and whether they included or excluded the dates of laying and hatching of the last egg. The latter could affect calculations by a full day.

In general eggs hatched in the order laid but this was often difficult to determine. Time only permitted one observation per day for each nest and this meant that in many cases the eggs had all hatched within the 24 hours preceding a visit. At Havelock North the incubation period from the last egg laid to the last egg hatched was 12.2 days and from the first egg laid to the first egg hatched, 14.5 days. These figures were calculated from 62 nests observed daily from the time of construction through until all eggs had hatched. The day of laying was included and the hatching day was included only up to the preceding half-day period according to the time of observation, i.e. if the observation was in the morning then the date of observation was not included. If the nest was observed in the afternoon then the incubation period for the last egg laid to the last egg hatched, included the day of laying plus all intervening time up to 1200 hours on the day of hatching. If, as is thought, the egg is laid at 06.00 hours, then by not including or including only half of the hatching day the 12-18 hour surplus so often included was done away with.

Middleton (1965) gives the average incubation period at Monash over two breeding seasons as 13.1 and 13.3 days respectively and his measurements were as accurate as those in this study. However, he did include both laying and hatching days which would mean that in New Zealand and Australia the incubation period is very similar. Conder (1948) gives a period of 11.7 days for Germany and Elliott (1969) approximately 12 days for United States. No measurements of attentiveness or inattentiveness were made.

As in other Goldfinch studies the female appeared to do all the incubating. On one occasion an extended incubating period occurred due to all eggs in the nest being infertile. The female in this instance sat on the clutch for 21 days before deserting. Van Tyne and Berger (1959) suggest that passerine birds tend to incubate about twice the normal period before they desert their eggs.

ix) Nestling period

The nestling period for any bird is the time between hatching of the egg and leaving the nest. As already stated, the eggs normally hatched within 24 hours and in the order in which they were laid. Both Conder (1948) and Middleton (1965) record hatching time per nest at $23\frac{1}{2}$ and 26 hours respectively. Consequently all chicks in a nest are of a similar age. The time of vacating the nest was also often difficult to determine because of the problem of premature departure due to disturbance by the observer. A reasonable guide to this was obtained from plumage of the young birds. Undisturbed nestlings usually flew on the day following the loss of the ring of natal down from the head. The presence of this ring on birds leaving the nest suggested premature departure. Calculation of the nestling period at Havelock North for the 1970-1971 season, where both hatching and flying days were included, was 14.0 days (range 12-17 days).

The growth rates of each brood were recorded and the average development of a Goldfinch nestling, based on results over the entire season, is shown in Figure 25. There was little difference in nestling development from broods raised in the early, mid or late periods of the breeding season, as already indicated in Figure 15. Lack (1968) states that in broods of above the normal

