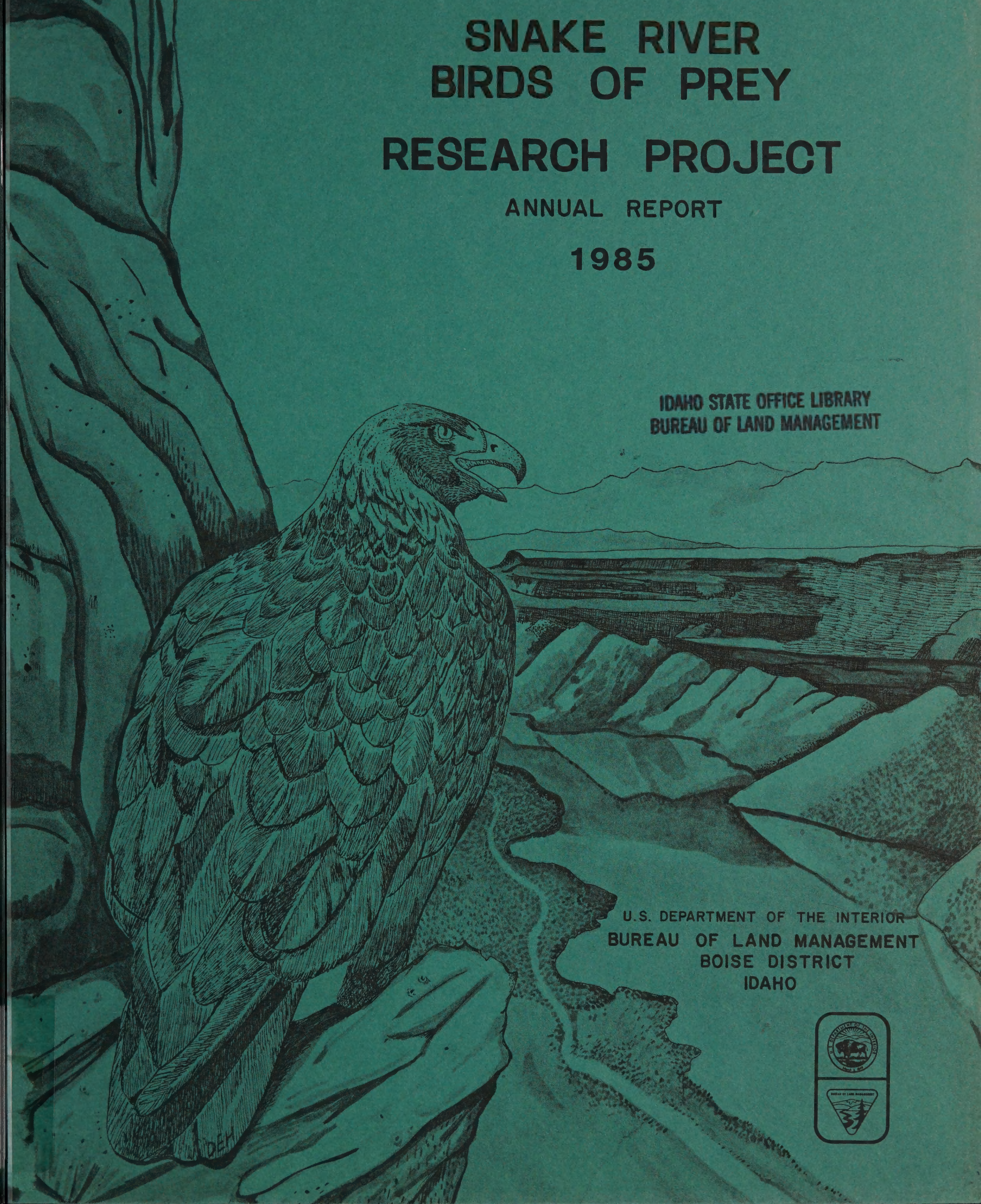
SNAKE RIVER BIRDS OF PREY

RESEARCH PROJECT

ANNUAL REPORT

1985



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
BOISE DISTRICT
IDAHO

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SNAKE RIVER BIRDS OF PREY RESEARCH PROJECT

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1985

Karen Steenhof and Michael N. Kochert
Editors

NOT FOR PUBLICATION

The data presented herein are preliminary and may be inconclusive. Permission to publish or cite any of these materials is therefore withheld pending specific authorization of the Boise District, BLM, and the specific Principal Investigator.

Michael N. Kochert
Research Leader

Martin J. Zimmer
Boise District Manager

Delmar Vail
Idaho State Director

PREFACE

This report summarizes research and monitoring activities in the Snake River Birds of Prey Area during calendar year 1985. As recommended by the 1982 Birds of Prey Review Committee, most work was directed towards technology transfer; however, significant effort was dedicated to initiating new cooperative research. The Committee recommended that outside funding be obtained to support continued and future research. In 1984 the BLM entered into cooperative agreements with Idaho Power Company and Pacific Power and Light Company to conduct cooperative research efforts. Two cooperative studies with Pacific Power and Light Company and 1 with Idaho Power Company were continued this year. In addition, 7 scientific articles were published and/or accepted for publication in 1985, and Birds of Prey staff members made numerous technical presentations at meetings.

Basic monitoring of the vegetation and certain prey and raptors continued in 1985. A draft long-term monitoring plan for the Birds of Prey Area was completed in spring of 1985. Monitoring work was conducted by the research staff and Bruneau Resource Area personnel.

Other 1985 field activities included continuing investigations of common barn-owl feeding ecology by Dr. Carl Marti, the association of mycorrhizae with desert shrubs by Dr. Marcia Wicklow-Howard, and nest box use, reproduction and food habits of western screech-owls John Doremus and Jeff Marks. Also a study of nest box use by American kestrels was initated this year.

The results of the 1985 field season of these studies are presented in this report.

ACKNOWLEDGMENTS

The Bureau of Land Management wishes to thank those agencies and individuals who assisted with the project. Appreciation is extended to the Idaho Department of Fish and Game and the U.S. Fish and Wildlife Service for special permits and assistance. Special thanks go to all other individuals who volunteered their services.

Special appreciation is extended to Mr. E. T. Evans for providing the area for the Melba field camp and other assistance. Terri Thomason deserves special thanks for typing the manuscripts.

COOPERATING AGENCIES AND INSTITUTIONS

Boise State University
Idaho Department of Fish and Game
Idaho Power Company
Pacific Gas & Electric Company
Pacific Power and Light Company
Shoshone District, Bureau of Land Management
University of Idaho
University of Wisconsin
U.S. Fish and Wildlife Service
U.S. Forest Service
Vale District, Bureau of Land Management
Virginia Polytechnic Institute
Weber State College
World Center for Birds of Prey

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PART I

TECHNOLOGY TRANSFER

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*Reprints of most of these articles are available from the Birds of Prey Research Project, Boise District, BLM, 3948 Development Avenue, Boise, ID 83705.

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2/6/85	Holthuijzen, A.M.A., A.R. Ansell, M.N. Kochert, J.C. Smith, K. Steenhof, and L.S. Young. The effects of industrial construction activities on breeding prairie falcons (Falco mexicanus) in southwestern Idaho. Symposium on Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecological Institute, Colorado Springs, Colorado
2/11/85	Pellant, M. Fire effects on salt desert shrub communities in southwestern Idaho. Annual Meeting, Society for Range Management. Salt Lake City, Utah.
2/19/85	Steenhof, K. Assessing trends in numbers of wintering bald eagles from count routes. Greater Yellowstone Bald Eagle Working Group. Idaho Falls, Idaho.
2/28/85	Roppe, J.A., M.N. Kochert, and K. Steenhof. Utilization of transmission lines by raptors and ravens. Oregon State Chapter of the Wildlife Society. Annual Meeting. Newport, Oregon.
3/5/85	Young, L.S. Movements of bald eagles associated with autumn concentrations in Glacier National Park. Idaho BLM Wildlife Workshop, Boise, Idaho.
3/5/85	Kochert, M.N. Raptor monitoring techniques. Idaho BLM Wildlife Workshop, Boise, Idaho.
3/5/85	Steenhof, K. 5-year trends in Idaho midwinter bald eagle counts. Idaho BLM Wildlife Workshop, Boise, Idaho.
3/5/85	Holthuijzen, A.M.A. The effect of human disturbance on the behavior of raptors: a preliminary review. Idaho BLM Wildlife Workshop, Boise, Idaho.
3/9/85	Kochert, M.N., and K. Steenhof. Utilization of a transmission line by nesting raptors and ravens in Idaho and Oregon. Idaho Chapter, The Wildlife Society. Boise, Idaho.
3/9/85	Holthuijzen, A.M.A., and A. R. Ansell. The effects of industrial construction activities on a breeding population of prairie falcons in southwest Idaho. Idaho Chapter, The Wildlife Society. Boise, Idaho.
3/9/85	Engel, K., L.S. Young, D. Aleshire, and K. Steenhof. Communal roosting of common ravens in southwest Idaho. Idaho Chapter, The Wildlife Society. Boise, Idaho.

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PART II

PROGRESS REPORTS

TITLE: Nesting and Productivity of Golden Eagles and Ferruginous Hawks and Movements of Raptors and Ravens in the Snake River Birds of Prey Area and Comparison Area.

INVESTIGATORS: Michael N. Kochert, Research Leader
Karen Steenhof, Associate Research Leader
John H. Doremus, Wildlife Biologist, Bruneau Resource Area

OBJECTIVES:

1. To determine occupancy, nesting success, and productivity at traditional golden eagle (Aquila chrysaetos) and ferruginous hawk (Buteo regalis) nesting territories.

2. To compare occupancy and productivity of golden eagle pairs in the Birds of Prey Area (BOPA) with those of eagle pairs in the Comparison Area.

3. To continue to record movments of banded and wing-marked raptors and ravens.

ANNUAL SUMMARY

Golden eagle productivity in the BOPA was the lowest ever recorded and was significantly lower than in the Comparison Area. More ferruginous hawks nested in the BOPA than in previous years, and their productivity (young fledged/pair) was similar to that in previous years. Ferruginous hawks nesting on artificial nesting structures were more productive than those nesting on natural substrates.

METHODS

Golden eagle territories in the BOPA and Comparison Area (Fig. 1) were surveyed from a Hiller/Soloy jet helicopter on 20 March and 14 June. Territories where breeding status could not be determined during the March helicopter flight were subsequently surveyed from the ground for signs of occupancy or breeding (see below for criteria). All known traditional ferruginous hawk territories in the BOPA outside the National Guard Training Area were searched on foot in April and May. Territories containing breeding pairs were revisited in June or July on foot or from a Hiller/Soloy jet helicopter to confirm fledging success. Potential ferruginous hawk nesting areas were also searched in conjunction with the walking surveys of traditional territories.

We attempted to ascertain the breeding status and nesting success of all pairs located prior to hatching. Additional information on reproduction was obtained from other pairs found later in the season. Pairs that showed no evidence of egg laying after repeated observations were categorized as "nonbreeding". A "breeding attempt" was confirmed if an occupied territory contained an incubating adult, eggs, young, or any other indication that eggs were laid (e.g., fresh eggshell fragments in fresh nesting material). A "successful nesting attempt" was a breeding attempt that produced 1 or

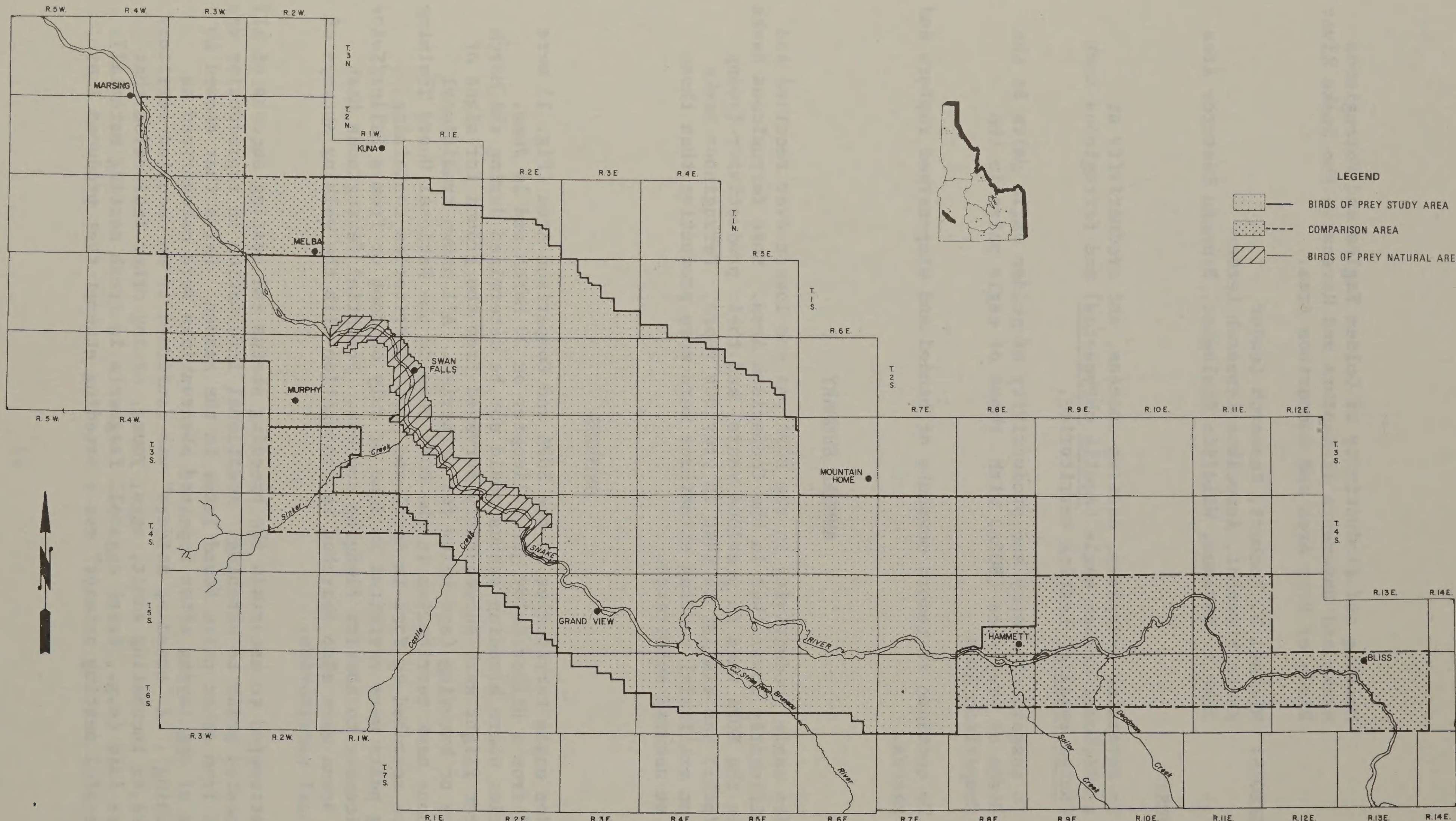

Fig. 1. LOCATION OF THE BIRDS OF PREY STUDY AREA (BPSA) AND COMPARISON AREA

more young that reached fledging age. Young were considered fledged if they reached 51 days for golden eagles and 33 days for ferruginous hawks (Steenhof 1986). Eagle nests discovered after young had fledged were considered successful if: 1) a platform decorated this season was worn flat and contained fresh prey remains, 2) fresh fecal matter covered the back and extended over the edge of the nest, and 3) no dead young birds were found within a 50-m radius of the nest.

Nesting Density

Golden Eagles

In 1985 golden eagle pairs occupied 32 (86%) of the 37 traditional eagle nesting territories in the BOPA. This includes the new eagle nesting territory that was established on the Pacific Power and Light (PP&L) transmission line in 1983; the remaining territories were associated with cliffs. This is an increase in occupancy of 1 territory from 1984 and 5 from 1983, the year of lowest eagle density in the BOPA. As seen in previous years some of the territories may have become permanently unsuitable for nesting. All 5 vacant territories had not been occupied since 1982, and 4 have been vacant for the past 6 years. One of these, "Bruneau Flats," has not been occupied since 1976. The territory newly reoccupied in 1985 (Swan Dam) was last occupied in 1979. Occupancy in the Comparison Area was similar to the BOPA with 23 of 26 traditional territories (88%) being occupied.

Ferruginous Hawks

More ferruginous hawks occupied nesting territories within the BOPA than in any previous year. A total of 31 occupied nesting territories was found, including 18 associated with natural substrates (cliff and ground), 5 with Idaho Power Company (IPC) 138 kV transmission poles, 4 with artificial nesting platforms (Howard and Hilliard 1980), and 3 with the PP&L 500 kV transmission line (See PP&L Nesting Study of this report). This occupancy rate far surpasses the next best year when 19 territories were occupied in 1977. Of the 41 territories known before 1985, 17 (41.5%) were vacant in 1985; however, 7 new territories were also occupied in 1985. Two of these new territories were associated with cliffs, and the remainder were on power line structures which have been in operation for more than 15 years.

Reproduction

Golden Eagle

Golden eagle reproduction in 1985 was the worst ever recorded in the BOPA. Of eagle pairs occupying territories, only 38% laid eggs, and only 16% successfully raised young (Table 1). Eagles fledged an average of only 0.16 young per pair. This is much lower than the next worst year (1973) when only 67% of the pairs laid eggs, and 30% of the pairs successfully raised young that fledged for an average of 0.43 young per pair.

Reproduction of golden eagles was higher in the Comparison Area than in the BOPA in 1985. Of pairs occupying territories in the Comparison Area, 65% laid eggs and 45% successfully fledged young, for an average of 0.61

Table 1. Nesting success and productivity of golden eagles and ferruginous hawks in the BOPA and Comparison Area, 1985. Sample sizes are in parentheses.

Species	% of Pairs Breeding	% of Attempts Successful	% of Pairs Successful	Number of Young/ Successful Attempt	Number of Young Fledged/ Pair
Golden Eagle BOPA	38 (32)	42 (12)	16 (32)	1.00 (4)	0.16
Golden Eagle Comparison Area	65 (20)	77 (10)	45 (22)	1.44 (9)	0.61
Ferruginous Hawk BOPA*	95 (20)	56 (25)	45 (31)	2.67 (14)	1.42

* Includes 3 pairs on the PP&L power line with the BOPA.

young produced per pair. This fledging rate is nearly 4 times greater than that in the BOPA.

Ferruginous Hawk

Of 20 preselected pairs, 19 (95%) attempted to breed, and of 31 hawk pairs occupying territories in the BOPA, 45% successfully fledged young for an average of 1.42 young per pair (Table 1) . Only 56% of the attempts were successful, averaging 2.28 young fledged per successful attempt (Table 1).

Productivity of ferruginous hawks varied with nesting substrate. On natural substrates (e.g., cliff and ground), only 8 of 17 breeding pairs were successful, producing an average of 1.25 young/attempt. Three of the 9 failures were attributed to unknown hatching failure, 1 to predation, and 5 to unknown causes. Six pairs built nests on the IPC 138 kV wooden transmission poles, and 4 of these contained confirmed nesting attempts. Only 2 of these 4 attempts were successful, producing a total of only 4 young or an average of 1.00 young/attempt. This low productivity was attributed to weather and unstable substrate. These nests were in the wood cross arms of the "H" design poles, and 4 of the 6 were blown out by wind. Six ferruginous hawk pairs nesting on the PP&L steel transmission towers produced an average of 2.01 young/attempt (see PP&L Nesting Study in this report). In addition to pairs on the IPC and PP&L power lines, 4 ferruginous hawk pairs occupied territories with artificial platforms. Two of these 4 pairs laid eggs, and both successfully fledged an average of 3 young/attempt. Productivity (average number of young fledged per attempt) for 3 breeding attempts on artificial platforms outside the BOPA was the same as that within the BOPA.

