SOME ASPECTS OF THE FEEDING OF THE HARRIER

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ABSTRACT

A study of the food habits of the Harrier Hawk (**Circus approximans gouldi** Bonaparte) was made in the southern part of the South Island.

Observations were made in the field and on two hawks kept in captivity, one an adult, the other a young bird.

A quantitative-qualitative analysis was carried out on 129 crops and 129 stomachs between February 1966 and December 1967; during this time 254 food items were identified.

The percentage occurrence of various groups of food items eaten between these dates are: traces of sheep 18.5%, small mammals 28.8%, Passerines (including eggs and nestlings) 30.8%, ducks (Grey and Mallard) 5.0% and miscellaneous items 17.8%. Of the Passerines 5.0% of their occurrence was either nestlings or traces of egg shell, the remaining 25.8% was adult birds. Eleven of the 13 duck food traces were found in hawks collected during the duck hunting season.

One interesting observation made during this research concerned sex determination.

Some books have stated that eye colour can be used as a sex determinant for differentiating between adult males and adult females. However, after determining the sexes of these specimens by dissection and gonad inspection it was discovered that, of 29 females considered to be adults 18 had yellow irides, 7 had brown ones and 4 had occluded irides. In comparing some of the yellow irides of the adult females with some of those found in adult males no distinctive differences could be observed.

The average weight of female hawks (juvenile and adult) was 822.5 grams with a variation from 622 to 1044 grams. The average male weight was 633 grams with variations from 392 to 725 grams.

In captivity, an adult with an average weight of 722 grams consumed an average of 111.5 grams of food per day or 15.4% of its body weight.

A young hawk was captured at 22 plus/minus 1 days of age. A food intake record was kept between days 24 and 55, and a weight record was kept between days 23 and 55. The average daily weight of the young hawk was 635 grams and it consumed an average of 128.8 grams of food per day between days 24 and 55. This is 20.3% of its body weight. Up to and including day 40 it consumed an average of 147.6 grams per day or 23% of its body weight while having an average weight of 635.4 grams. After day 40, a noticeable decrease in the average weight of food consumed was recorded. Between days 41 and 55 it consumed an average of 104.3 grams per day amounting to 16.4% of its average body weight of 635 grams.

INTRODUCTION

The New Zealand avifauna is unique in that there are only four established raptors, two nocturnal and two diurnal. One of the two nocturnal species was introduced while the other three raptors are native to New Zealand.

The ranges of the two diurnal raptors overlap little. The Harrier Hawk *(Circus approximans gouldi)* is confined mainly to the open country and to the edges of the native forests. The New Zealand Falcon *(Falco novaeseelandiae)* is restricted with a few exceptions to the native forests. The only major range overlap that exists between significant numbers of different species of raptors is that between the diurnal Harrier Hawk and the introduced, nocturnal Little Owl *(Athene noctua)*. Some competition for food exists between the Harrier Hawk and some of the mammalian predators such as the Weasel *(Mustela nivalis)*, Stoat *(Mustela erminea)* and the Rats (*Rattus* sp.) but this limited competition is unlikely to have any major effect on the diet of the hawk.

The hawk's competition for food with other predatory species in pre-European times was less than it is now judging from the few

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predatory animals then present. The number of hawks present was probably smaller than their present day population because at the time they lacked a plentiful food supply and an extensive range.

It is likely that the hawk's numbers increased considerably with two coinciding events. One was the clearing of forested areas to some extent by the pre-European Maoris for hunting but more so by the early Europeans for their large farms and stations. The destruction of native forests either for hunting purposes or to create new grazing land increased the potential range of the hawk. The other event was the introduction of potential prey species such as the European Rabbit *(Oryctolagus cuniculus)* and small passerines. Many of these new prey species have utilized this new range and supplied sufficient food for a sizeable population increase by the hawks.

The rabbit, because of its numbers, may have played an important part in the increase of the hawk population, but unfortunately there is no accurate account of the relative numbers of both species up to this time. However, firsthand accounts by long-time residents in the study areas have suggested that until twenty or twenty-five years ago, the hawk population was considerably larger than it is today.

Now that the rabbits are effectively controlled in most areas, their numbers have decreased markedly. This decrease in one of the major food sources of the hawk may reduce the number of hawks to suit the reduced number of prey unless the hawk can find a new food supply or seek a compromise by having its numbers reduced to suit a new-found food supply.

There has been no formal, published study done on the food habits of the Harrier Hawk with which a present day food analysis can be compared. Reports have been written, however, on occasional sightings of its capturing food and of some very limited gut content analysis as done by Travers (1866).

This study is an attempt to analyse the present-day food habits of the Harrier Hawk in the south-eastern two-thirds of the South Island. A quantitative and qualitative analysis has been done on 129 hawks collected from throughout this area. At the same time, the methods used by the hawks to capture, manipulate and eat food as well as their post-meal activities were studied with two hawks (one adult and one juvenile) kept in captivity at different times between March 21, 1967, and January 14, 1968. An analysis was also done, using these two birds, comparing their food intake to their body weight.

METHODS AND TECHNIQUES

Collection

Specimens of the hawk were collected by two methods. The first method was trapping which depended largely on the hawk's type of nutrition. The second method was by shooting them.

The Harrier Hawk, by choice, depends to a large extent on scavenging for its nutrition. Consequently trapping it during the autumn and winter, when food is relatively scarce, is reasonably easy. The main method of trapping was to place a sheep or some other dead animal out in a field where it would be easily visible to foraging hawks. Traps were set around this bait and held to the ground by an iron spike. A spike was also placed through the bait to prevent it from being dragged away.

Another method of trapping but less likely to injure the birds, was used by myself. The jaws of the traps were padded with one inch foam rubber held in place by friction tape. A piece of nylon cord about three feet long was attached to the chain.

These traps were placed on fence posts and the cord was attached to the middle strand of wire. The bait was suspended on the top strand of wire one foot to eighteen inches away from the post. The hawks would land on the post since it was the nearest vantage point to the food, and become caught. The trap would then fall to the ground and remain attached to the wire by the nylon cord. The cord was long enough so that the hawk would not become suspended upside down from the post, thus preventing unnecessary suffering.

The second method of obtaining specimens was by shooting. This was easily done when the hawks were coming into roost or after they had finished eating and were resting in fields or on fence posts.

Shooting hawks when they were coming in to roost is done with the aid of a call. The call is made by taking two spent shot-gun cartridges, detaching their bases, and knocking their detonators out. The open ends are fitted together forming a short cylindrical tube and small opening at either end where the detonators were. Blowing through this creates a shrill whistle almost like the distress signal of a hare or rabbit.

