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The red-tailed hawk on Sauvie Island, Oregon

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A study was undertaken to determine the abundance, distribution, perching heights, diets and territory sizes of Red-Tailed Hawks on Sauvie Island, Oregon. Sauvie Island supported a large wintering population of non-territorial Red-Tailed Hawks. The establishment of territories began around 10 January. Average perch height was found to be 14.2 m. Average perch height increased from fall to spring, corresponding to the onset of the breeding season and to the onset of egg-laying and incubation. Voles (*Microtus spp.*) were the principal prey year-round, though waterfowl were more important in terms of biomass in the winter and early spring. Territory sizes on the Island ranged from .31 - 3.73 km^2. The abundance of voles was assessed in different habitats within five Red-Tailed Hawk territories. Territory size was shown to be inversely correlated to the population density of voles. The implications of this finding for the type of territoriality exhibited by Red-Tailed Hawks is discussed, as are some proximate factors affecting habitat selection.

THE RED-TAILED HAWK ON SAUVIE ISLAND, OREGON

by

Kevin J. Lien

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INTRODUCTION

The Red-Tailed Hawk (*Buteo jamaicensis*) breeds throughout most of North America, and winters from approximately the Canadian border south to Central America (Udvardy 1977). Their diversity in habitat selection is matched by a high degree of variability in food selection and territory size.

Red-Tailed Hawks are of interest to wildlife managers and environmental scientists because as diurnal raptors they are relatively easy predators to study. They can be readily located during the breeding season, and have smaller ranges than most mammalian predators. Raptors are high trophic level consumers, and are often used as indicators of environmental contamination and/or disturbance (Kennedy 1980). For example, Seidensticker and Reynolds (1971), and Fimreite (1971) have shown that Red-Tailed Hawks concentrate such chemicals as DDE, DDT and methyl mercury.

The banning of DDT has helped to protect some raptor populations, but energy development in the western United States, and human encroachment all over North America pose serious threats to many raptors. There can be no adequate protection of these birds until the key aspects of their physical and biological environments are known. To do this, it is crucial to consider seasonal variation in ranges, food habits and other population characteristics. Such work would require several decades, and studies of this type are rarely feasible given limited budgets and time. Therefore, a large preexisting data base is essential for accurate impact assessments and informed management decisions. It is the purpose of this study to contribute to that data base, specifically with regard to distribution, diet, perch use and territory size.

Red-Tailed Hawks have been studied in north-central Oregon (Janes 1979), but I found no previous studies focusing on Red-Tailed Hawks in western Oregon. This study was conducted on Sauvie Island, 16 km north of Portland, Multnomah County, Oregon, at the confluence of the Willamette and Columbia Rivers. Sauvie Island is a significant area for the study of Red-Tailed Hawks for several reasons. The Island is an area of high raptor productivity, and Red-Tailed Hawks are the most abundant and conspicuous of these raptors (Gottfried 1972). Food resources are plentiful and varied, and perch sites are abundant. Consequently, there is a large resident population which provides an ideal setting for the study of these hawks in western Oregon.

The diet of Red-Tailed Hawks has been investigated in many areas throughout their range (Luttich 1970; Gates 1972; Stinson 1980; Korschgen 1972; McInvaille and Keith 1974; Kleiman 1978). The principal foods taken vary with availability and habitat. Prey items reported include mammals, birds, reptiles, insects and fish. On Sauvie Island, small mammals, passerine birds and game birds are abundant. Since all major food types are present on the Island, at least seasonally, the diet of Red-Tailed Hawks on Sauvie Island is of considerable interest. This high annual productivity and seasonal variability should be reflected in red-tail food selection on the Island.

Red-Tailed Hawk populations in north-central Oregon are limited by the number of available perches and their spacing (Janes 1979). One perch per sixteenth township section (.162 km^2) was required for productivity to occur at the replacement rate. Sauvie Island, in contrast, abounds with natural and man-made perches well in excess of this density.

The territory size of Red-Tailed Hawks is highly variable, ranging from .32 km^2 to 6.5 km^2 (Smith and Murphy 1973; Fitch, Swenson and Tillotson 1946; Craighead and Craighead 1956; McInvaille and Keith 1974; Johnson 1971). It was hypothesized that neither food nor perches would be limiting, at least locally on the Island, and that territory size should therefore approach a lower limit determined by behavioral factors.

The function of territories is still controversial. Lack (1966) suggested that territories serve mainly to space individuals in different habitats, and saw no reason to postulate that territorial behavior can be directly related to the available food supply. However, several workers have suggested just such a relationship (Fretwell 1972; Orians 1972; Seastedt and Maclean 1979; Verner 1977). It has also been suggested that solitary nesting bird species may not react to actual prey numbers in any one year, but to proximate factors associated with a given habitat (Seastedt and Maclean 1979).

METHODS AND MATERIALS

Sauvie Island is a fertile farming and game management area (Figure 1). Although several habitat types occur on the Island, wetlands and agricultural areas are characteristic. The Island is composed chiefly of gravel, sand and silt overlain by rich topsoil. Maximum elevation is 17 m above sea level. Prior to the construction of dikes and levees in 1942, flooding occurred each spring and early summer. The dikes and levees, coupled with the dams on the Columbia River, have curtailed natural flooding. Manipulation of flow rates in the Columbia River and selective flooding of fields by the Oregon Department of Fish and Wildlife are currently the major causes of flooding on the Island.

The dominant trees along watercourses and in marshy areas of the Island are Black Cottonwood (*Populus trichocarpa*), Oregon Ash (*Flaxinus latifolia*), Red Alder (*Alnus rubra*), and Willow (*Salix spp*). White Oak (*Quercus garryana*) can be found growing on various parts of the Island, most notably on Oak Island; it prefers gravelly bottomlands (Peck 1941). Patches of mixed Douglas Fir (*Pseudotsuga menziesii*) and Grand Fir (*Abies grandis*) are also present. Some agricultural areas are maintained by the Oregon Department of Fish and Wildlife to provide forage and shelter for waterfowl and other game species. Crops grown include rye-grass, corn and potatoes. Private farmlands grow commercial crops ranging from fruits and vegetables to shade trees. Horses,