Banding and Marking

During 1985, 91 raptors and ravens were banded with aluminum U.S. Fish and Wildlife Service bands. This includes 3 golden eagles, 10 ferruginous hawks, 4 American kestrels (*Falco sparverius*), 31 western screech-owls (*Otus kennicottii*), and 43 common ravens (*Corvus corax*). The eagles were banded for a local rehabilatator at the request of the U.S. Fish and Wildlife Service Special Agent and were subsequently released. All of the ferruginous hawks and kestrels were banded as nestlings, and 30 of the screech owls were banded as part of the screch-owl study (Screech Owl Study in this report). The remaining owl was a rehabilitated bird which was banded and released. Of the ravens, 12 adult and subadult birds received backpack radio transmitters and wing markers. The remaining 31 were nestlings, 7 of which received transmitters and wing markers.

Band Recoveries and Sightings of Marked Birds

We received band recoveries on 2 golden eagles, 1 red-tailed hawk, 2 ravens, and 49 western screech-owls. All screech-owl recoveries were owls captured at nest boxes, and most were recaptures (see Screech Owl Study in this report). The eagles were 3.9 and 4.6 years old and were found electrocuted in southern Idaho within 100 km of their marking locations. The 3.9 year old eagle was found in April within the Waterfall golden eagle nesting territory in the BOPA. The red-tailed hawk was 2.8 years old when it was found injured in January near Mesa, New Mexico. The 2 ravens were

0.8 and 1.2 years old, respectively, and were recovered within 20 km of their natal nests.

In 1985, 87 sightings of marked birds were recorded. Three sightings were of a red-tailed hawk that was trapped and wing-marked as an adult in 1975 and has been seen on the same territory (Priest) for 11 consecutive nesting seasons. A golden eagle, sighted wearing a backpack radio package, has been on the same territory (Indian Cove) since 1975 when it first arrived as a breeding bird. Another eagle marked in 1980 was observed on the Bobcat territory with an unmarked adult mate for the first time in 1985. Also a wing-marked adult eagle was sighted near Wendover, Nevada in October. The remaining 80 sightings were of adult, subadult, and post-fledged ravens in the BOPA.

ACKNOWLEDGMENTS

Pacific Power and Light Company is acknowledged for providing flight time to conduct the eagle helicopter surveys.

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TITLE: Raptor and Raven Nesting on the PP&L Malin to Midpoint 500 kV Transmission Line.

INVESTIGATORS: Karen Steenhof, Assoc. Leader, BLM Birds of Prey Research
Michael N. Kochert, Leader, BLM Birds of Prey Research
Jerry Roppe, Wildlife Biologist, Pacific Power & Light Co.
Mike Mulrooney, Line Patrolman, Pacific Power & Light Co.
Judy Putera, Prey Technician, BLM Birds of Prey Research
Deana Ramirez, Data Transcriber, BLM Birds of Prey Research

COOPERATOR: Pacific Power and Light Company

OBJECTIVES:

1. To identify all occupied raptor and raven nests on the first 371 miles of the PP&L Malin to Midpoint 500 kV transmission line.

2. To ascertain nesting success and productivity of raptors and ravens nesting on the first 133 miles of the line.

3. To ascertain nesting success and productivity of golden eagles and ferruginous hawks nesting on natural substrate near the intensively studied portion of the line for comparative purposes.

4. To identify preferred nesting locations on the towers and to document how these locations relate to nesting success and possible contamination.

5. To assess physiographic features that may influence use of towers by nesting raptors and ravens.

6. To determine if nesting densities on the line are related to estimated prey densities along the power line corridor.

INTRODUCTION

Electrical power lines have affected raptors both adversely and beneficially (Olendorff et al. 1980, 1981; Nelson 1982). One of the principal benefits of power transmission lines is that they provide nesting substrate for birds of prey (Gilmer and Wiehe 1977; Stahlecker 1979; Lee 1980; Nelson 1982; Kochert et al. 1984). Utilization of transmission lines by nesting raptors and corvids is common, especially in western North America and also in other parts of the world (R. Metcalf, J. Ledger, pers. commun.). The use of power lines by large birds has raised the following questions: 1) Does nesting interfere with power transmission? 2) Can raptor nesting density and success be enhanced by the presence of transmission lines? and 3) What types of tower designs and modifications can minimize interference with transmission and at the same time increase raptor nesting density and success?

The construction of a 500 kV transmission line across southern Idaho and Oregon in 1980-81 provided government and industry biologists with an opportunity to investigate these questions. The Pacific Power & Light

Company (PP&L), in cooperation with the Bureau of Land Management (BLM), agreed to construct 37 artificial nesting platforms (Nelson and Nelson 1976) along its 500 kV transmission line between Midpoint (Jerome), Idaho and Malin, Oregon (Fig. 1). Pacific Power & Light representatives, interested individuals, and BLM Birds of Prey Research biologists have surveyed the line since 1981. This report presents findings of the 1985 survey.

METHODS

Surveys were conducted in 3 study areas in 1985. The "intensive survey area" consisted of Miles 0-133 of the transmission line, and the "extensive survey area" consisted of Miles 134-371 (Fig. 1). To compare nesting success and productivity, golden eagles and ferruginous hawks were surveyed in a third "canyon study area" extending along the Snake River and its major tributaries from Glenns Ferry to Mile 135.

The entire line was surveyed from an Agusta helicopter on 8 and 9 April to locate incubating pairs. Follow-up surveys of the intensive study area were conducted from a Hiller/Soloy helicopter on 6 May, 24 May, and 14 June. The extensive area was re-surveyed on 20 May from a Bell 206 helicopter. Forty traditional golden eagle nesting territories in the Snake River Canyon were checked from a Hiller-Soloy on 20 March, and some were re-checked on 6 May. All other occupied eagle and ferruginous hawk nesting territories in the canyon were re-checked for productivity during the 14 June helicopter survey. Two additional canyon nests were checked during the survey of the line. During all surveys helicopters were flown at speeds of 70-95 km/hr; we usually hovered approximately 20 m from nests for 5-25 sec to view nest contents. Some nests were photographed from the helicopter, and some were subsequently observed from the ground.

Pairs were considered "breeding" if they laid at least 1 egg; this was confirmed by observing eggs, young, or an incubating adult. Because aerial surveys covered only the power line structures, some nonbreeding pairs could have been missed. We considered a breeding attempt successful if 1 or more young reached 80% of the average age when most young normally leave the nest. Nestlings were aged by comparison with photographs of known-age chicks (Moritsch 1983, 1985; BLM, unpubl. data).

We assessed topographic characteristics, cultural features, and land use from topographic maps, aerial photos, and PP&L plan and profile maps of the intensive survey area. For each nest where a breeding attempt occurred in 1985 and for 73 randomly selected towers that were not used for nesting, we calculated the amount of shrub, grass, and agricultural land within a 1 km radius of each nest and each randomly selected tower. We also assessed the presence and amount of roads, cliffs, buildings, and smaller power lines in the same radius, and we calculated the distance from the tower to the nearest road. The maintenance road following the transmission line was excluded from the analysis.

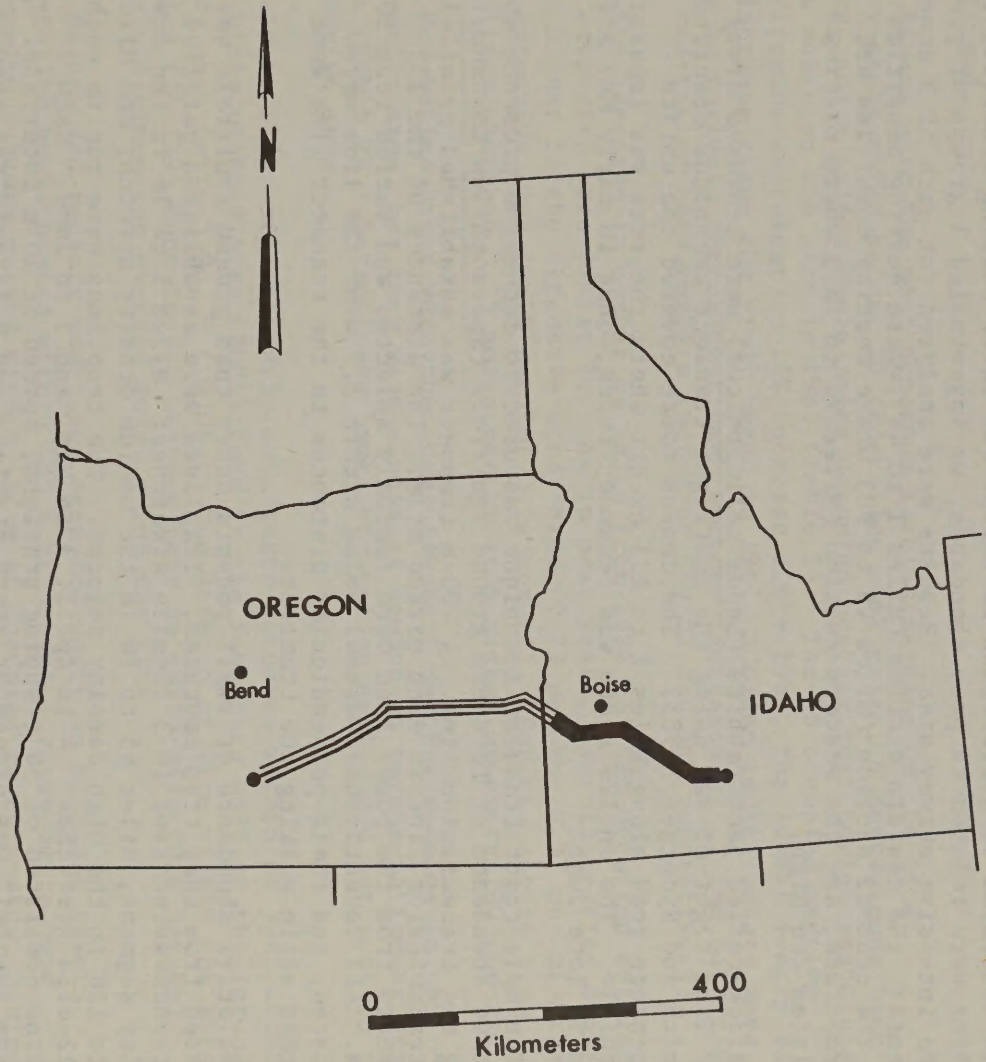

Fig. 1. Location of the Pacific Power and Light 500 kV transmission line. Intensive survey stretch is shaded.

During our helicopter surveys, we described the topography within a 1-tower span radius of each nesting and randomly selected tower as either flat (plateau), rolling, canyon/cliff, or valley floor. We also classified land use within the same radius as "agricultural" if 50% or more of the area was farmed, "range" if less than 10% was farmed, and "mixed" if between 10 and 50% was farmed.

Nest heights and tower types were tabulated from PP&L plan and profile maps. Topographic variation around each tower was calculated as the difference in elevation between the lowest and highest points within the 1 km radius.

To determine if differences in raptor and raven nesting densities on the line were related to prey abundance, we inventoried 3 groups of prey in the intensive survey area. Results were analyzed for each of 3 equal segments: the eastern section (Miles 1 to 44) where nesting densities are low, the central section (Miles 45 to 90) where nesting densities are intermediate, and the western section (Miles 90 to 133) where nesting densities are high.

Black-tailed jack rabbits (*Lepus californicus*) were censused along the power line right-of-way using the spotlight transect technique described by Smith and Nydegger (1985). The census route covered the entire maintenance road along Miles 1 to 133 except where the road was impassable by vehicle. The entire route was censused twice, once in early May and again in late June.

The hole count transect technique was used to determine presence and relative abundance of Townsend ground squirrels (*Spermophilus townsendii*) along the transmission line. A 400-m transect was established parallel to the transmission line in each marked mile. The distances of the 133 transects from the power line were randomly selected and varied from 10 to 500 m. All recently used mammal holes within 2.5 m of the line were tabulated, and their perpendicular distances to the transect line were recorded while walking the transect.

Relative abundance of small rodents other than ground squirrels was assessed from snap trap captures. Traplines were established parallel to the transmission line in 3 12-mile stretches: Miles 5 to 16 in the low density segment, Miles 65 to 76 in the medium density stretch, and Miles 107 to 118 in the high density segment. Ten traplines were run in each of the 12-mile stretches: 4 in April, 3 in May, and 3 in June. Each trapline consisted of 50 trapping stations, spaced at 10 m intervals. A "museum special" was placed at every station, and a larger "rat trap" was placed at every other station. Traps were pre-baited for 3 days with a mixture of peanut butter and rolled oats. They were then re-baited, set, and checked for the next 3 consecutive days. All traplines were in rangeland habitat, and distances from the power line varied from 10-500 m.

The dominant vegetation was recorded for each trapline and transect. Vegetation was grouped into one of 6 types: big sagebrush (*Artemisia tridentata*), sage-rabbitbrush (*Chrysothamnus* spp.), cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), cheatgrass/crested wheatgrass, and medusahead rye (*Elymus caput-medusae*).

RESULTS

Nest Density and Distribution

At least 84 towers were used by 83 pairs of raptors and ravens for nesting in 1985. One pair of ravens (Mile 90) apparently renested in a different tower, 2 towers away from their first unsuccessful attempt. In addition to the 84 confirmed breeding attempts on the line, there were birds associated with 5 additional towers. Two nonbreeding eagle pairs were observed near towers in which eagles had nested during previous years (Miles 7 and 119). In the extensive area, ravens were observed near 2 towers and red-tailed hawks near 1 where breeding attempts could not be confirmed.

Ravens were the most numerous species nesting on the line. Fifty-eight raven pairs, 20 red-tailed hawk pairs, 6 ferruginous hawk pairs, and 4 golden eagle pairs occupied nesting territories associated with nests on the line in 1985 (Table 1). The 88 occupied nesting territories represent an 11% increase since 1984, the lowest yearly rate of increase since the study began in 1981. Golden eagle numbers were the same as in 1984, ferruginous hawk numbers decreased by 1, and both raven and red-tailed hawk numbers increased (by 5% and 54% respectively).

The increase in number of pairs from 1984 to 1985 occurred entirely in the extensive area (Table 2). As in past years, overall nesting densities were higher in the intensive study area (0.23 per km; 0.37 per mi) than in the extensive area (0.10 per km; 0.16 per mi). For the entire line, densities averaged 0.15 nests per km or 5 nests for every 100 towers.

Red-tailed hawks were the least abundant nesting species in the intensive area, but they were almost as common as ravens in the extensive area (Table 2). Ferruginous hawks and golden eagles did not nest in the extensive area.

As in 1983, significantly more nests occurred within or just north of the Birds of Prey Area (BOPA) than in the remaining half of the intensive study area ($\chi^2 = 3.96$, $\underline{P} < 0.05$). One stretch of line within the BOPA (Miles 114-119) contained a nesting pair in every mile (0.6 per km), nearly 6 times the average density for the line.

Ravens and raptors sometimes occupied nests on adjacent towers. Red-tailed hawks nested within 385 m of occupied raven nests, and ferruginous hawks nested within 157 m of occupied raven nests. Minimum distances between conspecific nesting pairs, however, always exceeded 1.3 km.

Nest Site Selection

Raptors and ravens nested in tower types A, B, C, E, and T. Within the intensive area, the frequency with which the tower types were used differed significantly from the frequency with which tower types were available ($\underline{G} = 6.11$; $\underline{P} < 0.001$). Although A towers (Fig. 2) were the most commonly used towers, they were by far the most common tower type

Table 1. Number of occupied raptor and raven nesting territories found on the PP&L Malin to Midpoint 500 kV transmission line, 1981-85.

Species	1981	1982	1983	1984	1985
Golden Eagle	1	2	5	4	4
Ferruginous Hawk	1	3	9	7	6
Red-tailed Hawk	0	2	2	13	20
Common Raven	1	9	39	55	58
TOTAL	3	16	55	79	88

Table 2. Number of occupied raptor and raven nesting territories found in the intensive and extensive study areas, 1984-85.

	Intensive		Extensive	
	1984	1985	1984	1985
Golden Eagle	4	4	0	0
Ferruginous Hawk	7	6	0	0
Red-tailed Hawk	4	2	9	18
Common Raven	37	38	18	20
	52	50	27	38

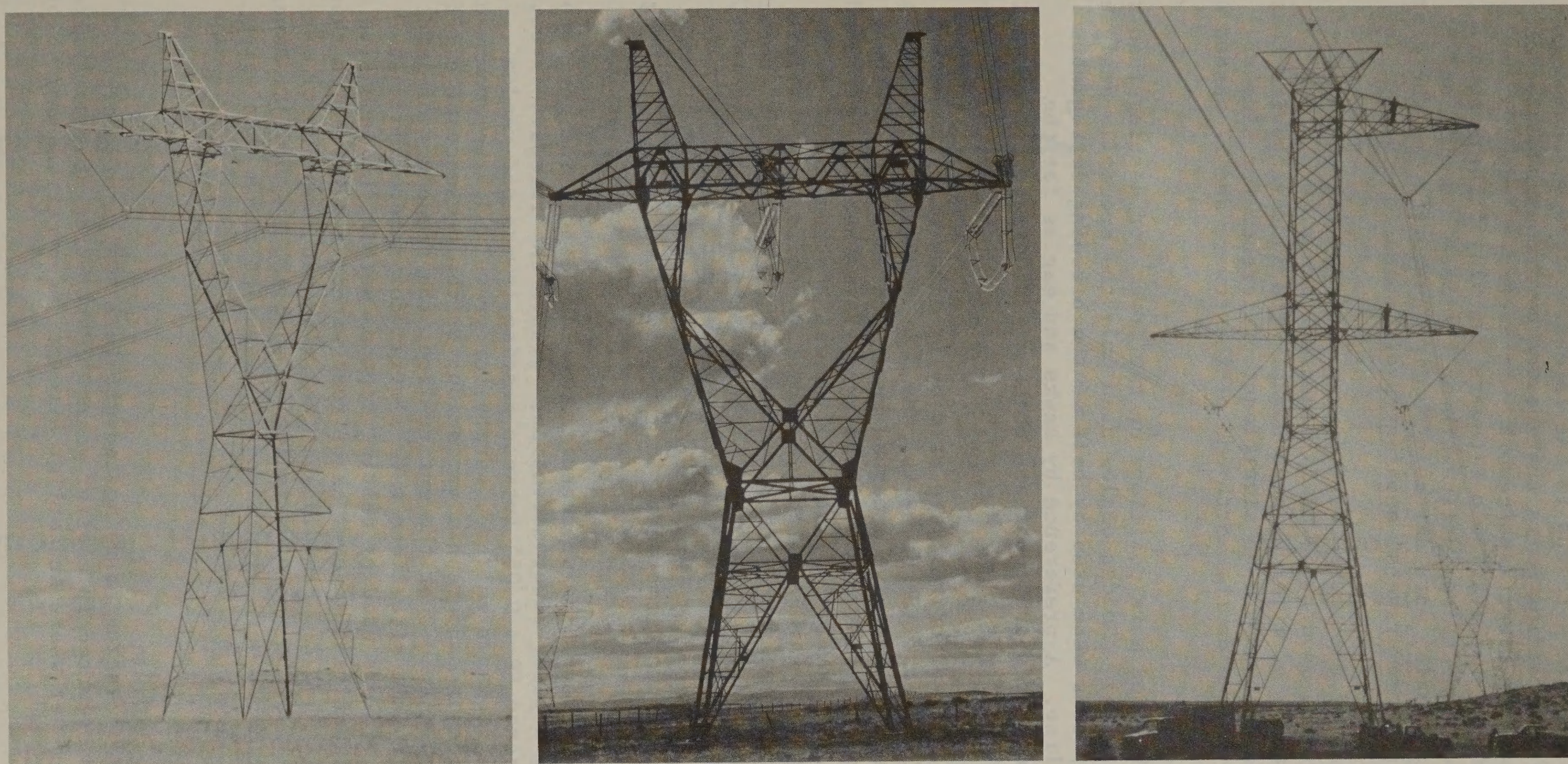

Fig. 2. Tower types used by raptors and ravens for nesting. The "E" (center) and "T" (right) towers were preferred over the more common "A" towers (left) apparently because of their sturdier and more extensive latticework.

available. Only 7% of the A towers in the intensive area were used in 1985, and 6 of the 33 breeding pairs that nested on A towers nested on platforms and not on the tower latticework. In contrast, raptors and ravens nested on 50% of the available T towers and 52% of the E towers, The sturdier and more extensive latticework on the less common T and E towers (Fig. 2) may provide more suitable nesting substrate and therefore account for the raptor and ravens' apparent preferences for them.