Originally it was hoped to collect approximately 200 hawks, 50 from each season, but only 129 were collected. The numbers collected in the spring and summer fell short of the set goal.

The lack of numbers during these two seasons was attributed to two reasons. During the spring and summer most of the hawks have separated into breeding pairs and do not roost communally as they do in the autumn and winter. The difficulty arises in that there is no high concentration, and therefore no easily obtainable numbers of hawks. Also during the spring and summer there is sufficient, easily accessible natural food so that the hawks do not have to rely on scavenging as much as they do in the autumn and winter; this makes it difficult to capture birds in set traps.

The months were grouped into seasons in the following manner: Spring (September-November), Summer (December-February), Autumn (March-May) and Winter (June-August).

Upon receiving a specimen the stomach and crop were removed and the contents were separated and identified immediately or they were labelled and put into a freezer until sufficient time was available.

Before the specimen was discarded its sex and iris, cere and leg colour were noted, a rump covert was also taken and tagged with a specimen's number for later use in attempting to find field sexing aids.

Sexing

Difficulties arise in sexing the Harrier Hawk in the field and sometimes even in the laboratory. In the field these difficulties are compounded by the additional problem of distinguishing between young adult and juvenile birds of the same sex. So far only two partially successful ways have been discovered that enable one to distinguish between adult males and females in the field. One method is by

colouration. The females of the same general age group tend to be darker than the male. The other method is by weighing the birds; here the female is generally heavier than the male. There are, of course, many difficulties arising from both of these methods. The females are said to have brown irides and the males yellow irides. This theory has been found to be invalid. Besides the adult females having yellow as well as brown irides, another complication is that juveniles of both sexes all have brown irides.

In this study 29 adult females were collected, 18 of these had yellow irides, 7 had brown irides and 4 had irides that were occluded through the birds having been hit on the head, the blood vessels around the eyes then rupturing.

TABLE 1 — BIRD WEIGHTS

	Number Examined	*Average Weight*	*Maximum Weight*	*Minimum Weight*
Adult Males	42	649.0	725.5	542.0
Adult Females	29	839.0	1044.0	744.5
Juvenile Males	32	617.0	720.0	392.0
Juvenile Females	21	806.0	1002.0	622.0

During this study an attempt was made to differentiate between adult males and females by the use of rump covert colouration. It was noted during a few casual observations of the specimens that the rump coverts of the adult males appeared to have a lighter background colouration than those of the adult female. The adult females also have a wider proximal and distal brown bar as well as a darker background colouration of the feathers. The brown vertical stripe up the rachis, between the bars, is wider in the adult females than in the adult males, where it is sometimes non-existent. The overall background colouration of the rump coverts in the adult males is almost pure white while in the adult females it ranges from a buff to a light cream colour.

From the results of these observations it is believed that iris colour, like feather colour, becomes lighter as the birds get older, and that apart from dissection the next most effective method of determining the sex of adult birds is by weighing them, possibly used in conjunction with rump covert characteristics.

SEPARATION OF FOOD CONTENTS

Frozen crops and stomachs were preferred for the weighing of the contents from these two organs, since frozen contents are easier to handle.

Separation of the food contents was carried out by the flotation method commonly used in industry. The crop or stomach contents were put in a glass beaker or bowl and placed at an angle on a frame containing a fine wire mesh over a sink. Water was run slowly into the container; at the same time the food was mechanically dissociated with a glass rod. The lighter contents such as feathers, grass and hair eventually passed over the top of the container with the slowly running water and became caught in the fine mesh.

The food contents of the mesh were separated under a gentle stream of water. The separated articles were put into separate dishes.

The heavier contents still in the container were poured on to the mesh and separated in a similar manner.

A small sample from each of the various dishes containing different, identifiable contents such as hair and feathers, was taken and dried for later use in identification while the remainder of the food contents was measured volumetrically. Contents of less than 0.5 cc. were considered to be traces. After the volume was determined, the feathers, hair, grass and bone constituents were left to dry and the meat was preserved in a solution of 8% formaldehyde.

The small samples from each of the dishes containing identifiable hair or feathers were then washed in xylol to remove the dirt and fat that coats them in the stomach. The feathers were dry mounted because mediums such as Canada balsam and depex have a refractive index that makes the nodes on the feather barbules very difficult to see. Hair mounted in depex is more easily identified because the medulla becomes visible whereas in dry mounts only the scale patterns are visible and these are not as distinctive as those of the medullary patterns.

IDENTIFICATION TECHNIQUES

In the gut contents of hawks, characteristics such as size, colour and shape of food items are lost, making identification by the use of whole animals impossible except in a few cases. In many cases only a single hair or feather was found in the gut contents; quantitative analysis will then depend upon being able to identify these hair and feather remains.

(i) HAIR IDENTIFICATION AND TECHNIQUE

There are generally two types of hairs found on animals. There is the guard hair which is long, straight and usually pigmented and there is the fine hair which is short, sharply bent or curled, fine, slightly pigmented and more numerous than the guard hairs.

The guard hair has a narrow proximal shaft with no constrictions and a flattened shield section which narrows to a tip.

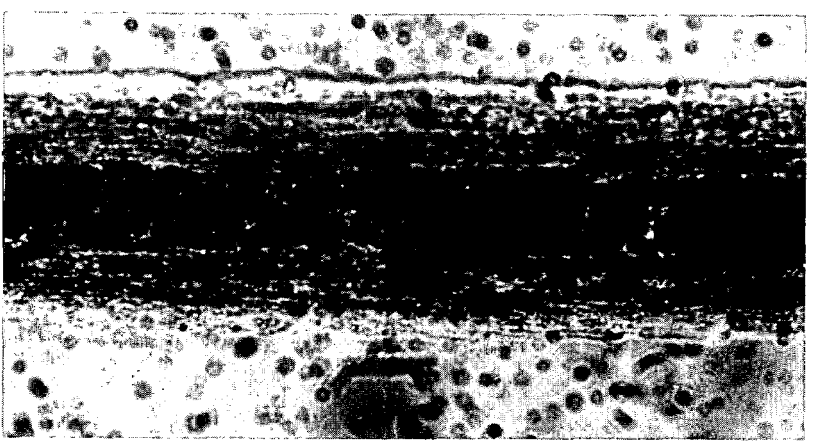


FIGURE 1: The hedgehog has an extremely thick, pigmented cortex, with two layers of keratin in the medulla. x 400.