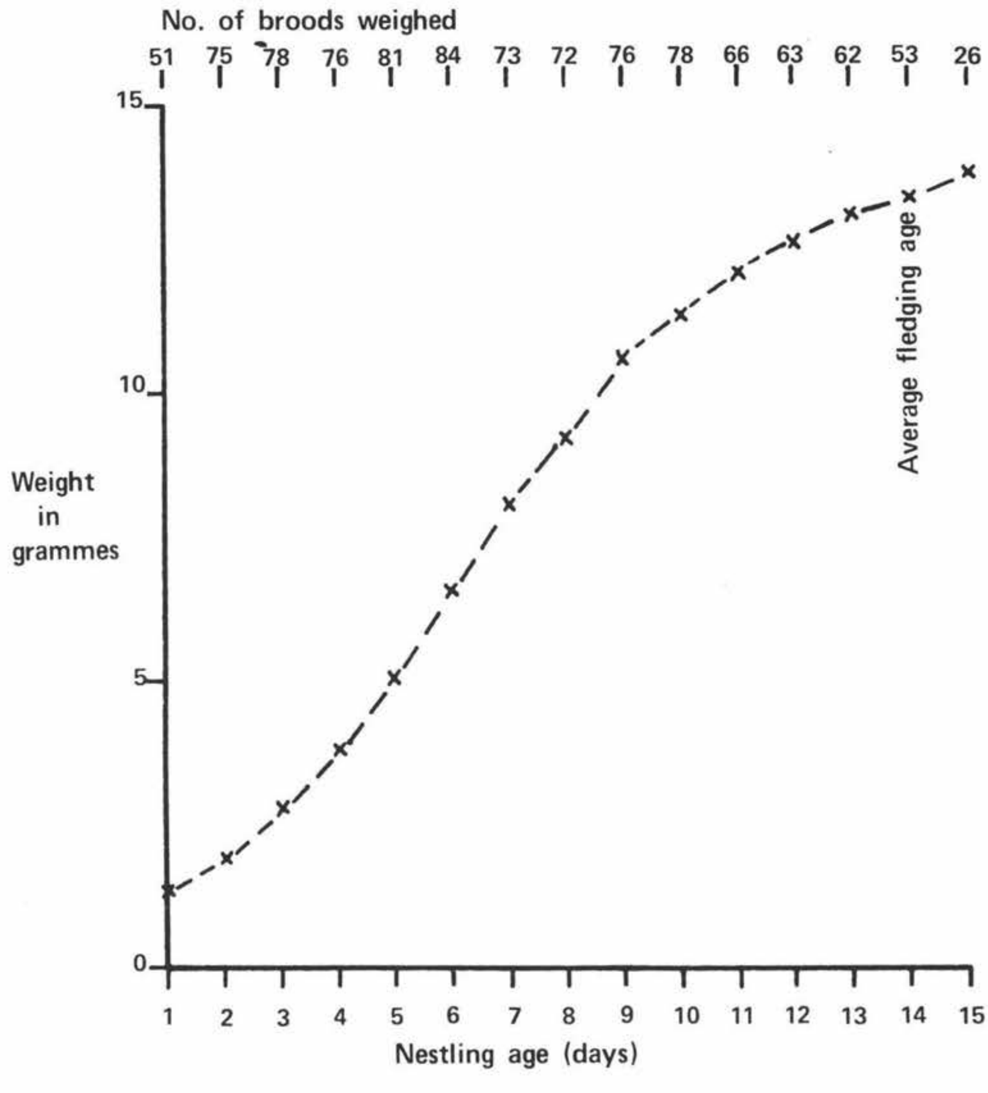


Figure 25 Weight gain of Goldfinch nestling, 1970–71 breeding season.

mean size the young tend to weigh less at fledging but results in Table 25 do not support his statement. However, the number of broods above the normal size was few. Recent information has shown that in several passerines, namely the Great Tit (Royama 1966), the House Sparrow and Tree Sparrow (Seel 1970), nestlings in larger broods receive proportionately less food than nestlings in smaller broods and therefore growth rates should be correspondingly slower. However, both studies have shown that heat loss is far greater for smaller broods than for larger ones and therefore more maintenance energy is required for smaller broods. Assuming that nestling goldfinches in smaller broods also receive proportionately more food than those in larger ones and that their maintenance energy requirements were also higher, this would explain the negligible difference between the growth rates of all the broods.

In general, the rate of growth of the nestling increased to day 7 and then decreased to day 13. During day 13 and 14 the rate was similar. On day 14 which was the average fledging date for the nestlings, the average weight was 13.5 grams, approximately 88 percent of the adult weight. This percentage is identical with that of House sparrow nestlings over the same period (Seel,1970).

The female brooded the young almost continuously during the first few days of the nestling period but as the young developed, broodiness waned and the female was rarely seen on the nest after about the eighth day. This appears to correlate closely with the development of the body temperature regulating mechanism which is rapidly

TABLE 25

Nestling weight in relation to brood size, (results from whole of 1970–71 breeding season).

Day	Brood size 1			Brood size 2			Brood size 3			Brood size 4			Brood size 5			Brood size 6		
	No. broods observed	Mean Wght. (grams.)	S.D.	No. broods observed	Mean Wght. (grams.)	S.D.	No. broods observed	Mean Wght. (grams.)	S.D.	No. broods observed	Mean Wght. (grams.)	S.D.	No. broods observed	Mean Wght. (grams.)	S.D.	No. broods observed	Mean Wght. (grams.)	S.D.
1	2	1.2	0.28	1	1.3	–	12	1.4	0.26	11	1.3	0.22	25	1.3	0.22	1	1.5	–
2	2	2.5	0.71	6	1.9	0.33	19	1.8	0.28	19	1.9	0.32	27	2.0	0.24	2	2.2	0.28
3	2	4.0	1.41	6	2.9	0.57	17	2.6	0.45	22	2.6	0.37	29	2.6	0.80	2	3.0	0.42
4	2	4.5	0.71	5	3.7	0.52	21	3.7	0.62	22	3.7	0.46	25	3.9	0.51	1	4.6	–
5	2	5.8	0.35	4	5.3	0.86	20	4.9	0.78	24	5.0	0.65	31	5.2	0.55	1	6.1	–
6	2	6.9	0.14	4	6.1	0.96	23	6.5	0.94	23	6.3	0.7	31	6.7	0.66	1	8.1	–
7	1	8.2	–	2	6.6	0.63	19	7.9	1.18	21	8.2	0.97	29	8.1	0.71	1	9.0	–
8	2	8.7	1.62	3	8.3	1.22	18	9.3	1.19	21	9.1	1.07	27	9.3	1.01	1	9.5	–
9	2	9.1	1.27	5	9.8	1.14	19	10.6	0.97	21	10.4	1.26	27	10.7	1.00	2	11.7	0.14
10	2	9.2	1.91	4	10.9	1.35	19	11.3	1.20	21	11.2	1.26	29	11.7	0.97	3	12.1	0.48
11	1	12.5	–	4	11.5	1.25	20	12.0	1.26	16	12.3	0.97	24	12.3	0.93	1	13.2	–
12	1	12.0	–	4	12.2	0.89	14	12.3	1.36	18	12.7	1.04	24	12.8	1.15	2	13.5	0.25
13	2	13.0	1.41	4	12.4	0.81	19	13.0	1.08	14	13.1	1.08	21	13.3	0.97	2	14.1	0.85
14	1	14.0	–	3	12.6	1.50	17	13.3	1.15	12	13.5	0.87	17	13.7	0.72	2	13.5	0.77
15							5	13.3	0.96	6	13.4	1.41	9	14.2	0.69	2	14.6	2.47

developing in the passerine nestling from about the seventh day onwards (Royama, 1966).