The "x" position of the tower (Fig. 3) was the most frequently used position on the towers, used by 53 of 54 breeding ravens, 6 of 19 red-tailed hawks, and 2 of 6 ferruginous hawks. The 53 raven pairs that nested in the x-position showed no significant preference for side of tower. Twenty-six nested on the north end of the tower, and 27 nested on the south side.

Red-tailed hawks used more positions on the tower for nesting than the other 3 species (Fig. 3). Golden eagles used only the specially designed platforms, and platforms were used by half of the breeding ferruginous hawk pairs on the line. A preference by hawks and eagles for the platforms is apparent when one considers that only 2% of the towers on the line contain platforms.

Ten of 37 available platforms were used by breeding raptors in 1985 (2 by golden eagles, 3 by ferruginous hawks, and 5 by red-tailed hawks). All 7 platforms used in the intensive area had been used in 1984. In the extensive area, red-tailed hawk pairs used a platform that had been used in 1983 but not in 1984 (Mile 282) and 2 platforms that had never been used previously. One of these (Mile 311) had been "baited" with sticks shortly after line construction; the other (Mile 292) was "baited" for the first time in January 1985. Five other platforms that were baited in January remained unused. Line patrolmen noted that many sticks disappeared shortly after they were placed in platforms by PP&L personnel. Additional platforms were "baited" and "re-baited" following the 1985 nesting season.

The habitat characteristics we measured provided little insight into factors influencing nesting tower selection. Within the intensive area, there was no difference ($\underline{P} < 0.05$) between nesting towers and random towers in the amounts of agriculture, shrubs, or grassland; the amount of habitat interspersion or topographic variation; or the presence of cliffs, buildings, or agriculture. Over the entire line, the frequency of land use types and topographic situations were similar for random and nest towers ($\underline{P} < 0.05$). Towers used by nesting raptors within the intensive area in 1985 had significantly fewer km of road within a 1 km radius than did random towers ($t = -2.27$, $\underline{P} = 0.03$). They also had fewer km of distribution power lines in the same radius ($t = -3.41$, $\underline{P} < 0.01$). Raven nests, on the other hand, were significantly closer to roads than were random towers ($t = -2.42$, $\underline{P} = 0.02$).

Nest Site Fidelity

In 1985, 65 of 88 nesting pairs nested within 2 towers of where a nesting attempt had occurred in earlier years. Forty-nine of these pairs nested on the same tower where an earlier attempt had occurred, and 46 of

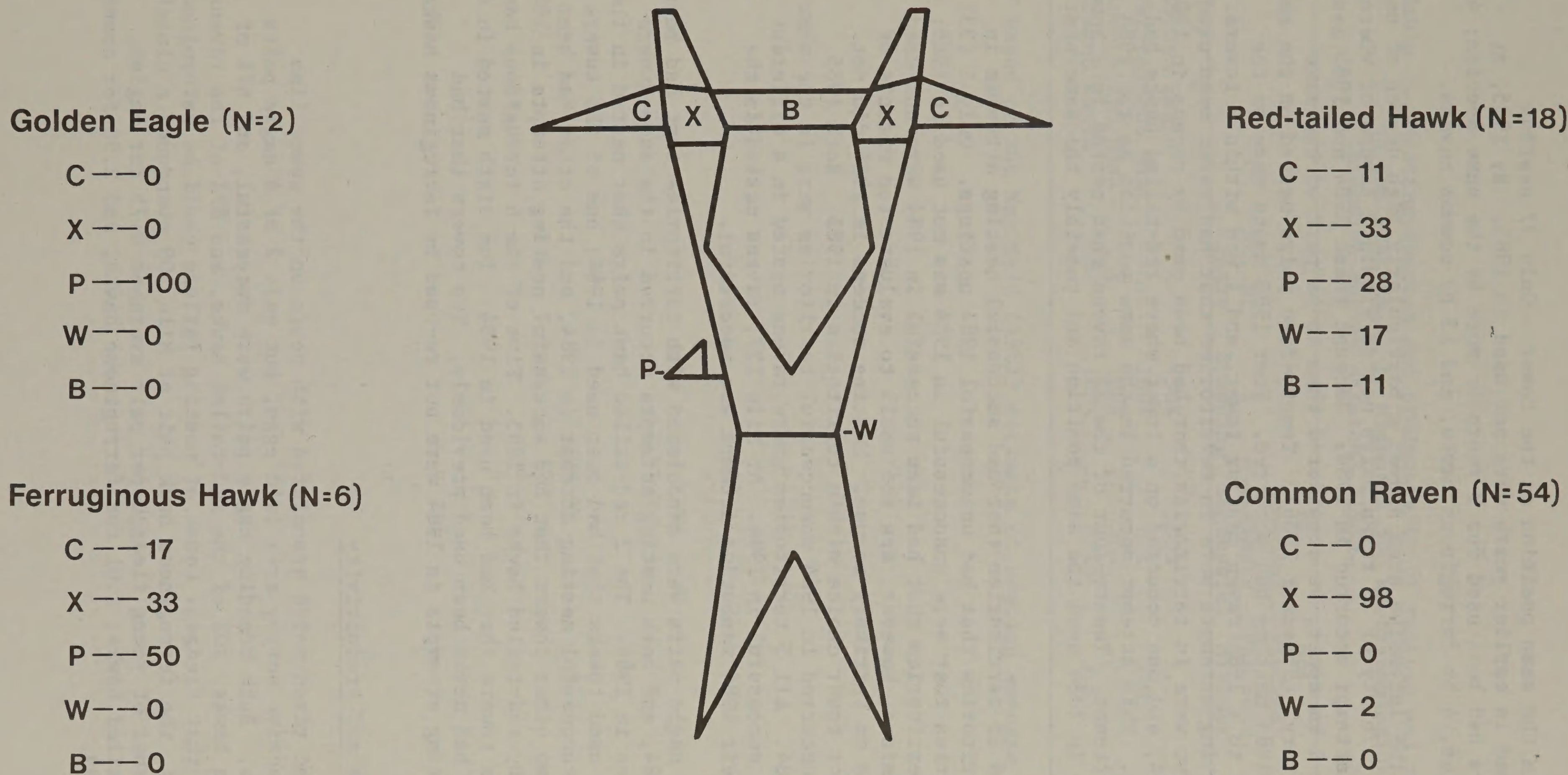

Fig. 3. Percent of raptor and raven breeding attemps in relation to tower position for the PP&L Malin to Midpoint 500kV transmission line, 1985. Sample sizes are shown in parentheses. Summaries do not include "T" towers.

these nested in the same position on the tower. Only 37 nesting territories used in earlier years were not used in 1985. By 1985, at least 21 towers had been used for 3 years or more by the same species; 4 towers by eagles, 4 by ferruginous hawks, and 13 by common ravens.

Ravens in the intensive area showed a particularly high degree of nest site fidelity. Thirty of 38 raven pairs nested within 2 towers of where a raven nesting attempt occurred in 1984. Because these 1984 and 1985 nests were less than 1 km apart, we considered them to be part of the same "nesting territory" (Steenhof 1986). Twenty-five pairs nested on the same tower where a 1984 nesting had occurred. Four 1985 nests were on the tower adjacent to a 1984 raven nesting tower, and 1 was within 2 towers. Five raven nesting attempts were in territories that had never been used previously. Two were in territories that had been used by ravens in 1983 but not in 1984, and one occurred on a tower where red-tailed hawks had nested in 1984. This attempt occurred in the same position as the 1984 hawk nesting attempt. Twenty-four of the 25 ravens that nested in a tower used by ravens in 1984 used the same position and possibly the same nest as in 1984.

Ravens used 25 territories that had successful nesting attempts in 1984 and 2 territories that had unsuccessful 1984 nestings. Only 1 (33%) of the territories that were unsuccessful in 1984 was not used in 1985; 6 (19%) of the territories that had been successful in 1984 were not used in 1985. Sample sizes, however, are too small to evaluate the effects of nesting success on territory re-use. Nesting success in 1984 did not appear to affect tower choice within territories in 1985. Both 1985 nestings that occurred in 1984 unsuccessful territories were in the same tower as in 1984. All 5 territories where ravens nested in a different tower had been successful in 1984. At Mile 127, ravens nested in the tower where their 1984 renesting attempt was successful.

All golden eagle pairs were associated with territories that had been occupied in 1984, and both nesting attempts occurred in the same towers and platforms as in 1984. The 2 red-tailed hawk pairs that nested in the intensive area used towers that had been used in 1984; one of the towers used had an unsuccessful nesting attempt in 1984, and the other had been successful. Two other towers that had successful nesting attempts in 1984 were not used by red-tailed hawks in 1985. Five of the 6 ferruginous hawk pairs nested in towers that had been used in 1984. The sixth nested in a territory that had never been used previously. Two towers that had successful nesting attempts in 1984 were not re-used by ferruginous hawks in 1985.

Nesting Success and Productivity

All hawk and raven pairs associated with nests on the power line within the intensive survey area laid eggs, but only 2 of 4 eagle pairs (50%) laid eggs. Both breeding eagle pairs were successful, and 67% of the ferruginous hawks, 50% of the red-tailed hawks, and 87% of the ravens produced young that fledged. Cause of nesting failure could be determined in only 1 case: the ferruginous hawk pair at Mile 109 abandoned a clutch of 4 eggs. Number of young fledged per pair averaged 0.75 for eagles, 1.50 for red-tailed hawks, 2.01 for ferruginous hawks, and 2.98 for common ravens (Table 3).

Table 3. Nesting success and productivity of raptors and ravens on the PP&L Malin to Midpoint 500 kV transmission line (intensive survey stretch), 1985.

	No. of Pairs	% Breeding	% of Breeding Attempts Successful	No. Fledged Per Succ. Attempt	No. Fledged Per Pair
Golden Eagle	4	50%	100%	1.5	0.75
Ferruginous Hawk	6	100%	67%	3.0	2.01
Red-tailed Hawk	2	100%	50%	3.0	1.50
Common Raven	38	100%	87%*	3.4	2.98

* based on the Mayfield (1961) estimate of nesting success

Reproductive rates of eagles nesting on the line were much higher than those of eagles nesting on nearby natural substrate. Fifty eagles nesting in the canyon adjacent to the power line fledged only 0.27 young per pair. Both percent breeding and percent of breeding attempts successful were higher on the line than on the cliffs (50% vs. 39% and 100% vs. 55% respectively). The 3 young produced by 4 eagle pairs on the line almost equalled the 5 young produced by 32 eagle pairs nesting in the BOPA.

Ferruginous hawk pairs nesting on the 500 kV line also produced more young per pair ($x = 2.01$) than pairs in the surrounding area ($x = 1.43$, $N = 25$). The difference was due mainly to higher success rates of pairs on the 500 kV line (67% vs. 56%). Data for pairs in the surrounding areas includes information on hawks nesting on other power lines and on artificial platforms described by Howard and Hilliard (1980). Pairs nesting on natural substrate in the surrounding area had even lower nesting success (44%, $N = 18$). Success rates of ferruginous hawk pairs nesting on other artificial structures (86%, $N = 7$) were higher than the PP&L nesters. Percent breeding and number fledged per successful attempt were similar for all 3 groups.

Prey Abundance

Jack rabbit densities for the entire power line right-of-way were estimated to be 0.09 per hectare. This density is slightly higher than that recorded along spotlight transects within the BOPA (0.02 per hectare; Doremus et al., this volume). Number of jack rabbits observed per km of survey route was highest in the high nesting density section (0.41 per km), but more rabbits were seen in the low nesting density stretch (0.34 per km) than in the medium density stretch (0.14 per km). Number of rabbits seen was too low to compute densities by segment.

The number of ground squirrel holes counted on transects corresponded more closely to the distribution of nesting raptors and ravens (Table 4). The number of ground squirrel holes was highest in the high nesting density segment, intermediate in the medium density segment, and lowest in the low density segment. Hole density of other prey species, however, did not correspond with raptor and raven density. Holes of kangaroo rats (*Dipodomys* spp.) and other small mice were most numerous in the low nesting density segment (Table 4). Badger hole density followed a pattern similar to that of ground squirrels, raptors, and ravens.

A total of 6,750 trap nights resulted in the capture of 547 small mammals during the 3-month trapping period (Table 5). Deer mice (*Peromyscus maniculatus*) were trapped most frequently, followed by Great Basin pocket mice (*Perognathus parvus*). Seven different species were captured. Capture rates were highest in the high nesting density section and lowest in the medium nesting density section.

Native habitats dominated by sagebrush had the highest capture rates and greatest species diversity. Crested wheatgrass seedings, cheatgrass, and medusahead rye habitats had low densities and species diversities.

Table 4. Number of mammal burrows counted along 3 segments of the PP&L Malin to Midpoint 500 kV transmission line, 1985.

	Western (High Density)	Central (Medium Density)	Eastern (Low Density)
Spermophilus townsendii	135	64	7
Dipodomys spp.	1	5	29
Taxidea taxus	57	10	1
Small mice	78	72	164
TOTAL	271	151	201

Table 5. Number of small mammals captured in high, medium, and low raptor and raven nesting density sections of the PP&L Malin to Midpoint 500 kV transmission line in southwestern Idaho, 1985.

Species	High Density	Medium Density	Low Density
Peromyscus maniculatus	271	73	129
Perognathus parvus	19	4	14
Spermophilus townsendii	3	10	0
Reithrodontomys megalotis	8	1	0
Tamias minimus	7	0	0
Mus musculus	2	2	3
Onychomys leucogaster	1	0	0
TOTAL	311	90	146

DISCUSSION

Earlier (Kochert et al. 1984), we presented 2 hypotheses to account for higher nesting densities on the Idaho portion of the line. The first was that habitat differences may be associated with differences in prey density and the quality of foraging habitat. The second was that in Idaho, the line is closer to established nesting populations that may be the source of birds using the line. Data from 1985 lend more support to the latter hypothesis than the first.

The similarity of habitat features at used and unused towers suggests that the quality of foraging habitat may not differ substantially along the line. Significant preferences for certain tower types suggests that characteristics of nesting substrate may be more critical than habitat characteristics in determining whether a particular tower will be used for nesting.

Raptors and ravens continued to concentrate in the vicinity of the BOPA, where raptors and ravens have nested at high densities in the canyon for several years (U.S. Dep. Int. 1979). After 5 years, no further increases occurred in the intensive area, but increases did take place on parts of the line that were distant from the BOPA. The lagging colonization of the extensively studied portion of the line may be due not to habitat suitability but to a lack of potential nesters in those areas. The portions of the line near the BOPA, on the other hand, may already be saturated.

Within the intensive area, Townsend ground squirrels were the only prey species whose relative abundance corresponded to raptor and raven nesting densities on the line. All other prey were quite abundant in the eastern (low nesting density) section, the portion of the line farthest from the BOPA (the presumed source of colonizing birds). Distribution and density of nesting raptors and ravens in the canyon is known to be related to ground squirrel abundance (U.S. Dep. Int. 1979) so it will be difficult to definitively identify the proximate reasons for density differences along the line. If densities continue to increase disproportionately in the extensive area, the second hypothesis will be even more tenable.

Plans for next year

Surveys of nesting raptors and ravens on the line will continue using the same procedures as in 1984. In addition, we will continue to gather comparative data on reproduction of golden eagles and ferruginous hawks nesting in the canyon. Habitat surrounding nesting and random towers in the extensive area will be characterized as maps and photos become available. Prey sampling will be discontinued.

ACKNOWLEDGMENTS

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TITLE: Implications of Communal Roosting by Common Ravens to Operation and Maintenance of the Malin to Midpoint 500 kV Transmission Line.

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COOPERATOR: Pacific Power and Light Company

OBJECTIVES:

1. Determine the extent of communal roosting by common ravens on the Malin to Midpoint 500 kV transmission line.
2. Evaluate ravens' use of transmission towers.
3. Evaluate different means of controlling fecal contamination of insulators.
4. Develop the ability to predict potential locations of raven communal roosts.

ANNUAL SUMMARY

Large concentrations of common ravens (*Corvus corax*) have roosted on towers of Pacific Power and Light Co.'s Malin to Midpoint 500 kV transmission line since at least 1982. Accumulation of large quantities of raven feces on insulators of roost towers and an inexplicably high rate of faulting for the line have prompted concern that accumulation of feces may be contributing to poor operational performance. Research to determine implications of raven communal roosting to operation and maintenance of the line continued during 1985. Objectives of the biological portion of the investigation are to 1) determine the extent of raven roosting on the line, 2) evaluate ravens' use of towers, 3) evaluate different means of controlling fecal contamination, and 4) develop the ability to predict potential roost locations. This report summarizes biological data collected from March to October 1985.

Work was conducted along miles 83-160 of the line, which encompasses 6 of the 8 communal roosts located during 1983 and 1984. This segment was surveyed once a month to locate occupied roosts. Towers at the Wilson Creek Roost (mile 131) were treated with wooden pegging, designed to prevent ravens from roosting on certain tower sections, and fiberglass shields, designed to protect insulators from contamination. To evaluate the responses of ravens to pegging and shields and to obtain additional data on roosting behavior, biweekly roost watches were made at the Wilson Creek Roost and 2 other (control) roosts. To evaluate the effectiveness of pegging and shields in reducing accumulation of feces and to examine relationships between numbers of ravens and contamination accumulation, contamination was estimated weekly at each of the roosts under observation. Contamination on insulator bells was scored according to a visual scale. To obtain information necessary to predict potential roost locations, ravens associated with roosts were captured and equipped with radio transmitters. Transmitter-equipped ravens were observed continuously from 30 min before sunrise until they settled into their

roosts for the night. Locations were recorded, and a detailed record of habitat use was kept. To examine relationships among roosting, habitat use, and diet of ravens, pellets regurgitated by ravens were collected beneath roost towers. Pellet composition was determined in the laboratory.

Ravens used 5 roosts on the line during 1985. Each of these roosts was also occupied during 1984. The Initial Point Roost (miles 107-113) remained the largest roost on the line, although numbers were considerably lower than in 1984. The peak count of 1,075 ravens involved 14 towers. A new high of 933 ravens was recorded for the Marsing Southwest Roost. Most ravens roosted above insulators; however, distribution of ravens among tower sections differed among roosts. Fewer ravens roosted above insulators during wind and rain. Many ravens in the study area roosted on Idaho Power Company 138 kV lines during summer.

Pegging and shields appeared to be at least a short-term success. Ravens did not roost on sections where pegging was installed, and shields appeared to prevent contamination from reaching insulators. Trends in numbers and distribution of ravens following installation of pegging and shields were consistent with adjustment of ravens to the devices. Pegging and shields did not significantly decrease natural dissipation of contamination. Hot-water washing was effective in removing large amounts of contamination; however, it did not restore insulators to clean condition.