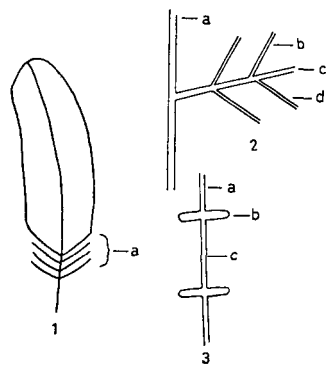
The fine hair has a less pronounced shield section with constrictions in the proximal shaft. Most hairs have three layers of keratin (Fig. 1). There is the scaly cuticle which surrounds the hair and is readily seen in dry mounts. There is the cortex which varies in thickness in different species of animals. Finally there is the medulla consisting of loosely packed cells often containing air.

(ii) FEATHER IDENTIFICATION TECHNIQUE

For use in microscopic feather identification body feathers are the most helpful. The downy area at the proximal end of these feathers (Fig. 2) contains the features most useful in diagnosing the order of the bird. Barbules in this area have no hooks or ridges thus giving the feather a downy appearance in this area. This is also very helpful in making these barbs easy to separate for diagnostic purposes. Day (1966) calls these the " downy barbules."

FIGURE 2: Diagram of the gross anatomy of the feather.

1. Body feather.
   (a) downy barbule region
2. Portion of a body feather showing positions of proximal and distal barbules.
   (a) feather rachis
   (b) distal barbule pointing to the tip of the feather
   (c) barb
   (d) proximal barbule pointing to the base of the feather
3. Barbule of a galliform with characteristic nodes.
   (a) pennulum
   (b) node
   (c) internode region

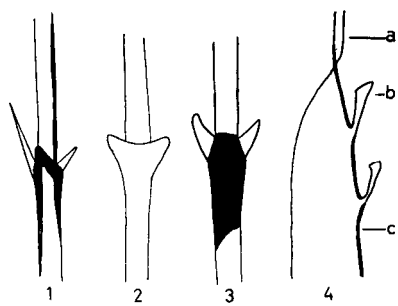


The structure of the downy area was examined before any attempt was made at describing diagnostic characteristics.

The barbules in this area have a short broad base followed by a narrower portion, the pennulum, swollen at intervals to form nodes. The unswollen lengths between the nodes are called internodes. It is the size, shape and distribution of these nodes (Fig. 3) that aid in determining to what order of bird the feather belongs.

FIGURE 3:—

1. Node of Falconiformes.
2. Node of Anseriformes.
3. Node of Passeriformes.
4. Passerine barbule, showing —
   (a) beginning of pennulum
   (b) villi
   (c) base of barbule



HARRIER HAWK PREDATION ECOLOGY

In discussing the various food items or possible prey items of the Harrier Hawk two important things must be considered. The first is the availability of the prey and the second is its vulnerability.

The 'availability of a prey species' simply means that if a particular prey species is present, it is an available food.

Vulnerability encompasses many things but is well summed up by Craighead (1956) as being "the result of the physical and biological conditions that cause one species to be preyed upon more heavily than another." These conditions include prey risks such as: protection, cover and food availability, concentration and dispersion of the prey, its health, and the speed, agility and escape reactions demonstrated by the prey species.

The density of the predator is the factor other than prey risk that should be taken into consideration in discussing predation.

(a) *Protection, Cover and Food Availability*

Cover for prey species or populations is one of the most important things determining prey risk. Despite the fact that hawks are often seen hunting hedgerows, these hedgerows offer good protection to small bird and mammal populations. It is when these potential prey leave this cover or it is destroyed that they become vulnerable to predation. If there is considerable cover and nesting facilities in these areas for small prey species, but litle food, then the number of prey individuals in this area will be low or else their vulnerability will rise because of the excursions that will take place away from the area of cover, in order to obtain food.

(b) *Concentration and Dispersion of Prey*

These factors may operate to increase or decrease the vulnerability of prey. An example of an increase in a prey population increasing its vulnerability is in the spring and summer when the numbers of a prey species may increase through breeding thus making these species more vulnerable. Most adult species have a tendency to protect their young, thus making the adults more vulnerable than if they fled. This increase in numbers of a particular prey species brought about by breeding causes an increase in vulnerability especially if this is a preferred food species. Also the young of a species are generally more susceptible to predation than the adults, thus making the species as a whole more vulnerable to most forms of predation.

The effect of dispersion of a prey species upon their predation is obvious. If there are none or few of these potential prey within a given area then the predation upon this species in this area will be nil or light.

(c) *Movement, Activity and Habits*

Movement by a prey species increases its risks of predation by making it more conspicuous and exposing it more frequently. Thus if a potential prey has to move about in search of water or food, then its chances of being captured by a predator have increased in proportion to the amount of time that it is foraging. Ducklings would be particularly vulnerable because they must search for food and water within a day after they hatch. A passerine that is feeding young also has its vulnerability increased because of the increased number of food gathering trips that it must make.

Activities of any species can modify its vulnerability to predation. For example, both opossums and hedgehogs are nocturnal, making them practically invulnerable to the hawk which is a diurnal predator. There are, of course, instances of overlap in the foraging times of these animals but in general they do not frequent the same area at the same time.

The habits of potential prey can increase their vulnerability. The voices of Blackbirds *(Turdus merula)* and Song Thrushes *(Turdus ericetorum)* draw attention to their presence, while the seclusive Hedge Sparrow *(Prunella modularis)* escapes detection. The habit of the Skylark *(Alauda arvensis)* of exposing itself to sing makes this bird particularly vulnerable to predation by the hawk.

(d) *Age*

The age of an individual prey item must be taken into consideration. The vulnerability of a prey species increases during the spring and summer because of the large influx of young which are particularly susceptible to predation. After an accessible nest containing young or eggs has been discovered by a hawk it is usually only a matter of time until all the occupants are taken.

During this period most young are incapable of defending themselves and usually make no attempt to escape the predator.

On the other hand, particularly old animals of a prey species, whose reflexes have slowed and senses have dulled become more susceptible to predation than the younger, more agile and alert individuals.

(e) *Size and Strength*

Large, strong animals are less susceptible to predation than those of smaller and weaker of the same or different species. An animal such as a mature Sheep (*Ovis* sp.) under normal conditions is not likely to fall prey to a hawk because of its size and strength but young rabbits and European Hares *(Lepus europaeus)* would be easy prey if they are accessible. It is possible, though, for a hawk to take by surprise prey that are larger than itself. One instance of this is the taking of a White-faced Heron *(Ardea novaehollandiae)*. This was observed by Mrs. E. Hannah.

