Predation by Great Horned Owls and Red-tailed Hawks in a prairie landscape enhanced for waterfowl

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Abstract

Several species of raptors are found in prairie landscapes managed and enhanced for waterfowl. Red-tailed Hawks (*Buteo jamaicensis*) and Great Horned Owls (*Bubo virginianus*) may benefit from such management in a manner that is counter to its goals and objectives; that is, waterfowl may comprise a significant proportion of their diet, resulting in a decline in waterfowl numbers. The overall aims of this three-year study were to determine whether the feeding habits of the two raptor species are selective and to determine if waterfowl is a preferred prey group. The diet was determined through pellet analysis, prey remains and direct nest observations during the nestling growth period. Availability of most prey species was assessed through small mammal trapping and by conducting waterfowl censuses. It was determined that both raptors select for duck species. The average waterfowl biomass consumed per nestling represented 21.5% of the total biomass consumed for Great Horned Owls and 23.5% for Red-tailed Hawks. With very high breeding duck densities, these values do not represent a high mortality rate for ducks (under 2% for both raptors combined). Although Great Horned Owls and Red-tailed Hawks select waterfowl as a preferred prey, currently they do not have a significant impact on the duck populations in these enhanced habitats.

Résumé

Plusieurs espèces d'oiseaux de proie sont présentes dans l'habitat de prairie améliorée pour la sauvagines. La Buse à Queue Rousse (*Buteo jamaicensis*) et le Grand Duc d'Amérique (*Bubo virginianus*) peuvent bénéficier de ce programme de gestion de façon contre-productive à leurs objectifs, c'est-à-dire que la sauvagine peut être une proie très importante dans leur diète. Le but premier de cette étude de trois ans est de déterminer si les habitudes alimentaires de ces rapaces sont sélectives et de déterminer si la sauvagine est une proie préférée. La diète fut déterminée en utilisant l'analyse de pelotes de régurgitation, les restes au nid, et l'observation des proies livrées aux nids durant la période pré-envol. La disponibilité de la majorité des espèces de proies a été déterminée à l'aide de trappage et de décompte et nous avons déterminé que la buse et le grand duc sélectionnaient les canards comme proie préférée. La biomasse moyenne venant de sauvagine consommée par les oisillons représentait 21,5 % de la biomasse totale consommée pour le Grand Duc d'Amérique et 23,5 % pour la Buse à Queue Rousse. Avec les densités de canard très élevées trouvées sur les sites, la prédation venant des deux rapaces ne représente pas une grosse partie de la mortalité (moins de 2 % pour les deux rapaces). Même si le Grand Duc d'Amérique et la Buse à Queue Rousse sélectionnent les canards comme groupe de proie favorite, pour le moment ils n'ont pas d'impacts significatifs sur les populations de sauvagines dans ces habitats améliorés.

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Introduction

In an effort to keep or restore duck populations to sustainable levels, several organizations are attempting to manage duck populations. The North American Waterfowl Management Plan (NAWMP) resulting from a formal arrangement among wildlife agencies of the U.S., Canada and Mexico and involving non-governmental partners such as Ducks Unlimited serves to coordinate management activities. The main strategy of the Prairie Habitat Joint Venture of NAWMP is to manage prairie landscapes modified by agriculture to enhance recruitment in waterfowl populations. Additional benefits to this program include increased use of managed habitats by non-waterfowl species such as raptors (Institute for Wetland and Waterfowl Research-IWWR, unpublished data). However, hawks and owls may benefit in a manner that is counter to the NAWMP goals and objectives. Recent observations by researchers from IWWR, as well as related reports, suggest that Red-tailed Hawks (*Buteo jamaicensis*), Swainson's Hawks (*B. swainsoni*), Northern Harriers (*Circus cyaneus*) and Great Horned Owls (*Bubo virginianus*) frequently prey on ducks and ducklings (Fig. 1.1).

These species are known to include waterfowl in their diet to varying degrees (Adamcik et al. 1978, Schmutz et al. 1980, Gilmer et al. 1983, Murphy 1993). In many regions, small mammalian prey such as ground squirrels, mice and voles are preyed upon heavily during the breeding season (Schmutz et al. 1980, Restani 1991, Janes 1994, Marti and Kochert 1995). Nevertheless, in other areas avian prey are also important (Petersen 1979, Gilmer et al. 1983, Murphy 1993, Andersen 1995). In his North Dakota study, Murphy (1993) showed that Red-tailed Hawks and Great Horned Owls relied heavily on prey from wetlands, especially ducks. However, Murphy focused mainly on raptor diet and historical changes in raptor populations in his study area and he did not present any data on factors associated with variation in raptor predation on ducks and other prey species. Furthermore, it is still necessary to identify whether waterfowl constitute important prey in raptor diets throughout the American and Canadian prairie-parkland region or merely in localized areas.

The level of the impacts of these four raptor species on nesting ducks and whether they comprise a significant source of mortality for ducklings and/or adult ducks is of concern to IWWR and other proponents of the NAWMP. Furthermore, other aspects need to be considered such as the density of raptor species in question, fluctuating numbers of alternate prey, other sources of mortality such as mammalian predators (Sargeant et al. 1993), and the percentage of the prey population impacted. Determining these effects must be accomplished in a way that provides insight into the habitat interface, i.e. under what situations are duck prey vulnerable? Therefore, a need exists to learn more about raptor foraging behaviour, habitat selection, spacing, alternate prey abundance, and reproductive success and then to relate these findings to those being collected for waterfowl. The information required on this subject can be broken down into two components, the first one being raptor - waterfowl interactions and the second being raptor use of waterfowl habitat. This M.Sc. project focuses on the first as another M.Sc. student is already working on the second.

This thesis considers only the Great Horned Owl and the Red-tailed Hawk, and their predatory interactions with waterfowl. The overall aim of this study is to determine their diets. Specific objectives were to determine whether Great Horned Owls and/or Red-tailed Hawks select ducks and/or ducklings as preferred prey, and to determine whether either of the two raptors has an impact on waterfowl populations in a prairie landscape managed to enhance waterfowl recruitment. Since the Great Horned Owl is a generalist (Houston et al. 1998), its diet should reflect the relative abundance of prey items. The Red-tailed Hawk is also a generalist (Preston and Beane 1993), therefore it should also take prey according to their availability. Due to the high densities of nesting ducks on the study areas (Johnsgard 1978, Bellrose 1976, IWWR unpublished data), neither should have an impact on waterfowl populations.

Figure 1. 1: Adult Red-tailed Hawk bringing a duckling to its chicks in Allan Hills study site, Central Saskatchewan, 1999.

Literature Review

Red-tailed Hawk

General Biology

In response to the widespread establishment of open wooded parkland instead of grassland or dense forest, populations of Red-tailed Hawk are increasing in much of North America. It has largely replaced the Red-Shouldered Hawk (*B. lineatus*) in partially cleared bottomland forest and has expanded its breeding range throughout the northern Great Plains as a result of increased tree growth in formerly treeless grasslands (Petersen 1979, Houston and Bechard 1983, Preston and Beane 1993). In Saskatchewan, the suppression of fire and the planting of trees and shrubs have resulted in a semi-open tree-grassland mosaic aiding its spread. Red-tailed Hawk numbers may have peaked in the 1970's but subsequent destruction of trees may have caused a slow decline in the red-tail population (Houston and Bechard 1983, Preston and Beane 1993).

Spring migration begins in February and may extend to June (Palmer 1988, Preston and Beane 1993). Red-tailed Hawks usually select open areas with many perching sites. Their habitats include scrub desert, plains and mountain grassland, agricultural fields, pastures, urban parkland, broken coniferous and deciduous woodland, and tropical rain forest (Palmer 1988, Preston and Beane 1993). The Red-tailed Hawk prefers tall trees within a woodlot, with good access to the nest within the crown and with a commanding view of the suitable hunting area nearby (Orians and Kuhlman 1956, Petersen 1979, Palmer 1988). Both adults select the nest site after visiting several nests from previous years. A few are repaired before one nest is selected. Their stick nest typically measures 71-76 cm in outside diameter and has a cup 35-37 cm wide by 10-13 cm deep. It is composed of deciduous sticks and twigs (1-2 cm diameter) and lined with bark strips, deciduous sprigs, aspen catkins, and other similar items (Preston and Beane 1993).

Usually two to four eggs are laid three to five weeks after nest selection. While both adults may incubate, the female sits on the eggs most of the time. The male takes over when she goes hunting, usually in mid-morning. The male brings food to the incubating female, but she also hunts for herself (Preston and Beane 1993). The incubation period lasts 34 days (Palmer 1988). The young take their first flight generally 42 to 46 days after hatching (Fitch et al. 1946, Palmer 1988)(Fig. 2.1). The mean number of fledglings per pair per year varies from 0.9 to 1.8 (Preston and Beane 1993).

Feeding Behaviour

The Red-tailed Hawk prefers to hunt small to medium-sized mammals, birds and reptiles from an elevated perch (Fitch et al 1946, Preston and Beane 1993). Small prey are usually taken to a feeding perch, usually lower than a hunting perch, or to the nest where small mammals are eaten whole and birds are beheaded, plucked and eaten. Larger items are eaten on the ground after being partially plucked and the remains are then carried to the feeding perch or the nest for continued feeding (Fitch et al 1946, Palmer 1988, Preston and Beane 1993).

The diet of the Red-tailed Hawk in northwestern parts of North America is dominated by Snowshoe Hares (*Lepus americanus*), Black-tailed Jackrabbits (*L. californicus*), and ground squirrels (*Spermophilus* spp.). Pocket gophers (*Geomys* spp.

and *Thomomys* spp.), waterfowl (*Anas* spp.), small birds including *Sturnus vulgaris, Agelaius phoeniceus, Sturnella* spp. and snakes such as *Pituophis melanoleucus, Elaphe* spp., *Thamnophis* spp., *Crotalus* spp. are also other important prey (Fitch et al. 1946, Luttich et al. 1970, McIvaille and Keith 1974, Palmer 1988).

In Central Alberta, Luttich et al. (1970) found that, over four years (1965-1968), mammals comprised 69% and waterfowl 4% of all prey caught by Red-tailed Hawks. In terms of biomass, mammals represented 66%, and waterfowl 12%. For three consecutive years (1969-1971) on the same study area, McInvaille and Keith (1974) reported 84% mammals and 5% ducks in occurrence, representing 86% and 8%, respectively, in biomass. The range of importance for each prey type varies tremendously from year to year. Murphy (1997) in northwestern North Dakota found 32.7% mammals and 63.3% birds with 36.7% being ducks. This shows the high variability of the dietary composition among regions, therefore the great adaptability of the Red-tailed Hawk as a generalist predator (Palmer 1988, Murphy1993, Preston and Beane 1993).

Great Horned Owl

General Biology

The Great Horned Owl is the most widespread owl in North America. Its varied habitat includes deciduous, mixed and coniferous forests, but it prefers open and secondary growth temperate woodlands, swamps, orchards, and agricultural fields. Most Great Horned Owls are permanent residents. They commonly use tree nests built by other species, but will also use cavities in trees and snags, cliffs, deserted buildings, and artificial platforms. They even lay eggs on the ground. Characteristics of the nest site depend on the builder, the most common being the Red-tailed Hawk, but also other hawks, crows, ravens, herons, and squirrels. Tree species vary regionally, e.g. Trembling Aspen (*Populus tremuloides*) is frequently used in Saskatchewan, and Cottonwood (*P. deltoides*) in North Dakota (Rohner and Doyle 1992, Murphy 1993, Holt 1996, Houston et al. 1998).

Breeding usually occurs during March and April. Clutch size varies from one to four eggs, the most common being two eggs (Houston et al. 1998). The 30-37 days of incubation are done entirely by the female; the male delivers prey to her at intervals throughout the night. Young leave the nest after 40 days and take their first flight at 45-49 days of age (Fig 2.2). Average brood size in Saskatchewan is 2.21 young per nest (Houston et al. 1998). Some of their rare predators are Red Fox (*Vulpes vulpes*) and Coyote (*Canis latrans*) that prey on owlets tumbling prematurely from the nest. Raccoon (*Procyon lotor*) are also known to eat eggs and nestlings. Some predation occurs from other raptors and other Great Horned Owls (Houston et al. 1998).