Eleven adult and subadult ravens were captured during 70 days of trapping. Capture success was higher with leghold traps than with a rocket net. Seven fledgling ravens were also equipped with transmitters. Over 1,000 locations were obtained from the 18 transmitter-equipped ravens; these ravens were observed for over 500 hours. Movements, habitat use, and food habits analyses have not yet been completed; these data will be presented in the final study report.

INTRODUCTION

Large concentrations of common ravens (Corvus corax) have roosted on towers of Pacific Power and Light Co.'s (PP&L) Malin to Midpoint 500 kV transmission line since at least 1982 (Engel and Young 1985). In 1984, up to 2,103 ravens roosted on as many as 17 towers between miles 107-113, within the Snake River Birds of Prey Area (Engel and Young 1985). This is by far the largest reported roosting aggregation of this species (Knight and Call 1980, Allen and Young 1982). Groups of up to 613 ravens have roosted at 7 other locations on the line.

Accumulation of large quantities of raven feces on insulators and an inexplicably high rate of faulting for the line have prompted concern that accumulation of feces may be contributing to poor operational performance. Insulators at many roost towers are being washed annually to control contamination. This is expensive not only in terms of labor and materials but also in terms of taking the line out of service for cleaning. Furthermore, the effectiveness of washing has not been determined.

Therefore, in 1983, PP&L and the Bureau of Land Management (BLM) initiated cooperative research to determine the implications of communal roosting by ravens to operation and maintenance of the transmission line. PP&L's goals are to determine the most effective approach for managing the contamination problem on the Malin to Midpoint 500 kV line, and determine how routing and design considerations can prevent similar problems on other transmission lines. BLM's goals are to obtain data needed to make informed decisions regarding routing of transmission lines across BLM lands, and obtain data needed to reduce potential wildlife/transmission line conflicts on BLM lands. Specific objectives of the continuing study are to determine the extent of raven roosting on the transmission line, evaluate ravens' use of towers, evaluate different means of controlling fecal contamination of insulators, and develop the ability to predict potential roost locations. Principal objectives of the 1985 field season were to test devices that would prevent insulator contamination, evaluate ravens' responses to these devices, and acquire information needed to define potential roost locations. This report summarizes biological data collected from March to October.

STUDY AREA

Work was conducted along miles 83-160 of the transmission line. This segment of the line runs along the western Snake River Plain, Idaho-Oregon (Fig. 1) and encompasses 6 of the 8 communal roosts that were located during 1983 and 1984 (Engel and Young 1985). The area is dominated by shrubsteppe vegetation and agriculture. Annual precipitation averages 20 cm (U.S. Dep. Inter. 1979), and most precipitation falls from late autumn to early spring. Summers are hot and dry. At the east end of the study area, the Snake River runs through a steep, narrow canyon, up to 250 m below the plain. The canyon diminishes as the river flows west, and at the west end of the study area, the river runs through flat to rolling terrain with scattered smaller cliffs and bluffs. In this area, the plain rises to the south to the Owyhee Mountains. The proportion of the plain that has been converted to agriculture generally increases from east to west. Throughout the text, towers are identified by mile and number (e.g., 131/3 identifies the 3rd tower in mile 131).

METHODS

Surveys

To locate occupied roosts, miles 83-160 were surveyed once a month. From March to August, miles 83-96 were surveyed from the ground, and miles 97-160 were surveyed from the air. During September and October, the entire stretch was surveyed from the ground. Aerial surveys were flown on 2 consecutive evenings, the 2nd Monday and Tuesday of each month. Miles 97-128 were flown on the 1st evening, and miles 129-160 were flown on the 2nd. Surveys began 10 min after sunset on clear nights and 5 min after sunset on overcast nights. Surveys were not flown when winds at Boise International Airport were greater than 18 km/hour 30 min before scheduled take-off. If inclement weather prevented a survey from being flown on the designated evening, it was flown on the next evening with suitable conditions. Surveys were flown in a Cessna 172 or 182 aircraft flying east to west at 167 km/hour, 46-61 m above ground level, 15 m south of the transmission line. An observer sat in the right front seat, and a recorder sat in the rear. Roosts were considered to be occupied if 3 or more ravens were present during an aerial survey. During the

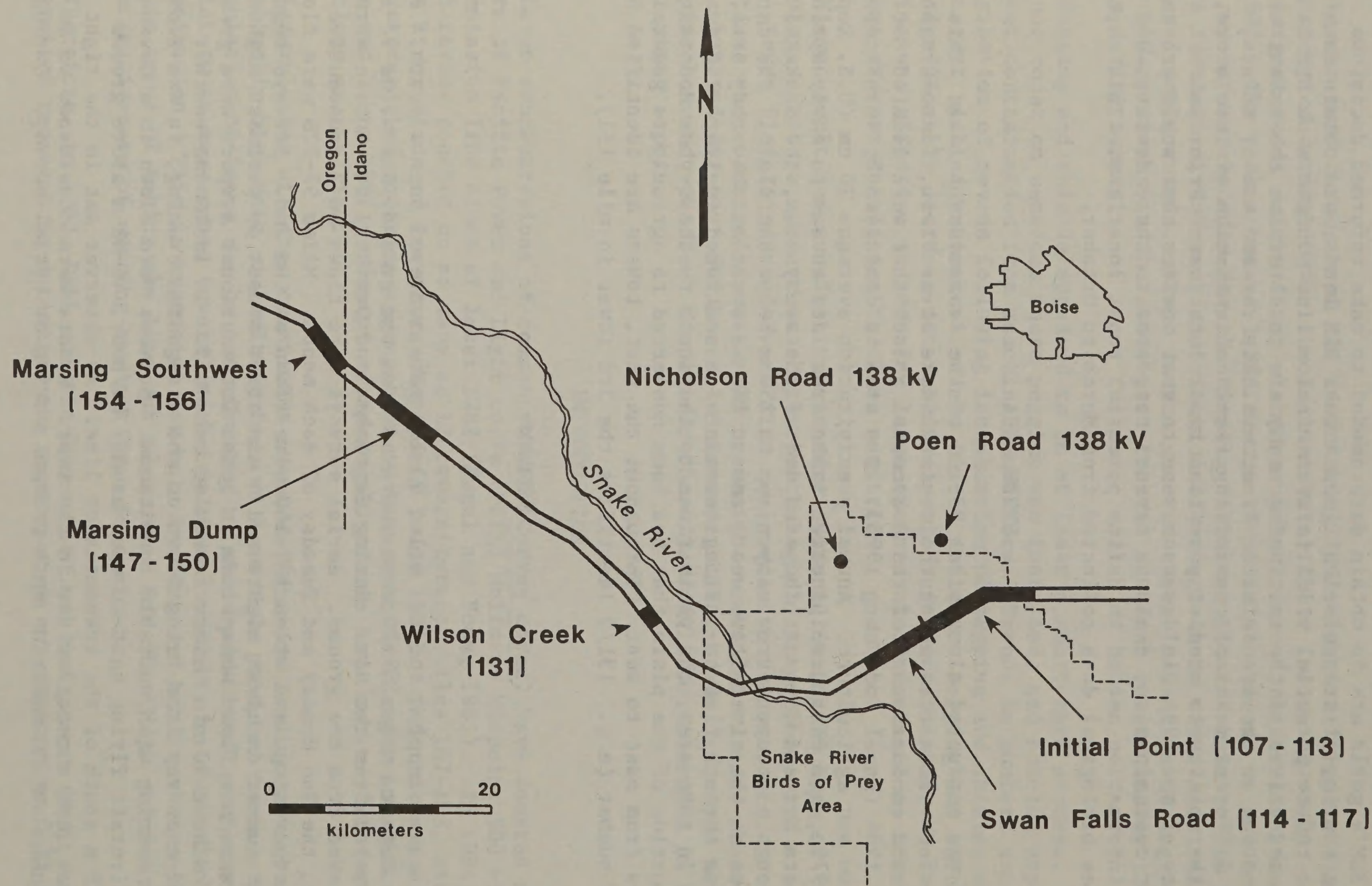


Fig. 1.--Raven communal roosts located in the study area, March-October 1985.

fledging period, family groups of ravens (3-10 birds) often roosted on or near their nest towers. These groups were readily apparent and, in this study, were not considered to be communal roosts.

Ground surveys were conducted by an observer driving maintenance roads adjacent to the line. Using a 20-45X or 15-60X spotting scope, the observer examined the insulators of each tower for accumulated feces. A tower was considered to be a potential roost tower if substantial contamination not associated with a nest was noted. Potential roost towers were observed on a subsequent evening to confirm use. Ground surveys replaced aerial surveys in September because ground surveys appeared to be more reliable for locating roosts: occasionally ravens did not occupy towers until dark, after the survey was completed.

Treatments

There appear to be 4 viable options for controlling fecal contamination of insulators: 1) prevent ravens from roosting on towers, 2) prevent ravens from roosting on portions of towers above insulators, 3) shield insulators from feces, and 4) continue washing. Preventing ravens from using known roost towers would not be a solution if ravens simply moved to other towers. Hence, a very large number of towers (probably several hundred) would have to be treated in order for this approach to be effective. This would be extremely expensive, and it would be virtually impossible to physically prevent roosting on all tower components. In addition ravens might adjust to the technique and return to treated towers after a short period.

Options 2 and 3 seem to hold greater promise. Both permit ravens to continue to use roost towers, while preventing insulator contamination. Only towers within a short distance of known and potential roosts would have to be treated since ravens would not have to shift from their preferred locations. Once towers in these favorable areas were treated, little further maintenance would be required.

To test these options, wooden pegging and fiberglass shields were installed at the Wilson Creek Roost (mile 131) and adjacent towers. A 20-tower span centered on the 2 central roost towers (131/3 and 131/4) was treated. Eighteen towers were treated with shields (Fig. 2) beneath the B and inner C sections (Fig. 3) and pegging (Fig. 4) on the outer C sections (Fig. 5). The 2 remaining towers were of a slightly different configuration: the B section of these towers was too wide for shields to be installed. Therefore, these 2 towers were treated with pegging on both B and C sections. Pegging and shields were installed working from the ends of the 20-tower span toward the center. Tower 131/4, the tower used by ravens at the time of installation, was treated last. Pegging and shields were installed on most towers between 12 and 20 June, and on tower 131/4 on 2 July.

To determine whether or not pegging and shields affected natural dissipation of contamination, we compared contamination declines at 4 treated towers and at an equal number of untreated towers. The 4 treated towers were the only towers at the Wilson Creek Roost that had been used by ravens before pegging and shields were installed. The towers we chose as controls were towers at other roosts that had been used by ravens during the spring and abandoned within 2 weeks of the time that pegging and shields were installed

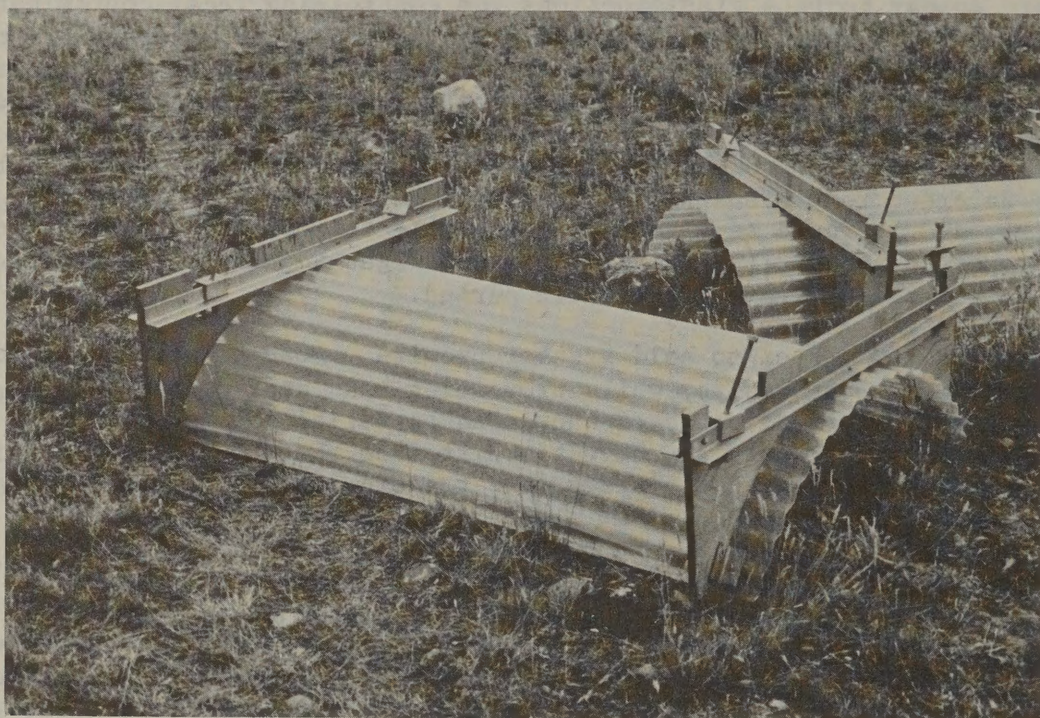


Fig. 2.--Fiberglass shield used to prevent insulator contamination.

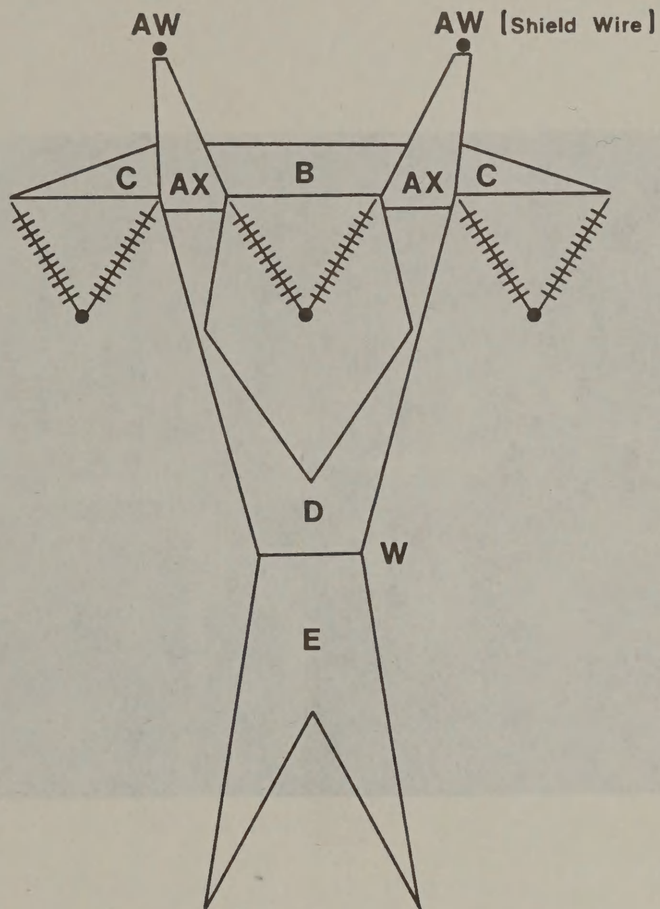


Fig. 3.--Tower sections identified for data collection.

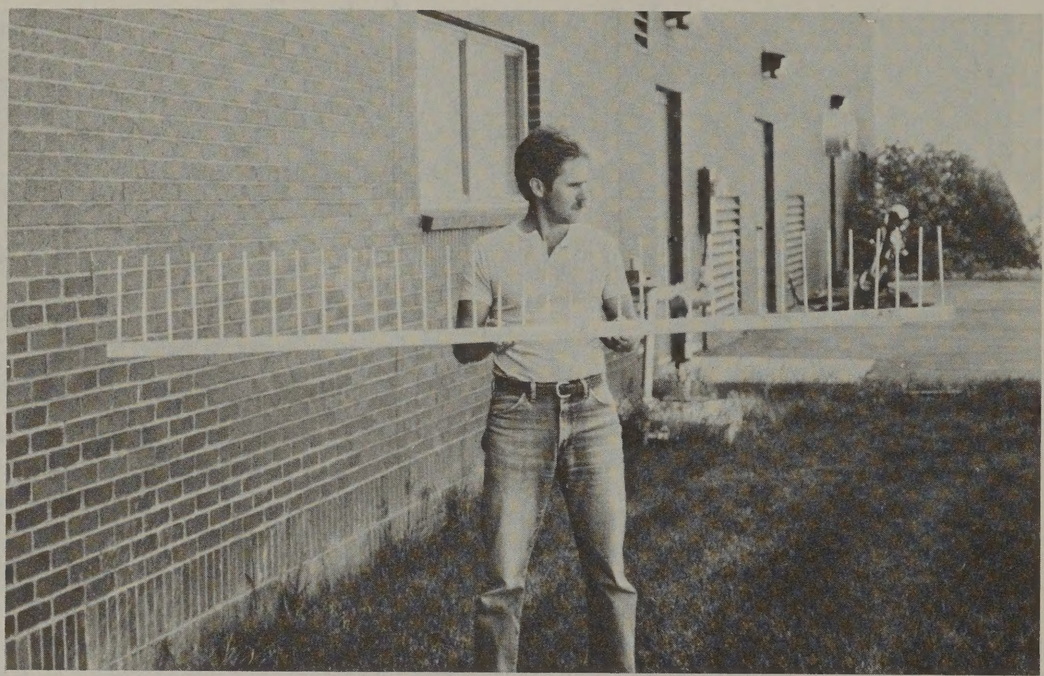


Fig. 4.--Wooden pegging used to prevent ravens from roosting on the outer C sections of towers.

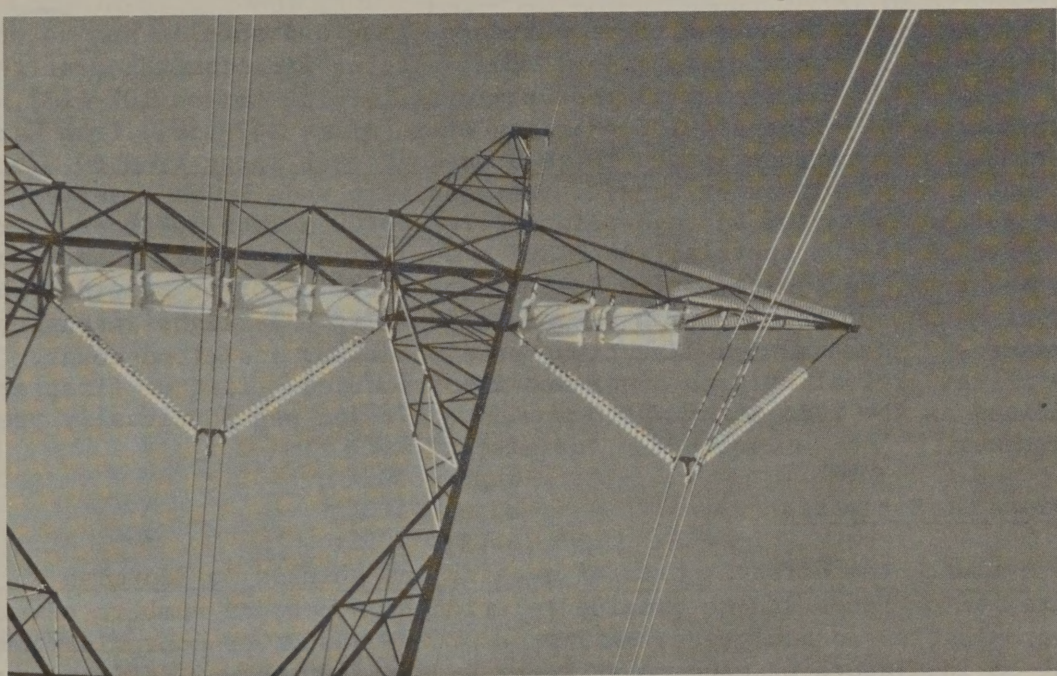


Fig. 5.--Shields and pegging installed on a tower.

at Wilson Creek. Controls had contamination levels similar to the 4 treated towers. We estimated contamination at treated towers when installation of pegging and shields was completed (2 July) and 1 mo and 2 mo later. We estimated contamination at controls within 3 weeks of the 1st reading at Wilson Creek and 1 mo and 2 mo later. Net declines were compared between the 2 groups for 1 mo and 2 mo intervals.