(f) *Health*

The health of a potential prey individual or species, for that matter, is important. The number of ducks taken by hawks during the hunting season compared with the rest of the year lends strength to this. Far more ducks were taken during this period than the total for the remainder of the study period. During this time of year many wounded ducks escape the hunter but are unable to escape the predation of the hawk whereas under normal conditions they would have no difficulty in escaping. The hawks, because of this seasonal increase in vulnerability of the ducks, tend to congregate around the swamps in larger numbers than there normally are.

(g) *Speed, Agility and Escape Reactions*

There is no doubt that speed and agility reduce the predation risk of individuals and species. Small, elusive birds such as White-eyes *(Zosterops lateralis)* and Fantails *(Rhipidura fuliginosa)* have much

better chances of eluding the hawk in flight than less manoeuverable species. Birds such as small waders *(Scolopacidae)* and adult ducks are faster than the hawk. The only way a hawk may have of catching a healthy bird of these orders is by surprise.

Two other factors determining predation of a collective prey should be mentioned. Craighead (1956) said that " predation is in general roughly proportional to the relative prey densities." That is, if, in a collective prey population one species is more abundant at any time than any of the other species, then the more abundant species would receive a greater amount of predation pressure than the less abundant species, provided that their vulnerability levels are relatively equal.

The second factor determining prey vulnerability and closely related to prey densities is predator density. An increased prey density or an increased prey vulnerability in given areas will tend to increase predator densities. The most common example of an increase in predator populations increasing the vulnerability of prey populations in a given area is in the duck hunting season. During this time the hawk populations over hunted ponds and marshy areas increase noticeably. This increases the vulnerability not only of the wounded ducks, which are the prime prey of the hawks, but of all the other prey species in this area.

While discussing the different prey species, the health of the separate prey items, except in one or two specific cases will not be drawn into the discussion, because unless one sees the actual taking of the prey it is difficult to say what state of health an individual prey item is in. Gustaf Rudebeck (1951), in his observations of hunting raptors, noted that they were more successful when hunting injured or lame prey: in the case of the Sparrow Hawk *(Accipiter nisus),* 6 out of 23 successful prey captures showed some deviation from the normal.

(h) *Seasonal Food Variation*

Because the Harrier Hawk is capable of taking a wide variety of food, its diet may vary depending upon the densities of its prey populations or the availability of certain foods at different times of the year. There are two main ways that a hawk may change its food habits to suit the availability of the food.

Firstly, it may migrate to areas where foods which are more accessible to it are present. This does not seem to be true of Harriers. According to Watson (1951) it was found that adults tend to stay within a radius of about five miles, while some of the young disperse up to several hundred miles. It is likely that this dispersal is caused by factors other than a seasonal variation of food.

The second manner in which a hawk may react to seasonal fluctuations in food is by eating other foods than its preferred ones. These are said to be staples. For example, during the spring and summer the hawk shows a predilection, or natural food preference, for the young and eggs of many passerines. These are considered to be preferred foods because they are chosen above all other foods available at this time. However, during the autumn and winter

TABLE 2

SEASONS	SPRING		SUMMER		AUTUMN		WINTER	
NUMBER OF BIRDS EXAMINED	12		9		52		56	
KIND OF FOOD	a.	b.	a.	b.	a.	b.	a.	b
Sheep (Ovis sp.)	1	3.9	3	12.0	12	11.4	31	30.0
European Rabbit (Oryctolagus cuniculus)	5	19.2	1	4.0	10	9.5	3	2.9
European Hare (Lepus europaeus)	1	3.9	0	0	6	5.7	3	2.9
Brush-tailed Opossum (trichosurus vulpecula)	0	0	2	8.0	6	5.7	3	2.9
Eurasian Hedgehog (Erinaceus europaeus)	0	0	1	4.0	11	10.5	12	11.6
Mouse (Mus musculus)	0	0	1	4.0	4	3.8	5	4.8
Norwegian Rat (Rattus norvegicus)	1	3.9	0	0	0	0.0	0	0.0
Unidentified hair	0	0	1	4.0	0	0.0	2	1.9
Blackbird (Turdus merula)	3	11.7	0	0	4	3.8	7	6.7
Song Thrush (Turdus e. ericetorum)	4	15.4	1	4.0	2	1.9	2	1.9
Skylark (Alauda arvensis)	0	0	0	0	4	3.8	0	0.0
Goldfinch (Carduelis carduelis britannica)	0	0	1	4.0	4	3.8	0	0.0
House Sparrow (Passer domesticus)	0	0	0	0	0	0.0	3	2.9
Unidentified Passerines	1	3.9	0	0	7	6.7	10	9.5
Ducks	1	3.9	1	4.0	10	9.5	1	1.0
Unidentified birds	0	0	1	4.0	6	5.7	8	7.6
Blackbird eggs	2	7.8	0	0	0	0.0	0	0.0
Song Thrush eggs	3	11.6	0	0	0	0.0	0	0.0
Skylark eggs	2	7.8	7	28.4	0	0.0	0	0.0
Miscellaneous birds	1	3.9	1	4.0	5	4.8	11	10.6
Lizards	1	3.9	1	0	1	1.0	1	1.0
Insects	0	0	2	8.0	12	11.4	2	1.9
Trout (Salmo trutta)	0	0	1	4.0	1	0.9	1	1.0
TOTAL	26	100.8	25	100.4	106	99.9	105	101.9

a = number of individual food traces
b = percentage of total

when these preferred foods are not available, the hawk must eat something else, which, though not necessarily a preferred food, is still considered to be a staple of the hawk's diet. Such foods are road killed opossums, hares and rabbits and dead sheep that may be found in fields.

The Harrier relies heavily on the preferred foods of nestlings and eggs in the spring and summer, with the staples such as road kills, sheep and adult birds forming a smaller percentage of its diet. During the autumn and winter, upon the disappearance of the eggs and nestlings, the staple foods take over the major role in the diet of the hawk.

FOOD HABITS:
FOOD ANALYSIS AND DISCUSSION OF RESULTS

During a crop and stomach analysis certain unavoidable difficulties are bound to be encountered which may lead to vagueness or in some cases error. Some of these difficulties apply to both gut content and pellet analysis while others apply only to gut analysis. The main areas that these problems are likely to arise in this gut content analysis are: determining the number of individual items in the gut; the failure to examine each hair in the gut; and the lack of knowledge of differentiating characteristics.

The difficulty in enumerating individual items in the gut or contents occurs particularly when the hawk has been eating large prey and all that may remain in the stomach is hair or feathers. Under these circumstances, it is very difficult, if not impossible, to tell the number of prey or carrion items of that particular species on which the hawk has been feeding, since there is nothing that can be used as a basis for counting the items. When the hawk has been eating smaller food items such as small birds, mice or lizards the task of enumeration is not so difficult. Since, with these smaller items the whole individual is usually consumed there is no difficulty in counting birds' feet, beaks, mouse skulls or even incisors.