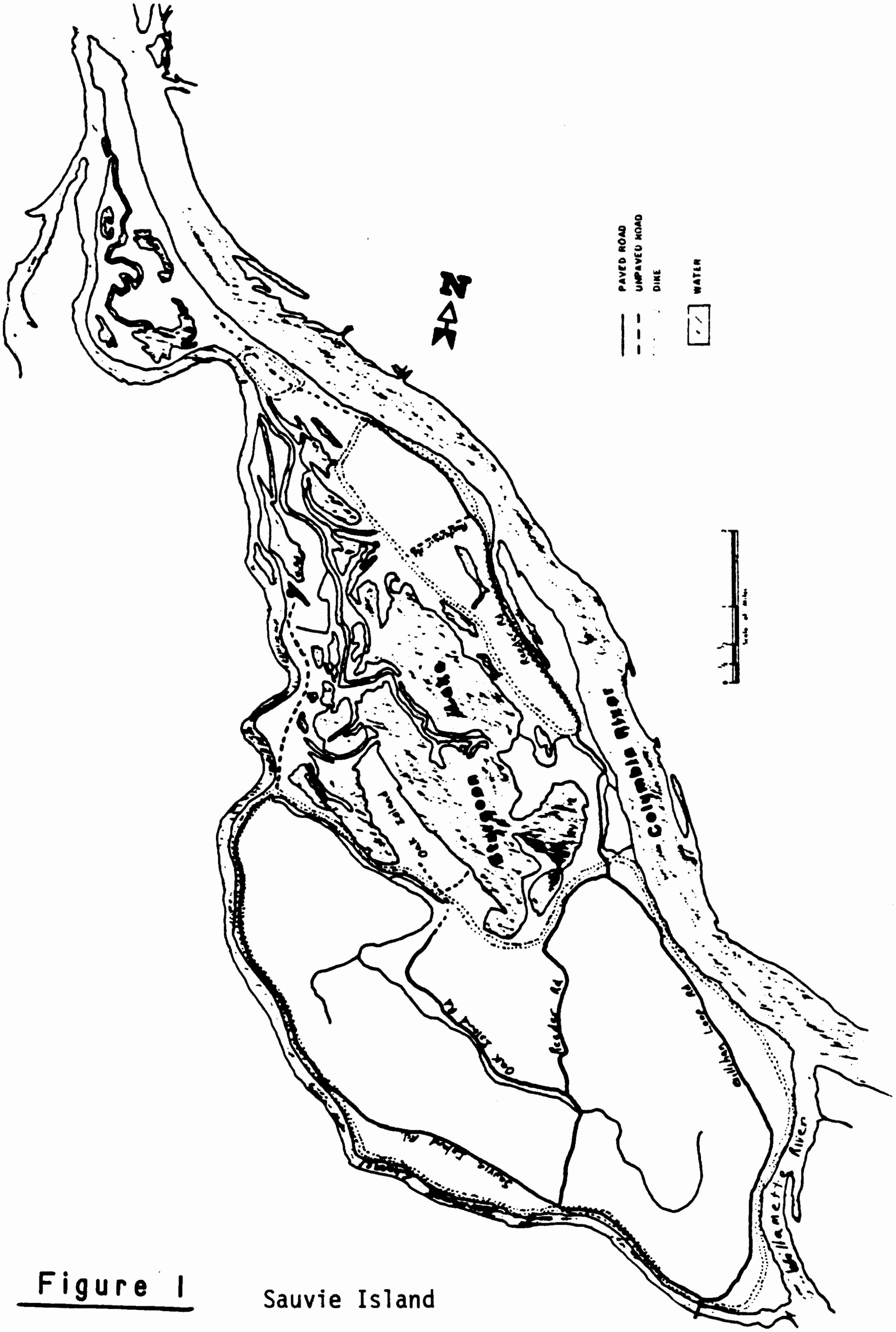

Figure I   Sauvie Island

sheep and cattle can be found grazing on private lands. Some cattle are grazed within the game refuge. Extensive areas of natural grassland and marshland occur on the Island.

Sauvie Island has an abundance of both resident and migratory wildlife. Complete lists of the ducks, mammals, and amphibians and reptiles known to occur on the Island, at least seasonally, are given in Appendices A, B and C, respectively.

Census

A census of Red-Tailed Hawks was conducted between 10 November 1981 and 1 April 1982 to detect seasonal changes in population density on the Island. Howell (1951) gave a method for reconciling relative abundance and absolute abundance using percentages of conspicuousness. Craighead and Craighead (1956) found that no percentage of conspicuousness was needed for Red-Tailed Hawks if the census route was driven at about 24 kph when the leaves were off the trees and binoculars were used. Accordingly, the 26.7 km census route was driven at about 24 kph, using 7 X 35 wide-angle insta-focus Bushnell binoculars and a 20-power Bushnell spotting scope, and no percentage of conspicuousness was tabulated. All birds within 0.4 km of the road on either side were counted. When a portion of the route was driven twice on any census, birds were only counted in one direction. The census route was driven once or twice per week. Censuses were not conducted during periods of rain or high winds to keep the census results as uniform as possible.

Nest Survey

In addition to the census, I conducted a nest survey consisting of two parts: an intensive ground search which covered nearly the entire Island during the course of the study, and an aerial survey in a Cessna 150 flying at between 300 and 500 feet on 28 February 1982. Nest locations were marked on a cover map. Every effort was made to determine if the located nests were active during the breeding season. The total number of active nests (and hence the breeding population) was estimated following the procedure used by Henney, Smith and Stotts (1973) in which $N = \frac{n_1 n_2}{m}$ where n_1 is the number of nests observed by the ground survey, n_2 is the number of nests located by the aerial survey, and m is the number of nests located by both methods. During the ground survey, the height of each nest observed was recorded.

Perch Use and General Observations

As each hawk was seen, its location, color phase, flight (flapping or soaring, direction and height), or perch height were recorded. In addition, observations were made on any direct interactions that the red-tails had with other species, any unusual vocalizations heard, and general behavior.

Diet

Diet was studied in several ways. Pellets were collected from beneath red-tail perches. Pellets were analyzed as suggested by Errington (1930). Each pellet was considered to represent a single prey item, unless the evidence indicated otherwise. All observed kills were noted and the type of prey was determined, if possible. Anecdotal data on the food habits of red-tails on the Island was collected. Finally, the scavenging behavior of red-tails was examined experimentally by placing various carcasses near a favorite perching site.

Winter Home Ranges and Nesting Territory Sizes

Winter home ranges and nesting territory sizes were ascertained. Both winter home ranges and nesting territories were assumed to be analagous to utilized territory (Odum and Kuenzler 1955).

Winter home ranges were defined as being undefended areas over which an individual resident red-tail moves and hunts (Craighead and Craighead 1956). Individual hawks were observed from 3 November 1981 until the onset of breeding season activities on 10 January 1982. Their locations were transferred to a cover map. Lines connecting peripheral sightings delimited the winter home range of that individual or pair.

Nesting territories were likewise defined as those areas within which the activities of the breeding cycle are carried out (Craighead and Craighead 1956). Territories were not always observed to be defended, due to a low indicence of aggression between adjacent pairs. Lines were drawn between peripheral observations of a pair on a cover map to delimit the nesting territory. Observations were recorded from 10 January to 7 April 1982.

Vole Censuses

Voles (*Microtus spp.*) make up a significant portion of the red-tail diet on the Island, so an effort was made to determine the relative abundance and activity of these rodents. Abundance and activity were measured in different habitat types within five red-tail territories. Transects one hundred yards long were used. In large areas, I threw a frisbee over my shoulder to determine the start of a transect. I then followed a cardinal direction as determined by a Lensatic compass. Each of the four cardinal directions was used. All runways and burrows were counted on either side of the transect line, giving totals of 100 square yards (technique suggested by Chris Maser, USFS). In smaller areas, only one transect was run with the cardinal direction being chosen by flipping two coins with HH representing north, HT west, TH east and TT south. In even smaller areas, the cardinal direction was dictated by the configuration of the habitat.

Data Processing

The winter home range, nesting territory and *Microtus* abundance data was processed using the Tektronics 4051 computer with a digitizer. A territory or habitat area could be traced on a map or aerial photograph with the digitizer and an area computed.

Territory sizes were calculated using a cover map bearing the perimeter points. Aerial photographs of the Island were obtained from the Army Corps of Engineers. Relevant portions, including five representative territories, were enlarged to 11 in x 14 in, allowing *Microtus* habitat areas to be measured. According to Pearson (1972), *Microtus canicaudus* numbers can be accurately assessed by assuming that six burrows represents one vole. This conversion factor was used to calculate vole numbers since *Microtus canicaudus* was found to comprise 65% of the voles captured in a study on the Island (Hennigar, unpubl. data). No such information is available for *Microtus townsendii*, the other vole commonly found on the Island.

RESULTS

Census

The results of the census are summarized in Figure 2. The first two censuses of the season were not used since they were probably less reliable. Eighteen Red-tailed Hawks on the Island were known to be residents (present on the Island year - round). Not all residents were observed on any one census. Many of the red-tails seen in the winter are migrant; this is reflected in the results. If the census strip is representative of the Island as a whole, the red-tail density can be estimated directly. An average of 6.3 red-tails were seen per census from 19 November 1981 until 29 December 1982. This average increased to 13.6 per census from 4 January 1982 through 21 February 1982. From 3 March 1982 to 1 April 1982, the average declined to 10.3 per census.

Nest Survey

The results of the nest survey are summarized in Figure 3. Nest building occurred from 20 February 1982 until 24 March 1982. Two nests were blown down in a windstorm on 14 November 1981. In each instance, new nests were constructed several trees away. The survey revealed that 29 of the nests were located within 50 m of water courses or bodies of water.