To evaluate the efficacy of hot-water washing, we compared contamination levels between washed and unwashed insulator strings. At 3 contaminated towers at the Wilson Creek Roost, 1 randomly selected insulator string of each phase was washed. The other string of each phase was left unwashed. Washing was done on 10 and 11 June, prior to installation of pegging and shields. Pre- and post-washing contamination estimates were compared between washed and unwashed strings.

Roost Watches

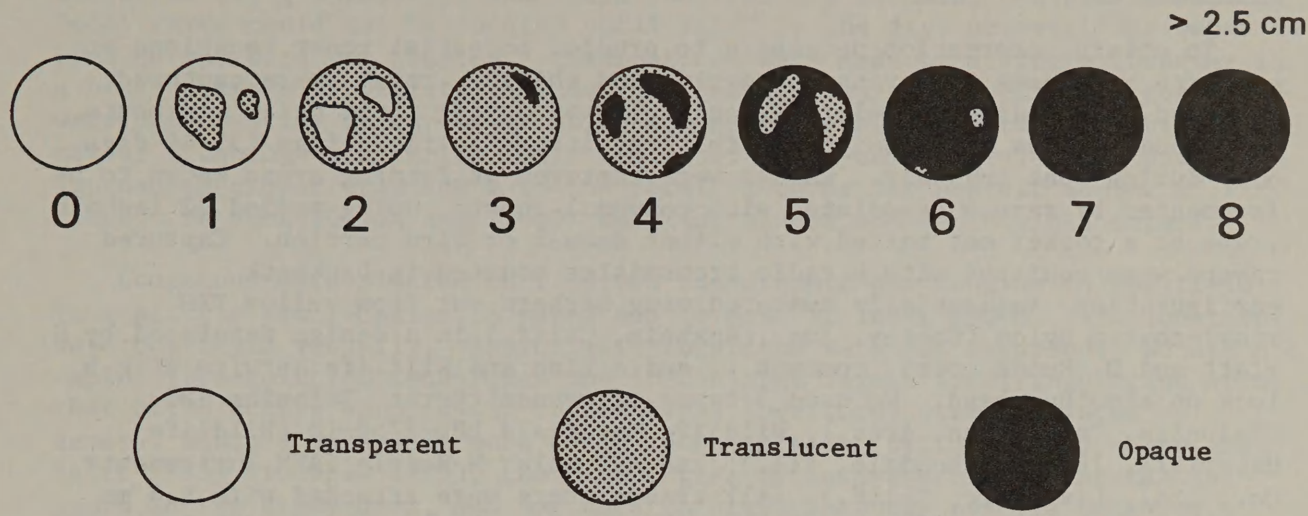
To evaluate the responses of ravens to pegging and shields and to obtain additional data on roosting behavior, roost watches were conducted at the Wilson Creek Roost and 2 control roosts (Initial Point [miles 107-113], Marsing Southwest [miles 154-156]/Marsing Dump [miles 147-150]) from March to October. Watches were conducted twice a week at each roost from 60 min before sunset until 30-40 min after sunset. Watches were made by an observer in a vehicle parked in a good vantage point at least 400 m from the nearest roost tower. Both a 15-60X spotting scope and a 50-130X Questar telescope (Questar Corp., New Hope, Pa.) were used. Every 10 min, the observer recorded the number of ravens perched on each tower section (Fig. 3), light intensity, temperature, wind speed and direction, precipitation, and cloud cover. Exact time of first arrival at each tower was also recorded. Time of first arrival was defined as the time after which at least 1 raven was continually present on the tower.

Contamination Estimates

To evaluate the effectiveness of pegging and shields in reducing accumulation of feces and to examine relationships between numbers of ravens and contamination accumulation, estimates of the amount of contamination present on insulators of each roost tower were made weekly. Estimates were made at all towers used by ravens at the 3 roosts under observation. Estimates continued throughout the season, whether or not a tower had been abandoned. After pegging and shields were installed at the Wilson Creek Roost, estimates were made at all treated towers, whether or not a tower had been used by ravens. The schedule was shifted if inclement weather prevented estimates from being made on the designated day. Occasionally, a week was skipped due to a prolonged period of inclement weather. Each insulator bell in each string (150 bells/tower) was scored separately according to a visual scale (Table 1). String and tower scores were then tallied for analysis. Insulators were scored by the same observer with 7X binoculars standing beneath the tower. The observer also photographed each insulator string using a camera equipped with a 500 mm lens and color slide film.

We examined the relationship between raven roosting and contamination by correlating the mean number of ravens roosting above insulators each night to the mean contamination score, for the months that each tower was occupied. We

Table 1.--Visual categories used to score contaminated insulator bells.



Score	Description[1]
0	100% transparent (clean)
1	>50% transparent, <50% translucent
2	<50% transparent, >50% translucent
3	>90% translucent
4	>50% translucent, <50% opaque
5	<50% translucent, >50% opaque
6	>90% opaque
7	100% opaque
8	100% opaque, depth >2.5 cm

[1]Distribution of contamination over bell may vary.

only used towers for which we had at least 1 contamination estimate for each month that the tower was occupied (N=32).

Telemetry

To obtain information necessary to predict potential roost locations and evaluate responses of ravens to pegging and shields, ravens were captured, equipped with radio transmitters, and followed during their daily movements. Additional ravens were equipped with transmitters as fledglings (35-40 days old) during June and July. Ravens were captured at feeding areas known to be frequented by ravens associated with communal roosts, using padded #2 leghold traps or a rocket net baited with either mammal or bird carrion. Captured ravens were equipped with a radio transmitter mounted in backpack configuration, sequentially numbered wing markers cut from yellow TXN vinyl-coated nylon (Cooley, Inc., Anaheim, Calif.) in a design developed by S. Platt and D. Runde (pers. communs.), and a Fish and Wildlife Service size 6 lock-on aluminum band. We used 3 types of transmitters: Telonics RB5 (Telonics, Inc., Mesa, Ariz.), Wildlife Materials LPB-2750-LD (Wildlife Materials, Inc., Carbondale, Ill.), and AVM Solar M Module (AVM Instruments Co., Ltd., Livermore, Calif.). All transmitters were attached with 6.4 mm tubular teflon ribbon (Bally Ribbon Mills, Bally, Pa.) secured with Braunamid 2/0 veterinary nylon (B. Braun Melsungen AG, Fed. Repub. Germany) or dental floss (Johnson and Johnson Products, Inc., New Brunswick, N.J.). We used all 3 types of transmitters with adult and subadult ravens, but only the relatively lightweight (21 g) LPB-2750-LD with fledglings. We followed the attachment procedure outlined by Tomkiewicz (1983) as refined by D. Anderson (pers. commun.).

We observed transmitter-equipped ravens for a maximum of 6 days per week. From April to mid-September, we attempted to allocate our observation effort evenly among ravens associated with the 3 roosts under observation. For sampling purposes, we considered the Marsing Dump and Marsing Southwest roosts as one because of their proximity and the apparent frequent interchange of ravens between them (Engel and Young 1985). Thus, 2 ravens from each roost usually were observed each week. The 2 ravens to be observed were randomly selected from the pool of transmitter-equipped ravens associated with that roost. If there was temporarily only 1 transmitter-equipped raven associated with a roost, then that bird was observed on both days. If there were temporarily no transmitter-equipped ravens associated with a roost, then both observation days allotted to the roost were dropped from that week's schedule. Observation days were randomly selected; however, no more than 2 ravens were observed (by different observers) on a single day.

By 15 September, 2 of the 3 roosts, including the Wilson Creek Roost, had been evacuated. Beginning in late summer, ravens also appeared to exhibit weaker allegiances to particular roosts, moving among roosts considerably. Therefore, starting on 15 September, we observed all transmitter-equipped ravens in a fixed sequence, then repeated the cycle. We still observed a maximum of 6 ravens per week and randomly selected observation days. We did not observe individual ravens more than once per week if there were temporarily fewer than 6 transmitter-equipped ravens. Ravens were added to the rotation as they were captured, and deleted from it if they left the study area or died, or if their transmitters failed.

On an observation day, the focal raven was located before daylight, using telemetry, and continuously observed from 30 min before sunrise until it had settled into its roost for the night. If the bird flew out of view, it was relocated using telemetry, and visual observation resumed. On some days, the focal raven could not be located until later in the day; observations began as soon as the bird was located. Observations were made by a single observer in a pick-up truck or utility vehicle. We almost always used existing roads and were conservative in our observation distances to minimize the possibility of ravens flushing or altering their behavior. In open country, we seldom approached closer than 400 m to the focal raven or the nearest member of its flock. We used 20-45X and 15-60X spotting scopes and various binoculars.

Locations were plotted on 1:24,000 topographic quadrangles in the field. To qualify a new location, a raven had to move at least 100 m. All locations were confirmed visually. Approximate locations were not recorded. We did not employ triangulation techniques due to the high degree of triangulation error that often occurs when making observations (bearings) over distances of several hundred meters or more or in rough terrain (Springer 1979, Hupp and Ratti 1983, Crenshaw 1985), the high degree of interspersion among habitat types in the study area, and our need to simultaneously observe behavior. Only locations where ravens perched or landed on the ground were recorded. We did not consider locations of flying or soaring ravens because we felt that these were ambiguous with respect to habitat use. Time spent at each location and habitat type were recorded on a field form. Each time a raven shifted to a different habitat, a new entry was made. Shifts in habitat often occurred without a corresponding shift in location: ravens commonly shifted between habitats without moving 100 m.

Additional information on roosting habits was obtained by checking all known communal roosts in the study area for the presence of transmitter-equipped ravens. Roosts were checked between 60 min after sunset and 60 min before sunrise on 3 randomly selected nights per week.

Pellet Collections

To examine relationships among roosting, habitat use, and diet of ravens, we collected pellets regurgitated by ravens beneath roost towers. A transect was established beneath 1 tower at each occupied roost on the 500 kV line. All pellets within 50 cm of a transect were collected weekly, and a random sample of 10 pellets was selected and stored for analysis. Transects were shifted as towers used by ravens changed during the season.

In the laboratory, pellets were weighed and measured, and pellet composition was determined. Five pellets per week per roost were analyzed. For animal remains, the minimum number of individuals per taxon was determined (Mollhagen et al. 1972). Vertebrate remains were identified to species, and invertebrate remains were identified to order. Amounts of different types of plant material were weighed to the nearest 0.01 g.

RESULTS

Use of Roosts

Ravens used 5 roosts on the 500 kV line during 1985 (Table 2, Fig. 1). Each was a roost that had been occupied during a previous year. The Pleasant Valley Road Roost (miles 101-103) was not occupied during 1985. This roost was the major roost on the line during 1983 and was occupied by up to 144 ravens from June to August 1984 (Steenhof 1984, Engel and Young 1985).

The Marsing Southwest Roost was already occupied when surveys began in early March. Numbers fluctuated between 183 and 328 ravens from March to mid-April, then dropped sharply during late April (Fig. 6). Numbers fluctuated between 4 and 77 birds between late April and the end of May. The roost was evacuated between 31 May and 3 June. Ravens reoccupied the roost during early August. Numbers increased rapidly during late summer and early autumn, reaching a high of 933 ravens on 18 October, shortly before observations were discontinued.

The Initial Point Roost was first occupied between 11 and 16 March. Numbers of ravens steadily increased to a peak of 1,075 birds on 14 July, then dropped rapidly during late July (Fig. 7). The roost was evacuated between 29 and 31 July and remained unused until late August. The roost was reoccupied during early September. Numbers fluctuated between 219 and 451 ravens during September and October.

The Wilson Creek Roost, the roost at which pegging and shields were installed, was first occupied between 20 and 22 March. Numbers built to a peak of 298 ravens on 21 May (Fig. 8). Numbers gradually declined during June, reaching a low of 16 birds on 25 June and 2 July. Numbers then gradually increased to a high of 154 ravens on 26 July, before dropping off rapidly during late July. The roost was evacuated for the season between 7 and 9 August.

Observations shifted from the Marsing Southwest Roost to the Marsing Dump Roost when the former roost was evacuated in early June. At this time, the Marsing Dump Roost had been occupied for about a month. Numbers fluctuated between 309 and 538 ravens from June to mid-September, then dropped rapidly to a low of 7 birds on 7 October (Fig. 9). The roost was evacuated for the season between 8 and 10 October.

Ravens occupied the Swan Falls Road Roost (miles 114-117) during August and September. Some ravens roosted on the 500 kV line, while others roosted on the Idaho Power Co. (IPC) 138 kV line that intersects the 500 kV line at mile 116. Numbers roosting on the 500 kV line ranged between 176 and 543 ravens during these months, while total numbers ranged between 329 and 949 ravens. On nights when ravens used both lines, the proportion of birds using the 500 kV line ranged from 45-81% ($\bar{x}$ = 64.4 $\pm$ 13%, N=8).

Ravens' use of towers at the Initial Point Roost was similar to 1984. From mid-March to early June, ravens consistently used relatively few towers (Fig. 10). As numbers approached a peak in mid-June, the number of towers used by ravens sharply increased. A peak of 14 towers was used on 10 and 14 July, the 2 counts prior to the sharp decline in numbers. Relatively few

Table 2.--Mean monthly numbers of ravens using roosts within the study area, March-October 1985. Starred (*) figures represent values obtained through monthly coordinated watches.

Roost (line miles)	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Initial Point (107-113)	160	368	530	741	523	25	363	310
Swan Falls Road (114-117)[1]	0	0	0	0	0	446*	214*	0
Wilson Creek (131)	29	178	224	58	81	6	0	0
Marsing Dump (147-150)	0	0	234*	392	470	389	393	46
Marsing Southwest (154-156)	227	227	31	0	0	199	217	838
500 kV	416	773	1019	1191	1074	1065	1187	1194
Swan Falls Road 138[2]	0	0	0	0	0	334*	55*	0
Poen Road 138	0	0	0	0	510*	263*	0	0
Nicholson Road 138	0	0	0	0	0	355*	22*	0
138 kV	0	0	0	0	510	952	77	0
TOTAL	416	773	1019	1191	1584	2017	1264	1194

[1]Indicates the 500 kV portion of the Swan Falls Road Roost.

[2]Indicates the 138 kV portion of the Swan Falls Road Roost.

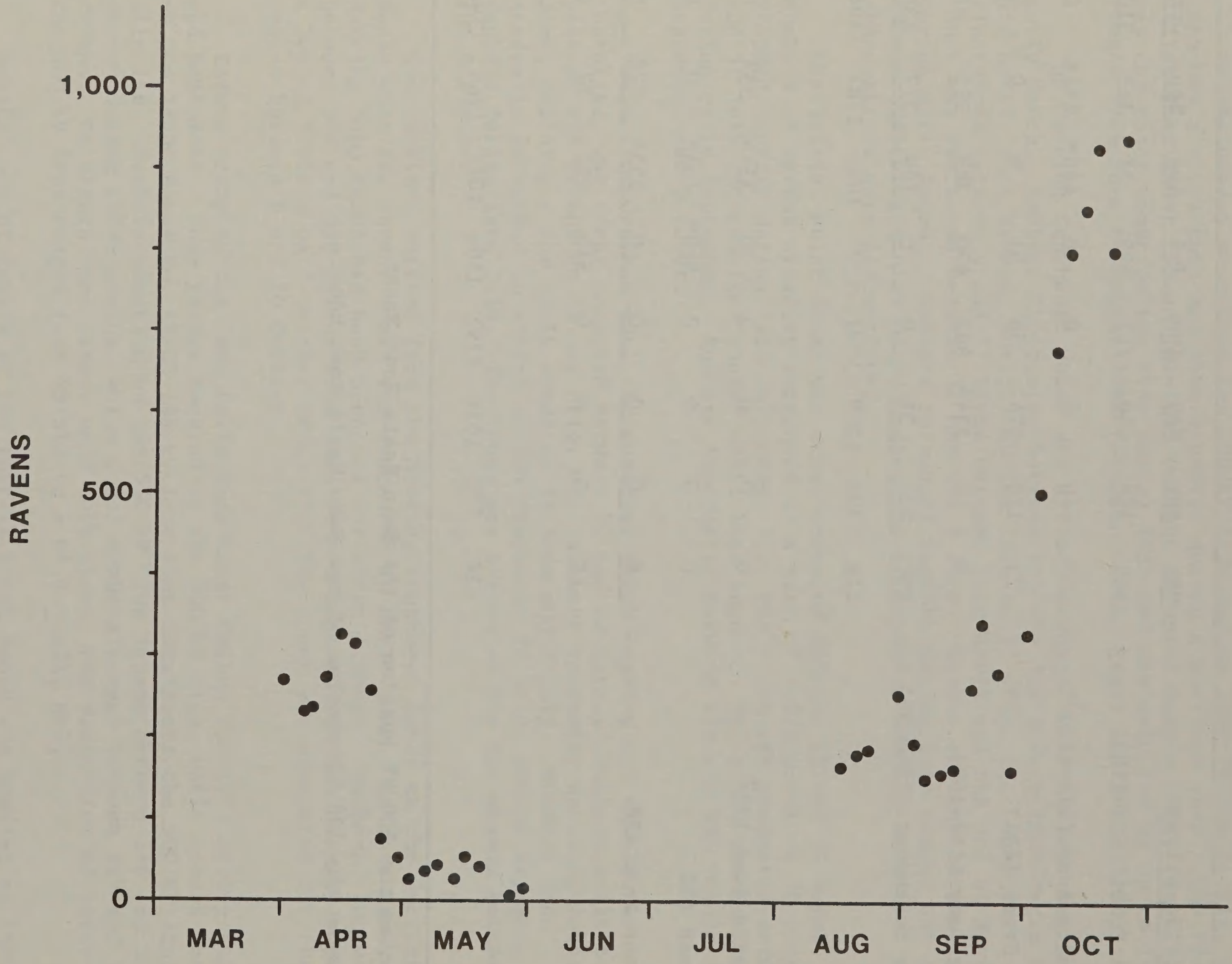


Fig. 6.--Numbers of ravens using the Marsing Southwest Roost (miles 154-156), March-October 1985.