The waning of brooding in the female brought a change in the feeding pattern of the young. In the early stages of the nestling period the male fed the female who in turn fed the young, but as broodiness waned the male became more aware of the nestlings and began to feed them directly. Typically the parent bird would stand on the rim of the nest and regurgitate its food into the gaping mouth of the nestling (Fig.26). Several young were fed at each visit and usually feeding stimulated defecation by the nestlings immediately they were fed. Faeces, produced in a gelatinous sac, were either carried off or eaten by the parents during the early stages of the brood. As the nestlings grew they developed the typical habit of most young passerines, of projecting their vents over the rim of the nest and depositing the faecal pellets in that position. The build-up of faeces around the rim gave the nest a very soiled appearance, illustrated in Figure 26. Conder (1948) has tried to explain this build-up of faeces around the rim by postulating that the female does not perceive the nest as a whole. The nestlings have to be in the cup and the faeces either coming from the nestlings or in the inside edge of the cup to release swallowing or removal (ibid). It became fairly evident in this study that Conder's (1948) explanation may not be entirely correct and that the presence of faeces may simply reflect firstly, the drop in food value of the pellets to the parents and secondly, the increase in

FIGURE 26. Adult Goldfinch feeding nestlings.

work load of the adults, as the brood gets older. Firstly, as already indicated, faeces of young nestlings often contained large amounts of undigested seed and these provided a ready source of food for the hard-working parent. Field observations indicated that faeces were either carried off or eaten by the parents during the early stages of the brood. However the digestive abilities of the nestlings increased with age and an examination of pellets from older nestlings showed that they no longer provided the parent with a source of food. This would mean that as the nestling grew older, less numbers of faecal pellets would be removed by the adults specifically for their own diet requirements and so the number of pellets left at the nest would increase. Secondly, field observations in this study gave the impression that the size of the brood had some correlation with the time when faeces first appeared on the rim. Results in Figure 27 show that there was an inverse relationship between brood size and the age of the brood when faeces first appeared. This relationship is probably explained in terms of work load of parents. With young nestlings present sufficient time is available in all brood sizes to remove faeces but as the nestlings grow the work load increases and therefore less time is available to keep the nest clean. Previous studies of altricial birds have shown that the more young in the nest the more frequent are the visits of the parents (Moreau 1947, Gibb 1955). A greater work load in larger broods should mean that faeces appear on the rim earlier in nests containing more chicks and results in Figure 27

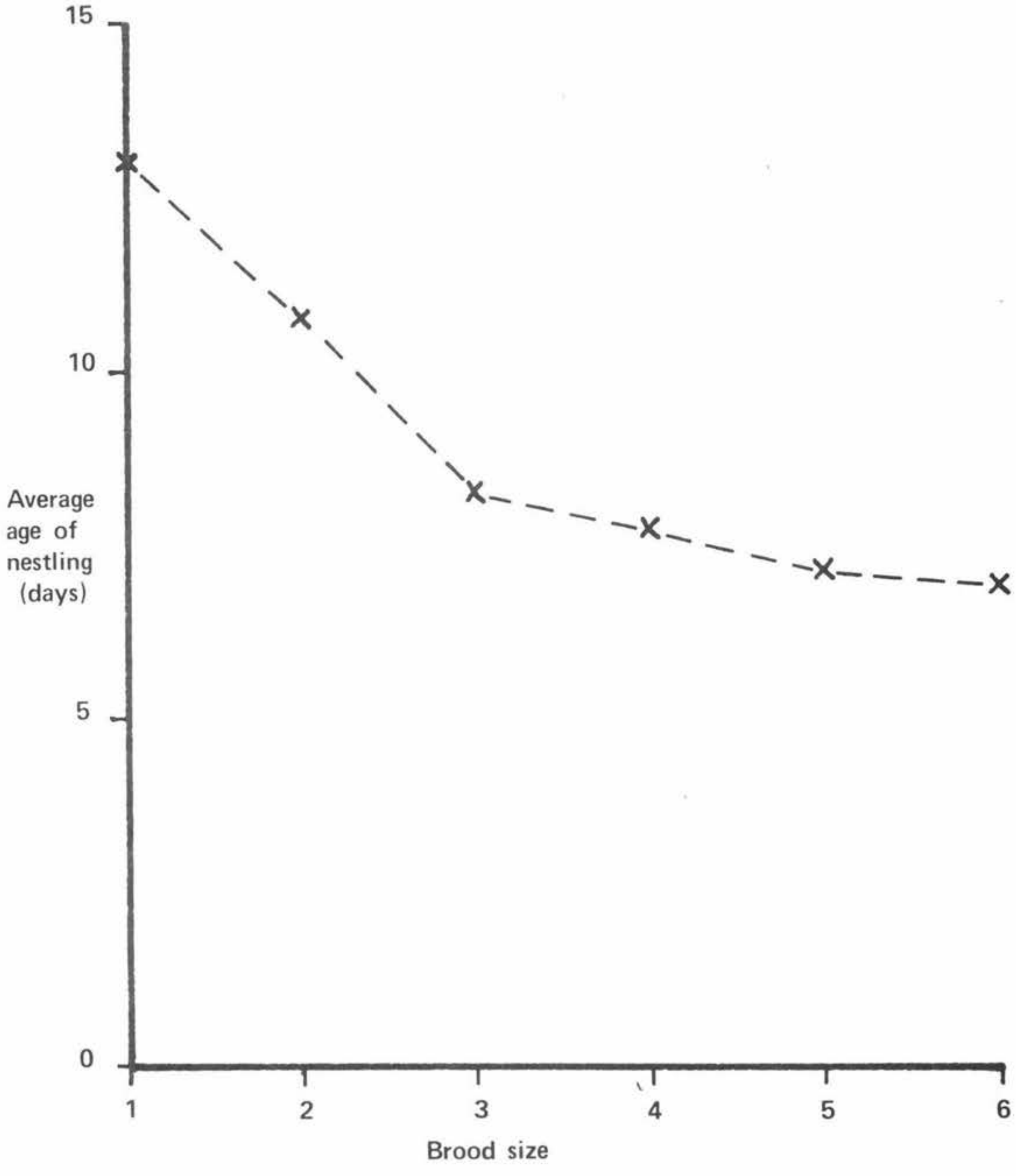


Figure 27 Nest sanitation in the Goldfinch as indicated by first appearance of faeces at the nest rim.