The number of active nests on the Island was estimated to

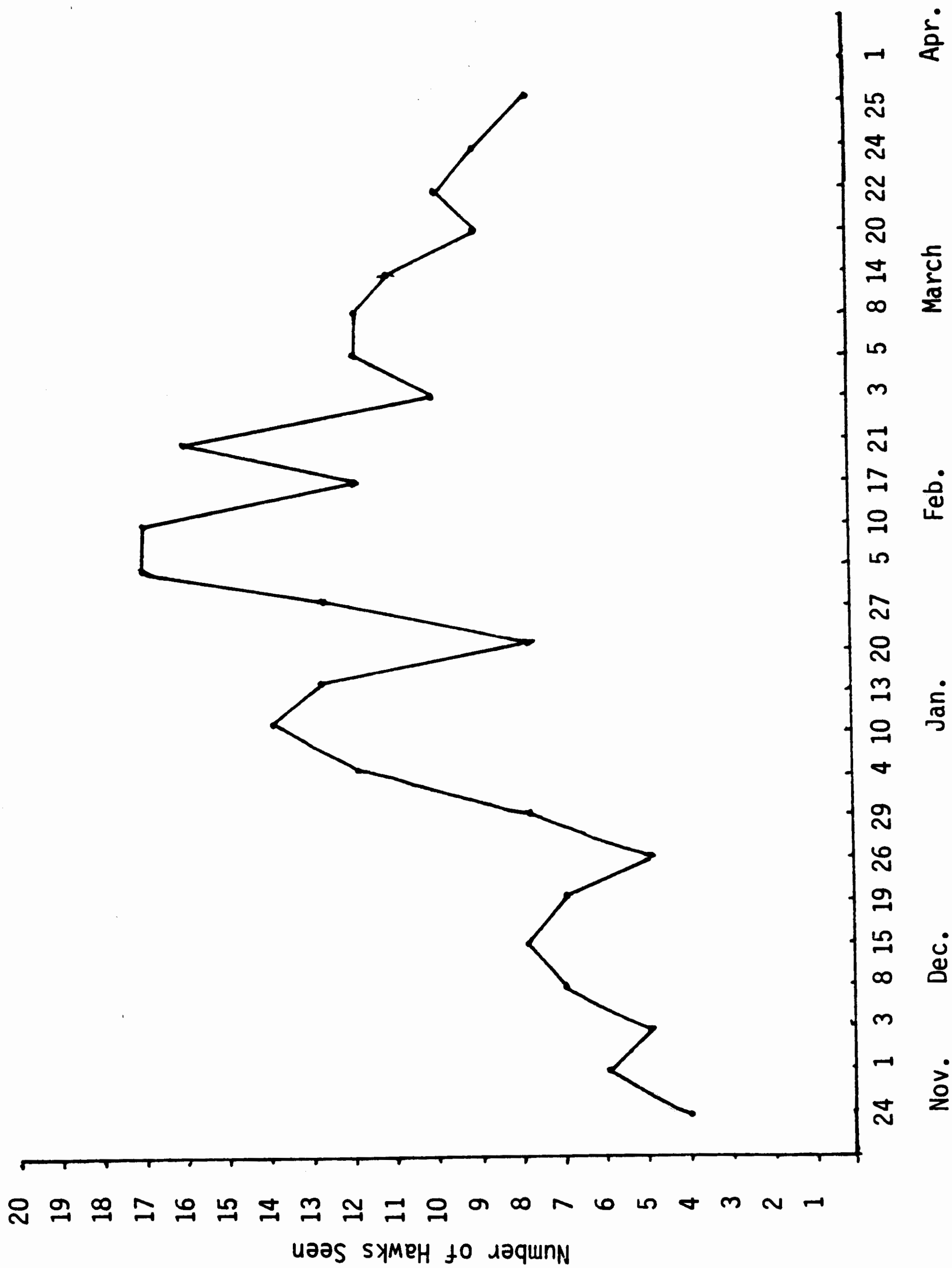

Figure 2 Census Results

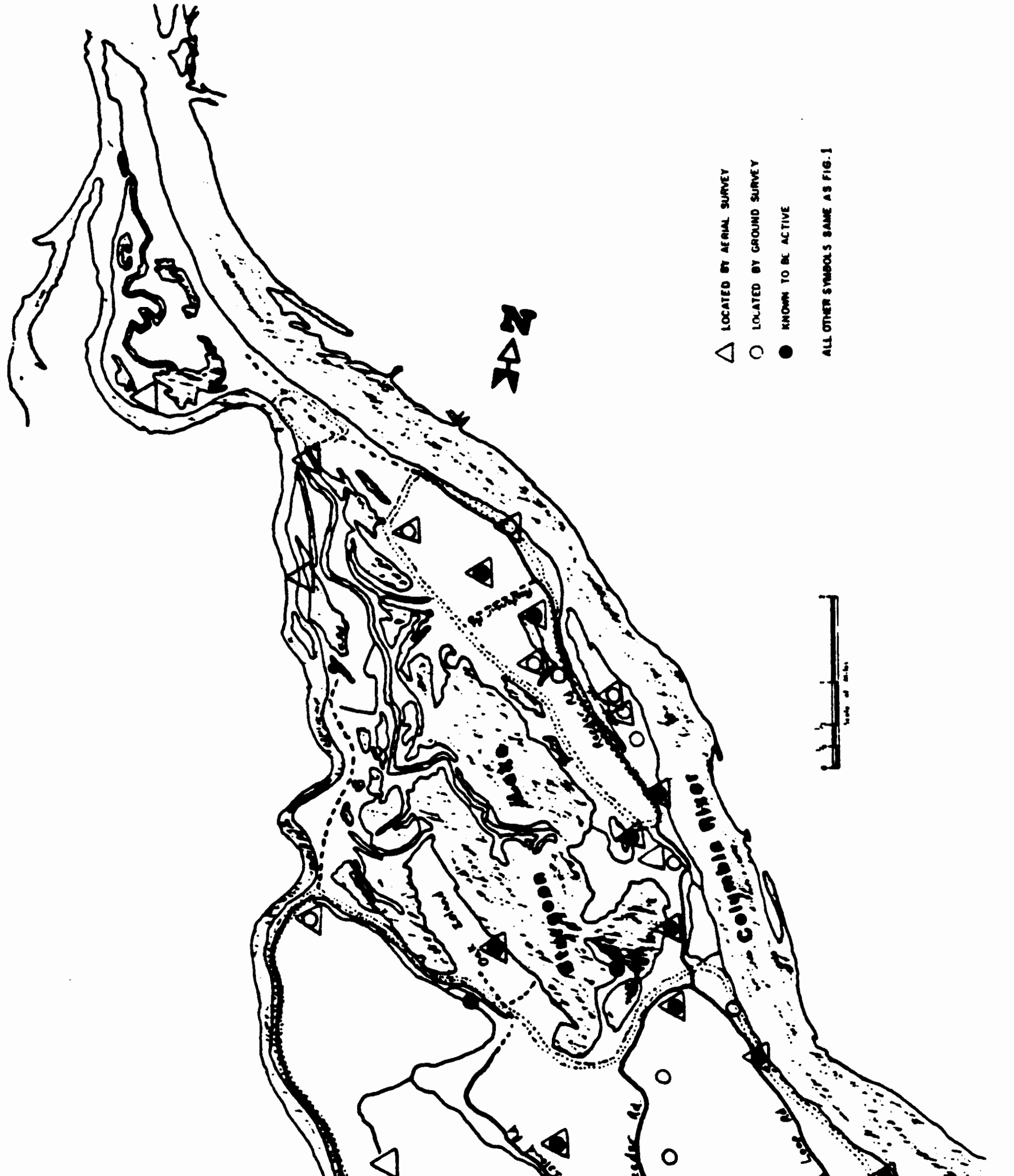

Figure 3 Nest Survey

be N = 14.4 using the Henney, Smith and Stotts (1973) equation with 31 nests located by the ground survey, 27 located by the aerial survey and 58 located by both methods. There were 15 active nests observed on the Island as of 24 April 1982, but there may have been a few more since not all nests could be checked.

The average nest height for 28 nests on the Island was 15.0 m. Most nests were located in Black Cottonwoods, though three nests were noted in White Oaks and one was in an Oregon Ash. Casual observation revealed that the tallest trees were selected for nesting. Nest positions averaged a little more than three-quarters of the height of the tree used (.77).

Perch Use

Perch heights (Figure 4) were observed to be normally distributed ($P \leq .05$, $X^2 = 15.3$, $n = 392$). The average perch height was 14.2 m with a standard deviation of 4.2 m. The perch heights were found to increase from late fall to winter ($P \leq .01$, $Z = 3.04$) and from winter to spring ($P \leq .01$, $Z = 4.74$). The average perch height from 13 October 1981 to 10 January 1982 was 12.9 m. From 10 January to 14 March 1982 the average perch height was 14.1 m. The average perch height increased again from 16 March through 10 April 1982 to 17.5 m. As a general observation, most of the perching was done in cottonwoods, though virtually every type of tree over 5 m tall was used. Hawks were observed perching on the ground on four occasions.