The failure to examine every hair or feather of the gut under the microscope can be well understood. This method of individual examination would take a very long time, so hairs and feathers were grouped microscopically at first and then representative sections of these groups were mounted on slides and identified. In some cases similar hairs of two separate species may have been placed in the same group and identified as one individual.

The lack of knowledge of differentiating characteristics is aggravated by the fact that there is no key available for differentiating the feathers of young Passerines. The problem was made even more difficult by the destruction of some of the identifying features by the physical and chemical action of the stomach. In pellets, feathers tend to be well ground and even powdery and the hair broken with the characteristic medullary patterns lacking, thus making very few complete hairs or feathers available for study.

Many of the contents of a gut like seeds and small grit (labelled detritus) may have been the result of the prey having eaten another animal and then having its crop, gizzard or stomach release these contents inside the hawk's stomach. These secondary foods may cause one to assume, for example, that the hawk has been eating insects,

TABLE 3

SEASONS OF THE YEAR	SPRING		SUMMER		AUTUMN		WINTER	
NUMBER OF BIRDS EXAMINED								
KIND OF FOOD	a.	b.	a.	b.	a.	b.	a.	b.
Sheep (Ovis sp.)	91.3	13.0	1053.3.	64.8	13.0	8.2	34.5	19.7
European Rabbit (Oryctolagus cuniculus)	173.3	24.8	1.8	0.1	17.0	10.7	83.7	47.7
European Hare (Lepus europaeus)	60.3	8.6	2.0	0.1	0.0	0.0	0.0	0.0
Brush-tailed Opossum (Trichosurus vulpecula)	47.1	6.7	1.4	-	0.0	0.0	0.0	0.0
Eurasian Hedgehog (Erinaceus europaeus)	45.0	6.4	133.7	8.3	0.0	0.0	3.6	2.1
House Mouse (Mus musculus)	8.1	1.2	20.0	1.2	0.0	0.0	0.0	0.0
Blackbird (Turdus merula)	8.1	1.2	35.1	2.2	64.0	40.2	0.0	0.0
Skylark (Alauda arvensis)	1.6	0.2	0.0	0.0	0.0	0.0	9.6	5.4
Goldfinch (Carduelis carduelis britannica)	1.5	0.2	0.8	-	0.0	0.0	5.0	2.8
House Sparrow (Passer domesticus)	0.0	0.0	72.5	4.5	0.0	0.0	0.0	0.0
Song Thrush (Turdus e. ericetorum)	3.2	0.5	81.5	5.1	52.7	33.0	0.5	0.3
Passerine	5.0	0.7	61.6	3.8	0.0	0.0	0.0	0.0
Miscellaneous birds	17.5	2.5	7.7	0.4	0.0	0.0	0.0	0.0
Duck	161.7	23.2	0.0	0.0	12.2	7.7	0.0	0.0
Brown Trout (Salmo trutta)	6.7	1.0	22.5	1.4	0.0	0.0	33.2	19.0
Unidentified meat	58.8	8.4	104.5	6.5	0.0	0.0	0.0	0.0
Bone	0.5	-	0.0	0.0	0.0	0.0	0.7	0.4
Plant matter	0.5	-	3.6	0.2	0.0	0.0	0.0	0.0
Detritus	9.0	1.3	12.4	0.8	0.5	0.3	4.0	2.3
TOTAL	699.2	100.2	1613.8	99.4	159.4	100.1	175.6	99.5

a = volume of food items
b = percentage of total

where in fact these are secondary foods. One of his prey may have eaten the insects and they were released from the prey's stomach or crop.

The final possibility of error is the fact that the hawk may have ingested some of its own feathers usually after having preened itself. In cases such as this the author's judgment was used to determine which cases were from preening and which were actually from prey or carrion.

In general most of the food items were discussed under the following topics: introduction, range, availability and vulnerability.

The heading introduction was discussed with reference to the means by which the species in question came to be in New Zealand. If it was introduced by Europeans its site was noted and a very brief history of its spread was given.

The range was considered from the standpoint of the present day distribution of the species. This of course ties in very closely with the vulnerability of the species. If, for example, the ranges of the food species in question and the Harrier Hawk show low signs of coincidence, then the availability of the food species in question will be low to foraging hawks. On the other hand, if the ranges of the food species and the hawk show considerable overlap the availability of the species will increase proportionately.

In discussing the availability of a food species the main factor taken into consideration was the range overlap between the hawks and the food species. In effect range overlap was equated with the degree of availability since as discussed earlier, availability was taken to mean the degree of presence of a food species in the hawk's range.

The discussion of the vulnerability of an animal took into consideration the attributes of each food species as discussed under the headings of: protection, cover and food availability, concentration and dispersion of prey, movement activity and habits, age, size and strength, health and the animal's speed, agility and escape reactions. All these points were assessed and the animal in question was given a vulnerability rating ranging between high and extremely low.

FOOD HABITS: BIRDS IN CAPTIVITY

(a) *Adult*

The purpose of this section of the study is to study the feeding habits of captive birds in conditions as close as possible to normal.

The food consumption of an adult bird and a partly fledged nestling were determined. These birds were kept in captivity and it is very likely that the food consumption of a wild bird would be greater than the results obtained here, if only because it is likely to be more active. At all times, except when experiments would not permit, these two birds were handled by normal falconry methods.

Keeping birds in captivity should have little effect on the manner in which the birds manipulate their food. Some of the food was obtained from road kills consisting for the most part of Rabbits, Hares, Opossums and an occasional Hedgehog, Thrush and Blackbird. The food item had to be recently killed to be considered suitable for consumption. This diet was supplemented by an occasional mouse, useful for tracing pellets, or meat purchased from a shop.

A certain amount of roughage, such as bones, hair and feathers, must be included in the hawk's diet. This roughage enables the

hawk to form pellets, which remove a layer of waste material that builds up on the inside of the stomach. The presence of this layer of waste, over a period of time, will cause the hawk's health to decline.

Another reason that makes it necessary to include roughage in a hawk's diet, is that the hawk's beak remains sharp and well trimmed through its pecking at the bones. If the hawk does not receive enough roughage in the form of bones the beak tends to become thick and recurved (Fig. 4). This will eventually prevent the proper closing of the lower mandible and therefore possible starvation. Also, the falcon tooth, not usually prominent on Harriers, tends to enlarge (Fig. 4). If symptons occur on a hawk's beak kept in captivity, the beak must be trimmed.