confirm this. If this relationship between presence of faeces and work load is correct, results shown in Figure 27 would indicate that the work loads of brood sizes 1,2 and 3 increase proportionately, but that the work loads of broods 3 to 6 were similar. Seel's (1970) work on the nestling House sparrow agrees with this. He found that as the rates of visiting frequency began to diverge the rates for broods of 1 to 3 increased almost proportionately, but there was no significant difference between the rates for broods of 3,4 and 5 young. Therefore it seems that the presence of faeces at the nest rim is determined largely by the age of the nestlings in relation to their digestive abilities, and the size of the brood as it affects the work load capacity of the parents.

x) Nest Defence

Apart from mobbing displays, already mentioned, no other nest defence responses in the Goldfinch have been recorded by previous authors. However, in this study an unusual nest defence response was observed during hatching and the early part of the nestling period. This involved a 'mock injury' display by the female when she was disturbed unexpectedly either while hatching was occurring or brooding very young nestlings. The display involved dragging both wings along the ground and on all occasions continued until the adult had dragged herself some nine metres from the nest site. One particular female, disturbed while the eggs were hatching, showed an almost extreme form of this behaviour. Both wings were dragged on the ground and the parent made a number of circling movements in front of the observer as it moved away. The display was continued until the observer had followed the bird several metres away from the nest site.

It appeared that the response was triggered as the eggs hatched and was strongest at this point. It disappeared after the fourth day of the nestling period and can probably be explained in relation to the vulnerability of disturbed nestlings to predators. Very young nestlings up to about their fourth day in the nest produce the typical begging action when disturbed. Older nestlings up to about the twelfth day will crouch in the nest with heads down and remain still and quiet. Fledglings will either crouch or explode from the nest in an endeavour to escape. Presumably young nestlings when left alone in the nest are more vulnerable to predators, because of their movement and pinkish bare skin, than older feathered nestlings which are cryptically coloured and crouch low in the nest. It seems, therefore, that this response by the parent functions to increase the protection of the nestling during its most vulnerable period to predators. This distraction display never occurred when the female was frightened from a nest where the eggs had not hatched.

xi) <u>Fledging</u>(Chicks leaving the nest).

Most observations indicated that fledging occurred in the morning and was observed several times. Each observed fledging took place at approximately 10.00 hours. Several nestlings flew directly from the rim of the nest while others climbed out, clinging to nearby branches before they flew. All nestlings flew when the adults were near and on two occasions the first flight from the nest was to a parent in a neighbouring tree. Food was received from the parent immediately the fledgling landed. This may suggest that some nestlings were coaxed away from the nest, a suggestion which Middleton (1965) disagrees with. Sharp calls were emitted by the fledglings after they left the nest and as soon as the parents came near the typical begging posture was assumed. Contrary to Lack (1968), the young seldom left the nest together, a feature which occurred only when the chicks were disturbed and exploded prematurely. On most occasions chicks left the nest as soon as they were able to fly and this meant that departure of the whole brood was usually spread over one or two days. However, the fact that nestlings usually left immediately they could fly may have been the result of the amount of handling they received and/or the usual disturbances from the surroundings every day. In one nest which was concealed by a large amount of creeper, the oldest nestling did not leave immediately it was able, but flew with the rest of the brood two days later.

Although chicks or parents were not marked it appeared that for the first week after leaving the nest the fledglings spent most of their time near the nesting site, but then as their flight powers increased they began to roam further afield. Fledglings could be easily found when the parents arrived to feed them. Loud begging calls were emitted and the typical feeding behaviour described by Conder (1948) was observed.

Parents appeared to feed their fledglings for approximately two to three weeks after leaving the nest. During this study a fledgling, which had just left the nest, was caught and placed in a small wire cage some 50 metres from the nest site. The parents fed the young bird through the wire of the cage for the following 16 days. For the first three days the other three fledglings of the same brood remained around the nest site and were also fed by the parents, but disappeared on the fourth day. Presumably these three fledglings were killed by domestic cats which lived close by. Middleton (1965) suggested that the young became independent after about three weeks and Conder (1948) also considers a similar time is involved. After becoming independent, the fledglings (juveniles) formed small flocks which gradually increased through the breeding season. One flock of approximately 200 juveniles was observed in mid-February 1971.

xii) Number of Broods

A considerable number of reference books indicate that the Goldfinch is double and even sometimes triple-brooded (Witherby et al,1938; Bannerman,1953; Elliott, 1969). These assumptions are based on the length of the breeding season and the discovery of late nests.

At Havelock North, as at Monash, at the very least eight weeks were required to raise a brood successfully. Taking the breeding season as beginning in mid-October and finishing in late February, the rearing of two or even three broods was therefore within the capabilities of the

Goldfinch. However, because birds were not banded or marked it was impossible to determine the number of broods raised by any one pair and only impressions gained during this study can be recorded.