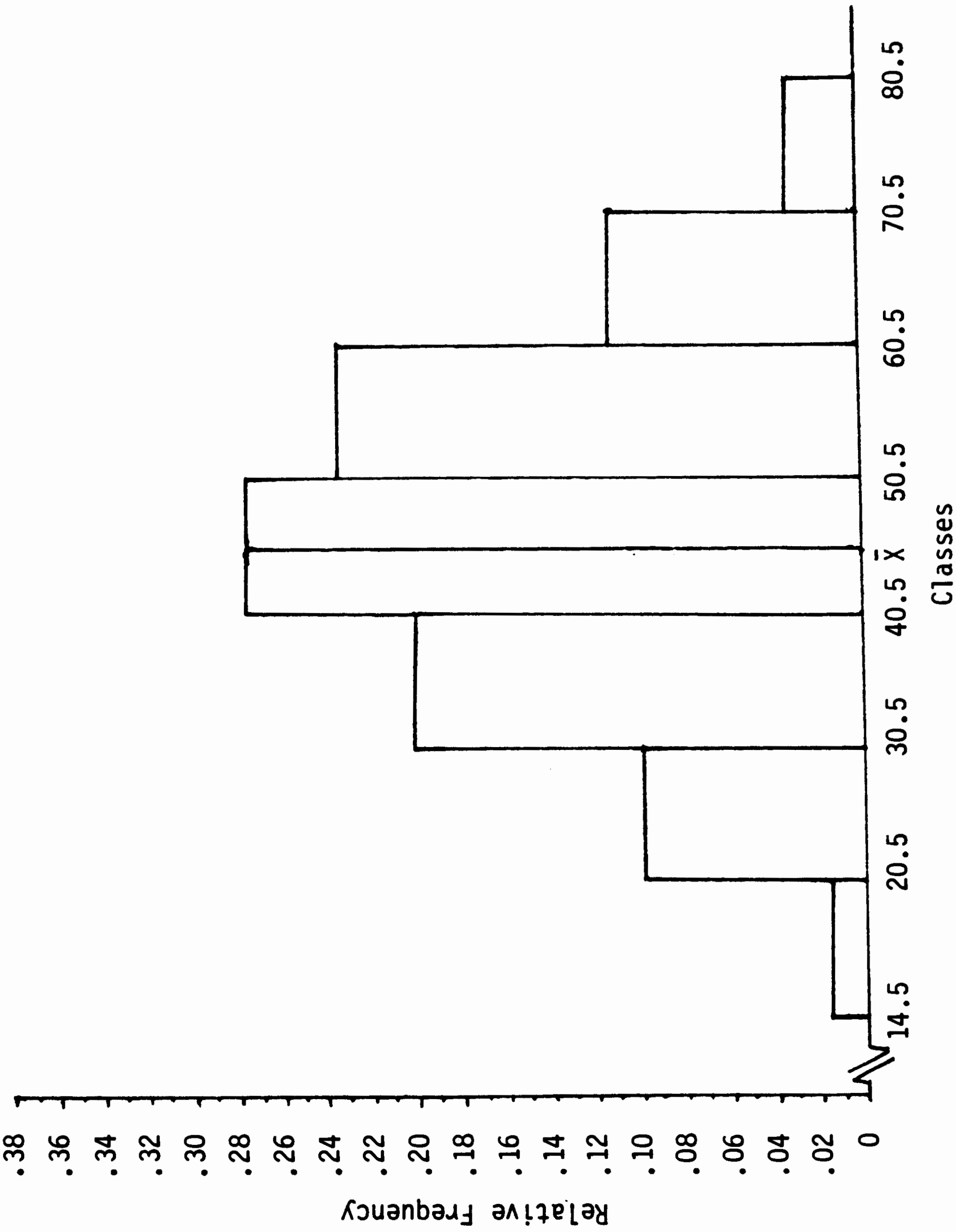

Figure 4 Perch Height Distribution

Flight

Red-tails flew more in sunny rather than cloudy weather ($P \leq .01$, $X^2 = 28.2$, $n = 296$). This includes both soaring and flapping flight. There was considerable individual variation in behavior patterns, however. Several red-tails were observed to use soaring and flapping flight even in cloudy, windy or rainy conditions.

Color Phases

Some color phase variation was noted among the red-tails on the Island, but 83% of all individuals sighted were clearly light phase as defined by Grossman and Hamlet (1964). Dark phase intermediates comprised 7% of the sightings and 9.5% were red phase intermediates. One dark phase and one red phase intermediate were found to be resident on the Island.

Interactions, Vocalizations and General Behavioral Notes

Relatively few interspecific interactions involving red-tails were noted. The most significant of these was an encounter in which a red-tail was chased from a section of its own range by a Marsh Hawk. In two other instances, a red-tail and a Marsh Hawk were seen to pass closely in flight with no apparent interaction.

On 3 August 1981, a young Turkey Vulture swooped at a red-tail. It was apparently playing, since Turkey Vultures and red-tails generally tolerated each other well and were often seen circling together during the summer months.

Both passerines and crows were occasionally observed to mob red-tails. The crows mobbed the red-tails more frequently (63% of the observed mobbings) and intensely than any other species.

Unusual Red-tailed Hawk vocalizations were heard twice during the study. On 17 February 1982, a red-tail perched and gave a series of three cries which sounded similar to a Raven or a Glaucous Gull: cark-ahr, cark-ahr, cark-ahr. On 25 March 1982, a male was observed to land on its mate's back and emit a series of squeaks - chee-chee-chee - while flapping to maintain his balance.

From 13-22 October 1981, two separate pairs of Red-tailed Hawks were observed to still be accompanied by a juvenile. One of these pairs continued what appeared to be breeding displays until 15 October 1981. They would take turns swooping onto each other and put their legs down at the point of closest proximity. In the spring, it was noted that a yearling revisited the parental territory from 10 February until 8 March 1982.

Egg-laying and the onset of incubation were found to begin on 24 March 1982 and extend until 7 April 1982.

Diet

In an attempt to quantify the diet of Red-tailed Hawks on the Island, 105 pellets were examined, 4 kills were observed and the remains of 5 ducks were identified. The results are summarized in Table I.

Pellet collections were divided into fall, winter and spring categories in order to determine how diet changed seasonally. Fall extends from the first collection on 3 August 1981 until all the leaves were off the trees on 19 November 1981; winter extends from 19 November 1981 until the emergence of leaves on 20 March 1982; spring extends from 20 March 1982 until the last collection on 24 April 1982. The results of this analysis are summarized in Table II. Plant material was found in 45.7% of the pellets, and is considered to be prey gut contents.

Pellets and remains indicating waterfowl in the diet were only recovered for red-tails living along the east side of Sturgeon Lake. Waterfowl were consumed, for the most part, in the winter and early spring. Consumption probably increased during the hunting season, but waterfowl were preyed upon even after all hunting had ceased.

Insects were consumed mostly in the fall and spring rather than winter, as would be expected in a moderately cold climate. The relatively high proportion of insects in the diet was surprising. Perhaps even more surprising is the fact that some red-tails on the Island eat earthworms when they can find them (Frank Newton, pers. comm.).

The carcasses of a raccoon, a grey squirrel, a mallard and a merganser were placed 5 m from a perch tree in each of the

TABLE I

Diet

	Number	Number Percent	Indiv. Biomass (g)	Total Biomass (g)	Percent Biomass
Microtus sp. Voles	102	61.45	43.3[1]	4416.6	38.97
Neotoma cinerea Bushy-tailed Woodrat	1	.60	300[2]	300	2.65
Thomomys sp. Pocket Gopher	1	.60	305[2]	305	2.69
Scapanus townsendii Townsend's Mole	1	.60	117.5[2]	117.5	1.04
Unidentifed shrew	1	.60	12.6[2]	12.6	.11
Total Mammal	106	63.85		5151.7	45.45
Anas discors Blue-winged Teal	1	.60	420.5[3]	420.5	3.71
Anas platyrhynchos Mallard	1	.60	1179.5[3]	1179.3	10.41
Unidentified duck	6	3.63	761.4[3]	4568.4	40.31
Unidentified passerine	1	.60	41.2[4]	41.2	.36
Total Bird	9	5.41		6209.4	54.79
Coleoptera beetles	51	30.72	.28[5]	14.28	.13
TOTAL	166	100.00		11335.4	100.00

1 Pearson (1972)
2 Maser, Mate, Franklin and Dyrness (1981)
3 Bellrose (1976)
4 Craighead and Craighead (1956)
5 Smith and Murphy (1973)

TABLE II

Seasonal Diet

		Fall	Winter	Spring
	Number	41	22	43
Mammal	Percent	64.06	73.33	64.18
	Percent Biomass	69.45	27.91	48.03
	Number	1	4	4
Bird	Percent	1.56	13.33	5.97
	Percent Biomass	30.31	72.07	51.84
	Number	22	4	20
Insect	Percent	34.38	13.33	29.85
	Percent Biomass	.25	.03	.12

cardinal directions respectively. Three red-tails perched in the tree separately and in combination. Each of them also soared over the carcasses. However, none of the carcasses was scavenged during the entire four and one-half hour observation period.

Winter Home Ranges and Nesting Territories

The nesting territories which could be accurately delimited during the course of the study are shown in Figure 5. Territory and home range sizes are listed in Table III. Winter home ranges could only be determined accurately for two pairs. These winter home ranges are presented in Figures 6 and 7, along with the nesting territories for comparison. Winter home ranges were considerably larger than the respective nesting territories and these ranges overlapped with those of adjacent individuals or pairs.