<u>Feeding Behaviour</u>

The Great Horned Owl is a generalist and opportunistic feeder that hunts primarily at night from a perch, but may also forage in broad daylight (Packard 1954). Peaks of hunting activity in Utah were from 20:30 to 24:00 and again from 04:30 to daybreak (Houston et al. 1998). It has the broadest diet of any North American owl (Marti and Kochert 1995), ranging in size from small rodents to larger hares and rabbits and large birds such as ducks, geese and herons. They usually crush the skull or decapitate prey before swallowing it. Small mammals, birds, and invertebrates are generally swallowed whole, headfirst. They usually discard the head and feet of larger prey that are dismembered before consumption. When food is abundant, they can store large quantities of prey in the nest (e.g. 15 Northern Pocket Gophers (*Thomomys talpoides*) and two Snowshoe Hares recorded in one Saskatchewan nest) (Houston et al. 1998). The mean prey size varies from 28g (in California) to 266g (in Chile) (Petersen 1979, Houston et al. 1998). In grasslands alone, the diet of the Great Horned Owl varies greatly from 61% mammalian biomass in Wisconsin (Petersen 1979), to 17% in North Dakota (Murphy 1993). This variation is due to the great adaptability of the Great Horned Owl while it responds to prey abundance (Houston et al. 1998).

Ecological Relationship of Red-tailed Hawks and Great Horned Owls

Red-tailed Hawk and Great Horned Owl are known to compete with one another. In addition to competition for prey, they also compete for nesting sites. The Great Horned Owl can be largely dependent on the Red-tailed Hawk for its nest, although they do not exclude each other from their territories (Baumgartner 1939, Gilmer et al. 1983, Johnsgard 1988, Palmer 1988). Sometimes they use the same nest in alternate years (Orians and Kuhlman 1956). Marti and Kochert (1995) showed that Red-tailed Hawk and Great Horned Owl prey on the same taxonomic classes with a 91% overlap but with only 50% overlap at the species level. These two raptors have a very versatile diet in general and local diets are mainly opportunistic (Marti and Kochert 1995).

Prey Availability for Great Horned Owls and Red-tailed Hawks in South Central Saskatchewan.

Common potential prey include ducks (Anserinae), American Coot (*Fulica Americana*), grebes (Podicipediformes), passerine birds (Passeriformes), Sharp-tailed Grouse (*Tympanuchus phasianellus*), Ruffed Grouse (*Bonasa umbellus*), Meadow Vole (*Microtus pennsylvanicus*), Southern Red-backed Vole (*Clethorionomys gapperi*), Deer Mouse (*Peromyscus maniculatus*), Western Jumping Mouse (*Zapus princeps*), Thirteen-lined Ground Squirrel (*Spermophilus tridecemlineatus*), Northern Pocket Gopher, Muskrat (*Ondatra zibethicus*) and Snowshoe Hare. Although population density is a useful index, it does not always represent the availability of each prey species. Bechard (1982) showed a correlation between foraging and prey biomass after the latter had been adjusted for vegetative concealment, thus computing the available biomass instead of the total biomass.

Prey Selection

Understanding prey selection is a key asset when trying to manage a raptor species. To be able to determine the degree of selection we need to determine the use of each prey species in relation to its availability. Very few authors have studied prey selection of wild birds, especially for generalists like Great Horned Owls and Red-tailed Hawks. The great range of possible prey makes the assessment of prey selection very difficult and imprecise.

Waterfowl Predation

Many authors (Preston and Beane 1993, Johnson 1995, Dubowy 1996, Leschack et al. 1997, Austin et al. 1998, Houston et al. 1998, Mowbray 1999) have reported predation on ducks by Red-tailed Hawks and Great Horned Owls but they do not give estimates as to how much of the predation is directly linked to these two raptors. Other predators such as the Red Fox seem to have a significant impact on duck populations. Sargeant et al. (1984) suggested that 900,000 ducks are consumed annually by foxes in the mid-continent area. The most vulnerable species for foxes seem to be dabbling ducks and in some areas, 6.02 ducks/km^2 are taken.

Figure 2. 1: Red-tailed Hawk chick at 45 days, a few days before fledging, Allan Hills study site, Central Saskatchewan, 1999.

Figure 2. 2: Great Horned Owl chick just fledged from its nest at Allan Hills study site, central Saskatchewan, 1999.

Methods

Study area

This research was conducted in the center of the prairie-parkland region of Saskatchewan, which supports the highest densities of waterfowl breeding pairs in continental North America (Bellrose 1976, Johnsgard 1978). More specifically, the study areas consisted of Saskatchewan Prairie Habitat Joint Venture (PHJV) assessment sites. Each of these areas is 65 km^2 in size and presents considerable variability in habitat composition (Fig. 3.1 and 3.2) both among and within-sites, e.g. wetlands, crop fields, woodlots, grassland, and planted waterfowl nesting cover. In addition to having different interspersions of habitat variables, the PHJV sites also show large variability in waterfowl and raptor densities, rendering possible comparisons of predation pressure based on their respective densities.

Another compelling reason for using the PHJV assessment sites was the unique opportunity for joint studies on the assessment sites, i. e. this study would not have been feasible without data collected by IWWR crews on the sites. Also there was an ongoing study estimating small mammal abundance in various cover types on the assessment sites by Dr. Maria Pasitschniak-Arts from University of Saskatchewan.

Figure 3. 1: Prairie landscape in Allan Hills, central Saskatchewan, 1999.

Figure 3. 2: Prairie landscape in Allan Hills, central Saskatchewan, 1999.

To date, 19 PHJV sites have been assessed throughout the prairie provinces. IWWR has assessed two such sites in Saskatchewan per year and the location of these sites has changed every year. This research was conducted at four of these sites over three years. In 1997, the first study area was the Willowbrook assessment site (WIL97) (51.1°N; 102.8°W) located approximately 30 km west of Yorkton, and the second site was at Allan Hills West (ALL97) (51.6°N; 106.1°W) located approximately 70 km southeast of Saskatoon. In 1998, the main study area was the Jumping Deer Creek site (JDC98) (51.1°N; 104.2°W) in the Touchwood Hills south of the Quill Lakes. Intensive work was not conducted at a second study area, Farrardale (51.5°N; 105.8°W) near the town of Hanley, because raptor densities were too low. In the third and final year of the study (1999), only one assessment site was studied, the Allan Hills East site (ALL99) (51.6°N; 106.1°W) two km southeast of the 1997 Allan Hills West site.

Nest Searching

Each spring, the study areas were searched for all potential Great Horned Owl and Red-tailed Hawk nests. The entire area of each site was systematically censused on foot. Stick nest locations were plotted on aerial photos. All Great Horned Owl and Red-tailed Hawk nests were found. Precautions were taken to minimize disturbance to nesting raptors during searches (Fyfe and Olendorff 1976) and nests were observed from more than 200 m during potentially sensitive courtship and incubation stages of nesting. After the eggs were presumed to have hatched, the nest was visited to assess the fate of its contents and to count young.

Prey Availability

Appendix I shows the prey species available. This list was compiled from, sightings, trapping and a literature review. Potential prey common to both predators included several duck species, American Coot, grebes, passerine birds, Sharp-tailed Grouse, Meadow Vole, Southern Red-backed Vole, Deer Mouse, Western Jumping Mouse, Thirteen-lined Ground Squirrel, Northern Pocket Gopher, Muskrat and Snowshoe Hare.

Waterfowl

Adult ducks

The number of breeding pairs per unit area was compiled for Mallard (*Anas platyrhynchos*) and for all ducks collectively by IWWR crews for each study area. Pair counts were performed to estimate waterfowl breeding densities within the study area. These counts were performed during the "optimal census period" (usually in late April / early May). At this point, the Mallard paired to unpaired male ratio approaches 1:1, which for IWWR, indicates that about half the females have begun to nest. At each site, two consecutive counts were conducted on 6 of the 25 transects covering the study area. Pair counts were done on foot using binoculars, with the observer walking from pond to pond on the transects and counting duck pairs. This technique is detailed in a manual by IWWR (2000).

Ducklings

The availability of ducklings was calculated from the number of adult breeding pairs. We assumed a maximum average of 12 ducklings per breeding pair. The assumption is an overestimation of the actual numbers of ducklings since not all pairs breed successfully and not all clutches are that large.

American Coot

The number of American Coots was obtained from the Canadian Wildlife Service in Saskatoon (Clark and Leach, personal communication). The technique used by USFWS-CWS to conduct these air-ground transects is explained in Cowardin and Blohm (1992) and Alisauskas and Arnold (1994). We used Strata 33 and 34, averaged the results, and converted it to the number of individuals per km^2.

Pocket Gopher and Ground Squirrels

The relative densities of Northern Pocket Gopher, Thirteen-lined Ground Squirrel, Richardson's Ground Squirrel (*Spermophilus richardson*) and Franklin's Ground Squirrel (*S. franklinii*) were assessed in 1998 (JDC98) and 1999 (ALL99). The Northern Pocket Gopher is known to build a fan-shaped mound made of excavated dirt. These mounds are located off short lateral burrows from the main tunnels and are from 1 *l* to 35 *l* in volume (Banfield 1974, Whitaker 1980, Forsyth 1999). The mounds are easily distinguished from the holes produced by ground squirrels. Ground squirrels only dig a hole and spread the excess dirt evenly (Banfield 1974, Whitaker 1980, Forsyth 1999). Thus, by counting the number of mounds and holes we can get an index of the relative density of both pocket gophers and ground squirrels. Assuming that every hole is linked to a burrow which contains more than one individual and that one burrow probably has more than one hole, it was estimated that every hole represents one individual. This estimation probably underestimates the population, but no other authors give a better estimate of the ratio of holes per individual. Banfield (1974) and Forsyth (1999) mention that a burrow contains more than one hole but they do not elaborate.

In 1998, the field crew conducted 43 transects covering 37,250 m^2 and in 1999, 53 transects covering 53,000 m^2 were used. Transects of 5m by 200m (1000 m^2) were generally used, and depending on the terrain, smaller transects were also done. The method simply consisted of counting all the holes and mounds found in the sample area.

Voles and Mice

The populations of small rodents were estimated during three trapping sessions through the summer. In 1997 and 1998 (ALL97, WIL97 and JDC98), these censuses were conducted by Dr. Maria Pasitschniak-Arts of University of Saskatchewan. In ALL99 the census was done by our crew using her methods. Each three-night census was done around the 15th of the months of May, June, and July of each year. In each session 20 trap lines were set up in two random zones of the study area with two trap lines for each major habitat type (Wetland edge, woodlot, native grass, crop field and dense nesting cover (DNC)). Each line consisted of 10 trapping stations 10 m apart on which two snap traps were attached with a 1.5 m rope. Flagging tape was attached to the rope permitting us to relocate the traps easily. The relative abundance was expressed in number of small mammals caught per 100 trap nights. To calculate the relative abundance, the number of rodents caught was divided by the corrected number of trap nights. The corrected number of trap nights consisted of the number of trap nights minus 0.5 trap night for every occupied and sprung trap.

This relative abundance can be converted to the minimal population density by compiling the number of animals caught over the approximate area covered by the traps. The area covered by a trap lines is 150 m^2.

Diet Determination

To assess the diet of Great Horned Owl, pellet analysis was used. To determine the Red-tailed Hawk diet, three methods were used concurrently: 1) pellets were collected in and under nests; 2) nest-trees were climbed and all prey items present in the nest at that time were recorded; and, 3) a sample of nests was observed from blinds to record prey deliveries.

Pellet collection and analysis

In ALL97, WIL97 and JDC98, owl pellets were collected in and around nests, plucking perches and roosting sites. Each pellet was collected, identified immediately to species, date and nest location, and frozen for later analysis. A total of 459 pellets was collected and analyzed from 19 nests (Table 3.1). While over a thousand Red-tailed Hawk pellets were collected from 10, 19, 18 and 11 nests in ALL97, WIL97, JDC98 and ALL99 respectively, only 399 pellets were analyzed (Table 3.1), due to time and resource constraints, but principally because their analysis did not yield any more accurate estimates of numbers of prey consumed. In 1997 only the pellets from all 10 ALL97 nests were analyzed, this was chosen randomly over WIL97. In JDC98 and ALL99 only pellets from observed nests were analyzed, thus permitting a comparison of the two methods.

Table 3. 1: Number of pellets of Great Horned Owl (GHO) and Red-Tailed Hawk (RTH) analyzed from nests on each study area in Saskatchewan, 1997-1999.

		ALL97	**WIL97**	**JDC98**	**ALL99**	***Totals***
GHO	Pellets analyzed	154	109	196	-	***459***
	No. of nests	7	9	3	-	***19***
RTH	Pellets analyzed	210	-	65	124	***399***
	No. of nests	10	-	3	6	***19***

To determine raptor diet from the pellets, an adapted version of the technique described by Marti (1987) was used. The first step consisted of thawing and air-drying the pellets under a fume hood for 48 hours or more. A meticulous dissection of each pellet then followed, separating small bones from feathers and hair using forceps and fingers. Occurrence of each group of prey species was then recorded. However, numbers of individuals could not be derived from pellets since only hair and feathers were generally found. Mammals were identified to prey group, but birds were generally identified to species.