On five occasions previous nesting trees were used again some three weeks after chicks had fledged. Because breeding birds were not marked it was difficult to determine whether the pairs were the same parents as the previous ones but there is the possibility that several of these were genuine second broods. Middleton (1965) has shown that at Monash birds came into breeding condition at varying times of the breeding season and were capable of breeding for only a restricted part of that season and he suggests that only one brood was raised in Australia. Further research is needed in New Zealand before any definite conclusions can be drawn.

xiii) Nesting Success

Several sources of bias can affect an analysis of nesting success. The inclusion of nests found in an advanced stage bias the sample in favour of success. Nests found are also those most likely to be found by predators and therefore to fail (Newton,1964). However, together these two, to some extent, balance each other and so possibly bias was largely avoided.

Table 26 shows that the total nest production for the 1970-1971 breeding season was 278 chicks which flew from 159 nests, a mean of 1.7 chicks per nest. Also both Tables 26 and 27 indicate that the overall production per nest declined as the breeding season advanced. This can possibly be explained by facts already mentioned that in

TABLE 26

TOTAL NEST PRODUCTION FOR THE 1970-1971 BREEDING SEASON.

Time of Season	No.of nests laid in	No.of successful chicks	No.of Chicks flew/nest
Early (Oct. 18-Nov.26)	36	79	2.2
Mid (Nov. 27-Jan.15)	87	153	1.8
Late (Jan. 16-Feb.16)	36	46	1.3
Whole of Season	159	278	1.7

TABLE 27

RELATIONSHIP BETWEEN NESTING SUCCESS AND TIME OF LAYING.

Month nests began	Successful	Unsuccessful	Percent Success
October	4	1	80.0
November	20	18	52.6
December	31	27	53.4
January	18	28	39.1
February	5	7	41.6
Total	78	81	49.0

TABLE 28

FLEDGING SUCCESS FOR ALL EGGS LAID.

Season	Total eggs laid	Total eggs hatched	Percentage eggs hatched	Total young fledged	Percentage young fledged from eggs laid
1970-71	638	470	73.0	227	35.6

most species the older more experienced birds are usually first to breed and lay larger clutches than those breeding for the first time. Evidence supports the view that younger individuals find it harder than older birds to raise young (Lack,1968) and so ideally there should be a decline in nest production as the breeding season progresses. However other factors such as raising of second and third broods can complicate this trend, but as already mentioned, no conclusions can be drawn on the number of broods attempted at Havelock North.

Fledging success (Table 28) was approximately 10% higher than at Monash (Middleton,1965) and it appears according to Middleton's account, that inclement weather was responsible for a higher nest failure. Causes of nest failure in this study are discussed later on. In terms of hatching success and fledging success, clutch-size six was the most successful (Table 29). Also brood-size six produced the most surviving young per brood (Table 30). Lack (1968) has defined optimum clutch-size in an altricial species as the number of eggs which, as a result of natural selection, corresponds with that brood-size from which, on average, most surviving young are produced. The limit normally being set by the amount of food that the parents can collect for their nestlings. He recognises that larger clutch sizes often do produce more fledglings per clutch but gets around this by saying that in broods of above the normal size the young tend to weigh less at fledging, and to survive less well after fledging than in broods of normal size. Survival rates of fledglings were not measured at Havelock North

TABLE 29

FLEDGING SUCCESS IN WHICH A FULL CLUTCH WAS LAID.

Clutch size	No.of Clutches	Total eggs laid	No. hatched	Percentage eggs hatched	Number successful chicks	% Chicks flew	% eggs successful (flew)	Number chicks/ flew/ clutch
3	11	33	23	69.6	18	78.3	54.5	1.6
4	29	116	78	67.2	40	51.3	34.5	1.4
5	77	385	292	75.8	129	44.2	33.5	1.7
6	16	96	77	80.2	40	51.9	41.7	2.5
Total	133	630	470	74.6	227	48.3	36.0	1.7

TABLE 30

THE NUMBER OF NESTLINGS WHICH FLEDGED IN ALL BROODS OF GOLDFINCHES INCLUDING TOTAL BROOD FAILURES

Initial brood size	Number of broods	Number of young hatched	Young fledged		
			Total number	Percentage	Number per brood
b/1	1	1	1		
b/2	5	10	3	30.0	0.6
b/3	25	75	42	56.0	1.7
b/4	28	112	51	45.5	1.8
b/5	48	240	117	48.8	2.4
b/6	4	24	11	45.8	2.8
Total	111	462	225	48.7	2.0

but growth rates and weights of fledglings in brood-size six were slightly higher than those in the smaller clutches (Table 25). This suggests a higher subsequent survival rather than lower as postulated by Lack.

Taking all losses during the nestling period into account, the Goldfinch at Havelock North reared an average of 2.0 young per brood and 49% of all young which hatched. About 41 percent of all broods which hatched failed to survive the nestling period. Approximately 36% of all eggs laid produced fledged young.

xiv) Causes of Failure

Almost 51 percent of the nests which were laid in failed to produce any young to the fledging stage. Also a large number of nests were either deserted or destroyed before being laid in which suggests that a much smaller percentage of nests which were initially commenced were actually successful in rearing young.

Causes of failure can be best discussed in relation to the stage that failure occurred; i.e. whether at the nest building stage, during laying/incubation, or during the nestling period.