Vole Censuses

Transects to measure *Microtus* abundance and activity within five representative red-tail territories were conducted. The results of these transects are summarized in Table IV. The voles appeared to be the most vulnerable in the recentely flooded pond habitat of territory 1 where they were concentrated without adequate vegetative cover. They were probably the least vulnerable in the tall, thick grass of the marshy habitat in territory 1.

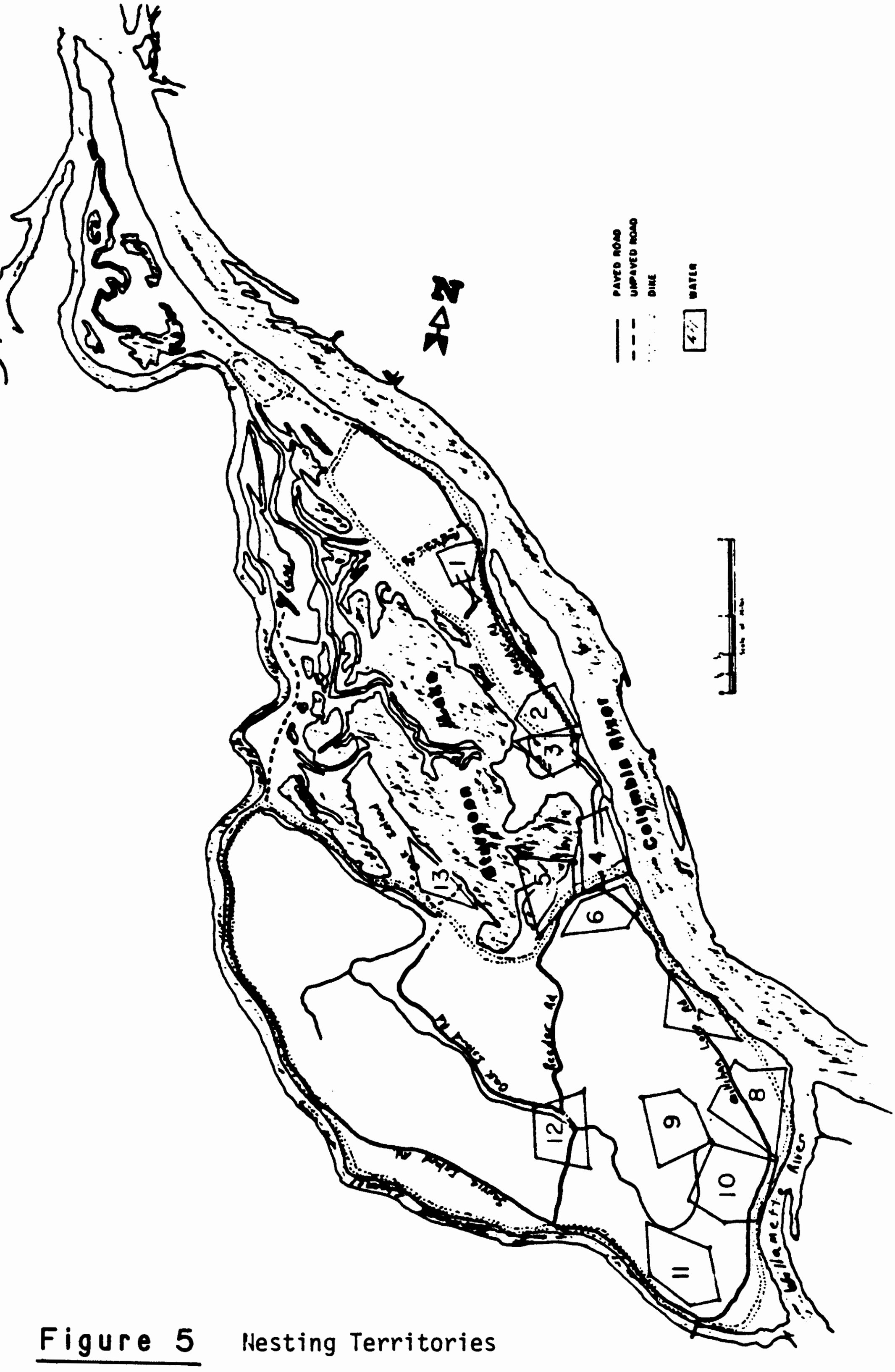

Figure 5 Nesting Territories

TABLE III

Nesting Territory and Winter Home Range Sizes

Territory	km^2
1.	.31
winter home range	1.01
2.	.98
3.	1.17
4.	.75
winter home range	1.32
5.	1.04
6.	1.06
7.	1.22
8.	2.12
9.	.93
10.	2.62
11.	1.76
12.	1.45
13.	.67

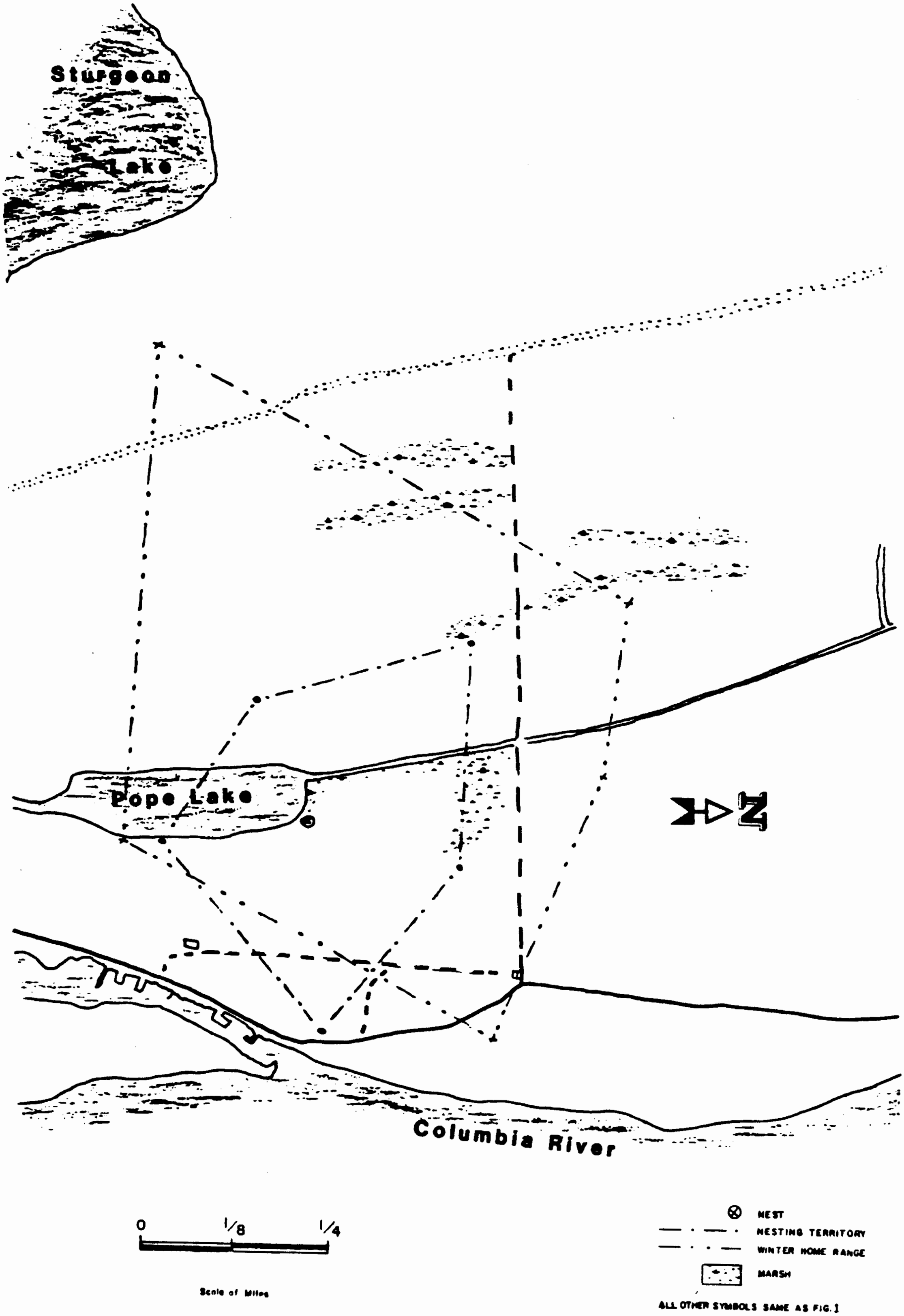

Figure 6 Territory 1.