Because of similarities in hair structure and color (Moore et al. 1974), voles, mice and pocket gophers were classified in the same prey group. For the same reason the three species of ground squirrels were also classified in the same prey group.

The reliability of pellet analysis is generally higher for owls (Errington 1932, Marti 1987). Many factors reduce its accuracy in Falconiformes. Prey may be dismembered before swallowing and may not be entirely ingested (Craighead and Craighead 1956, Cade 1982). Furthermore, the digestive system of the Great Horned Owl has a higher pH being less acidic than that of the Red-tailed Hawk (Schipper 1973, Duke et al. 1975, Cummings et al. 1976). Consequently, more bones are left behind in the pellets. Since the Red-tailed Hawk digests its prey more thoroughly, little or no bones are left rendering the identification more tedious. Thus, the technique for the Red-tailed Hawk differed from that used for the Great Horned Owl because the contents of their pellets differ.

For the Great Horned Owl, once the bones were grossly separated from fur and feathers, a sample of the fur and most feathers was kept for later identification. The left-over material (fur, feathers and small bones) was then immersed in a 4% solution of sodium hydroxide (NaOH) to dissolve fur and feathers. The mixture was boiled to speed up the process. On average the material was left in solution for 5-10 min, depending on its content. Once the mixture was very liquid and very little fur and feathers were left, cold water was then added to stop the reaction and rinse the bones. The bones were rinsed thoroughly, since the base still disintegrates bones as they dry up. The sinking bones were then collected, air-dried and added to the larger bones separated earlier.

The Red-tailed Hawk pellets were carefully dissected by hand with forceps. The rare bones were separated from the rest of the materials and identifiable feathers and hair were set aside. We did not use the NaOH solution for Red-tailed Hawk pellets.

Identification of all bones, hair and feathers then commenced. The bones most commonly used for identification were tibia, pelvis, femur, humerus, skull and jaw. These bones were easily identified to species or genus by comparing them to a reference collection previously made from animals found on the study area. For small mammals (mice and voles) tibia, pelvis, femur and humerus only lead to the general group (i.e. small mammals), whereas in the other mammals (Northern Pocket Gopher, ground squirrels, House Rat (*Rattus rattus*), Snowshoe Hare, Muskrat), they lead to species identification. Skulls, jaws and teeth always resulted in species classification. Hairs were also identified by comparing them to a collection of pelts from the study area. Feathers were identified to species by comparing them to birds collected on the study area as well as to those in a collection held in the Department of Natural Resource Sciences at McGill University.

For the Great Horned Owl pellets, the minimum number of individual small prey (voles and mice) consumed in each pellet was determined from the maximum number of one particular bone. For example, if a pellet had 7 skulls, 4 left tibia, 5 right tibia, 6 left femur and 9 right femur, it was concluded that at least nine individuals were consumed. For larger prey items (larger than gophers), bones found in the pellets over a 5-day period were pooled. From this pool we counted the minimum number of individuals found.

For Red-tailed Hawk pellets, occurrence of each group of prey species was recorded. Numbers of individuals could not be derived since only hair and feathers were generally found. Mammals were identified to prey group, but birds were generally identified to species.

Conversion to biomass

The conversion of the number of individual prey to biomass consumed was done by multiplying the number by the average prey weight. Most prey weights were taken from CRC Handbooks (Dunning 1993, Silva and Downing 1995). Body masses of voles and mice were determined from animals collected on the study areas (M. Pasitschniak-Arts, unpubl. data). Appendix I lists the respective mean body masses of the prey species.

To obtain biomass from pellets, which only gave the occurrence of each species, we used the Great Horned Owl results from pellet analysis, determined the regression between occurrences and number of individuals in each pellet, and applied it to the Red-tailed Hawk pellet results. We base this on the fact that Red-tailed Hawks and Great Horned Owls exhibit dietary equivalence in terms of prey group consumption (Marti and Kochert 1995). Assuming that they consume their prey in a similar way, for each prey species, an occurrence should represent an average number of individuals for both Great Horned Owls and Red-tailed Hawks.

To derive the slope of the regression for each prey group, data from Great Horned Owl pellets were compiled the same way as Red-tailed Hawk pellets. To reduce inaccuracy, we grouped the prey into 10 categories (Northern Pocket Gopher, Voles and Mice; Other Large Mammals; Ground Squirrels; All Ducks; Ducklings; American Coot; Small Other Birds; Large Other Birds; Other). Once the results were in the same format we could then proceed to calculate a slope of the regression between occurrence and number of individuals.

Simple ANOVA's were built on all values not equal to zero. The intercept had to be fixed at zero, since no occurrence leads to zero. The sample size for each regression was 19. Since this analysis is based on the assumption that Great Horned Owl and Red-tailed Hawk prey in similar ways and due to the general ecological nature of this study, the confidence level was set at 80%. Table 3.2 gives the group coefficients and their range at the 80% confidence interval. Data for the Northern Pocket Gopher, Voles and Mice group are used as an example. Table 3.3 gives the occurrences and numbers for all nests. With the intercept set to zero, the results for this ANOVA are shown in Table 3.4.

Table 3. 2: Average biomass and coefficient of occurrence and numbers in Great Horned Owl pellets for each prey group with 80% confidence interval.

	Average Biomass (g)	*Mean Coefficient*	*Confidence Interval*	
			Minimum	*Maximum*
NPGO, Voles and Mice	40	3.02	2.61	3.43
Other Large Mammals	1076	0.59	0.49	0.68
Ground Squirrel	202	1.0*	1.0*	1.0*
Ducks	674	0.56	0.52	0.61
Ducklings	75	1.50	1.35	1.65
American Coot	642	0.51	0.45	0.56
Small Other Birds	425	0.93	0.85	1.01
Large Other Birds	42	0.74	0.68	0.80

*All three points are on the curve y=x.

Table 3. 3: Occurrence and numbers for the prey group Northern Pocket Gophers, Voles and Mice found in Great Horned Owl pellets in ALL97, WIL97 and JDC98.

GHO Nest	Occurrences	Numbers
ALL#1	30	96
ALL#2	6	14
ALL#3	13	24
ALL#4	44	217
ALL#5	2	6
ALL#6	23	118
ALL#7	12	26
WIL#1	20	46
WIL#2	14	42
WIL#3	14	27
WIL#4	24	64
WIL#5	23	59
WIL#6	11	28
WIL#7	10	22
WIL#8	2	4
WIL#9	10	14
JDC#1	36	45
JCD#2	21	48
JDC#3	37	91

Table 3. 4: ANOVA of occurrences versus number for the prey group Northern Pocket Gophers, Voles and Mice found in Great Horned Owl pellets in ALL97, WIL97 and JDC98.

ANOVA

	df	SS	MS	F	Significance F
Regression	1	30772.87	30772.87	32.67	1.51E-05
Residual	18	15527.65	862.65		
Total	19	46300.53			
Intercept	0				
Slope of the regression	3.02	Lower 80%:	2.61	Upper 80%:	3.43

The coefficients and their range were used to determine the range of numbers of individual prey of each group in each pellet. Deriving the biomass consumed for each species group was then just a matter of multiplying the number by the average weight of the prey group. The average biomass (Table 3.2) of each prey group was calculated using results from Great Horned Owl pellets. The total biomass for a prey group was divided by the total number of individuals in that prey group. By calculating the average biomass this way, we represent the average biomass of the group as it was consumed by the owl and not only the mean of all the prey species in each group.

Nest Observations

In attempt to determine whether there was bias in the pellet analysis, direct observations were made on three and six successful nests in JDC98 and ALL99, respectively. At both JDC98 and ALL99, one additional nest was observed, but the chicks died prematurely due to unknown causes. An observation platform was built in adjacent trees. If no suitable trees were found, a tower was built. The observation blinds were always higher than the nest to allow clear sighting of prey found in the bottom of the stick nest. In JDC98, two tree-stand blinds were built and one tower was erected. In ALL99, three tree platforms and three towers were used. These blinds and towers were pre-constructed off site and then assembled on site to minimize the amount of time spent around the nest. The average height of the observation structure was 10 m and ranged in area from $0.75m^2$ to $3m^2$. The method and guidelines used are described by Marti (1987).

During the brood-rearing stage, observation periods were distributed through all daylight hours, beginning from 30 min before sunrise to 30 min after sunset. In JDC98 and ALL99, each nest was observed an average of 254 h and 88 h, respectively, for a total of 1295 h. Observations usually lasted a minimum of 8 h. The observer climbed to the observation station and waited until the adult hawk returned to normal activities (approx. 30 min). For each prey delivery, species, size, sex and condition (whole, half, partly eaten) were recorded when possible along with the sex of the adult Red-tailed Hawk delivering the prey. In occasional cases of uncertainty, the nest-tree was climbed later that day to verify identification of prey.

<u>**Nest Intrusions**</u>

In addition to pellet analysis and direct nest observations, another method of assessing the Red-tailed Hawk diet was used in JDC98 and ALL99. Nest trees were climbed and all prey remains found in the nest were recorded (Fig 3.3). Only nests in climbable trees, i.e., the trees were alive, large and safe enough to support the climber, were part of the sample. This technique is described by Marti (1987) and Murphy (1993). Five cm spikes and a tree-climbing belt were used to climb trees (Fig 3.4). A rock climbing rope and ascender were also used to belay the climber.

Prey Selection

The level of prey selection was determined using the rank method proposed by Johnson (1980). This method was the most appropriate because of the following properties: it gives largely comparable results whether the analysis includes or excludes doubtful items, and significance tests can be made for differences in preferences among items. The rank method is explained in Johnson (1980). Once the ranks of use and availability for each prey item in each nest were known, they were entered in the program PREFER (Johnson 1980).

Level of Predation on Duck Population

The level of predation on ducks was calculated using a simple equation derived for this research. To be able to express the importance of predation, a comparison between duck density and predation levels was made (Equation 3.1). During the pre-fledging period, Red-tailed Hawk and Great Horned Owl chicks require a certain biomass (B) to grow to the fledging stage (McInvaille and Keith 1974). Multiplying this amount by the proportion of ducks in the diet (P) should give the total duck biomass consumed by one chick. Dividing this biomass by the average weight of ducks (W) equals the number of adult ducks needed per raptor chick. Multiplying this number by the number of chicks on the study site (C) should yield the total number of ducks killed during the pre-fledging period on the entire study area. Dividing this by the total area studied (A) gives the number of ducks killed per unit area. The number of ducks consumed per unit area over the density of breeding adult ducks (D) equals the level of predation on ducks (L). This equation can be modified to calculate the level of predation on any prey population by any given predator group if the values of the necessary variables are known. The same calculation can be done for adults. Houston et al. (1998) and Palmer (1988) give daily biomass intake for Great Horned Owl and Red-tailed Hawk (116 g/day and 140 g/day, respectively). The units for this equation have to be the same for biomass and average prey weight, as well as for area and prey density as the units will cancel each other.

Equation 3. 1: Equation applied to determine the level of predation on a population of a specific prey group *(L)*. Total biomass needed *(B)*, proportion of prey biomass in diet *(P)*, average weight of prey *(W)*, number of predators *(C)*, area *(A)*, prey density *(D)*. The units for this equation have to be the same for biomass and average prey weight, as well as for area and prey density as the units will cancel each other.

$$L = \frac{B * P * C}{W * A * D}$$

Figure 3. 3: Red-tailed Hawk chicks in a nest with duck prey remains (behind the chicks to the left), Allan Hills, Saskatchewan, 1999.

Figure 3. 4: Nest intrusion with tree climbing equipment and rope, Allan Hills, Saskatchewan, 1999.

Results

Prey Availability

Although prey biomass density of each prey varied from year to year and from one area to another (Table 4.1), ranks of prey groups did not change from year to year nor from area to area. The most numerous prey group, Northern Pocket Gopher, voles and mice, also had the highest biomass per km^2.

Table 4. 1: Prey biomass density (kg of biomass/km^2) and rank of availability for Great Horned Owl and Red-tailed Hawk prey in four study areas ofcentral Saskatchewan, 1997-1999.

	ALL97		**WIL97**		**JDC98**		**ALL99**	
	Density	**Rank**	**Density**	**Rank**	**Density**	**Rank**	**Density**	**Rank**
Waterfowl	85	4	34	4	64	4	74	4
Ducklings	57	5	23	5	42	5	49	5
NPGO, voles and mice	16471	1	7369	1	8967	1	34049	1
American Coot	321	3	321	3	123	3	225	3
Ground Squirrel	1750	2	1750	2	2056	2	1600	2

NPGO: Northern Pocket Gopher.