A number of nests failed during construction and it appeared that the breeding pair were most easily disturbed at this time. Quite often the foundation and cup of a nest was built and then the birds would reject the nest site and build somewhere else. On one occasion a nest half-way through construction was deserted and then completed and laid in two weeks later, presumably by the same parents.

Material from nests only partly constructed was often carried away by the breeding pair to a new nest site and other species may have also used this readily available nestling material. Conder (1948) observed a Greenfinch stealing material from a partially constructed Goldfinch nest and he considered this to be the cause of desertion. Middleton (1965) attributed egg damage to the Greenfinch at Monash and he states that the Greenfinch was commonly found interferring with Goldfinch nests presumably as a result of territorial disputes. A number of greenfinches were breeding in the two orchards used in this study and although no actual nest stealing or damage was observed it is possible that they contributed to some nest failures. Observer's activities close to the nest during this stage before egg laying, appeared to cause the failure of at least three nests.

Failure during laying and incubation was quite high. As indicated in Table 28, only 73 percent of the total eggs laid actually hatched. Table 31 lists the causes of failure during this stage. Predation accounted for almost half of the failures and although no eggs were observed being taken several signs would indicate that predation had taken place. Usually the nest was ruffled and bits of egg shells were present. Nest lining was often stained with yolk (Fig.28).

Eggs that failed to hatch were either infertile or contained dead embryos. Altogether there were 38 nests in which some or all eggs failed to hatch and usually this involved only one egg out of a full clutch. On only two occasions did an entire clutch fail to hatch.

FIGURE 28. Predated Goldfinch nest showing egg remains.

FIGURE 29. Dead Goldfinch nestling showing predation marks made by a Magpie.


GF 29

TABLE 31

CAUSES OF NEST FAILURE DURING EGG-LAYING AND INCUBATION.

Causes of failure	No.of Eggs	Percentages	No.nests affected
Predation	78	46.4	21
Failed to hatch	56	33.3	38
Eggs lost	13	7.7	8
Desertion	12	7.1	3
Weather	9	5.4	3

In both cases, the clutches were deserted after incubation had continued for approximately 20 days after which the eggs were examined and found to be infertile. Desertion during laying and incubation only occurred on three occasions and may have been the result of interference from predators or death of either or both parents. In general parents were reluctant to leave their nest site once egg-laying had commenced.

Weather was not an important cause of nest failure at Havelock North. At Monash, Middleton (1965) records that nests were frequently blown out of trees during strong winds. At Havelock North only one nest was blown from its site and on one other occasion the branch of the tree containing the nest was snapped as a result of strong winds. Heavy rain caused the failure of another nest. The compacted lining prevented the water from seeping through and the nest containing two eggs remained full of water for several days. It appeared that the heavy rain had prevented the female from beginning incubation which allowed the nest to fill with water.

In eight nests either one or two eggs went missing during incubation. This unexplained egg loss is known to most ornithologists and remained as such during this study. Presumably a predator was involved.

Causes of failure during the nestling period are shown in Table 32. Approximately 48 percent of the chicks that hatched actually flew and over 80 percent of chick deaths were due directly to predation. Signs of predation were not hard to find but the identity of the predator was. On two occasions a Magpie (Gymnorhina tibicen) was disturbed while eating half-grown nestlings and on another occasion nestlings were killed by a Magpie and left at the nest site. Figure 29 shows the predation marks on one of the dead chicks. Thomson (1922) mentions the Kingfisher (Halcyon sancta) as a predator on young Goldfinch nestlings in New Zealand and on several occasions during this study a Kingfisher was observed perching on wires close to Goldfinch nests which had just been destroyed. The Australasian Harrier (Circus approximans) was a frequent visitor to one of the breeding orchards, block B, and was probably responsible for several nest failures. On two occasions after a Harrier had visited the area, only the foundation material of a nest was left at the nest site, the rest of the nest and its contents having disappeared. Bull,P.C. (pers. comm.) has on one occasion found a completely intact Goldfinch nest at a Harrier nest site and so it seems likely that the observed Harrier in Block B was an active predator. No harriers or nest disappearances were observed in block A. Other potential predators present were the Myna (Acridotheres tristis), Greenfinch (Chloris chloris), brown rat (Ratus norvegicus) and the domestic cat (Felis domesticus).

TABLE 32.

CAUSES OF NEST FAILURE DURING THE NESTLING PERIOD.

Causes of failure	No. of chicks	Percentage	No. nests affected
Predation	211	81.8	53
Desertion	5	1.9	1
Retarded development	4	1.6	3
Nest structure	13	5.0	4
Miscellaneous	25	9.7	15

Faulty nest structure was the cause of failure in four nests containing young chicks. Two of the nests were built on a slant and as the young chicks began to move about they soon toppled out of the nest and died on the ground. A third nest with only a partially built rim was laid in and as soon as the eggs hatched the young chicks fell onto the ground. The fourth nest fell apart before the chicks were ready to fly with resultant death to the whole brood.

Several nestlings died as a direct result of overcrowding at nest sites. On two occasions when the nest failed to stretch sufficiently to accommodate the growing nestlings, one chick from each nest was crowded out. This may well have happened at other nests especially if all eggs in the clutch had hatched. Holcomb (1969) mentions a similar situation in the American Goldfinch (Spinus tristis) and suggests that the construction of a nest that can expand probably plays an important part in the success of most nests.