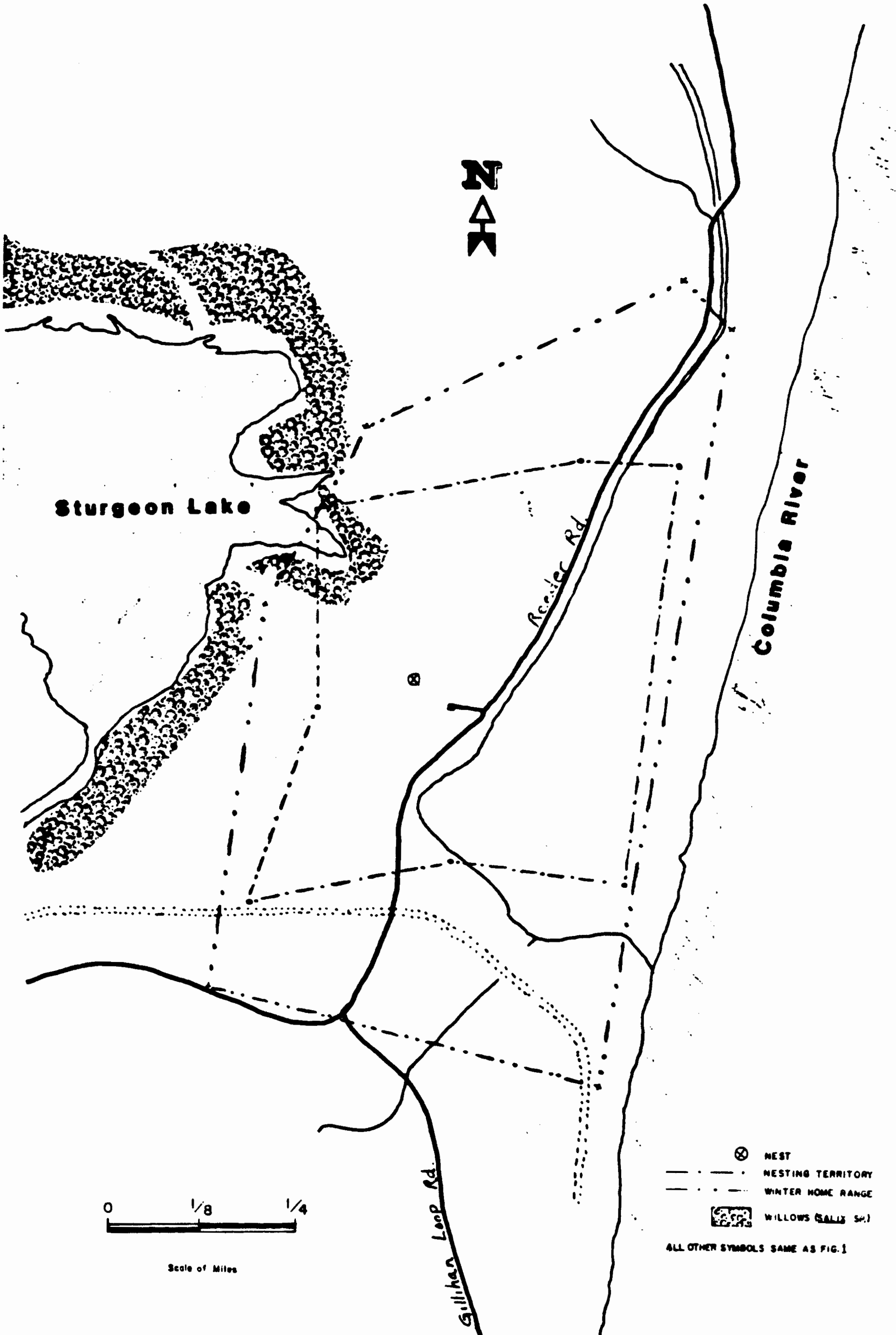

Figure 7 Territory 4.

TABLE IV

Microtus Numbers in Relation to Habitat

Habitat	Area (m^2)	Percent of of Territory	Number of Voles/100 m^2	Number of Voles
Territory 1				
Thick grass	43321 ± 1819	13.95	9.37	4059
Planted grass	50607 ± 1771	16.30	1.20	607
Pond Edge	14174 ± 5934	4.56	25.51	3616
TOTAL VOLE POPULATION ---	8282	DENSITY ---	.02668 voles/ m^2	
Territory 4				
Clover field	42065 ± 967	5.54	6.88	2895
Planted grass	139961 ± 560	18.43	0.80	1120
Fallow grass	85372 ± 7939	11.25	4.58	3910
TOTAL VOLE POPULATION ---	7925	DENSITY ---	.01044 voles/m^2	
Territory 6				
Fallow grass	125851 ± 5789	11.75	4.58	5764
Fields	175925 ± 36782	16.45	0.60	1055
Grazed grass	22461 ± 1033	2.09	0.60	135
TOTAL VOLE POPULATION ---	6954	DENSITY ---	.00649 voles/m^2	
Territory 10				
Fields	1550334 ± 16031	59.45	0.60	9302
Pasture	82010 ± 8365	3.14	0.60	492
Ungrazed pasture	68384 ± 2393	2.62	5.78	3953
TOTAL VOLE POPULATION ---	13747	DENSITY ---	.00527 voles/m^2	
Territory 11				
Clover	35300 ± 499	2.00	15.35	5419
Grazed	160335 ± 8498	9.08	0.60	962
Ungrazed	21545 ± 3576	1.22	5.78	1245
Planted grass	103963 ± 27532	5.89	0.80	832
Fields	411587 ± 85610	23.31	0.60	2469
TOTAL VOLE POPULATION ---	10927	DENSITY ---	.00619 voles/m^2	

Relationship of Territory Size and Vole Abundance

The five territories for which *Microtus* abundances were examined included the largest and the smallest territories. All territories included significant portions of agricultural land. Calculated *Microtus* densities were compared with the territory sizes using the Spearman Rank Correlation (McClave and Dietrich 1979). There was a significant negative correlation between territory size and relative *Microtus* density ($P \leq .05$, $r = 1.00$).

DISCUSSION

Census

The results of the census support the casual observation that Sauvie Island is an important wintering ground for Red-tailed Hawks in western Oregon. Little is known about densities and habitat preferences of wintering raptors. A raptor preserve was found to have a peak red-tail population density of $2/km^2$ in a study of wintering raptors in the Sacramento Valley; maximum numbers outside the preserve were $.75/km^2$ (Wilkinson and Debban 1981). Peak numbers observed in this study were $.39/km^2$. It is possible that prime wintering areas further south attract more migrants than do more northerly areas.

The low numbers of Red-tailed Hawks counted in the fall ($\bar{x}$ = 6.3) as compared to the spring ($\bar{x}$ = 10.3) probably reflects the fact that red-tails are distributed differently during the fall than they are during the breeding season (Craighead and Craighead 1956). Nests were often located near the census route. Roads are usually near the perimeter of the Island; nests were generally built in tall trees within 50 m of a body of water. The fall and winter counts probably reflect the population on the Island as a whole better than the spring counts because of this aggregation effect along the census route during the breeding season. Red-tails seemed to remain fairly well dispersed during the winter, and groups of more than three hunting Red-tailed Hawks were never seen, though aggregations of five or more were sometimes seen in the same general area.

The period of peak wintering populations also corresponds to pair formation and the reinitiation of courtship behavior among the resident red-tails. The establishment of territories at this time may, by advertising the density of the breeding population, help to discourage migrants from settling on the Island.

Nest Survey

Dunstan and Harrell (1973) reported that the height of red-tail nests in South Dakota averaged 19.2 m with a range of 12.8 m to 24.7 m. In Ontario, nests reportedly range from 9.2 m to 21.3 m in height (Creighton 1972). Nest heights on Sauvie Island are generally lower than those in South Dakota, but are in the same height range of those in Ontario. The preference for water edges reported here could be due to the fact that the tallest trees tend to grow next to water. Several reports also mention the preference of red-tails for the tallest trees available in a given habitat both in South Dakota and Northern Alberta (Dunstan and Harrell 1973; Schumtz et al. 1980).

The Henney, Smith and Stotts (1973) method of estimating the number of active nests yielded a result (N = 14.4) which is reasonably consistent with the 15 known active nests on the Island. The technique appears to be fairly reliable even with the relatively small sample sizes obtained on Sauvie Island. Red-tailed Hawk nests on the Island lent themselves to an aerial survey due to their height in deciduous trees. This contrasts with other Buteo nests which may be less successfully surveyed by air since they are often concealed within the tree canopy (Johnson 1981).