Diet Determination

Great Horned Owl diet was relatively simple to determine compared to that of the Red-tailed Hawk. Although only one method (pellet analysis) was used, the results obtained for the Great Horned Owl were straightforward to interpret because they lead directly to numbers of individuals consumed and they are easy to convert into biomass consumed. Results of the three methods (pellet analysis, nest intrusions and nest observations) used to determine the diet of Red-tailed Hawk were not as easy to examine and compare. Each method had its own biases, indicating different proportions of prey species consumed.

Great Horned Owl Diet

Pellet analysis

The 459 regurgitated food pellets collected during the pre-fledging period during the three years of the study led to the identification of 1481 prey items. Overall, 46 owlets from 22 nests fledged successfully at the four sites, however the diet of only 40 owlets from 19 nests was analyzed (Table 4.2). This discrepancy occurred because early nesting of Great Horned Owl nests in ALL99 made it impossible to cover the entire pre-fledging period (i.e. field crews arrived on 22 April when the chicks were already approximately 15 days of age). Only one breeding pair at JDC98 failed to fledge young successfully. The numbers of pellets collected per site were unequal due to a much higher nesting density in both study areas used in 1997.

To compare these results with other studies, data were pooled from all breeding sites. Although mammals represented 78.2% in relative frequency of prey, avian prey represented the greatest proportion of biomass consumed by Great Horned Owls (Table

4.3). Overall, Meadow Vole (28.5%) was the most common prey followed by Deer Mouse (13.5%) and Northern Pocket Gopher (11.6%) (Table 4.3).

Table 4.2: Great Horned Owl breeding success and nest densities in central Saskatchewan from 1997 to 1999.

	Young Fledged	**Successful Breeding Pairs**	**Young per Successful Breeding Pair**	**Pair success**	**Nest Density (pairs/ km^2.)**
ALL97	18	7	2.6	100%	0.1
WIL97	18	9	2.0	100%	0.1
JDC98	4	3	1.3	75%	0.1
*ALL99	6	3	2.0	100%	0.1

*Great Horned Owl diet was not analyzed due to early nesting.

Overall, avian prey represented 57.3% of the biomass consumed and mammals constituted 42.6%. American Coot was the most important prey with an average of 27.1% of total biomass followed by Snowshoe Hare (14.2%) and Northern Pocket Gopher (11.4%). The average prey size was 147.3g.

For comparison with the diet of the Red-tailed Hawk, prey were grouped into 10 categories. Pocket gophers, voles and mice, making up one prey group, were most common in terms of numbers (average 74.4%), followed by coots (6.2%) and ducks (4.6%) (Fig. 4.1). Coots were still the most important prey in terms of biomass (average 27.1%) followed by larger mammals (hares, muskrats, etc) (21.2%), ducks (21.0%) and gophers, voles and mice (20.2%) (Fig. 4.2).

Table 4.3: Prey consumed by 19 Great Horned Owl families in Central Saskatchewan during pre-fledging period in 1997-1998, based on prey items pooled from all owl families.

	Frequency		Biomass	
SPECIES	N	%	g	%
Mammals	1158	78.2%	92867.9	42.6%
Meadow Vole (*Microtus pennsylvanicus*)	422	28.5%	10592.2	4.9%
Boreal Red-Backed Vole (*Clethrionomys gapperi*)	27	1.8%	577.8	0.3%
Western Jumping Mouse (*Zapus princeps*)	89	6.0%	1771.1	0.8%
Deer Mouse (*Peromyscus maniculatus*)	200	13.5%	3820	1.8%
Thirteen-lined Ground Squirrel (*Spermophilus tridecemlineatus*)	9	0.6%	1530	0.7%
Richardson's Ground Squirrel (*S. richardsonii*)	3	0.2%	1050	0.5%
Least Chipmunk (*Tamias minimus*)	1	0.1%	48	0.0%
Northern Pocket Gopher (*Thomonomys talpoides*)	171	11.5%	24795	11.4%
Norway Rat (*Rattus rattus*)	11	0.7%	2200	1.0%
Shrew sp. (Family Soricidae)	122	8.2%	658.8	0.3%
Snowshoe Hare (*Lepus americanus*)	20	1.4%	31000	14.2%
Muskrat (*Ondatra zibethicus*)	11	0.7%	12980	6.0%
Weasel (Genus *Mustela*)	1	0.1%	70	0.0%
Unknown small mammal (*Microtus*)	71	4.8%	1775	0.8%

Table 4.3: Continued.

SPECIES	Frequency		Biomass	
	N	%	g	%
Birds	256	17.3%	125011	57.3%
Mallard (*Anas platyrhynchos*)	17	1.1%	17935	8.2%
Blue-winged Teal (*A. discors*)	24	1.6%	9264	4.2%
Gadwall (*A. strepera*)	1	0.1%	919	0.4%
Northern Shoveler (A. *clypeata*)	2	0.1%	1226	0.6%
Northern Pintail (*A. acuta*)	3	0.2%	3030	1.4%
American Wigeon (*A. americana*)	3	0.2%	2268	1.0%
Lesser Scaup (*Aythya affinis*)	3	0.2%	2460	1.1%
Horned Grebe (*Podiceps auritus*)	14	0.9%	6342	2.9%
American Coot (*Fulica americana*)	92	6.2%	59064	27.1%
Ruddy Duck (*Oxyura jamaicensis*)	10	0.7%	5450	2.5%
Short-Eared Owl (*Asio flammeus*)	2	0.1%	694	0.3%
Red-winged Blackbird (*Agelaius phoeniceus*)	2	0.1%	104	0.0%
Ducklings (All spp.) (*Anseriformes*)	13	0.9%	975	0.4%
Sparrow spp. (Passeriformes)	4	0.3%	60	0.0%
American Crow (*Corvus brachyrhynchos*)	3	0.2%	1344	0.6%
Gray Partridge (*Perdix perdix*)	1	0.1%	385	0.2%
Sharp-tailed Grouse (*Tympanuchus phasianellus*)	1	0.1%	885	0.4%
Ruffed Grouse (*Bonasa umbellus*)	10	0.7%	5760	2.6%
Blackbird spp.	14	0.9%	630	0.3%
Magpie (*Pica pica*)	3	0.2%	531	0.2%
Sora (*Porzana carolina*)	1	0.1%	75	0.0%
Unknown Large (Larger than a teal)	5	0.3%	3250	1.5%
Unknown Medium (Smaller than a teal)	10	0.7%	2000	0.9%
Unknown Small (Passerine)	18	1.2%	360	0.2%
Insect	55	3.7%	55	0.0%
Amphibians	12	0.8%	165	0.1%
TOTAL	**1481**	**100.0%**	**218099**	**100.0%**

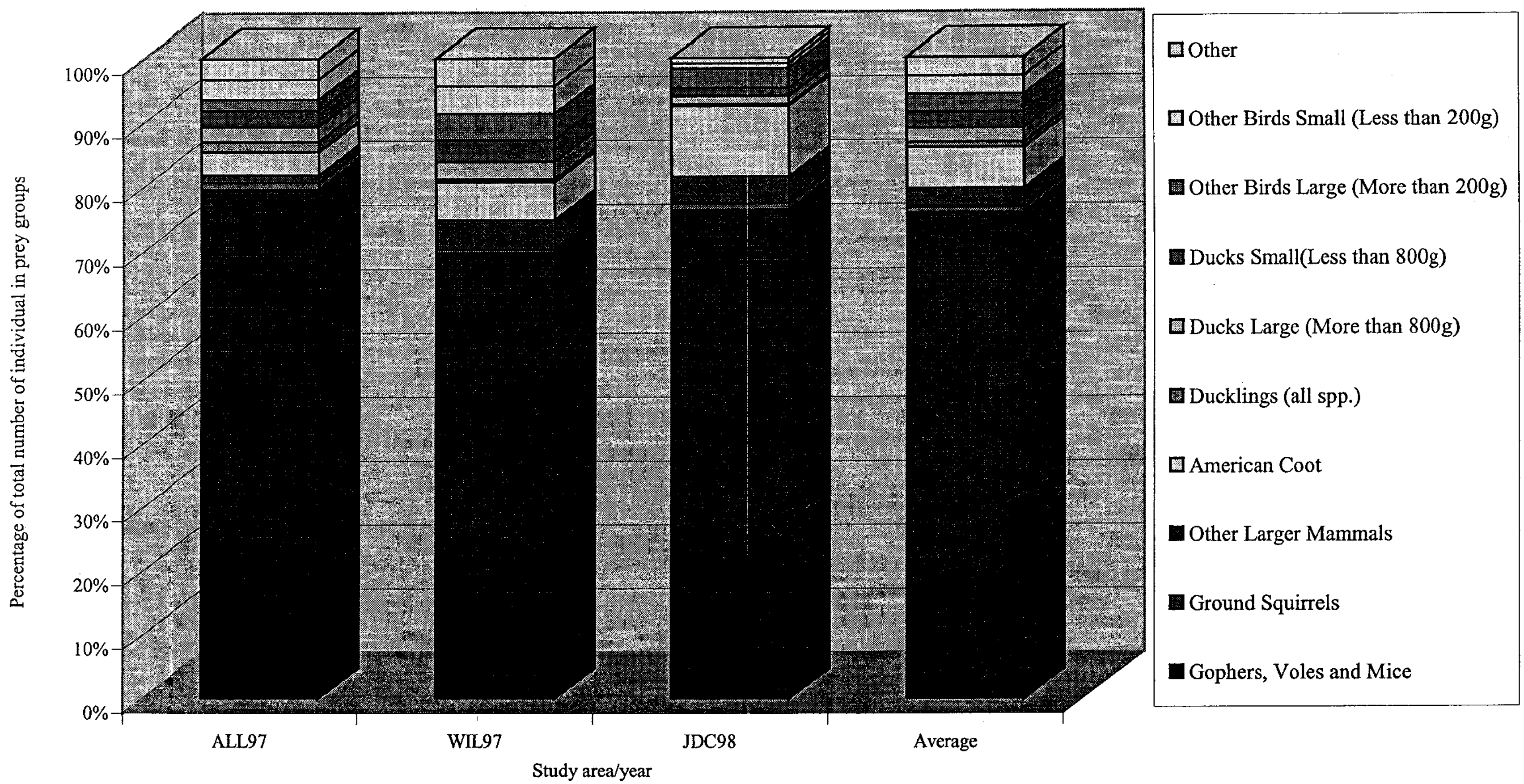

Figure 4.1: Composition of prey groups in number of individuals recorded in pellets used by 19 Great Horned Owl families in central Saskatchewan during pre-fledging period in 1997-1998.

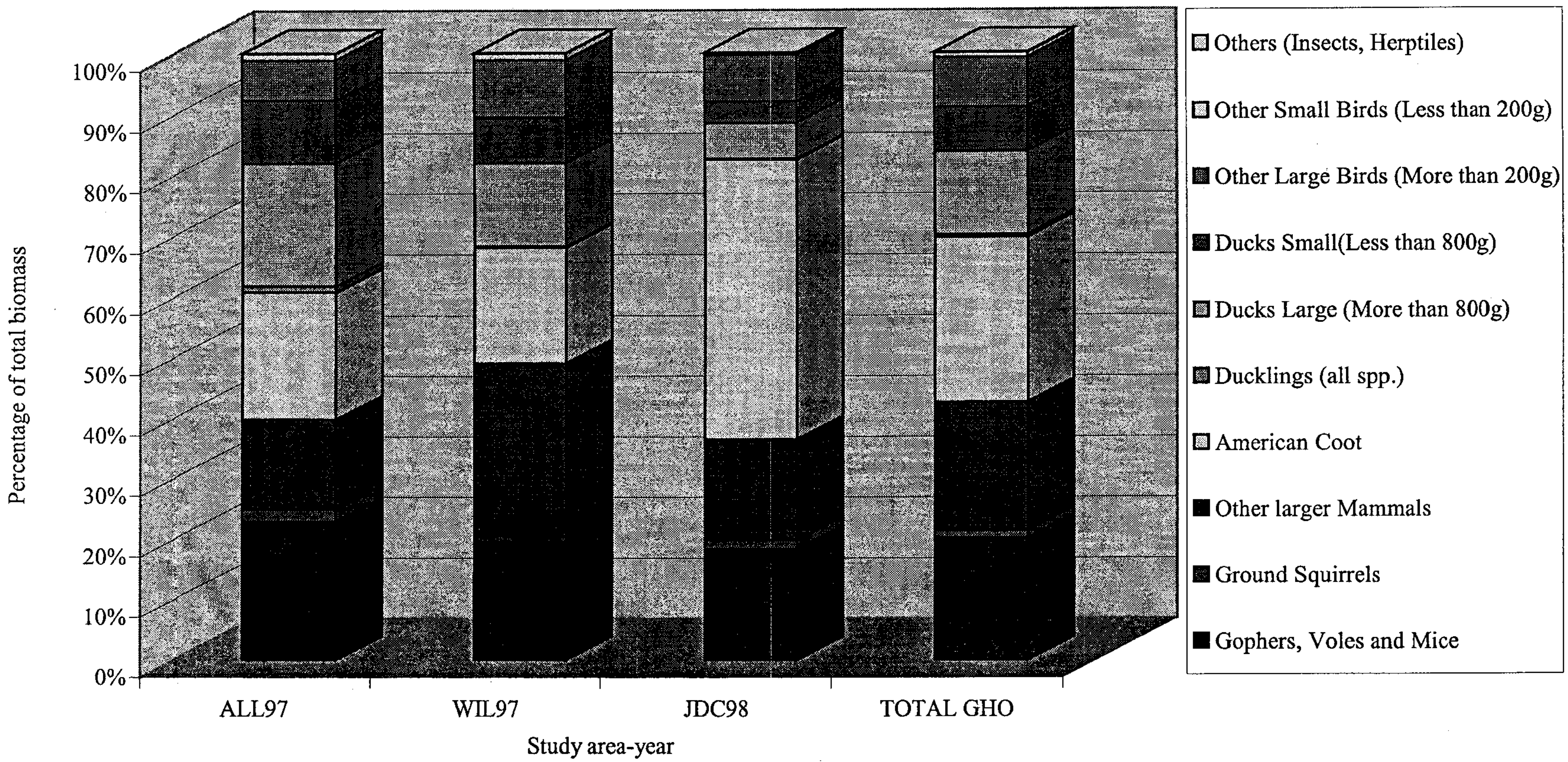

Figure 4.2: Composition of biomass used by Great Horned Owl from analysis of pellets in central Saskatchewan during pre-fledging period in 1997-1998