Other causes of failure included under the term 'miscellaneous' in Table 32 were death due to trampling, and human activity which caused 5 nestlings from one brood to explode from the nest before they could fly. Several nestlings exhibiting anomalous growth were found on the ground under the nest and these could have been thrown out by the parent birds. Strokov (1968) observed adults removing nestlings exhibiting abnormal growth in several passerines.

Generally, nestling success at Havelock North was fairly similar to studies of the same species elsewhere. Middleton (1965) recorded that 25.8 percent young fledged from all eggs laid and Elliott (1969) indicates that nest predation was often high at Massapequa. Lack 1954, Nice 1964, Holcomb 1969, Seel 1970, and Roseberry and Klimstra 1970, all indicate high nest failures as a result of predation in other altricial open-nesting species.

CHAPTER V

SUBSPECIFIC STATUS OF THE GOLDFINCH IN NEW ZEALAND.

A great deal of controversy exists over the subspecific status of the New Zealand Goldfinch. As already stated, Thomson (1922) records that the Goldfinch was first introduced into New Zealand by the Nelson Acclimatization Society in 1862. Presumably the birds came from Great Britain and would, therefore, belong to the British subspecies Carduelis carduelis britannica. However, Moncreiff (1931) has suggested that since the Germans were to the fore as bird exporters at that time, the New Zealand Goldfinch is more likely to belong to the Continental subspecies C.c.carduelis. Recently Neithammer (1971) has used wing and tail measurements to prove the New Zealand bird stems from the British stock. Measurements from specimens sampled in this study have been compared with those of both Great Britain and Germany.

5.1 METHODS

Bill length measurements were recorded for all goldfinches sampled in the stomach analysis section of this study. Wing measurements were taken from 75 birds sampled during May and June 1969. Methods of both bill and wing measurements followed those summarised by Gurr (1947). All measurements were taken with vernier calipers accurate to 0.01 mm.

5.2 RESULTS AND DISCUSSION

Table 33 and 34 indicate the bill length and wing measurements respectively of the Goldfinch. Bill length measurements cannot be compared statistically because Newton (1967a) provides no standard deviation figures. However, on an average the measurements of the Goldfinch bill at Havelock North are 0.8 mm and 0.5 mm shorter for male and female birds respectively. When the wing measurements are compared there is a significant difference between both Great Britain and Havelock North birds and Germany and Havelock North birds ($p < 0.001$, Appendix 3).

Therefore it seems evident that change has taken place since the bird was introduced. Middleton (1965) suggests that signs of morphological change may already be apparent in the Goldfinch in Australia which was introduced to the Australian mainland even later than in New Zealand. Johnson and Selander (1964) have found that the North American house sparrows already differ morphologically from their ancestral European stock approximately only 100 years after their introduction. That change has taken place in the New Zealand Goldfinch appears certain and therefore its subspecific status must remain in doubt.

TABLE 33

BILL LENGTH OF THE GOLDFINCH (In each case the range of values given in parenthesis).

Place	Sex	Number measured	Mean length (mm)	S.D.
* Southern England	♂	79	12.4 (10.5-14.0)	-
	♀	38	11.3 (9.5-12.0)	-
Havelock North, New Zealand	♂	198	11.6 (10.0-13.0)	0.52
	♀	156	10.8 (9.5-12.0)	0.51

* Newton (1967) P. 65

TABLE 34

WING MEASUREMENTS OF THE GOLDFINCH.

Place	Sex	Number measured	Mean (mm)	Range	S.D.
* New Zealand	♂	20	77.55	75-79	1.7
	♀	11	76.18	75-77	2.64
* Great Britain	♂	24	77.79	75-80	1.47
	♀	6	75.00	73-78	1.8
Germany	♂	43	79.44	77-82	1.55
	♀	22	76.55	74-78	1.44
Havelock North, New Zealand	♂	40	76.40	71-80	1.97
	♀	35	72.66	69-76.5	2.26

* Neithammer (1971) P. 215

SUMMARY

1. The feeding ecology and breeding biology of the European Goldfinch, *Carduelis carduelis*, was studied at Havelock North, New Zealand, between May 1969 and April 1971. The history of the Goldfinch in New Zealand was briefly reviewed. The species was introduced in 1862 and in just over 100 years has become well established in both the North and South Islands and most of the outlying land areas.

2. The feeding behaviour of the bird was observed and flocking as a social phenomenon was discussed. In the New Zealand Goldfinch the primary function of flocking is probably connected with a more efficient exploitation of an unevenly distributed food supply.

3. Food of the adult Goldfinch was determined by field observation and the analysis of crop and proventriculus contents. A total of 6,467 birds were observed feeding in the field between August 1969 and April 1970. The stomach analysis involved 342 birds and samples were taken for each month of the year. Field observations did not record as wide range of food types as the stomach analysis. Weed seeds were the predominant food source.

4. The seasonal change in the adult diet can be briefly summarised as follows. From March until the end of August Amaranthus retroflexus was predominant and then was replaced by Poa annua for all of September. During October P.annua and Erodium cicutarium formed the bulk of the diet while Carduus tenuiflorus predominated during November and December. Both C.tenuiflorus and Cirsium lanceolatum shared dominance in January and then C.lanceolatum dominated during February. A.retroflexus again became available in March.

5. Small quantities of insect material were eaten throughout most of the year. Aphids were the most common. Certain foods did appear to be preferred by the adults and factors indicating food preference were discussed.