Perch Use

The approximately normal distribution of perching heights indicates that while higher and lower perches were available, the preferred range centered around a specific value. Chamberlin (1974) found that 58.9% of the hunting perches were from 12.5 m to 18.3 m. In the present study, 49.5% of the perches were observed to be in that range. Craighead and Craighead (1956) noted that the average perching height of red-tails was 11.0 m with 12.2 m as the most frequently used height. The average perch height on Sauvie Island seems to agree with observations made on two Midwestern populations. In north-central Oregon, junipers averaging under 10 m tall were almost exclusively used as perch sites. Red-tailed Hawks perched at or near the tops of these junipers and would perch higher if taller perches were available (Janes 1979). Therefore, the perch height found in this study is probably the optimal height for prey detection in a grassland/ agricultural habitat. Optimal perch height may vary between habitats. Red-tailed Hawks in north-central Oregon may prefer perch heights lower than the 14.2 m average for Sauvie Island in order to scan beneath scrub vegetation (Janes, pers. comm.).

The removal of perches above 12 m would undoubtedly decrease the hunting ability of these hawks in grassland/agricultural habitats and necessitate larger territories, given similar prey densities.

The increase in perch height from fall to winter corresponds to the onset of breeding behavior among the resident red-tails on the Island. Fitch et al. (1946) noted that red-tails establishing territories would often perch higher and more conspicuously than they would during the fall and early winter. An increase in perch height at this time probably serves to advertise the ownership of the territory. The increase in perch height from winter to spring seems to correspond to the onset of egg-laying and incubation. The detection of nest predators may be enhanced by an increase in perch height during this period.

Flight

The fact that Red-tailed Hawks fly more on sunny days than on cloudy ones is significant. It has been known for some time that clear skies facilitate soaring flight and that the rate at which thermals form is related to temperature (Cone 1962). The continual bubbling of heated air from the ground may similarly cause flapping flight to be more energetically economical for the red-tails. This would allow them to move between perches within their home range more often on a sunny versus a cloudy day, thus increasing hunting efficiency. I noted a marked increase in soaring on sunny days when the temperature was above 22°C. Wilkerson and Debban

(1980) found that the number of red-tails observed soaring over their study area was positively correlated with temperature. Therefore, it seems reasonable that both full sun and a sufficiently warm ambient temperature are necessary for a shift from perching to aerial behaviors.

Increased soaring allows for more freedom of movement. Soaring is an energy efficient method of travel, and red-tails are known to be able to overfly a neighboring territory by gaining sufficient altitude (Craighead and Craighead 1956; Fitch _et al._ 1946). Overflights were observed on the Island, but on one occasion sufficient height was not maintained and the pair was "escorted" out of the territory of an adjacent pair.

Color Phases

The color phases observed on Sauvie Island seem to be typical of the Western Red-tailed Hawk. Grossman and Hamlet (1964) state that light phase, red phase, and dark phase individuals as well as many intermediates can be found in the Plains States. Taverner (1936) reports that the different phases interbreed where they occur together. The characteristics of thrre or even four phases can sometimes be recognized in a single individual. As it is not known in what proportion the different phases occur in other populations throughout the West, it is impossible to relate the data from Sauvie Island to other areas.

General Behavioral Notes

Johnson (1973) noted that in Montana young left the parental territory up to 70 days after fledging, and may make several movements out form and back to the home territory during this time . This would indicate that the young should leave the parental territory around 14 August, given a fledging date of 5 June on Sauvie Island. However, some young remained until October. No records were found to indicate a return of the young to the parental territory the following spring in Montana as was observed on Sauvie Island. Apparently the resident status of many of the hawks on the Island may serve to increase the cohesiveness of the parents and the young.

The onset of egg-laying and incubation on Sauvie Island corresponds with dates given for other red-tail populations throughout North America. Hawks in Ontario, Utah, South Dakota and Eastern Oregon laid in late March or early April (Creighton 1972; Smith and Murphy 1973; Dunstan and Harrell 1973; Janes 1979). However, in Central Alberta, hatching occurred in early June, indicating a laying date around 1 May (McInvaille and Keith (1974).

Diet

The adult Red-tailed Hawk is considered to be a generalist in its feeding behavior (Craighead and Craighead 1956). The red-tails on Sauvie Island were found to feed primarily on *Microtus sp.*, although ducks became more important in terms of biomass during winter and spring. Voles were also the principal prey of Red-tailed Hawks in Michigan and Missouri (Craighead and Craighead 1956; Korschgen 1972). McInvaille and Keith (1974) noted a functional response of red-tails to increasing numbers of voles. In addition, both Luttich (1970) and McInvaille and Keith (1974) found waterfowl to be a significant portion of the diet. Therefore, red-tail food habits on Sauvie Island are similar to those in areas with high densities of microtines and waterfowl.

The most conspicuous feature of the diet of Red-tailed Hawks on Sauvie Island is the general lack of larger mammals. The Island has few rabbits or tree squirrels. California Ground Squirrels (*Spermophilus beecheyi*) are sparse, but seem to be increasing in number and extent (Frank Newton, pers. comm.); perhaps ground squirrels will constitute an increasing proportion of the red-tail food supply in the future. When given a choice between two prey items, a red-tail generally prefers the larger of the two up to the size it is willing to take (Snyder 1975).

Microtines from California are known to have approximately four-year population cycles (Vaughn 1978), and it is likely that the microtines on Sauvie Island also exhibit such cycles. These cycles should affect the Red-tailed Hawks on the Island. Microtines are important components in the diets of most red-tails. *Microtus spp.* population fluctuations affect clutch sizes even in areas in which ground squirrels are the chief prey (McInvaille and Keith

1974).

The Red-tailed Hawks on the marshy, waterfowl-rich east side of Sturgeon Lake preyed or scavenged more on waterfowl than those on Oak Island. This observation is supported by studies in Alberta (Luttich et al. 1970; McInvaille and Keith 1974) in which the effects of cover types within a .75 mi radius of nests are strongly correlated with red-tail food habits. It was found that consumption of waterfowl increased with agricultural and aquatic cover types.

Red-tails seemed to hunt more over the water-land boundary than would be expected if they were hunting equally over all cover types within their territories. Perhaps voles in this area are more vulnerable, or the red-tails are looking for injured or sick ducks hiding along the shore.

The reluctance of Red-tailed Hawks on Sauvie Island to scavange carcasses may be due to the preference of these hawks for live prey, when available. Red-tailed Hawks in the Midwest were known to be tremendous feeders on road kills when snow made the capture of live prey difficult (Forbes, pers. comm.).

Winter Home Ranges

As in the Craighead and Craighead (1956) study, it was found that winter home ranges were larger and less exclusive than nesting territories. Hawks were seen to aggregate in certain areas and to tolerate the perching of other hawks in what would become their nesting territory several months later.

Nesting Territories and Proximate Factors

The smallest red-tail territory on the Island was slightly smaller than the smallest territory cited in the literature. Average territory size on the Island was 1.24 ± .23 km^2 (range .31 - 2.62 km^2). Fitch et al. (1946) reported territory sizes ranging from .32 - .81 km^2 in California; Craighead and Craighead (1956) reported territory sizes of 3.76 ± .54 km^2 in Michigan and 1.89 ± .28 m^2 in Wyoming. Johnson (1971) reported sizes of 2.6-4.6 km^2 in Montana, and in Utah, an average territory size of 6.5 km^2 was reported (Smith and Murphy 1973). Territories on the Island tend to be smaller than those reported from the Midwest, and generally comparable with those from California. However, territories on the Island have a much wider range than those reported from California. This range undoubtedly reflects the highly heterogeneous habitat composition of the Island. As found by Luttich (1970) red-tails may have found prey more abundant or vulnerable in wet-land habitats where they captured 26% more prey items. As a general observation, the smaller territories on the Island appeared to have a higher proportion of their areas as wetlands.

Two other modifying factors of red-tail nesting territories should be mentioned. First, there is probably a lower limit of territory size tolerated by Red-tailed Hawks. Both this study and that of Fitch et al. (1946) arrived at a minimum territory size of about .31 km^2. Fitch et al. (1946) reported numerous aggressive encounters between red-tails. The lack of aggressive encounters on

Sauvie Island is probably due to the extreme heterogeniety of the habitat. In both cases food did not appear to be limiting even in the smallest territory. Therefore, it can be assumed that given an infinitely suitable habitat, red-tails would space themselves into .31 km^2 territories and this limit would be maintained by behavioral factors. Secondly, while food is essential, Red-tailed Hawks sometimes seem to value other proximate environmental factors more highly. On the Island, red-tails generally nest in the tallest trees within 50 m of a water course or body of water. Other areas of the Island which do not have the tallest trees and consequently have no nesting red-tails can still have high *Microtus* densities (16.5/100 m^2). Trees in the region of this transect were 9 to 13 m tall, and red-tails in the Northern Alberta taiga-tundra ecotone eagerly sought out trees of this height for nesting (Schmutz et al. 1980). Therefore, proximate factors other than prey density appear to exert a powerful influence over habitat selection in Red-tailed Hawks.