Red-tailed Hawk Diet

The diet of the Red-tailed Hawk was assessed using three different methods: pellet analysis, nest intrusions and nest observations. Due to their biases, each method yielded dissimilar results. Of a total of 91 hawk families, 61 were studied at the three sites. Nests from WIL97 were not analyzed owing to time constraints. ALL97 had the lowest nest density, but fledged most young producing the highest young per successful breeding pair. Overall nest density for the Red-tailed Hawk was four times the overall nest density of the Great Horned Owl (Tables 4.2 versus 4.4).

Table 4.4: Red-tailed Hawk breeding success and nest densities in central Saskatchewan 1997-1999.

	Young Fledge	**Successful Breeding pair**	**Young per successful breeding pair**	**Breeding pair success**	**Nest Density (pair/ km^2.)**
ALL97	26	12	2.2	92.3%	0.2
*WIL97	23	19	1.2	65.5%	0.5
JDC98	24	18	1.3	52.9%	0.5
ALL99	18	12	1.5	78.3%	0.4

*Red-tailed Hawk pellets were not analyzed.

Pellet Analysis

The analysis of 399 pellets yielded 763 different occurrences in 10 prey groups. The most common prey group was Northern Pocket Gopher (NPGO), voles and mice (average 39.2%) followed by ducklings, ducks and ground squirrels (Table 4.5). Unfortunately, these numbers do not represent the diet with certainty because evidence from a small prey species may represent more than one individual. Also, it may take several occurrences from a large prey to represent one individual.

By converting occurrence into numbers of individuals, the Red-tailed Hawk diet becomes clearer. NPGO, voles and mice (average 66.2%) are still the most common prey group, followed by ducklings (16.2%) and ground squirrels (6.5%) (Fig. 4.3).

Converting to biomass allows further understanding of the Red-tailed Hawk diet and enables comparison with the results of the Great Horned Owl diet and other studies. Overall, ducks constituted 23.5% of the biomass consumed, closely followed by the pocket gophers, voles and mice group (22.9%) and the other large bird group (16.0%) (Fig. 4.4).

Table 4.5 : Occurrence of each prey group found in the Red-tailed Hawk pellet analysis in Central Saskatchewan, 1997-1999.

	ALL97		JDC98		ALL99		**Total RTH**	
	Occ.	%	Occ.	%	Occ.	%	**Occ.**	**%**
NPGO. Voles and Mice	151	39.2%	98	39.4%	50	38.8%	**299**	**39.2%**
Other larger Mammals	15	3.9%	-	-	2	1.6%	**17**	**2.2%**
Ground Squirrels	37	9.6%	33	13.3%	18	14.0%	**88**	**11.5%**
All Ducks	30	7.8%	54	21.7%	13	10.1%	**97**	**12.7%**
Ducklings (all spp.)	110	28.6%	27	10.8%	10	7.8%	**147**	**19.3%**
American Coot	13	3.4%	11	4.4%	18	14.0%	**42**	**5.5%**
Other Large Bird (More than 200g)	29	7.5%	20	8.0%	15	11.6%	**64**	**8.4%**
Other Small Bird (Less than 200g)	-	-	6	2.4%	3	2.3%	**9**	**1.2%**
Total	**385**	**100%**	**249**	**100%**	**129**	**100%**	**763**	**100%**

NPGO = Northern Pocket Gopher

Nest Observations

The 1296 hours of nest observation of Red-tailed Hawks led to the sighting of 404 prey deliveries. Altogether, 50.9% of deliveries were pocket gophers, voles and mice, 19.6% ground squirrels and 10.4% ducks (Fig. 4.5). Transformed into biomass, the most important prey group involved ducks (25.8%) followed by American Coot (25.7%) and ground squirrels (22.1%) (Fig. 4.6).

Nest Intrusions

The 208 nest intrusions performed at JDC98 and ALL99 led to the recording of 297 prey items. The most common prey group was that of ducks which represented 38.0% of total recordings and 69.9% of total biomass (Figs. 4.7 and 4.8, respectively). This accounted for a much higher value for ducks than the other two methods of diet determination. The next most abundant prey group was that of pocket gophers, voles and mice which accounted for 24.9% of total numbers and only 2.9% of biomass (Figs. 4.7 and 4.8, respectively). Another important prey in terms of biomass was American Coot with 9.6% (Fig. 4.8).

Prey Selection

The use of the rank method to analyze the level of selectivity by the two raptors produced non-equivocal results. Both the Great Horned Owl and the Red-tailed Hawk are selective towards ducks (average of +2.2 and +1.7, respectively). The null hypothesis, i.e. that no prey selection is made by Great Horned Owl and/or Red-tailed Hawk, is rejected ($F\ (4, 15) = 216.3$ and $F\ (4, 16) = 18.6$ respectively). Therefore, it must be concluded that the owls and hawks were selective for their prey. Both raptors avoided ground squirrels (average of –2.4 and –1.4, respectively) (Fig 4.9). The selectivity among different prey groups is significant for both raptors.

Predation on Ducks

Using Equation 3.1 (See Methods), the level of predation on duck populations was calculated for each study site. The average mortality rate for adult duck due to Great Horned Owl predation was determined to be 0.47%, for the pre-fledging period (45 days), ranging from 0.06% to 0.86%. These values represent an average of 0.9 adult ducks preyed upon per km^2 during a period of 45 days. Red-tailed Hawk predation was more than double that of Great Horned Owl with a value of 1.01%, ranging from 0.56 % to 1.31 % duck mortality rate, which represents an average of 2.8 ducks per km^2, again for a period of 45 days (Table 4.5).

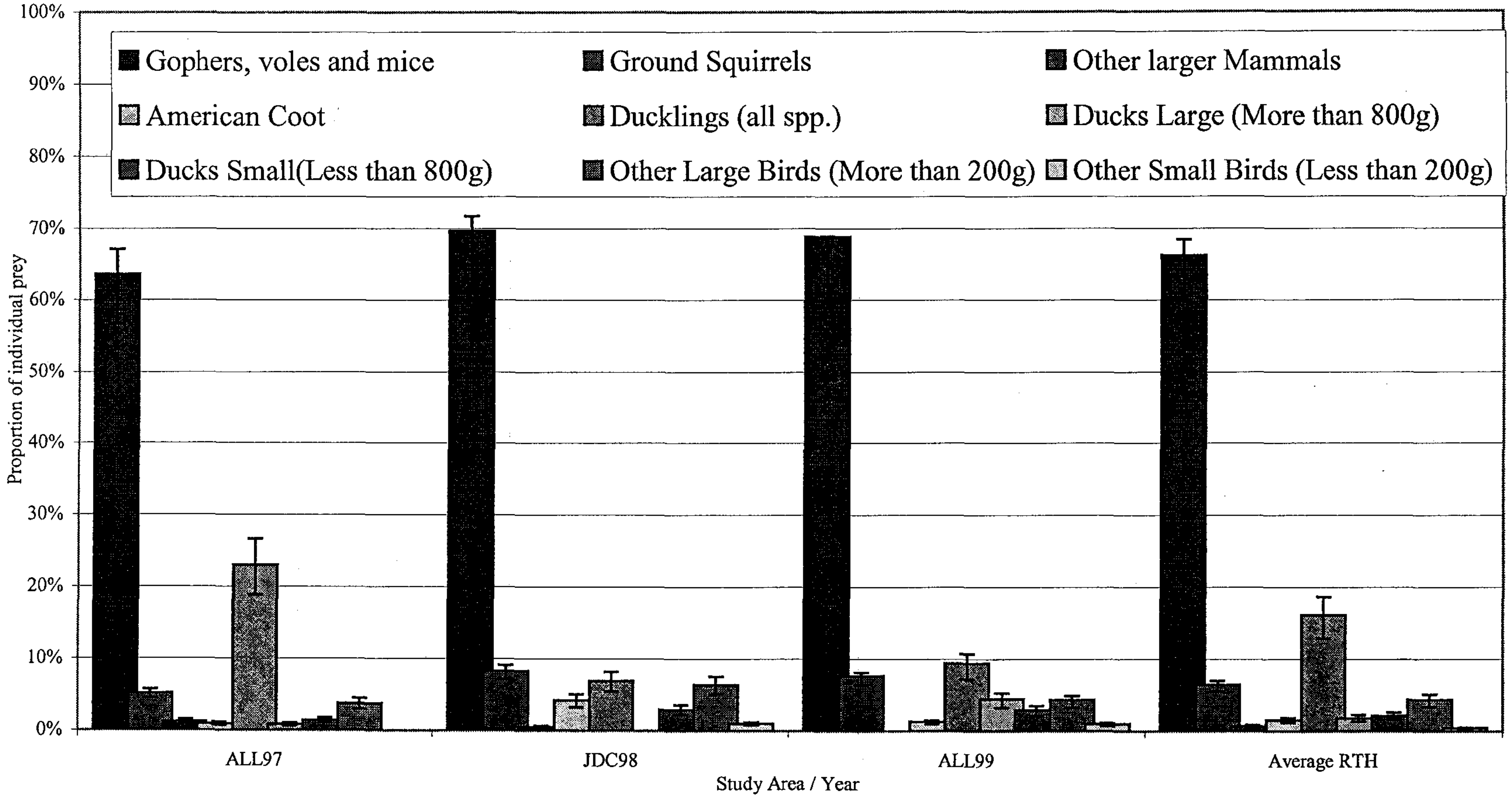

Figure 4.3: Proportion of individuals per prey group found in the Red-tailed Hawk pellet analysis from Central Saskatchewan, 1997-1999. Error bars represent the degree of error of the slope regression between the number of individuals and occurrences with 80% confidence interval.