(a) (b)

FIGURE 4: (a) Beak deformation because of lack of roughage.
(b) Normal beak.

The casting of pellets often occurs just before feeding. The hawk points its head downwards, opens its mouth wide, draws its shoulders up around its neck, shakes its head sideways several times and then disgorges its pellet.

During the food consumption study, the following procedure was followed. At 4.30 p.m. the food for the day was weighed on a pan balance to the nearest gram and then put on a stand in the mews (a room where raptors are kept) at 5 p.m. The hawk had been removed from the mews at 1 p.m. and weighed on a specially constructed beam balance. It was then put outside on its weathering block or flown if time permitted until 5 p.m. when it was returned to the mews and released until 1 p.m. the next day .

Enough food, about 275 grams, was always put into the mews to ensure that it was never all eaten.

Certain precautions were taken to ensure that as little weight as possible was lost by the food. All doors leading to the mews were shut preventing any cats or dogs from getting in. A screen and fly netting were put over the window to stop flies from getting

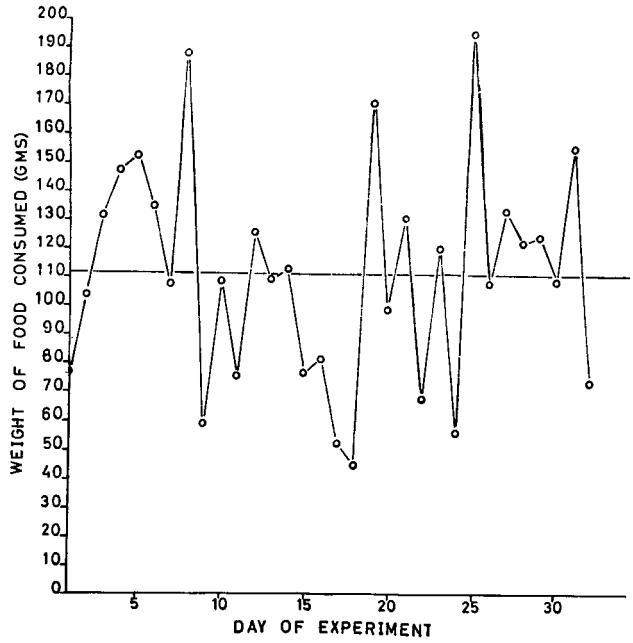


FIGURE 5a: Daily food consumption of the adult Harrier kept in captivity. The straight line is the average daily food consumption.

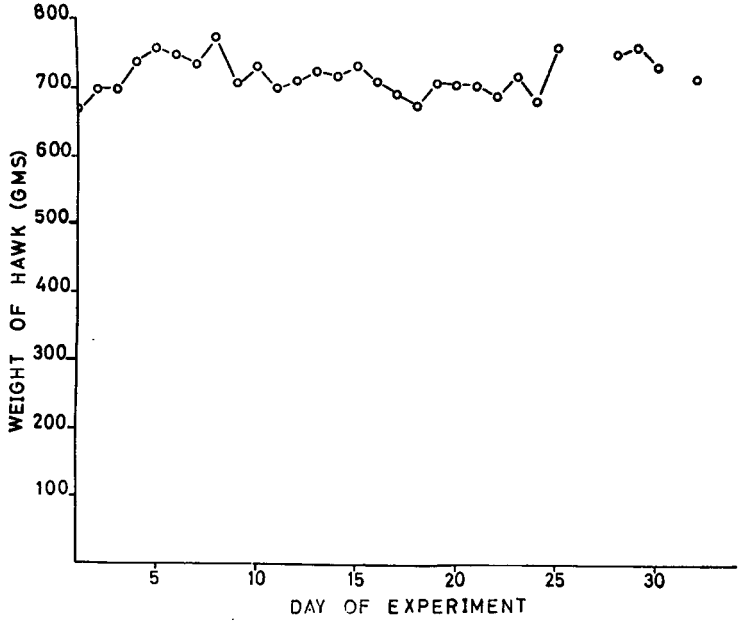


FIGURE 5b: Daily weight fluctuations of the adult Harrier kept in captivity. No weights were recorded on days 26, 27 and 31.

in during the summer. No mice or mouse traces were noticed during the year that the room was used as a mews. The only controlled factor of weight loss by the food was evaporation.

It was found that the average daily weight of food consumed by the adult hawk was 111.5 grams. The average daily weight of the hawk throughout the 32 day experimental period was 722 grams. The hawk was therefore consuming approximately 15.4% of its body weight in food per day (Figs. 5a and 5b).

On day 8 the food consumption was unusually high (188.0 grams) because the weighing took place at 3 p.m. rather than 1 p.m. This means that more food was consumed on day 8 and less on day 9 because of this extra meal on day 8's food. A similar situation occurred on day 25. On days 26, 27 and 31 I was away collecting the nestling and therefore unable to weigh the hawk, but the food was put into and removed from the mews at the prescribed times by a technician. The food that was removed daily was stored and weighed later.

For several months before the study of the weight relationships between the hawk and the weight of food it consumed, observations were made on the food habits of the captive bird.

The methods the Harrier used to capture and kill its prey were studied. The first experiment consisted of having the Harrier capture an already dead Blackbird, to which a length of string was attached. The lure was dragged past the Harrier in order that it might be caught without too much difficulty.

After the Blackbird was "captured" the string was given several sharp jerks to give it life-like qualities. After these jerks the hawk delivered its coup de grace to the "struggling" bird: in very quick succession, it lifted its feet a fraction of an inch off the Blackbird's body and thrust them down again so that the hind talons penetrated the body of its prey. After each foot was thrust down and the hind talon had entered the body of its prey, the Hawk then clenched its foot causing the inner and hind talons to slide closely past one another.

These two talons are extremely strong and it is with these that hawks kill their prey. These talons are almost directly opposed to one another and when the foot is closed the hind talon passes on the outside, between the inner and middle talons so that a pincer-like movement is obtained (Fig. 6). The middle and outer talons only serve to manipulate and hold food. The third or longest toe is often used to remove pieces of food that become stuck on the end of the hawk's bill.

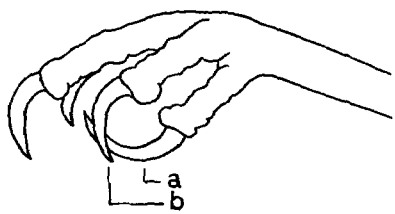


FIGURE 6: The pincer-like movement of the back (a) and inner (b) talons of the hawk.