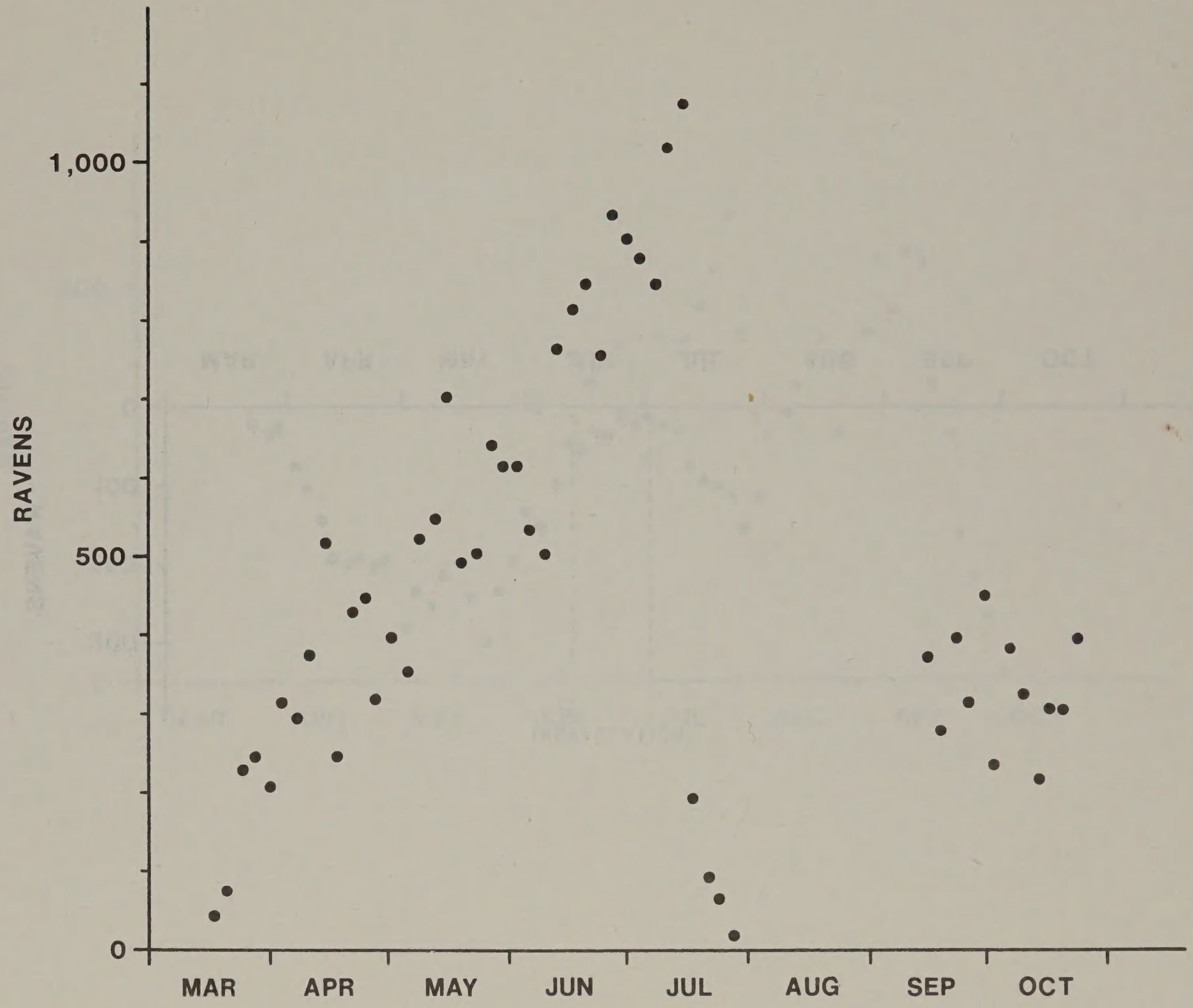


Fig. 7.--Numbers of ravens using the Initial Point Roost (miles 107-113), March-October 1985.

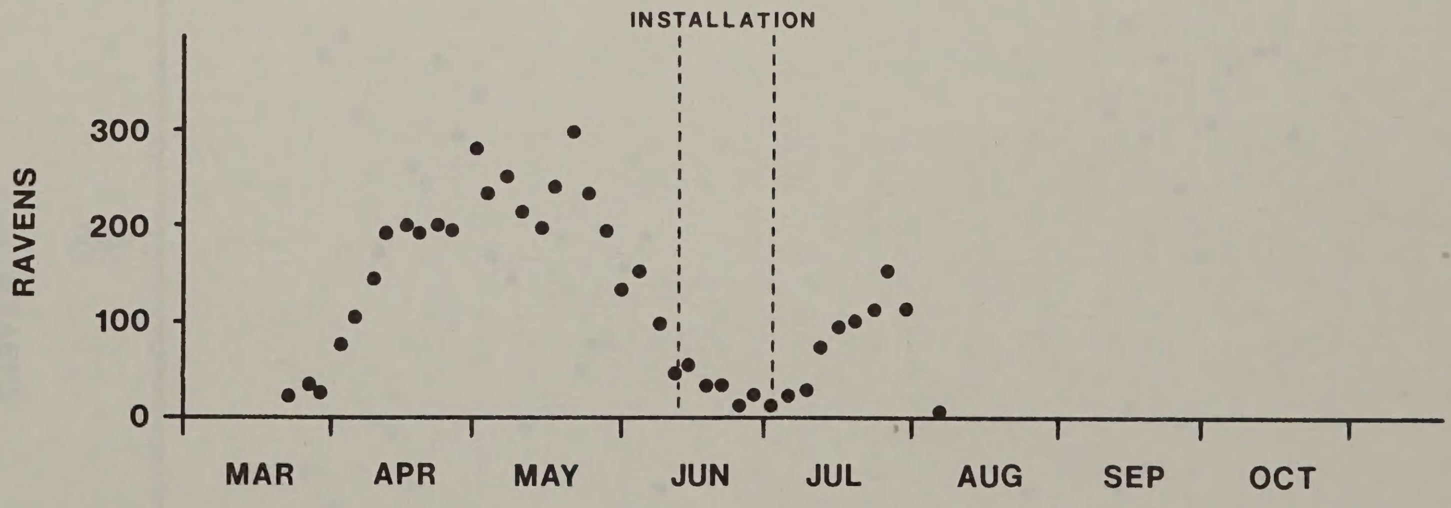


Fig. 8.--Numbers of ravens using the Wilson Creek Roost (mile 131), March-October 1985.

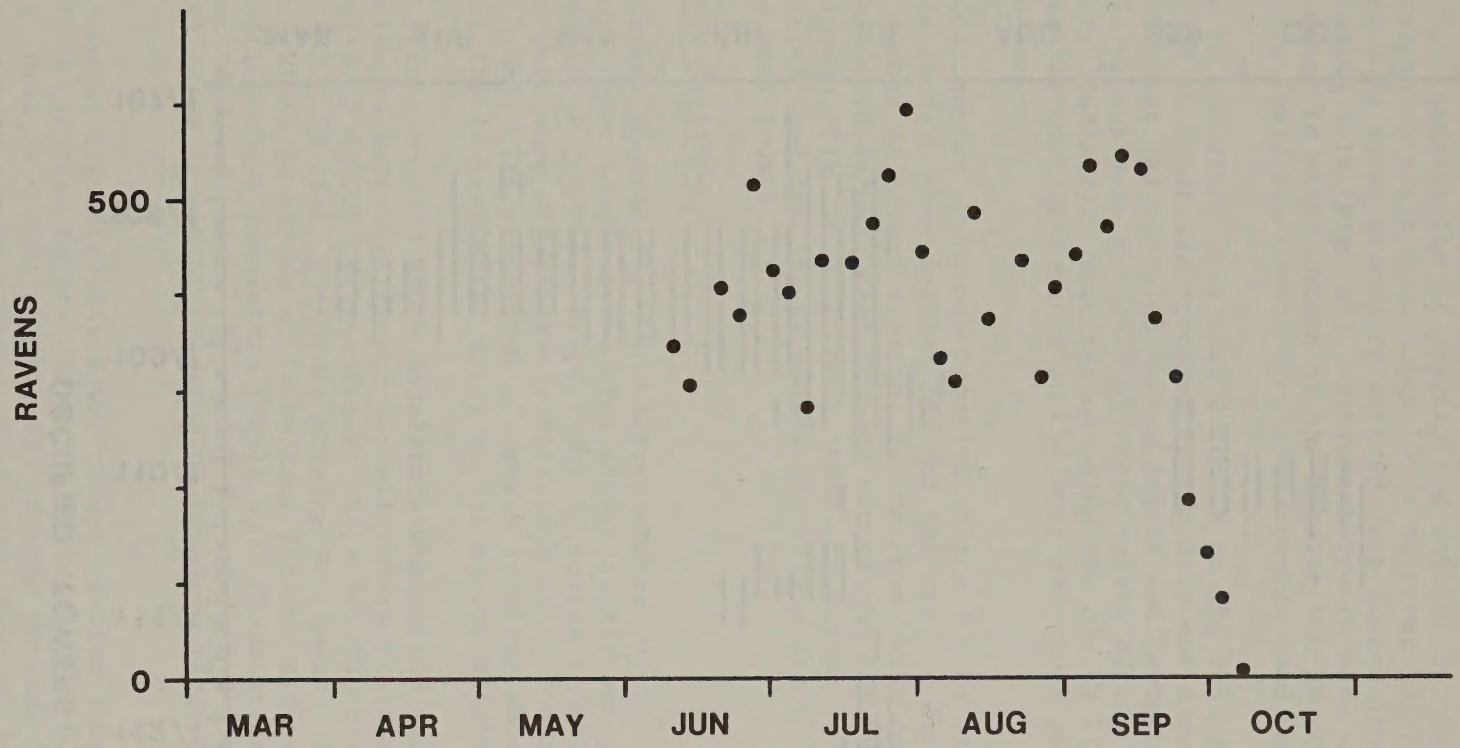


Fig. 9.--Numbers of ravens using the Marsing Dump Roost (miles 147-150), March-October 1985.

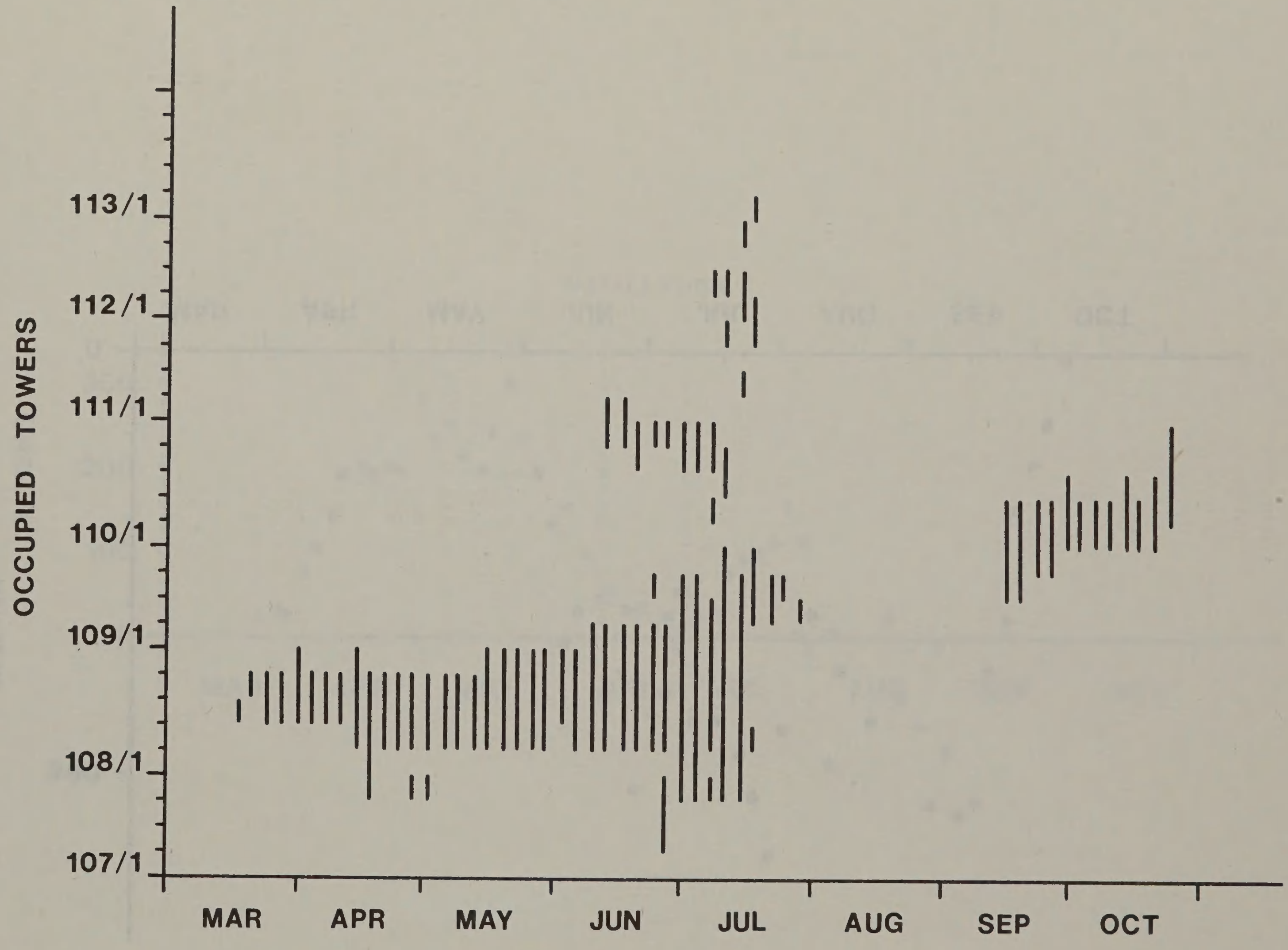


Fig. 10.--Towers used by ravens at the Initial Point Roost (miles 107-113), March-October 1985.

towers were consistently used during September and October, after the roost was reoccupied.

Shifts in use of towers were less pronounced at the other roosts on the 500 kV line. Installation of pegging and shields at the Wilson Creek Roost prompted ravens to shift from tower 131/4 to tower 131/5 (Fig. 11). Ravens at the Marsing Dump Roost gradually shifted from towers in mile 148 to towers in mile 149 during July (Fig. 12). Different towers were occupied between spring and late summer to early autumn at the Marsing Southwest Roost (Fig. 13); however, relatively few towers were consistently used during both periods.

Ravens in the study area used 2 roosts on IPC 138 kV lines (Fig. 1). The Poen Road 138 kV Roost was occupied during July and August, and the Nicholson Road 138 kV Roost was occupied during August and September. Maximum counts of 510 and 355 ravens were recorded at these roosts during July and August, respectively (Table 2). Most ravens using the 138 kV lines roosted on shield wires. Smaller numbers roosted on the tops and cross member of the wooden, H-shaped poles.

The total number of ravens roosting on the 500 kV line rose quickly to 1,019 birds in May, then leveled off for the rest of the season (Fig. 14). The total number of ravens roosting in the study area rose steadily to a peak of 2,017 birds in August, then dropped off as the 138 kV roosts were evacuated in early autumn (Fig. 14). At peak count, in August, 47.1% of all ravens in the study area used the 138 kV roosts (including the 138 kV portion of the Swan Falls Road Roost).

Use of Tower Sections

Most ravens roosted above insulators (Table 3); however, distribution of ravens among tower sections differed significantly among roosts (X^2 = 4417.43, df=18, $P < 0.01$). Proportions of ravens roosting above and below insulators were also significantly different among roosts (X^2 = 2304.71, df=3, $P < 0.01$). The proportion of ravens roosting above insulators ranged from 83% at the Initial Point Roost to 99% at the Marsing Southwest Roost.

Fewer ravens roosted above insulators when winds exceeded 8 km/hour (Table 4). Differences were significant for all roosts (Initial Point: X^2 = 1110.86, df=1, $P < 0.01$; Wilson Creek: X^2 = 401.10, df=1, $P < 0.01$; Marsing Dump: X^2 = 501.74 df=1, $P < 0.01$; Marsing Southwest: X^2 = 255.74, df=1, $P < 0.01$). Winds in excess of 16 km/hour further reduced the proportion of ravens roosting above insulators (Table 5). These differences were also significant (Initial Point: X^2 = 1553.96, df=2, $P < 0.01$; Wilson Creek: X^2 = 593.91, df=2, $P < 0.01$; Marsing Southwest: X^2 = 260.11, df=2, $P < 0.01$).

At 2 roosts, significantly fewer ravens roosted above insulators during precipitation (Initial Point: X^2 = 151.48, df=1, $P < 0.01$; Wilson Creek: X^2 = 31.71, df=1, $P < 0.01$) (Table 6). At the Marsing Southwest Roost, significantly more ravens roosted above insulators during precipitation (X^2 = 22.00, df=1, $P < 0.01$); however, few ravens roosted below insulators there throughout the study (0% during precipitation, 1% at other times).

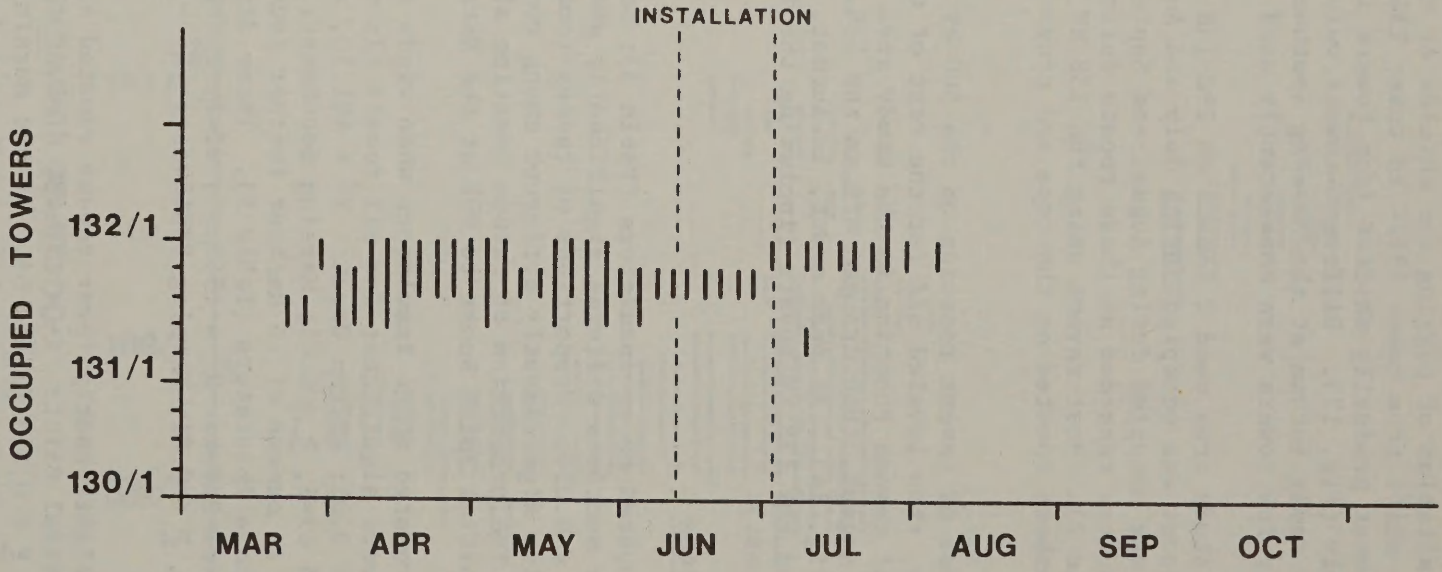


Fig. 11.--Towers used by ravens at the Wilson Creek Roost (mile 131), March-October 1985.