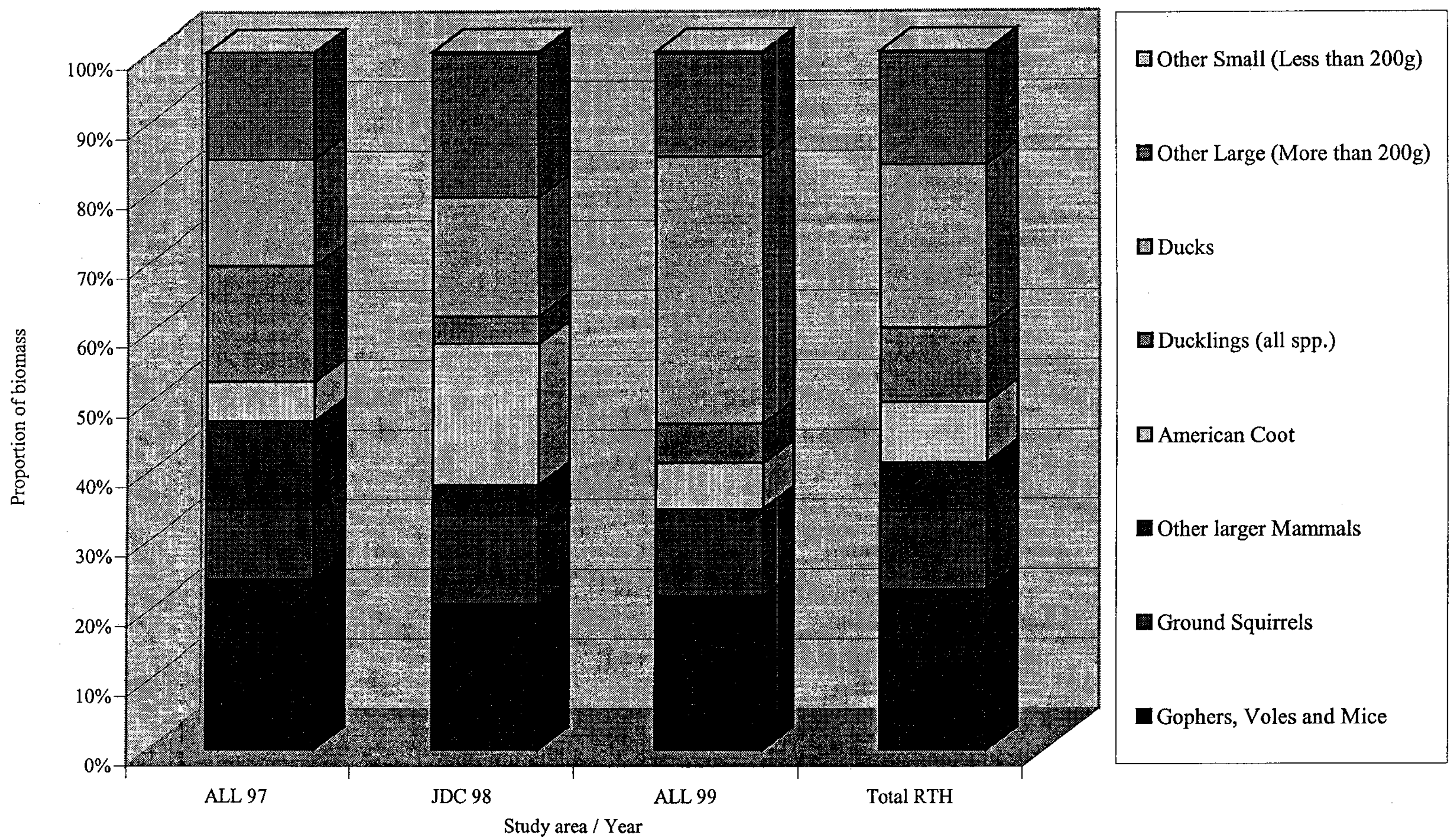

Figure 4.4: Proportion of biomass per prey group consumed by Red-tailed Hawk during pre-fledging period for ALL97, JDC98 and ALL99, central Saskatchewan, 1997-1999.

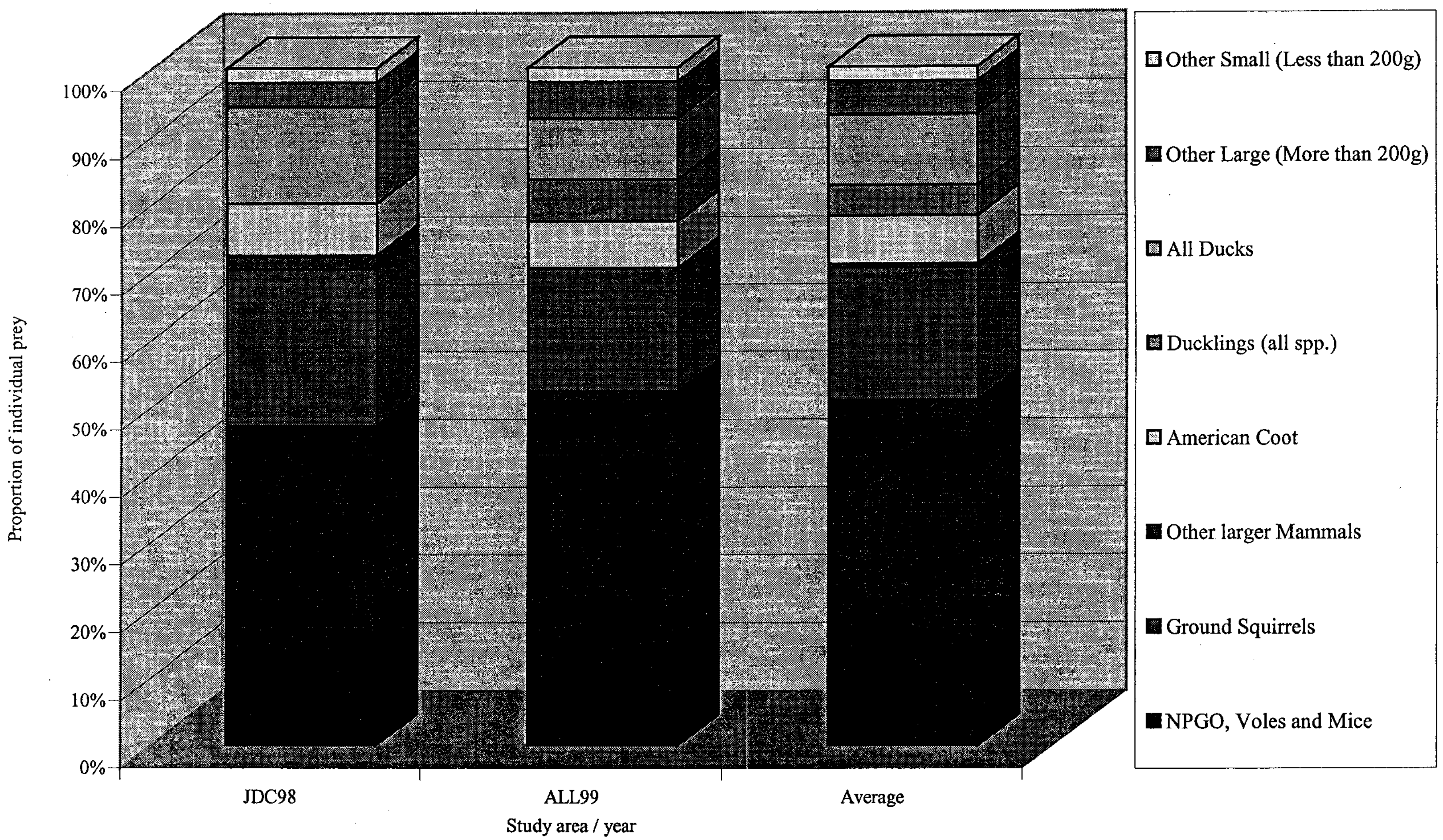

Figure 4.5: Proportion of individual prey delivered to Red-tailed Hawk nests calculated from nest observations in JDC98 and ALL99, central Saskatchewan, 1997-1999.

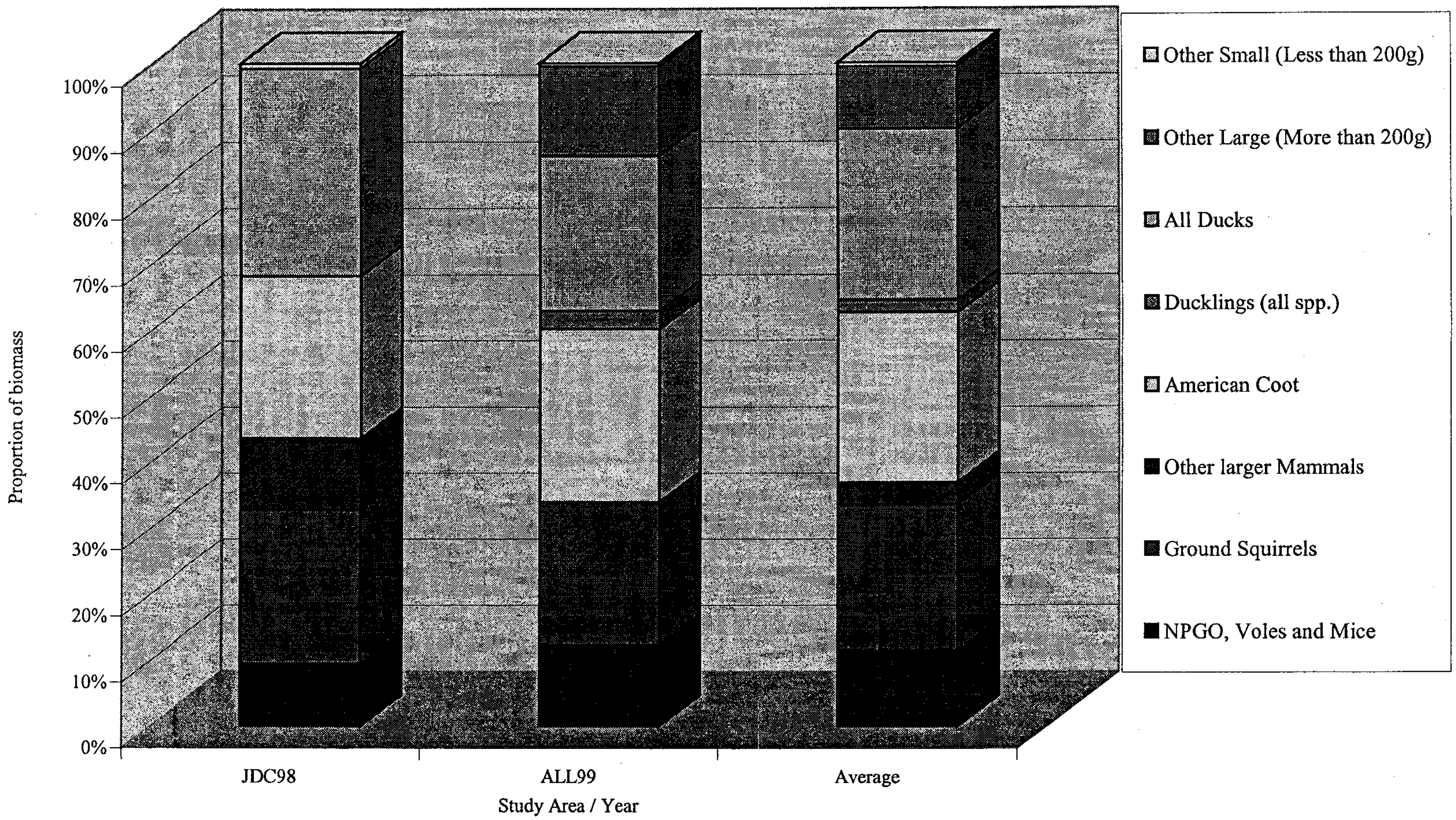

Figure 4.6: Proportion of prey biomass delivered to Red-tailed Hawk nests calculated from nest observations in JDC98 and ALL99, central Saskatchewan, 1997-1999.