Mice were obtained and released in the mews in order to study from close quarters the methods by which these hawks capture, kill and eat their food. Here is a description of a typical capture and killing of a mouse.

The hawk jumped off its perch and landed on the running mouse, striking it with its back talons. These two back talons are actually the leading part of the hawk's feet when it stoops (dips) at a prey (Fig. 7). After capturing the prey in its talons the hawk would fall forward thus causing the tendons operating its back talon to lock them automatically into its prey. The hawk, righting itself, would then begin mincing its feet in the manner described above. In some cases this failed to kill the mouse; if this happened, the hawk would then take the mouse's head in its beak and crush its skull.

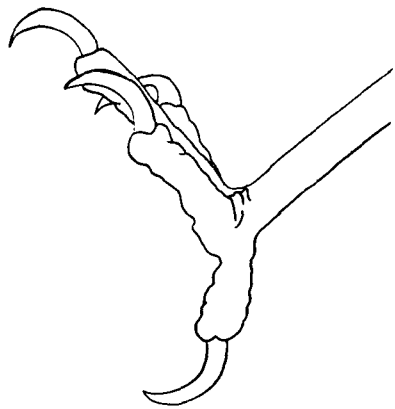


FIGURE 7: The hind talon is the leading part of a hawk's feet when striking a prey while in flight.

If the hawk missed the mouse on its initial attempt the hawk would then chase it on the floor until it became cornered. The hawk would then open its wings to their full extent across the corner and then catch the mouse with quick jabs of its feet.

An intact, but dead, hedgehog was given to the hawk to determine how it would go about eating one. The initial entry into the body was made by the hawk tearing the hedgehog's throat just below the chin. After the skin was broken it was peeled down to the lower abdomen. The hawk then removed and ate all the ribs. The backbone was broken off at the atlas vertebra and removed intact for about threequarters of the body length, but it remained attached by the last lumbar vertebra to the pelvic girdle.

Pluming takes place when the hawk obtains a meal covered with either hair or feathers. The action consists of taking a beak-full of hair or feathers, ripping them off the animal and disposing of them with a short, sharp, sideways flick of the head. This action continues until a suitable area is cleaned for eating or gaining entry into the muscular tissue. This may constitute a whole animal as in the case of birds brought to the nest for feeding the young, or it may only be a few square centimeters as in the case of a road-killed opossum.

Closely associated with pluming is the removal of grass, leaves and sometimes soil from the food. The disposal of the offending matter is carried out in the same manner as with hair or feathers.

After the plucking has taken place and the skin is broken open, the hawk begins eating, but it does so in such a way that it removes all the meat from under the skin in the area of the opening and occasionally pulls it back, often ripping it. This has the effect of skinning the animal.

If the hawk is hungry when receiving food, or whenever its food is in jeopardy, it will assume a mantling posture (Fig. 8). This consists of raising its feathers, spreading and lowering its wings and tail and assuming a $\frac{3}{4}$-crouch position. At the same time the head is lowered and sometimes the mouth is opened. Also, on occasion, the hawk may emit a loud piercing scream, but this occurs only when an approach towards the food is made.

FIGURE 8: The mantling posture is commonly used in defence of food.

When eating, all hawks stand on their food. This enables them to exert an efficient leverage on the food enabling them to hold it steady while eating it. Tearing food consists of taking food in its bill and giving it a quarter twist of the head and an upward jerk all in the same motion. If the food is easily torn only the upward vector of these two forces may be used.

Evidence of the forces exerted by a hawk while tearing its food was observed one day after a dead rabbit had been in the mews with the hawk overnight. Next morning the skull had been broken into pieces, none of which were more than one square inch.

When eating meat, especially soft meat such as liver or kidney and even tissue that is more muscular, it occasionally becomes lodged on the upper palate or stuck on the tip of the upper mandible. This is removed by shaking the head violently, by hooking it off with its middle talon or with its tongue.

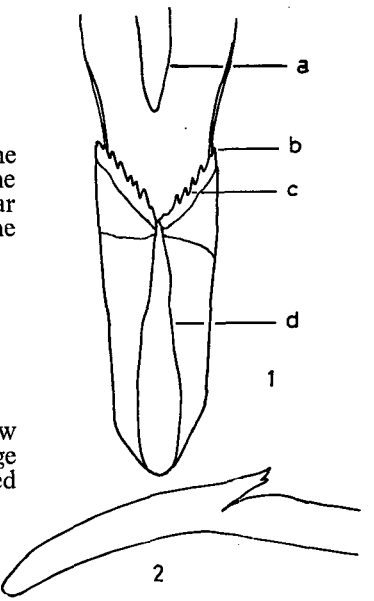


FIGURE 9: The two points and the serrated edge on the back of the hawk's tongue enable it to clear food off the palate or from the tip of the beak.

1. (a) opening to larynx
   (b) point
   (c) serrated edge
   (d) groove.
2. A tongue in position to show how the posterior serrated edge rises when food is being removed from the palate or beak.

The hawk's tongue (Fig. 9) is triangular in shape with the apex of the triangle forming the tip. The base of the tongue is serrated and has two prominent projections, one on either side, pointing towards the back of the mouth. When meat becomes stuck at the front of the mouth, the tongue is flicked forward and upwards and then drawn back in an attempt to catch the meat on these two projections or serrations and dislodge it by drawing the tongue back into the mouth.

After finishing its meal, the hawk begins to clean up. First it picks any remaining pieces of meat, no matter how small, off its talons, then it proceeds with a process known to falconers as feaking. This is simply a method of cleaning the beak by rubbing its sides and bottom alternately on anything that happens to be near such as a block of wood, the ground or even a rock. After this initial cleaning the hawk often dips its beak into water and then shakes it after removing it from the water.

Occasionally the beak must be cleaned while plucking food since the hair or feathers become stuck in the mouth. This is done in one of two ways, either by feaking or less commonly by raising one of its wings, inserting the head and beak under the wing, lowering the wing and then drawing the beak out thus removing the hair or feathers on the undersurface of the wing and on the body.

Another act that takes place during short pauses while eating, as well as after eating, is the controlled movement of food from the crop to the stomach. There are two ways of accomplishing this. The first consists of raising the head in an upward and slightly backward direction. The head and neck are both moved forward in this

raised position so that they come over the crop which is now trapped between the neck and the V-shaped furcula. The neck is lowered thus putting pressure on the crop and causing the food to be forced into the stomach. The second manner in which this is done is by a shrugging of the shoulders which raises the crop against the curved neck with the result that the food is again forced into the stomach.