6. A slight difference in the diets of the two sexes was observed when thistle seeds and other readily available food seeds were present. Bills of males were, on an average, 0.8 mm longer than females which may have enabled them to utilise the thistle supply more efficiently.

7. In the summer season it seems probable that goldfinches consume approximately 1.6 gm of seed per day and increase during the colder winter months. Throughout most of the year males averaged 0.75 gm heavier than the females and body weights showed some reflection on food resources present throughout the year.

8. The diet of Goldfinch nestlings was investigated. The food was examined by direct observation through the transparent skin of the neck and identifications and accuracy were checked by examining 22 nestlings in the laboratory. Also contents from older nestlings were sometimes withdrawn from the gullet using a small plastic tube attached to a 1 cc syringe. A total of 3,316 nestling diet observations were made and the percentage frequency occurrence and percentage composition by volume of food for each day during the nestling period was calculated.

9. Animal protein formed a much greater percentage of the young chicks diet and the proportion of invertebrates given declined with increasing age of the young. Significant differences in the percentage animal protein fed to nestlings did not produce any significant difference in growth rates of broods concerned. The dietary pattern of the nestlings changed as the breeding season progressed but the percentage of animal and vegetable material fed to them remained fairly constant.

10. Experimental work was carried out to investigate the process involved in selection of food for the young. Results confirmed Newton's (1967a) ideas that, in those species which give fewer invertebrates to their young as they get older, this was a direct response to the appearance of the young themselves.

11. Two crop damage reports were carried out to ascertain how much damage the Goldfinch was causing to strawberry crops and fruit buds on pear trees. A stomach analysis carried out on birds shot on 12 hectares of strawberries showed that house sparrows, goldfinches and skylarks were responsible for seed picking of the fruit and that the greatest amount of damage was done in that order. Thrushes, blackbirds and mynas were important fruit eaters. A correlation was found for the Goldfinch between the peak period of damage and interval between the ending and beginning of two main food types. Bird damage over a 20-day period was estimated at $2,092.32c.

Forty-two goldfinches were shot in an orchard where heavy pear bud damage was occurring and contents of the crop, proventriculus and gizzard were analysed in the laboratory. No sign of fruit buds were found in any of the birds.

12. The start of the breeding season was marked by the break-up of winter flocks. Nesting took place between mid-October and early March. Nests were mainly built in fruit trees and territorial defence was confined to the nesting tree once the eggs were laid. Several loose breeding colonies were found. Clutch size at Havelock North was 4.7 and the incubation and nestling periods averaged 12.2 and 14.0 days respectively. There was little difference in nestling growth rates from broods raised in the

early, mid or late periods of the breeding season. In general, the rate of growth of the nestling increased to day 7 and then decreased to day 13. During day 13 and 14 the rate was similar. On day 14 the average weight was 13.5 gm, approximately 88 percent of the adult weight. Only 49 percent of the nests in which eggs were laid produced fledglings. Predation accounted for most nest failures.

13. The presence of faeces at the nest rim appears to be determined largely by the age of the nestlings in relation to their digestive abilities and the size of the brood as it affects the work load capacity of the parents.

14. Nest defence displays by the female were observed when she was disturbed unexpectedly either during hatching or brooding very young nestlings.

15. The subspecific status of the Goldfinch in New Zealand was investigated. Wing and bill length measurements indicate that change has taken place since the bird was introduced and therefore its subspecific status remains in doubt.

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APPENDICES

In all cases test of unit deviation (d) was calculated from the formula :

$$d = \frac{\text{mean 1} - \text{mean2}}{\sqrt{\dfrac{\text{Variance}_1}{\text{No.in Sample 1}} + \dfrac{\text{Variance}_2}{\text{No.in Sample 2}}}}$$

APPENDIX I

Significance of difference between mean body-weights of male and female goldfinches.

Sex	No.in sample	Mean Weight (gm)	Variance	d required (p=0.001)	d obtained
Male	186	15.64	2.47	3.291	4.412
Female	141	14.89	2.70		

APPENDIX II

Significance of difference between mean animal protein units in the nestlings diet,Block A and B.

Area	No.of observa-tions	Mean No.of animal units/ observation	Variance	d required (p=0.001)	d obtained
Block A	1,238	1.145	6.131	3.291	11.808
Block B	2,078	0.224	1.066		

In all cases "Student" t was calculated from the formula :

$$t = \frac{\text{mean}_1 - \text{mean}_2}{\sqrt{\begin{pmatrix}\text{Standard}\\ \text{Error}_1\end{pmatrix}^2 + \begin{pmatrix}\text{Standard}\\ \text{Error}_2\end{pmatrix}^2}}$$

APPENDIX III

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN WING MEASUREMENTS OF GOLDFINCHES.

Locality	Sex	No.in sample	Mean (mm)	S	S.E.M.	fχ	t required(p=0.001)	t obtained
*Germany		43	79.44	1.55	0.237	81	3.646	7.775
Havelock North, N.Z.		40	76.40	1.97	0.312			
*Germany		22	76.55	1.44	0.307	55	3.646	7.923
Havelock North, N.Z.		35	72.66	2.26	0.383			
*Great Britain		24	77.79	1.47	0.300	62	3.646	7.326
Havelock North, N.Z.		40	76.40	1.97	0.312			
*Great Britain		6	75.0	1.80	0.735	39	3.646	3.406
Havelock North, N.Z.		35	72.66	2.26	0.383			

* Niethammer (1971) p.