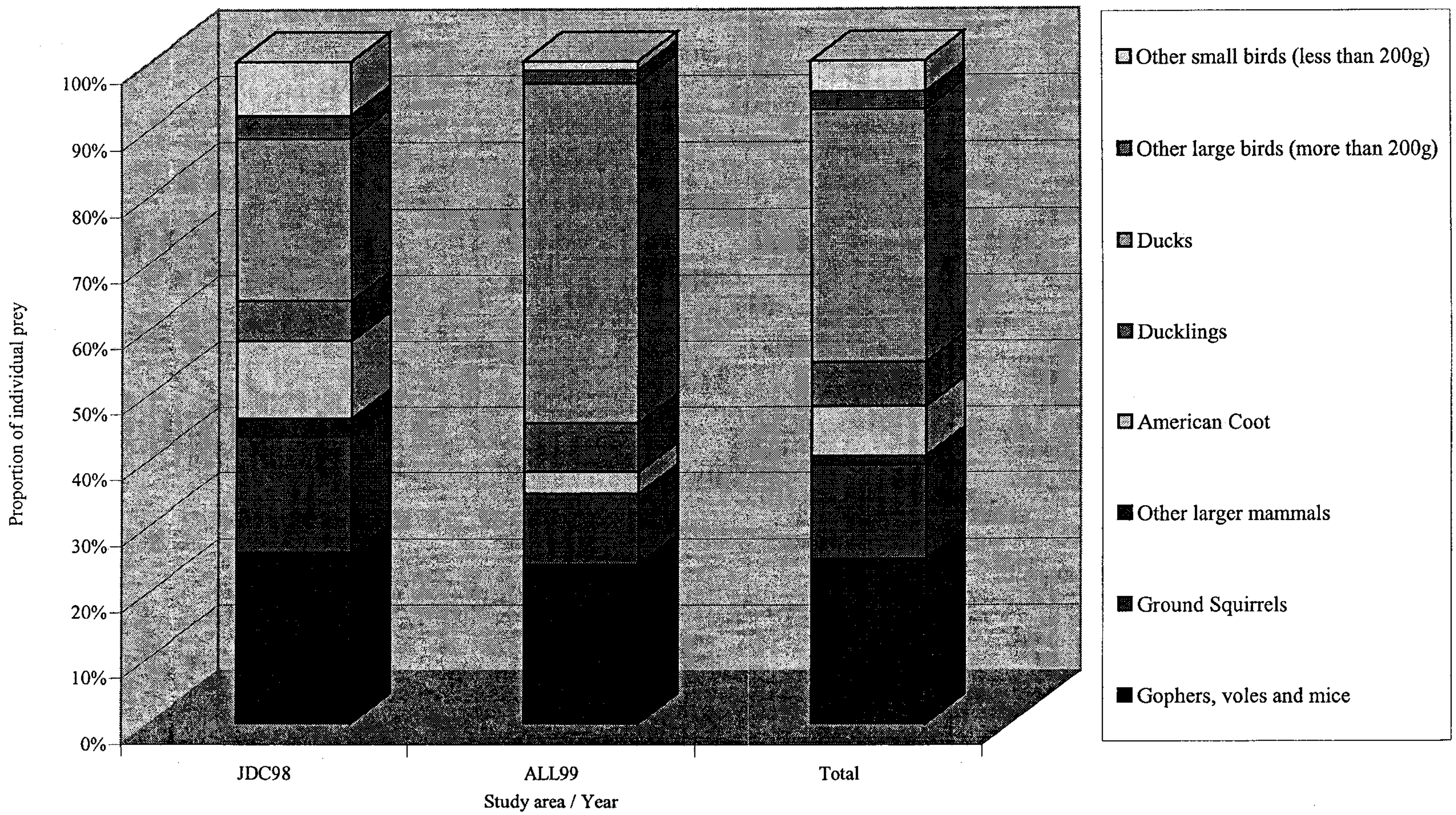

Figure 4.7: Proportion of individual prey delivered to Red-tailed Hawk nests calculated from nest intrusions in JDC98 and ALL99, central Saskatchewan, 1997-1999.

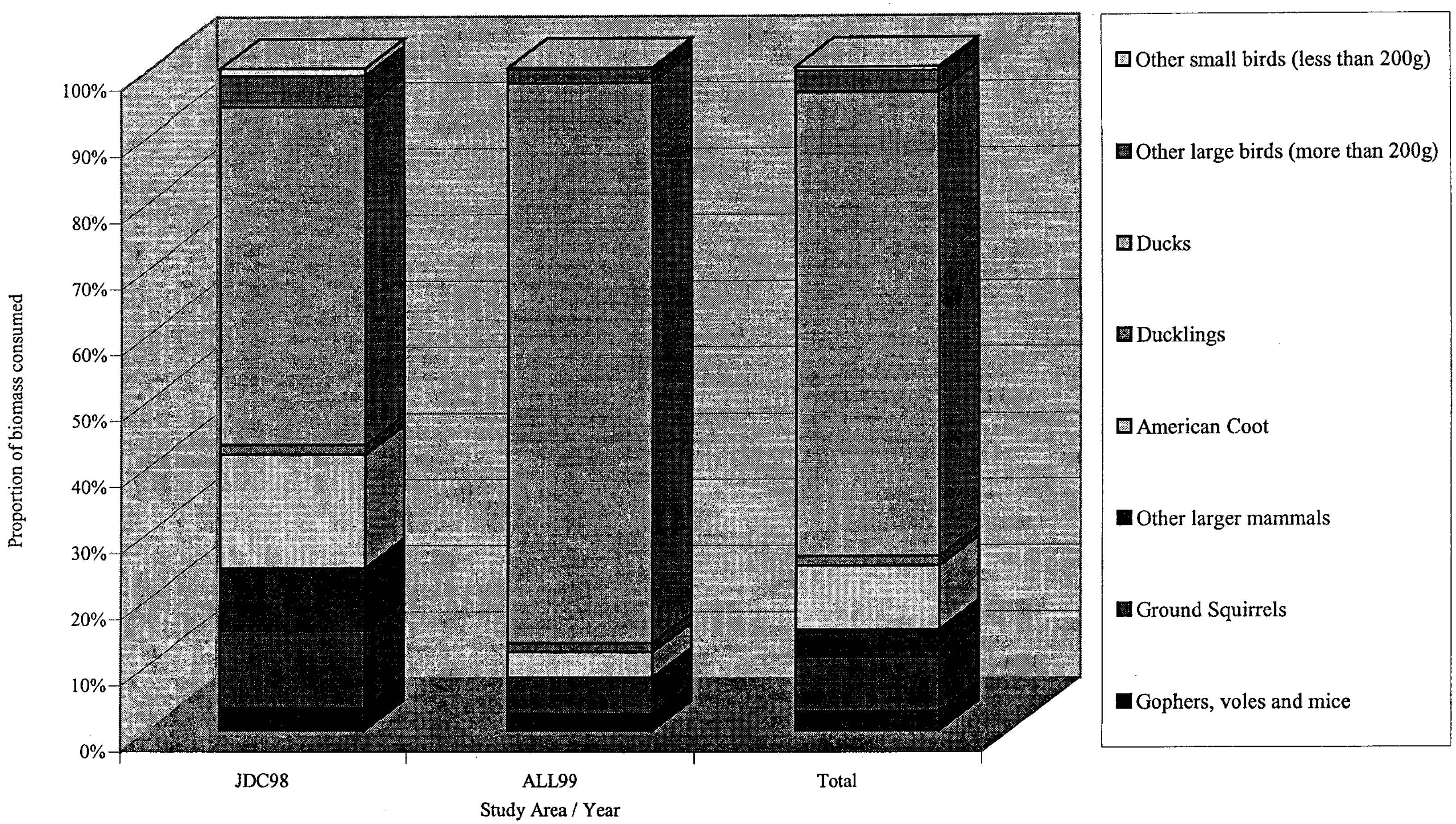

Figure 4.8: Proportion of prey biomass delivered to Red-tailed Hawk nests calculated from nest intrusions in JDC98 and ALL99, central Saskatchewan, 1997-1999.

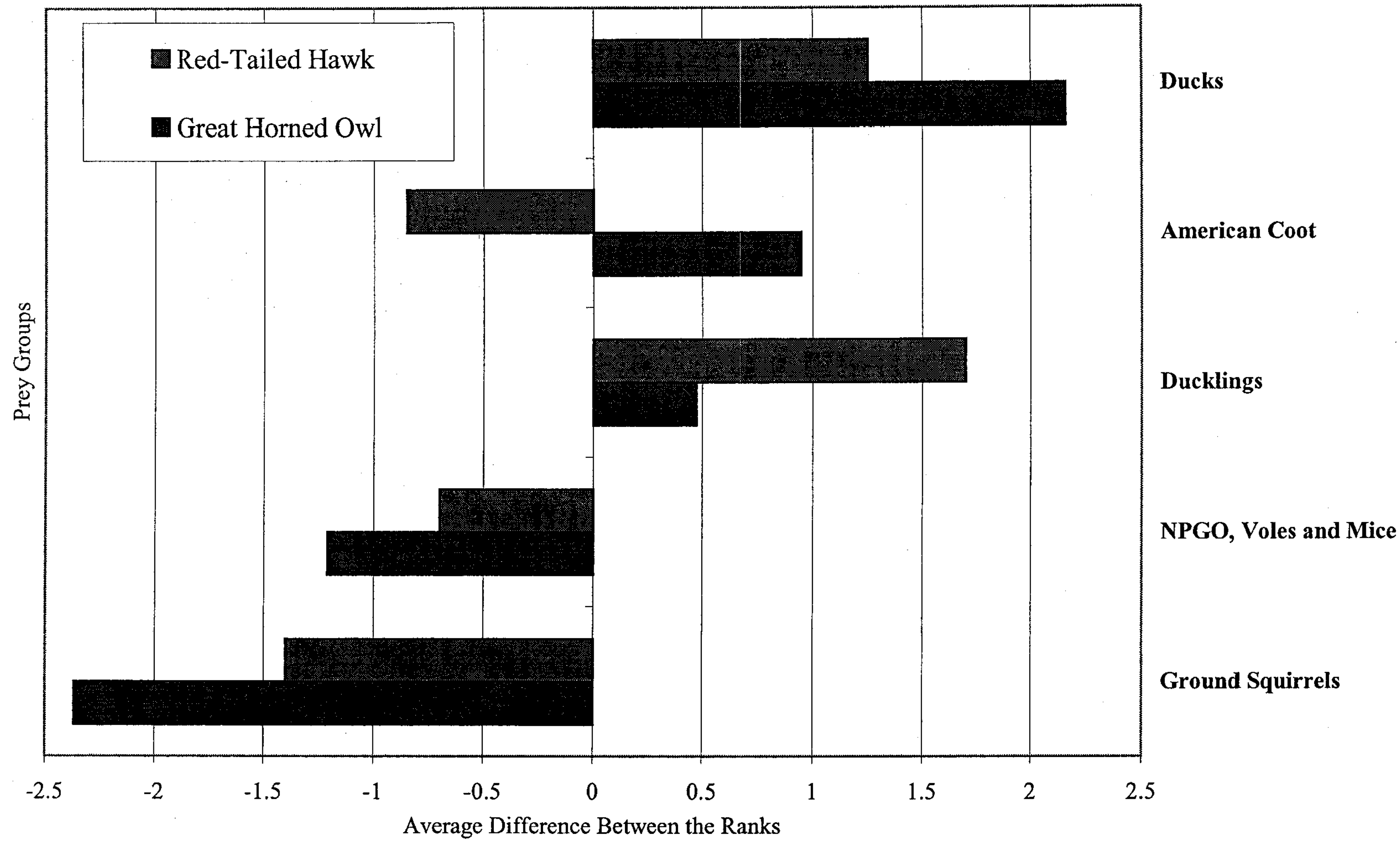

Figure 4. 9: Average difference in ranks for prey group for Great Horned Owl and Red-tailed Hawk using the rank method (Johnson 1980), central Saskatchewan. 1997-1999. Positive value = selected for. Negative value = selected against.

Table 4.6: Predation by Great Horned Owl and Red-tailed Hawk on duck populations for each study area in central Saskatchewan, 1997-1999, during the pre-fledging period (45 days) based on the biomass required to fledge for chicks (McInvaille and Keith 1974), average biomass consumed per day for adults (Preston and Beane 1993, Houston et al. 1998) and the proportion of duck biomass consumed in pellets.

		Mortality	*ALL97*	*WIL97*	*JDC98*	*ALL99*	***Average***
Great Horned Owl	*Chicks*	% Population killed	0.32%	0.54%	0.03%	-	**0.30%**
		Ducks killed/ km^2	1.04	0.71	0.07	-	**0.61**
	Adults	% Population killed	0.15%	0.32%	0.03%	-	**0.17%**
		Ducks killed/ km^2	0.48	0.42	0.08	-	**0.32**
Red-tailed Hawk	*Chicks*	% Population killed	0.40%	-	0.55%	0.79%	**0.58%**
		Ducks killed/ km^2	1.30	-	1.34	2.24	**1.63**
	Adults	% Population killed	0.16%	-	0.62%	0.52%	**0.43%**
		Ducks killed/ km^2	0.52	-	1.51	1.49	**1.17**

Discussion

Diversity in the diets of Great Horned Owls and Red-tailed Hawks was evident from the compilation of prey consumed. The large number of potential prey species present on the study area (Appendix 1) gave these predators ample opportunity to select specific prey. Throughout the study, numbers in prey groups varied (Appendix 2). Along with these changes in prey numbers came changes in the percentage of each prey group within the Great Horned Owl and Red-tailed Hawk diets, reflecting their adaptability to changes in the availability of prey. In essence, the results of this study indicate the high level of generalism these two raptor species exhibit.

Great Horned Owl

Nest densities during this study were on average higher than in other studies (0.09 nests per km^2 vs. 0.02 in North Dakota (Gilmer et al. 1983) and 0.04 in Alberta (McInvaille and Keith 1974)). In North Dakota, Murphy (1993) observed nest densities similar to those of this study (0.11 nests per km^2). The average number of young fledged per successful breeding pair was 2.09, i.e. in the range of previous reports (Houston et al. 1998).

Diets derived from this study were comparable to those in other studies performed in similar habitats. The importance of ducks in the Great Horned Owl diet (4.6% frequency and 21.0% of biomass) was lower than in other studies. Murphy (1993) found that 45% of the biomass consumed consisted of ducks. Gilmer et al. (1983) found the frequency of ducks to be 15.2%. Both of these studies were conducted in North Dakota in semi-arid grassland. In Central Alberta, in upland habitat, McInvaille and Keith (1974) reported ducks to be less important in the Great Horned Owl diet, although the upland habitat of Central Alberta is slightly different from the eastern mixed grass habitat and the prairie-parkland region of Saskatchewan.