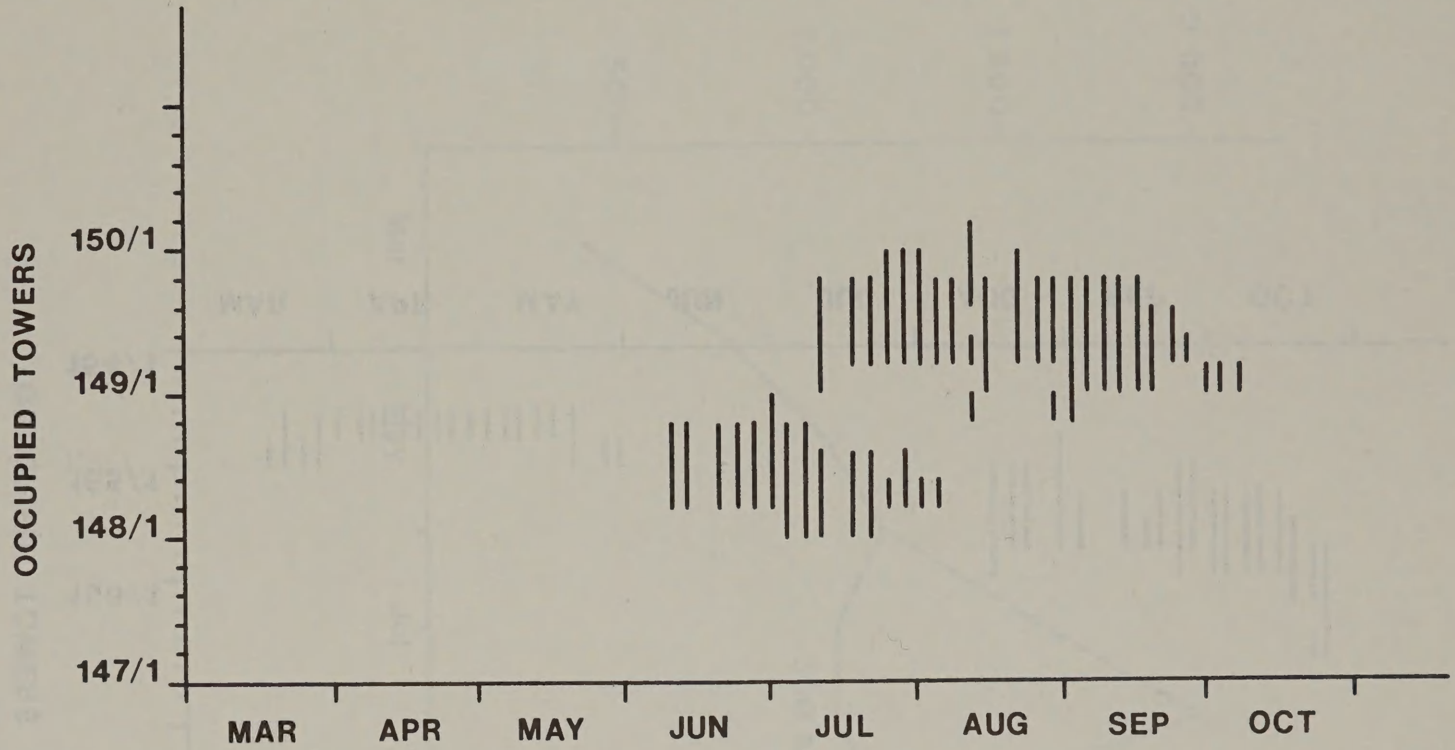


Fig. 12.--Towers used by ravens at the Marsing Dump Roost (miles 147-150), March-October 1985.

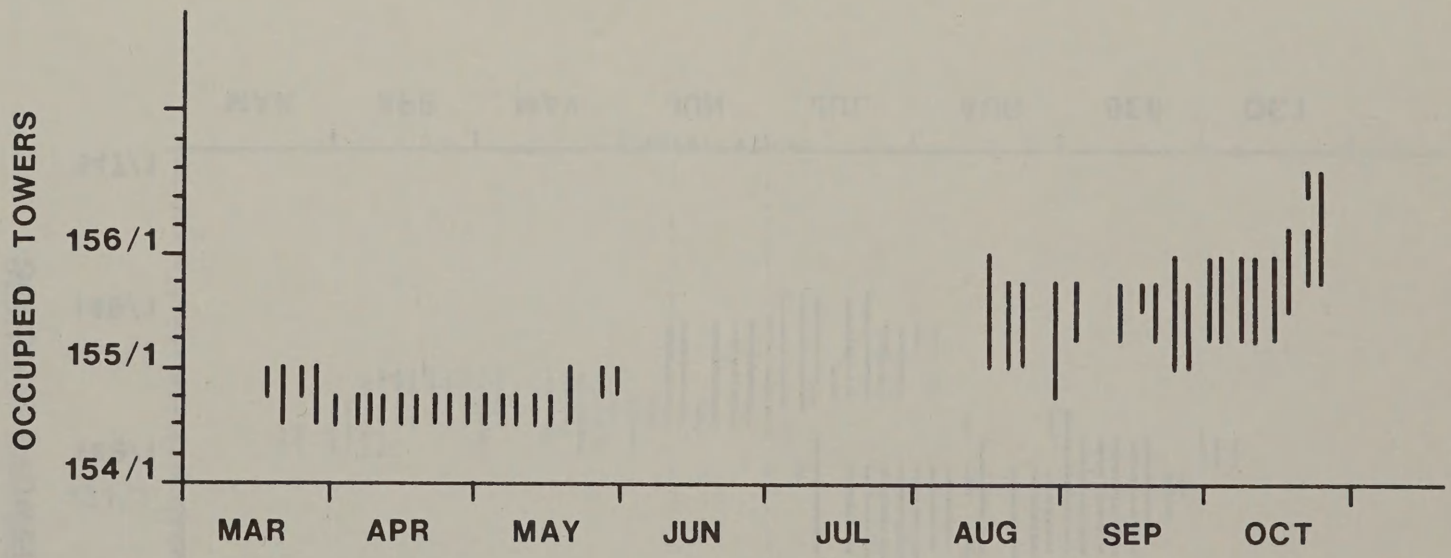


Fig. 13.--Towers used by ravens at the Marsing Southwest Roost (miles 154-156), March-October 1985.

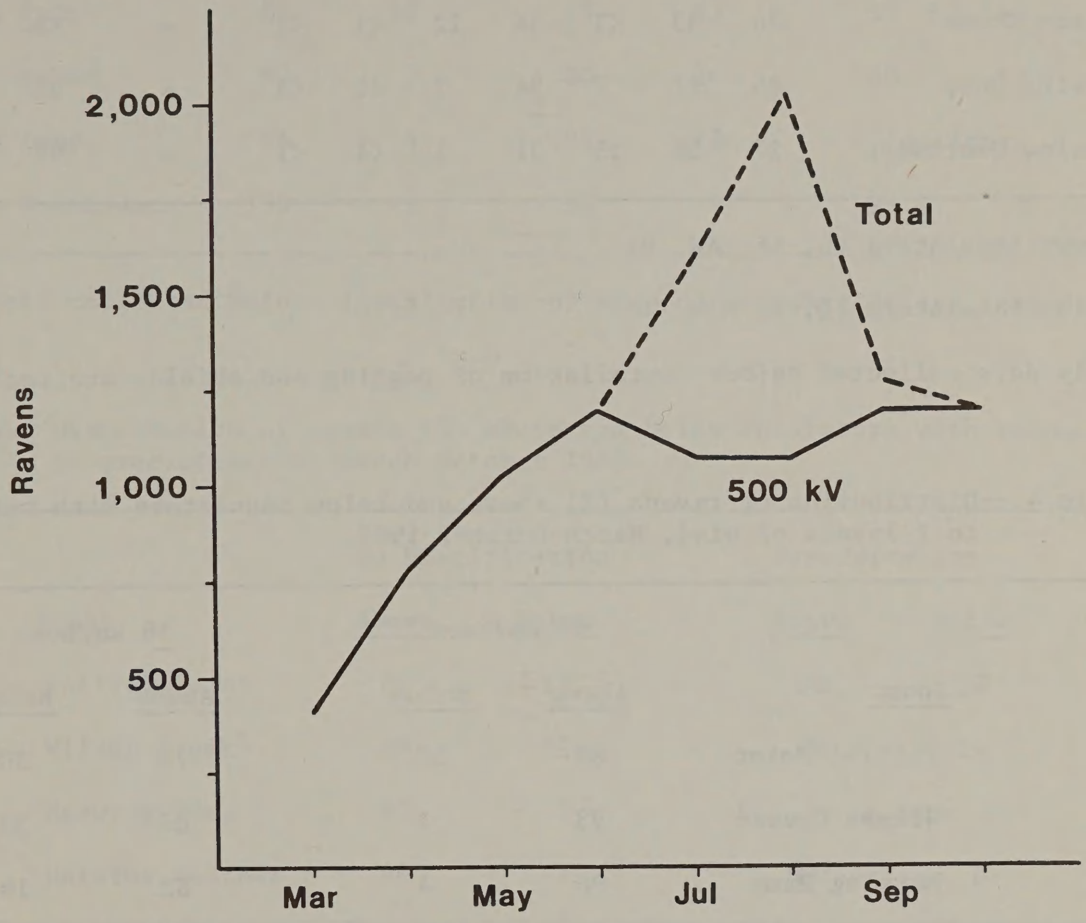


Fig. 14.--Total numbers of ravens roosting on the 500 kV line and within the study area, March-October 1985.

Table 3.--Distribution of ravens (%) among tower sections at the Initial Point, Wilson Creek, Marsing Dump, and Marsing Southwest roosts, March-October 1985.

Roost	C	AX	AW	B	D	W	E		Above[1]	Below[2]
Initial Point	23	25	2	33	15	1	2	=	83	17
Wilson Creek[3]	20	33	<1	34	12	<1	<1	=	88	12
Marsing Dump	25	27	7	34	7	<1	<1	=	93	7
Marsing Southwest	27	28	13	31	1	<1	<1	=	99	1

[1]Above insulators (C, AX, AW, B).

[2]Below insulators (D, W, E).

[3]Only data collected before installation of pegging and shields are included.

Table 4.--Distribution of ravens (%) above and below insulators with respect to 2 levels of wind, March-October 1985.

	<8 km/hour		≥8 km/hour	
Roost	Above	Below	Above	Below
Initial Point	88	12	70	30
Wilson Creek[1]	93	7	67	33
Marsing Dump	96	4	82	18
Marsing Southwest	>99	<1	96	4

[1]Only data collected before installation of pegging and shields are included.

Table 5.--Distribution of ravens (%) above and below insulators with respect to 3 levels of wind, March-October 1985.

Roost	<8 km/hour Above	<8 km/hour Below	8-15 km/hour Above	8-15 km/hour Below	≥16 km/hour Above	≥16 km/hour Below
Initial Point	88	12	77	23	57	43
Wilson Creek[1]	93	7	80	20	48	52
Marsing Dump	96	4	82	18	no data	
Marsing Southwest	>99	<1	96	4	95	5

[1]Only data collected before installation of pegging and shields are included.

Table 6.--Distribution of ravens (%) above and below insulators with respect to precipitation, March-October 1985.

Roost	No Precipitation Above	No Precipitation Below	Precipitation Above	Precipitation Below
Initial Point	83	17	70	30
Wilson Creek[1]	88	12	76	24
Marsing Dump	93	7	no data	
Marsing Southwest	99	1	100	0

[1]Only data collected before installation of pegging and shields are included.

Contamination

Trends in contamination scores were similar to trends in numbers of ravens (Table 7). Peak contamination scores at the Initial Point Roost were recorded in July and August (Table 7). The mean number of ravens roosting above insulators each night was significantly correlated with the mean contamination score, for the months that each tower was occupied (Spearman coefficient = 0.85, $P < 0.01$). To obtain this correlation, we discarded 1 pair of values that far outlay the rest of the data; however, the correlation was still significant when this pair of values was included (Spearman coefficient = 0.77, $P < 0.01$).

Evaluation of Pegging and Shields

Pegging and shields were installed at tower 131/4 on 2 July. Ravens had roosted there since 20 June, when installation was completed at all other towers at the roost. On the evening of 2 July, ravens repeatedly flew back and forth between their staging area and tower 131/4. Just before dark, all (16) ravens flew west, as a group, along the line. Between towers 131/5 and 132/1, they reversed their course and landed on the D section of tower 131/5, where they roosted. Ravens roosted predominantly on tower 131/5 until the roost was evacuated between 7 and 9 August.

Numbers of ravens using the Wilson Creek Roost had begun to decline before installation started (Fig. 8); this decline continued during the installation period (12 June to 2 July). Following installation, numbers steadily increased to a high of 154 birds on 26 July, then dropped off sharply as the roost was evacuated for the season.

Installation of pegging and shields altered ravens' use of tower sections. Before installation, most ravens (88%) roosted on upper sections (Table 8). On the 1st 3 nights following installation, all ravens roosted on the D section of tower 131/5, and during the 1st 5 watches following installation (2-16 July), few ravens (37%) roosted on the upper sections (Table 8). Ravens, however, gradually returned to upper sections. During the next 5 watches (19 July - 6 August), 76% of ravens roosted on upper sections (Table 8), and on 26 July, before numbers began to decline, 121 of 126 ravens roosting on tower 131/5 (96%) roosted on upper sections. Pegging appeared to be an effective perching deterrent. Even after most ravens had returned to upper sections, no ravens roosted on portions of the C sections that had been treated with pegging (Table 8). Use of the shield wires (AW) increased dramatically following installation (Table 8).

Pegging and shields appeared to prevent insulator contamination. From 2 July, when installation was completed, to 6 August, just before the roost was evacuated for the season, the contamination score of tower 131/5 dropped from 1.75 to 1.69, although an average of 45 ravens per night roosted above insulators. Large amounts of contamination accumulated on top of shields during this period. Tower 132/1 was the only other tower at the Wilson Creek Roost where ravens were known to roost above insulators following installation: 6 ravens were observed roosting above insulators on 26 July. The contamination score of tower 132/1 increased from 1.16 to 1.23 between 2 July and 6 August. However, it is likely that both this apparent increase and the slight decrease recorded for tower 131/5 reflect measurement error rather

Table 7.--Seasonal changes in contamination scores of selected towers at the Initial Point, Wilson Creek, and Marsing Southwest roosts, March-October 1985. Values represent the mean monthly contamination score for each tower (mean of the individual scores of all 150 insulator bells). Parenthetical values represent the mean monthly number of ravens roosting above insulators of the tower.

Tower	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Initial Point:								
108/3	2.6	3.4	3.8	3.5	4.3	3.8	2.8	2.7
	(86)	(142)	(118)	(109)	(93)	(0)	(0)	(0)
108/4	3.0	3.8	3.8	4.2	4.7	4.4	3.3	3.4
	(104)	(102)	(128)	(105)	(98)	(0)	(0)	(0)
Wilson Creek:								
131/3	1.0	1.7	1.6	2.0	1.7	1.7	1.1	1.1
	(30)	(28)	(27)	(13)	(0)	(0)	(0)	(0)
131/4		2.8	3.0	2.8	2.9	2.8	2.2	2.0
	(0)	(72)	(111)	(57)	(0)	(0)	(0)	(0)
Marsing Southwest:								
154/4	3.5	2.6	2.0	1.9	2.0	2.2	1.8	1.9
	(216)	(0)	(8)	(0)	(0)	(118)	(0)	(0)

Table 8.--Distribution of ravens (%) among tower sections at the Wilson Creek Roost, before and after installation of pegging and shields. "After 1" represents the 1st 5 watches made after installation (2-16 July); "after 2" represents the 2nd 5 watches (19 July - 6 August).

	C	AX	AW	B	D	W	E		Above[1]	Below[2]
Before	20	33	<1	34	12	<1	<1	=	88	12
After 1	0	24	2	11	63	0	0	=	37	63
After 2	1[3]	24	31	20	24	0	0	=	76	24

[1]Above insulators (C, AX, AW, B).

[2]Below insulators (D, W, E).

[3]All these ravens roosted on the shielded portion of the C section.

than actual changes in contamination levels.

Contamination did not dissipate as quickly from towers treated with pegging and shields as from untreated towers (Table 9). However, differences in dissipation rates between treated and untreated towers were not significant for either 1 mo or 2 mo intervals (Mann-Whitney; U's = 3.0, 5.0; P's = 0.15, 0.49). Hot-water washing significantly reduced contamination (Mann-Whitney, U = 8.0, $P < 0.01$), although substantial contamination remained on insulators after they had been washed (Table 10).

Movements and Habitat Use

Eleven ravens were captured during 70 days of trapping (Table 11). Ten ravens were captured with leghold traps, and 1 raven was captured with a rocket net. Capture success was higher with leghold traps (1 raven per 28.3 set hours) than with the rocket net (1 raven per 90.1 set hours) and was higher during spring than during summer and early autumn. Before 1 June we captured 7 ravens during 26 days, but after 1 June we captured only 3 ravens during 44 days. Before 1 June, we captured 1 raven per 12.3 set hours with leghold traps. This rate declined to 1 raven per 68.2 set hours after 1 June. Seven fledgling ravens were equipped with transmitters.

Eight ravens were equipped with AVM Solar M Modules, 8 were equipped with Wildlife Materials LPB-2750-LD's, and 2 were equipped with Telonics RB5's (Table 12). All 8 AVM Solar M Modules failed within 1 mo after they were fitted to ravens. It appeared that the solar recharging mechanism was inoperable: transmitters did not perform well after the initial charge in the battery dissipated. These transmitters functioned intermittently during midday and did not work at all in early morning, in late evening, or at night. This resulted in loss of many data. We were forced to drop the ravens equipped with AVM Solar M Modules from the tracking rotation in June, as soon as additional ravens were fitted with the other 2 types of transmitters. Subsequent locations of ravens equipped with AVM transmitters were obtained opportunistically, when observers read the coded wing markers of these birds during other work. Wildlife Materials LPB-2750-LD's functioned satisfactorily, but the relatively short range of these transmitters made tracking difficult. Telonics RB5's functioned well: range of these transmitters was much greater than those of the other 2 types of transmitters, and signal characteristics were excellent. This enabled observers to relocate these ravens more quickly than ravens equipped with the other 2 types of transmitters, after they had moved out of view. Even though these transmitters were fitted to ravens mid-way through the season, we obtained more locations from these birds than from any other transmitter-equipped ravens (Table 12).

From April to October, we obtained 1,094 locations of the 18 transmitter-equipped ravens. Sample sizes ranged from 1 to 215 locations per bird ($\bar{x}$ = 61 $\pm$ 62 locations) (Table 12). We observed transmitter-equipped ravens for a total of 520 hours. Observations ranged from 2.8 to 112.6 hours per bird ($\bar{x}$ = 34.7 $\pm$ 30.6 hours, N=15) (Table 12). Seven of the transmitter-equipped ravens are known to have died by the end of October (Table 12). Two of these birds were electrocuted on IPC distribution lines, 1 was killed by a golden eagle (*Aquila chrysaetos*), and the cause of death could not be determined for the other 4. Five of the 7 ravens that died were marked

Table 9.--Differences in contamination dissipation rates between treated and untreated 500 kV towers. Values represent change in the mean contamination score for each tower over 1 and 2 mo intervals. Parenthetical values represent mean contamination scores.

	TREATED				UNTREATED		
	0	+1 mo	+2 mo		0	+1 mo	+2 mo
131/3		-0.06	-0.83	111/1		-0.29	-0.70
	(1.78)	(1.72)	(0.95)		(1.68)	(1.39)	(0.98)
131/4		-0.15	-0.69	107/4		-0.96	-1.74
	(2.82)	(2.67)	(2.13)		(2.86)	(1.90)	(1.12)
131/5		-0.06	-0.26	107/3		-0.24	-0.34
	(1.75)	(1.69)	(1.49)		(1.37)	(1.13)	(1.03)
132/1		+0.07[1]	-0.33	107/2		-0.02	-0.54
	(1.16)	(1.23)	(0.83)		(1.19)	(1.17)	(0.65)
Mean		-0.05	-0.53			-0.38	-0.83
	(1.88)	(1.83)	(1.35)		(1.78)	(1.40)	(0.95)

[1]Apparent increase probably due to measurement error.

Table 10.--Effects of hot-water washing on contamination scores of towers at the Wilson Creek Roost. Values represent the mean contamination score for each string (mean of the individual scores of all 25 insulator bells).