Territoriality

Territories, according to Fretwell (1972) can be classified as ideal-free, in which each individual goes to the habitat of highest suitability; ideal-despotic, in which residents of a habitat, by their territorial behavior, lower the success of unsettled individuals attempting to enter the habitat and individuals no longer necessarily go the habitat of highest suitability; or as serving only to space individuals within a habitat without regard to suitability. If red-tails have an ideal-free distribution of nesting territories, then their nesting success rates should be equal across habitats of different red-tail densities. If the red-tail population has an ideal-despotic distribution, the success rate in an area of high density would be greater than that in an area of low density. If the distribution is not consistently ideal-free or ideal-despotic, then the function of territorial behavior would be only to space individuals. Success rate, or suitability, can be measured in terms of clutch size. Clutch size has been related to the available food supply of a habitat (Greenlaw 1978). Red-tailed Hawk clutch sizes as reported from Michigan, Wyoming, Kansas, Minnesota, and Saskatchewan were not significantly different from each other (Smith and Murphy 1972). However, clutch sizes from Smith and Murphy's (1973) study (2.87 ± .13) were found to be significantly larger than those listed above using a paired t-test. Smith and Murphy (1973) also reported the largest territory sizes of any of the regions listed. Therefore, the ideal-despotic model of red-tail territories may be eliminated. However, it is difficult to tell whether the ideal-free or the spacing mechanism gives the best fit to the available information. Most, but not all, habitats appear to be equally suitable. The increased suitability of the low density habitats is especially interesting in light of the fact that raptor populations are thought to be declining in that study area (Smith and Murphy 1973).

In order to differentiate between the ideal-free and the spacing hypothesis of Red-tailed Hawk territories, it is necessary to collect data which may indicate relationships between territory size and suitability using other criteria. Since clutch size has been related to the food supply of a habitat (Greenlaw 1978), food resource abundance is the logical choice. In this study, territory size is inversely correlated with prey density. If red-tail territoriality merely spaces individuals, then territory size should not be correlated with indices of suitability. Therefore, it appears that the territorial behavior of red-tails is of the ideal-free type, in which territoriality serves as a density assessment mechanism. This result could be expected if only those resources which are necessary for successful reproduction are defended (the adequate resource hypothesis) or the cost of defense per unit area increases in areas of high prey density and territories are larger than required for a barely adequate food supply (the super-territory hypothesis) (Verner 1977). On Sauvie Island there is a very low rate of aggressiveness between pairs. Most of the aggressive interactions seen were between residents and migrants. However, not enough data was collected to differentiate between these two types of ideal-free territoriality on Sauvie Island.

SUMMARY

1. Sauvie Island is an important wintering area for Red-tailed Hawks in western Oregon. Light phase individuals comprised 83% of the Red-tailed Hawks sighted on the Island.

2. Fifteen active Red-tailed Hawk nests, averaging 15 m in height, were located on the Island. A technique for estimating the number of active nests from aerial and ground surveys was examined.

3. Perch heights were normally distributed with a mean of 14.2 m and a standard deviation of 4.2 m. Perch height increased from fall to winter and from winter to spring. This was probably related to the onset of territorial behavior and the onset egg - laying and incubation, respectively.

4. Red-tailed Hawks on the Island flew more in sunny rather than cloudy weather. This enabled the hawks to fly more between perches in sunny weather and probably increased their hunting efficiency over what it was in cloudy weather.

5. Two winter home ranges were measured as 1.01 km^2 and 1.32 km^2, respectively. Winter home ranges were observed to overlap. Thirteen non-overlapping nesting territories were delimited. They ranged in size from .31 km^2 to 2.62 km^2. Egg-laying and the onset of incubation began on 24 March and extended to 7 April 1982.

Some Red-tailed Hawk young on the Island stayed in the parental territory until mid-October 1981. One young hawk was observed to return to the parental territory briefly in late winter 1982.

6. The diet of Red-tailed Hawks on the Island consisted mainly of voles (*Microtus spp.*). Vole population densities were inversely correlated with nesting territory size. Ducks were an important food source, and sometimes the major item in terms of biomass, from late fall until early spring. Large numbers of insects were consumed during the warmer months of the year. Red-tailed Hawks on the Island were not observed to scavange carcasses.

7. Comparisons were made with other North American Red-tailed Hawk populations which have been reported in the literature. The distribution of tall nesting trees near water was found to be a major proximate factor governing habitat selection. The Red-tailed Hawks on the Island appeared to exhibit an ideal-free type of territoriality; whether these territories were just large enough to secure adequate food for the nesting pair or were larger than needed could not be determined.

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APPENDIX A

Ducks on Sauvie Island*

Common Name	Scientific Name
Mallard	*Anas platyrhynchos*
Gadwall	*Anas strepera*
Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Blue-winged Teal	*Anas discors*
Cinnamon Teal	*Anas cyanoptera*
European Widgeon	*Anas penelope*
American Widgeon	*Anas americana*
Northern Shoveler	*Anas clypeata*
Wood Duck	*Aix sponsa*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Canvasback	*Aythya valisineria*
Greater Scaup	*Aythya marila*
Lesser Scaup	*Aythya affinis*
Common Goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
Oldsquaw	*Clangula hyemalis*
White-winged Scoter	*Melanitta deglandi*
Surf Scoter	*Melanitta perspicillata*
Black Scoter	*Melanitta nigra*
Ruddy Duck	*Oxyura jamaicensis*
Hooded Merganser	*Lophodytes cacullatus*
Common Merganser	*Mergus merganser*
Red-breasted Merganser	*Mergus serrator*

* Common Name From: Wildlife of Sauvie Island Wildlife Area. Oregon Department of Fish and Wildlife, Portland.

Scientific Name From: Udvardy, 1977.

APPENDIX B

Mammals on Sauvie Island*

Common Name	Scientific Name
Opossum	*Didelphis marsupialis*
Vagrant Shrew	*Sorex vagrans*
Trowbridge's Shrew	*Sorex trowbridgii*
Shrew-mole	*Neurotrichus gibbsii*
Townsends' Mole	*Scapanus townsendii*
Coast mole	*Scapanus orarius*
Little Brown Bat	*Myotis lucifugos*
Big Brown Bat	*Eptesicus fuscus*
Brush Rabbit	*Sylvilagus bachmani*
Eastern Cottontail	*Sylvilagus floridanus*
Townsends' Chipmunk	*Eutamias townsendii*
Northern Flying Squirrel	*Glaucomys sabrinus*
Beaver	*Castor canadensis*
Nutria	*Myocastor coypu*
Muskrat	*Ondatra zibethica*
Camas Pocket Gopher	*Thomomys bulbivorus*
Dusky-footed Woodrat	*Neotoma fuscipes*
Bushy-tailed Woodrat	*Neotoma cineria*
Deer Mouse	*Peromyscus maniculatus*
Creeping Vole	*Microtus oregoni*
Townsends' Vole	*Microtus townsendii*
Gray-tailed Vole	*Microtus canicaudus*
House Mouse	*Mus musculus*
Norway Rat	*Rattus rattus*
Red Fox	*Vulpes fulva*
Coyote	*Canis latrans*
Racoon	*Procyon lotor*
Striped Skunk	*Mephitis mephitis*
Mink	*Mustela vison*
Long-tailed Weasel	*Mustela frenata*
River Otter	*Lutra canadensis*
Black-tailed Deer	*Odocoileus hemionus*

* Common Name From: Wildlife of Sauvie Island Wildlife Area. Oregon Department of Fish and Wildlife, Portland.

Scientific Name From: Ingles, 1965.

APPENDIX C

Amphibians and Reptiles on Sauvie Island*

Common Name	Scientific Name
Northwestern Salamander	*Ambystoma gracile*
Ensatina Salamander	*Ensatina eschscholtzi*
Western Toad	*Bufo boreas*
Pacific Treefrog	*Hyla regilla*
Bullfrog	*Rana catesbeiana*
Red-legged Frog	*Rana aurora*
Painted Turtle	*Chrysemys picta*
Western Fence Lizard	*Sceloporus occidentalis*
Northwestern Garter Snake	*Thamnophis ordinoides*
Common Garter Snake	*Thamnophis sirtalis*
Rubber Boa	*Charina bottae*
Rough-skinned Newt	*Taricha granulosa*
Long-toed Salamander	*Ambystoma macrodactylum*

* Common Name from: Wildlife on Sauvie Island Wildlife Area. Oregon Department of Fish and Wildlife, Portland.

Scientific Name From: Behler and King, 1979.