(b) *Nestling*

A Harrier's nest was discovered in the Otapiri Gorge in Southland by Mr. Roger Sutton. It was observed by Mr. Sutton at least once and sometimes twice a week. The nest originally contained 6 eggs. Two chicks hatched on the 13th or 14th of November, 1967. Two more eggs hatched on the 18th or 19th of November, while the remaining eggs showed no signs of hatching. On the 26th of November the two older chicks and one of the younger ones were present while the other small one was missing. On the 4th of December only two large chicks and two eggs remained at the nest. The two eggs were cold and it is assumed that they were addled. Their measurements were 51.4 x 36.3 mm. and 48.9 x 39.4 mm. The eggs were absent when the chick was taken from the nest on the 11th of December. By this time the chicks were approximately 22 days old. The remaining chick was banded and left at the nest.

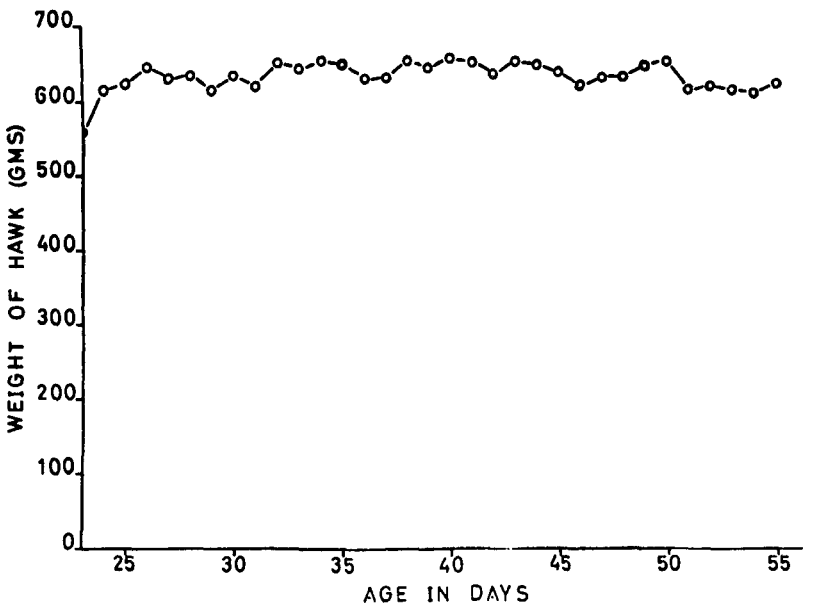


FIGURE 10: The daily weight of a 23 day old Harrier in captivity up to day 55.

Nothing further was seen of the two youngest chicks and it is assumed that they had both fallen victim to nest cannibalism. This is common among hawks and falcons but it contributes to their survival.

When the eggs are laid incubation usually begins with the second egg, and sometimes even with the first, thus any eggs laid after this will hatch proportionately later. This gives a staircase effect in the size of the chicks. The survival value comes at a time of food shortages. If the adults have been unable to capture sufficient food to feed the young properly, or if the adults are scared off the nest for a few hours, the larger and stronger birds will rip apart and eat the weaker ones. This extra meal increases the older chicks' chances of survival.

The chick was fed five times a day, the times being: 8 a.m., 11 a.m., 2 p.m. 5 p.m., and 10 p.m. The day's weight was taken just before the 2 p.m. feeding (Fig. 10).

On day 23 (the approximate age of the chick) the first weight was taken after a day's trip from Invercargill. During this day and the previous one the chick ate very little. This would account at least in part for the low weight at the time. There was no way of measuring the food consumed during these two days.

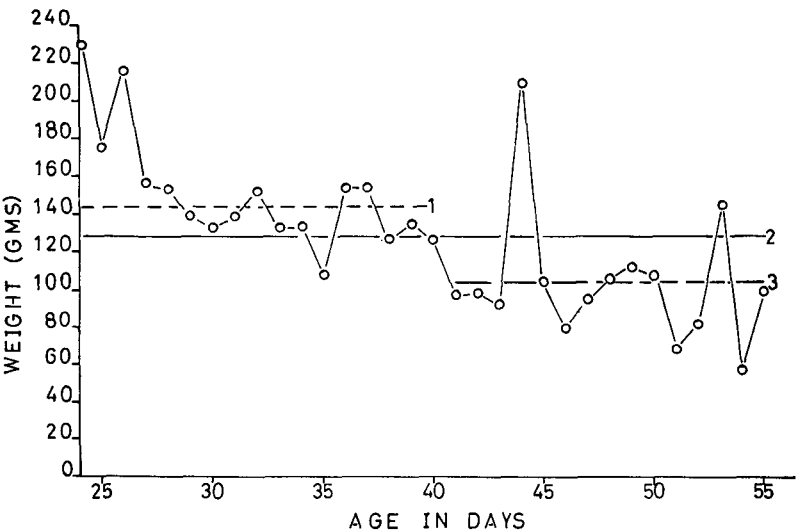


FIGURE 11: The daily food consumption of a young Harrier kept in captivity.

1. The average weight of food eaten up to day 40.
2. The average weight of food eaten during the study period.
3. The average weight of food eaten from day 41 until the completion of the study.

FIGURE 12: A young Harrier, 43 days old.

On all but two occasions, days 36 and 42, the chick was weighed just prior to its 2 p.m. meal. On these occasions, both feeding and weighing times were later. On day 29 the feeding times came two hours earlier than usual and the weighing was carried out at the regular time. This will probably explain, in part, the decrease in weight on day 29. On day 51 the chick received an injury to the right wing which caused him some pain, and probably caused some decrease in food consumption. On day 56 the injury was aggravated and no food was consumed. It was decided to end the study at this time since the bird seemed to be fully fledged.

It was found that the average weight of food consumed daily during this time was 128.8 grams (Fig. 11), while the chick's average weight was 635.0 grams. Before day 41, where the food graph drops to what appears to be about its final average judging from the results obtained from the adult hawk (whose daily food consumption in percent of the body weight was 15.4% per day) it required a daily average of 147.6 grams to support 635.4 grams of hawk. After day 41 it required only 104.3 grams to support an average of 635 grams of hawk.

	Average Chick Weight	*Average Food Consumption*	*Food Consumption expressed in terms of % of Bird's Weight*
Overall total	635.0	128.8	20.3%
To Day 40	635.4	147.6	23.0%
From Day 41	635.0	104.3	16.4%

The noticeable drop in food consumption beginning at approximately day 41 occurred at about the same time the hawk's feather growth appeared to be finishing (Fig. 12). Feather growth of this type, where all feathers are growing at once, takes a considerable amount of energy and to supply this energy the bird must eat more food than it normally would.

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