Great Horned Owls are known to adapt to varying prey numbers (Houston et al. 1998). However in this study, more data are needed on prey availability to be able to fully assess the level of prey selection by Great Horned Owl.

Pellet Analysis

Although the pellet analysis technique tends to overestimate large prey and underestimate small prey consumption (Collopy 1983, Marti 1987), its results are most reliable for owls (Marti 1987). The results are thus assumed to represent the actual composition of the Great Horned Owl diet.

Average prey size (147.26g) was larger than in other studies. It appears that the density of large prey species was higher than in the other studies in different habitats. Knight and Jackman (1984) found an average prey size of 55g on forested study sites. However, in similar habitat, Murphy (1993) observed average prey size to be 197g. This discrepancy is due to the higher rates of predation on ducks than those observed in this study (45.0% vs. 21.0%, respectively).

The Great Horned Owl selected its prey, i.e. they selected ducks more than any other prey group. This selectivity could be due to the profitability of this prey group compared to other smaller and more conspicuous prey. Since ducks are one of the largest prey items in terms of size, they represent a large amount of energy consumed per predatory effort.

Red-tailed Hawk

Although three methods were used in its assessment, the diet of the Red-tailed Hawk in these PHJV sites was difficult to establish. Each method has its own biases and each produced different dietary results.

The average nest density (0.39 nest per km^2) observed in this study was similar to other studies. In their literature review Preston and Beane (1993) reported nesting densities ranging from 0.02 to 0.63 nests per km^2. In similar habitats however, the maximum value of the range is only 0.38 nests per km^2. In this study, the average falls close to this upper limit and two of the nest densities (WIL97 and JDC98) are much higher than this range maximum (0.45 and 0.53 nests per km^2, respectively).

The number of young fledged per successful nest in this study (1.66) falls in the higher portion of the range of fledging rates (0.91-1.80) reviewed by Preston and Beane (1993).

Although they present biases, because the sample size was larger, results from the pellet analysis were assumed to be the closest to the actual diet of the Red-tailed Hawk. Furthermore, results from pellet analysis were available for all years whereas results from the other methods were only used in the last two years of the study.

Pellet Analysis

Few authors, if any, have used pellet analysis to determine the diet of Red-tailed Hawk in the wild. Comparing the results from this study to those of other studies can be misleading because different techniques have been used to assess the diet of Red-tailed Hawk. Murphy (1993) relied exclusively on nest intrusions, which tend to underestimate and even overlook small prey and overestimate larger prey. His results show a higher proportion of waterfowl consumed (36.7% frequency) than in this study (4.0% frequency). This difference likely due to biases toward large prey modifies all proportions of prey species. Because the proportions are linked, i.e. if one species decreases, all the others will increase proportionally, the effect of any bias in the method used is multiplied, making comparison difficult.

Collopy (1983) assessed biases from pellet analysis and found no difference between pellet analysis and direct observation in determining diet of Golden Eagles (*Aquila chrysaetos*). Although pellet analysis tends to underestimate daily prey deliveries, the proportions of biomass or proportions of frequency of each prey species are not affected. Although tedious, this method is effective in determining diet.

Use of the Great Horned Owl occurrences-numbers ratio helps in determining proportions of individuals consumed for each species. The ideal way to determine this ratio for the Red-tailed Hawk would be to make continuous direct nest observations on a large number of nests and to compare the results. Once this ratio is established for Red-tailed Hawks in a particular habitat, then pellet analysis can be fast and efficient in determining the diet with precision. Only a quick dissection is then needed to determine all the prey species present. The occurrences can then be transformed reliably to numbers of individuals and to the proportion of biomass consumed.

Nest Observations

Direct nest observations were valuable for many reasons. The observations allow one to see and identify prey brought to the nest and they also permit the field crew to better understand the ecology of the animals studied. One can see the close relationship between the chicks and the female and how each family is different in its food habits, behaviour and reaction to the presence of humans, etc. Direct observation from blinds can offer the most accurate and complete information on the diet of many predatory birds, as well as on the behaviour of the birds (Collopy 1983, Marti 1987). Observations can also be used to determine the total biomass delivered and the frequency of deliveries. Some investigators (Snyder and Wiley 1976, Newton 1978, Collopy 1983) have used this method instead of tethering young to a platform (McInvaille and Keith 1974, Murphy 1993) to estimate the numbers of prey brought to the young. The main constraint with this technique is the amount of observer-time needed to obtain an adequate sample.

The main goal of using this technique was to determine the exact prey consumption of a small sample of nests and to find a correlation between occurrences in the pellets and the number of prey. However, the observations were less useful than anticipated in deriving this correlation. On many occasions prey were found in the pellets but not during observations at the same nest. This could be due to misidentification and from pellets resulting from prey consumed away from the nest by adults, but is more likely the result of the small amount of time spent observing the nests (26.7% of daylight hours during the pre-fledging period), which may also represent approximately 27% of prey deliveries. Although the observation periods were chosen randomly to cover all hours of daylight, three-quarters of prey deliveries were not observed. During these unobserved hours, prey deliveries certainly took place. Statistically, these deliveries should be in the same proportion as those during the observation period. However the presence of prey species in pellets that were never seen during observation periods would indicate otherwise.

To increase the accuracy of this method, observation periods of roughly 16 hours or the totality of daylight should be used (Collopy 1983, Marti 1987). Collopy (1983) suggested that by entering the blinds at mid-day the observer does not flush the adult female and expose the chicks to the chilling temperatures of the mornings or evenings. Observations are continuous until nightfall and then the observer spends the night in the blind only to resume observations at the first ray of light. Understanding that this method is the most efficient, one must also consider human error due to fatigue as well as overworked field technicians.

Nest Intrusions

Nest intrusions to record prey remains are effective, but the biases are too great. This technique underestimates small prey and overestimates large prey, therefore doubling the effect. Because small prey are consumed fairly quickly and at a higher rate (Mollhagen et al. 1972) and bones may be lost in the nest structure, it results in an underestimation of their contribution to the diet (Marti 1987). Larger prey are overestimated because their bones stay in the nest longer and are more visible (Marti 1987). Even so, when the nests are visited at an interval of less than five days, Marti

(1987) suggested that the problem is reduced. During this study nests were visited every two to four days and the overestimation of large prey was still evident. By comparing results with the other two methods, the biases are clearly apparent. Duck numbers are especially prone to being overestimated because their wings and pectoral girdles are almost always discarded around the nest or left in the nest, making them more visible to the observer. This was detected during the direct nest observations. Their size also makes it easier to find them than other dismembered small prey.

The reliability of results from nest intrusions may be increased by using these data in conjunction with another method. Nest intrusions and pellet analysis are very easy to employ simultaneously, as climbing to the nest provides access to a large number of pellets in the nest cup which are not obtainable without a climb. The results of the two techniques can then be used together to derive the diet.

Comparison of Methods Used

There are pros and cons for each diet assessment technique used in this study. Some have biases; others have drawbacks, e.g. the time it takes to have the complete spectrum of the diet. Marti (1987) insisted that not any one method is best but a combination of two or more methods is the best approach in a study of raptor food habits. In this study combination of the three methods helped to determine the biases and to reveal the variety in the Red-tailed Hawk diet.

Although time-consuming, direct nest observations are most accurate. The least time-consuming is nest intrusion, but it overestimate numbers of large prey. Pellet analysis is useful for analyzing a large sample of nests and was an efficient tool in the determination of the Red-tailed Hawk diet. The use of nest observations increases its precision and decreases time consumption for performing a pellet analysis.

Prey Selection

Because the two raptors are known to be generalists, we must consider the rather surprising indication that they are both selective toward ducks in the context of habitat and prey available. Population densities do not always represent availability for different predators. Prey like voles and mice are much more concealed by vegetation than larger prey. Their size makes them less conspicuous and harder to locate than ducks for example. If there were a way to determine the actual prey availability to the specific predator, then the results would be easier to interpret. When looking at specific habitats and specific prey groups, the Great Horned Owl and Red-tailed Hawk are probably selective, but when looking at the habitats over larger ranges and the totality of prey consumed, selectivity is less apprarent.

Predation on Duck Populations

To determine the impact of Great Horned Owls and Red-tailed Hawks on waterfowl populations, the proportion of the biomass consumed had to be converted to predation per unit area. Once this conversion was done, the impact of these two raptors on duck populations appears to be minimal. The estimated mortality rates, for adult Green-winged Teal (*A. crecca*) vary between 50% and 72% depending on the region (Johnson 1995), and 34% and 42% for adult American Wigeon (*A. americana*) (Mowbray 1999).

Although the predation is 1.01% overall for Red-tailed Hawk, it only represents 2.8 adult breeding ducks per km^2 which is not a large value.

Considering overall predation by all predator species, raptor predation is one of the least significant. Mowbray (1999) reported that survival rates of American Wigeon increased from 0.218 to 0.650 after the construction of an electric fence to dissuade terrestrial predators, therefore indicating the large proportion of predatory mortality attributable to terrestrial predators. Sargeant et al. (1984) observed predation by foxes to be as high as 6.02 ducks per km^2, averaging 4.13 dabbling ducks per km^2 annually.

Although the figures given in this study are for only 45 days (pre-fledging period), the annual predation might fall somewhere between one and a half to double the amount of predation for the approximate four months of coexistence between the raptors and the ducks. It likely falls between 4.2 and 5.6 ducks per km^2 because the biomass requirements of the chicks are reduced 2.5 times from the fledgling stage to adulthood (McInvaille and Keith 1974, Preston and Beane 1993).

Conclusion

Overall, this study showed that Great Horned Owl and Red-tailed Hawk do rely on waterfowl for prey and do select them as preferred prey items. Even with the very high raptor nest densities observed on all study areas, neither Great Horned Owls nor Red-tailed Hawks appear to have a large impact on duck populations. The wide variety of other potential prey contribute to the low impact on any one particular species of waterfowl.

The management of these habitats to increase waterfowl productivity does attract more raptors. At this time, no management of Great Horned Owl and Red-tailed Hawk populations is necessary. However, this may have to be re-evaluated if the population of these two predators continues to increase.

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Appendix I: Body masses of prey found on the study areas - Saskatchewan.

Body masses from CRC Handbooks (Dunning 1993, Silva and Downing 1995). Body masses of voles and mice were determined from animals collected on the study areas (M. Pasitschniak-Arts, unpubl. data)

Mammals

Common Name	*Scientific Name*	Body mass (g)
Meadow Vole	*Microtus pennsylvanicus*	25.1
Southern Red-backed Vole	*Clethrionomys gapperi*	21.4
Western Jumping Mouse	*Zapus princeps*	19.9
Deer Mouse	*Peromyscus maniculatus*	19.1
Thirteen-lined Ground Squirrel	*Spermophilus tridecemlineatus*	170
Richardson's Ground Squirrel	*S. richardsonii*	350
Franklin's Ground Squirrel	*S. franklinii*	500
Least Chipmunk	*Tamias minimus*	48
Northern Pocket Gopher	*Thomomys talpoides*	145
Norway Rat	*Rattus rattus*	375
Shrew spp.	Family Soricidae	5.4
Snowshoe Hare	*Lepus americanus*	1550
Muskrat	*Ondatra zibethicus*	1180
Weasel	Genus *Mustela*	70
Unknown Small mammal		25

Birds

Mallard	*Anas platyrhynchos*	1055
Blue-winged Teal	*A. discors*	386
Gadwall	*A. strepera*	919
Northern Shoveler	*A. clypeata*	613
Northern Pintail	*A. acuta*	1010
American Wigeon	*A. americana*	756
Lesser Scaup	*Aythya affinis*	820
Horned Grebe	*Podiceps auritus*	453
American Coot	*Fulica americana*	642
Ruddy Duck	*Oxyura jamaicensis*	545
Short-Eared Owl	*Asio flammeus*	347
Red-winged Blackbird	*Agelaius phoeniceus*	52
Duckling	*Anseriformes*	75
Sparrow sp.	Passeriformes	15
American Crow	*Corvus brachyrhynchos*	448
Gray Partridge	*Perdix perdix*	385
Sharp-tailed Grouse	*Tympanuchus phasianellus*	885
Ruffed Grouse	*Bonasa umbellus*	576
Blackbird sp.	*Icteridae*	45
Black-billed Magpie	*Pica pica*	177
Sora	*Porzana carolina*	75
Unknown Large Bird (>BWTE)		650
Unknown Medium Bird (<BWTE)		200
Unknown Small Bird (Passer)		20

Appendix II: Total relative density per 1000 m^2 per habitat type for Northern Pocket Gopher and ground squirrels (subtracting transects with the two extremes).