	WASHED STRING			UNWASHED STRING		
Phase	Pre	Post	Net	Pre	Post	Net
131/3 N	2.08	1.04	-1.04	1.24	1.88	0.64
131/3 C	2.92	2.84	-0.08	2.68	3.08	0.40
131/3 S	1.04	0.88	-0.16	1.44	2.28	0.84
131/4 N	2.84	1.20	-1.64	3.36	2.64	-0.72
131/4 C	4.56	3.12	-1.44	4.52	4.28	-0.24
131/4 S	3.04	1.36	-1.68	2.00	2.00	0.00
131/5 N	2.52	2.52	0.00	1.44	1.40	-0.04
131/5 C	2.84	1.84	-1.00	2.76	3.00	0.24
131/5 S	2.32	1.48	-0.84	1.52	1.52	0.00
Mean	2.68	1.81	-0.77	2.33	2.45	0.12

Table 11.--Capture effort, April-October 1985.

Date	Time (Hours)[1]	Type (No. Sets)[2]	Bait	Ravens Captured
04-15-85	0530-1928 (13.97)	RN (1)	calf	0
04-16-85	0516-1929 (14.22)	RN (1)	calf	0
04-17-85	0514-0700 (1.77)	RN (1)	calf	0
04-18-85	0513-0730 (2.28)	RN (1)	calf	1
04-20-85	0510-1934 (14.40)	RN (1)	calf	0
04-24-85	0503-1939 (14.60)	RN (1)	calf	0
04-25-85	0502-1950 (14.80)	RN (1)	calf	0
04-25-85	0502-0645 (1.72)	LH (4)	mouse (4)	1
04-26-85	0535-0700 (1.42)	LH (3)	mouse (3)	1
04-27-85	0500-0736 (2.60)	LH (1)	mouse	0
04-29-85	0556-0920 (3.40)	LH (1)	mouse	0
04-30-85	0554-0635 (0.68)	LH (3)	mouse (3)	1
05-01-85	0553-1530 (9.62)	LH (1)	mouse	0
05-01-85	1610-2047 (4.62)	LH (1)	badger/mouse	0
05-02-85	0551-1245 (6.90)	LH (1)	badger	0
05-04-85	0600-0900 (3.00)	LH (1)	badger	0
05-05-85	1730-2120 (3.83)	LH (1)	lamb	0
05-06-85	0600-0630 (0.50)	LH (1)	lamb	1
05-07-85	0545-0940 (3.92)	LH (1)	lamb	0
05-07-85	1630-2054 (4.40)	LH (1)	lamb	0
05-08-85	0550-0940 (3.83)	LH (1)	lamb	0
05-09-85	0542-0635 (0.88)	LH (1)	pheasant	1
05-13-85	0537-1102 (5.42)	LH (1)	pheasant	1
05-15-85	0535-0730 (1.92)	LH (1)	pheasant	0
05-18-85	0532-0748 (2.25)	LH (1)		1
05-23-85	0528-0900 (3.53)	LH (1)	pheasant	0
06-02-85	0521-1000 (4.65)	LH (2)	mouse (2)	0
06-05-85	0600-1000 (4.00)	LH (1)	pheasant	0
06-07-85	0519-0945 (4.43)	LH (1)	pheasant	0
06-09-85	0519-0945 (4.43)	LH (1)	pheasant	0
06-11-85	0520-0900 (3.67)	LH (1)	none	0
06-12-85	0518-1000 (4.70)	LH (1)	pheasant	0
06-14-85	0518-0845 (3.45)	LH (2)	pheasant (1), eggs (1)	0
06-18-85	0518-0900 (3.70)	LH (1)	rabbit	0
06-20-85	0518-0900 (3.70)	LH (1)	rabbit	0
06-21-85	0518-1000 (4.70)	LH (1)	rabbit	0
06-25-85	0520-0915 (3.92)	LH (2)	pheasant (1), rabbit (1)	0
06-27-85	0520-0900 (3.67)	LH (1)	eggs	0
06-27-85	0520-0630 (1.17)	LH (2)	dog (1), rabbit (1)	1
06-29-85	0521-1200 (6.65)	LH (3)	calf (2), rabbit (1)	0
07-01-85	0522-0914 (3.87)	LH (2)	calf (1), mouse (1)	0

[1]Traps were considered to be operative 45 min before sunrise.

[2]LH = leghold trap, RN = rocket net.

Table 11 (continued).

Date	Time (Hours)	Type (No. Sets)	Bait	Ravens Captured
07-02-85	0523-0645 (1.37)	LH (1)	calf (1)	1
07-03-85	0523-0900 (3.62)	LH (1)	calf (2)	0
07-04-85	0524-0915 (3.85)	LH (1)	calf	0
07-07-85	0526-0915 (3.82)	LH (1)	pheasant	0
07-11-85	0529-0915 (3.77)	LH (1)	pheasant	0
07-12-85	0530-0900 (3.50)	LH (1)	calf (2)	0
07-19-85	0536-0930 (3.90)	LH (1)	pheasant	0
07-24-85	0540-0930 (3.83)	LH (1)	pheasant	0
07-26-85	0542-0930 (3.80)	LH (2)	pheasant (1), mouse (1)	0
07-28-85	0545-0930 (3.75)	LH (2)	pheasant (1), mouse (1)	0
07-29-85	0546-0930 (3.73)	LH (2)	pheasant (1), mouse (1)	0
07-31-85	0548-0900 (3.20)	LH (1)	pheasant	0
08-16-85	0605-0800 (1.92)	LH (1)	pheasant/mouse	0
08-17-85	0606-0800 (1.90)	LH (2)	pheasant (2)	0
08-18-85	0608-0810 (2.03)	LH (2)	pheasant (1), mouse (1)	0
08-19-85	0609-0830 (2.35)	LH (2)	rabbit (1), mouse (1)	1
08-20-85	0610-0800 (1.83)	LH (2)	rabbit (1), mouse (1)	0
08-21-85	0611-0800 (1.82)	LH (2)	rabbit (1), mouse (1)	0
08-23-85	0613-1030 (4.28)	LH (2)	rabbit (1), mouse (1)	0
08-29-85	0620-1000 (3.67)	LH (2)	eggs (1), mouse (1)	0
08-31-85	0622-0930 (3.13)	LH (2)	eggs (1), mouse (1)	0
09-30-85	0656-0930 (2.57)	LH (3)	rabbit (1), pheasant (1), mouse (1)	0
10-15-85	0714-0930 (2.27)	LH (1)	eggs	0
10-16-85	0900-1200 (3.00)	RN (1)	calf	0
10-17-85	0716-0945 (2.48)	LH (1)	eggs	0
10-21-85	0721-0945 (2.40)	LH (1)	elk scraps	0
10-28-85	0630-1000 (3.50)	LH (1)	grain	0
10-30-85	0633-1739 (11.10)	RN (1)	calf/rabbit/mouse	0
10-31-85	0634-0900 (2.43)	LH (1)	pheasant	0

Table 12.--Observation effort, transmitter-equipped ravens, April-October 1985.

Bird No.	Age[1]	Date Marked	Roost	Transmitter[2]	No. Locations[3]	Obsv. Hours
0	J	4 June	MSW	WMI	1*	0
1	A	18 April	MSW	AVM	80	13.8
2	S	25 April	WC	AVM	13	10.7
3	S	26 April	WC	AVM	29	5.9
4	A	30 April	WC	AVM	120	33.2
5	A	13 May	IP	AVM	1	0
6	A	18 May	IP	AVM	16	2.8
7	J	3 June	WC	WMI	28*	29.7
8	S	6 May	MD	AVM	47	11.3
9	J	10 June	IP	WMI	38	53.1
11	J	15 June	IP	WMI	57*	43.9
12	A	27 June	MD	TEL	199*	90.9
13	A	2 July	WC	TEL	215	112.6
14	S	19 August	MD	WMI	75	31.6
18	J	21 June	IP	WMI	39*	20.8
19	J	22 June	IP	WMI	1*	0
20	J	2 July	MD	WMI	109	48.6
99	S	9 May	MD	AVM	26*	11.2

[1]A = adult, S = subadult, J = juvenile (marked as a fledgling).

[2]AVM = AVM Solar M Module, TEL = Telonics RB5, WMI = Wildlife Materials LPB-2750-LD

[3]Starred (*) sample sizes indicate ravens that died during the study period.

as fledglings; only 2 of the 11 older birds are known to have died. Five of the 9 remaining older ravens are known to be alive and still in the study area. Movements and habitat use data have not yet been analyzed; they will be presented in the final study report.

Food Habits

Pellets collected between April and October have been analyzed; however, results have not yet been tabulated. These data will also be presented in the final study report.

DISCUSSION

Use of Roosts

No new roosts on the 500 kV line were located in the study area, although 2 new roosts were located on nearby IPC 138 kV lines. One roost on the 500 kV line that was occupied during the preceding 2 years was not occupied during 1985. Occupancy patterns were similar to previous years, although reoccupancy of the Initial Point Roost in early autumn contrasts with 1984. The Initial Point Roost remained the largest roost on the line, although fewer ravens were recorded at peak count than in 1984. The peak of 933 ravens recorded at the Marsing Southwest Roost is a new high for that roost. These ravens were concentrated on 3 towers in contrast to the Initial Point Roost, where the peak count of 1,075 ravens involved 14 towers.

Peak numbers of ravens roosting on the 500 kV line occurred during summer and autumn, although many ravens in the study area roosted on IPC 138 kV lines at this time. The 138 kV roosts may have compensated for the lower numbers recorded on the 500 kV line. The combined high for the 500 kV line and the 138 kV roosts (2,017) is similar to the 1984 high for the 500 kV line (2,289), and both high counts occurred in August. We do not know, however, whether or not large numbers of ravens roosted on the 138 kV lines during 1984.

Use of Tower Sections

Ravens usually roosted above insulators at all roosts; however, distribution of ravens above and below insulators, and among tower sections, varied among roosts. These differences are important in interpreting the contamination potential posed by a given number of ravens. The proportion of ravens roosting above insulators increased steadily from east to west, although no corresponding environmental variable that would influence distribution can be suggested. Winds and rain had the same effects we observed in 1984: fewer ravens roosted above insulators under these conditions. The proportion of ravens roosting above insulators at the Initial Point Roost (83%) was the same as in 1984.

Evaluation of Pegging and Shields

Pegging and shields appeared to be at least a short-term success. Ravens continued to use the Wilson Creek Roost after installation. The trends in numbers and distribution of ravens among tower sections are consistent with adjustment of ravens to the devices. Ravens did not roost on sections where pegging had been installed, and shields appeared to prevent contamination from reaching insulators. Pegging and shields did not significantly decrease natural dissipation of contamination.

Treating several towers adjacent to each end of the roost appears to have been important to the success of the operation. On the evening after installation was completed, ravens appeared to search for an untreated tower adjacent to their previous roost tower. If an untreated tower had been available nearby, they probably would have chosen it for roosting. Instead, when confronted with several more treated towers, they returned to their traditional roost location. At the Wilson Creek Roost, 9 towers on either side of the occupied towers were treated. We recommend several towers be treated on either side of any other roost at which pegging and shields are installed.

Similarly, working gradually from the ends of the 20-tower span toward the middle probably was important. If installation had started in the middle, at the occupied towers, ravens may have shifted farther and farther away from these towers as installation progressed. We recommend this pattern of installation be employed at any other roost where pegging and shields are installed. Not working within 2 hours of sunrise and sunset, and minimizing disruption in the vicinity of the roost may also have been important to the success of the operation. We recommend these procedures be followed if other roosts are treated.

Although ravens appeared to adjust to pegging and shields, success of these devices cannot be fully assessed until spring of 1986, when the roost is usually reoccupied for the season. Devices can be considered a complete success from a biological standpoint if ravens reoccupy the Wilson Creek Roost, avoid pegged tower sections, and are typically distributed among other tower sections; and if contamination does not increase.

Hot-water washing appears to be useful for removing large amounts of contamination; however, it does not restore insulators to clean condition. Post-washing contamination scores averaged 1.81, and a score of 3.12 was recorded for 1 string (Table 11). Contamination declines were highly variable, ranging from 0.00 (no decline) to 1.68 (Table 11).

1986 DATA NEEDS

Evaluation of pegging and shields should continue during 1986. The long-term success of these devices will be largely determined by whether or not ravens reoccupy the Wilson Creek Roost. Further observations of ravens' responses to pegging are also necessary. Surveys to locate occupied roosts and monthly coordinated roost watches should continue. These will allow us to monitor the roosting population and will increase data on occupancy of traditional roosts and seasonal trends in numbers. Telemetry work should also continue. As of October, there were relatively few transmitter-equipped ravens for which we had obtained a large number of locations (Table 2). This is largely due to the rapid failure of all AVM Solar M Modules that were fitted to captured ravens. We need to increase the number of transmitter-equipped ravens with large numbers of locations in order to draw the most accurate and powerful conclusions possible about habitat affinities.

Pellet collections should continue through April 1986. This will give us a full year of food habits data.

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TITLE: Behavior and Productivity of Nesting Prairie Falcons in Relation to Construction at Swan Falls Dam and Experimental Blasting

COOPERATORS: Idaho Power Company
Pacific Gas & Electric Company

INVESTIGATOR: Anthonie M A Holthuijzen, Principal Investigator

OBJECTIVES:

1. To evaluate the possible effect of construction and recreational activities on the behavior and productivity of nesting prairie falcons.

2. To establish a data base from which raptor management guidelines can be developed for industries and government agencies as well as for the BOPA.

SUMMARY

The objectives of this study were to: (1) continue monitoring the possible effects of construction and recreational activities in the Snake River Birds of Prey Area (BOPA) on the behavior and productivity of a nesting population of prairie falcons, and (2) determine the effects of experimental blasting on the behavior and productivity of nesting prairie falcons (Holthuijzen 1985). Construction in the Swan Falls area started on 13 May 1985 with the mobilization and delivery of equipment. However, heavy construction activities did not start until mid-June when the nesting season was almost over.

The study was conducted from March through June 1985. A total of 16 pairs of prairie falcons was observed; 12 in the BOPA (4 pairs exposed to construction activities, 4 to recreation and 4 control pairs) and 4 pairs outside the BOPA exposed to experimental blasting. Prairie falcons re-occupied 3 traditional nesting territories in the construction area, located 40-60 m above the new access road; 2 nesting territories remained vacant. Seven of 8 traditional nesting territories in the area exposed to recreational activities which were occupied every year from 1976 to 1978 were used in 1985. Two disturbance variables (people weighted by their activity, and traffic flows) were used to evaluate the effects on prairie falcon behavior during the nesting season. Sound levels were measured but not included in the analysis because they remained relatively constant over time. Associations between indexes of disturbance and behavioral variables were not found.

Behaviors of prairie falcons did not differ substantially among the 4 study locations. Traffic flows in the Swan Falls study location increased 2.4 times that recorded in the same period (March-June) in 1984. Falcons exposed to blasting showed a short instantaneous reaction to blasting (<2 min) and no substantial differences in their behaviors compared to falcon pairs not exposed to blasting. Productivity was similar among the 4 study locations. One pair nesting in the construction

area failed, but this may have been due to natural causes (predation), rather than to human disturbance. Estimated hatching dates did not differ significantly among the 4 study locations. Productivity in each of the study locations was within the range of productivity figures reported in the BOPA between 1973 and 1983.

INTRODUCTION

Continued Research at Swan Falls

The reconstruction of the Swan Falls hydroelectric power plant located in the Snake River Birds of Prey Area (BOPA), scheduled to take place from 1983 through 1987, prompted a cooperative agreement between the Idaho Power Company (IPC) and the Bureau of Land Management (BLM), Boise District, to evaluate the possible effects of industrial activities on the behavior and productivity of nesting prairie falcons (*Falco mexicanus*). Pacific Gas and Electric (PG&E) joined the cooperative effort in 1985. In most studies productivity of nesting raptor populations has been used to evaluate the possible effect of disturbance (Fraser 1984). However, in this study the behavior of the nesting falcons was investigated as well as productivity, because behavioral changes in the nesting falcons were likely to be detected prior to changes in productivity. The study, which was initiated in 1984, had 2 objectives: (1) to evaluate the possible effect of construction and recreational activities on the behavior and productivity of nesting prairie falcons, and (2) to establish a data base from which raptor management guidelines can be developed for industries and government agencies as well as for the BOPA. In 1985, construction activities in the Swan Falls area started on 13 May with the mobilization and delivery of equipment. Subsequently, access roads to the spillway were constructed, and work was started to remove the rocky point at the north side of the spillway (Appendix I). However, removal of the rocky knob and heavy construction activities associated with the building of the cofferdam were not started until mid-June. Thus, construction during the nesting season was relatively light, and heavy construction did not commence until approximately 80% of the nesting season had passed. The objective of the 1985 study in the Swan Falls area was to continue monitoring the possible effects of construction activities on the behavior and productivity of nesting prairie falcons.

Experimental Research at Reynolds Creek

During the 1984 study (Holthuijzen 1984) it became clear that an experimental approach would be desirable to evaluate the effects of specific disturbance activities on the behavior and productivity of breeding prairie falcons. In the 1985 field season this idea was realized with supplemental funding provided by PG&E. Blasting was chosen as an experimental manipulation because this activity was considered potentially most likely to show an impact on nesting falcons. Since blasting takes place frequently in construction projects, such investigations would provide valuable information to developers and regulatory agencies. The specific objectives of the experimental study were to: (1) investigate the instantaneous reaction of prairie falcons to blasting, (2) compare the behavioral repertoire of prairie falcons exposed to blasting (experimental group) to falcons not exposed to blasting (comparison or control group), and (3) compare productivity between falcons exposed to blasting to those which were not.

STUDY AREA

Three of the study locations, Swan Falls, Dedication Overlook and Tick Basin, were located in the Snake River Birds of Prey Area (BOPA; Fig. 1), which is administered by the Bureau of Land Management, Boise District. The BOPA is situated in the Western Intermountain Sagebrush Steppe Region (West 1983). Descriptions of the climate, vegetation and natural environment of the BOPA can be found in U.S. Department of the Interior (1979) and West (1983). The blasting experiment was conducted in the foothills of the Owyhee Mountains (Reynolds Creek), outside the BOPA (Fig. 1). The Reynolds Creek study location is approximately 650 m higher in elavation than the BOPA. The annual precipitation averaged 280 mm over a 20 year period (1962-1982; Hanson 1983), and the average annual temperature was 7.2°C as measured at the Reynolds Creek Agricultural Research Service station. In 1985 average monthly temperatures were approximately 3°C below normal for January, February and March at both Swan Falls and Reynolds Creek (Table 1). This situation reversed from April through June with average monthly temperatures 2-3°C above normal. Precipitation was below normal in spring and early summer. Thus, the weather during the spring and early summer was warmer than usual and relatively dry. In Reynolds Creek the average temperatures were about 5°C lower and precipitation was slightly higher than at Swan Falls. A detailed description of climate, vegetation and geology of Reynolds Creek can be found in Hanson (1983) and Stephenson (1977).

Research in 1984 showed substantial recreational activity in the Dedication Overlook study location (Holthuijzen 1984), which served as a control study location in the 1984 nesting season. In 1985, a new control study location was selected. Tick Basin is located approximately 4 km upstream from Swan Falls Dam and supports similar densities of nesting raptors as the latter location. Tick Basin is largely inaccessible to vehicles and is exposed to minimal human disturbance (M.N. Kochert, pers. commun.). Studies in the Dedication Overlook study location were continued to evaluate the possible effects of recreational activities on nesting prairie falcons.

METHODS

Disturbance Quantification

As in the 1984 field season, 4 measures of industrial and recreational activity were quantified: (1) sound levels (dB), (2) traffic flows (daily number of vehicles passing specific points), (3) heavy or noisy machinery (daily number of trucks over 2 tons or excessively noisy machinery passing through the study areas), and (4) recreational activity (number of daily visitors, their location and the activity they engaged in). Sound levels and traffic flows were

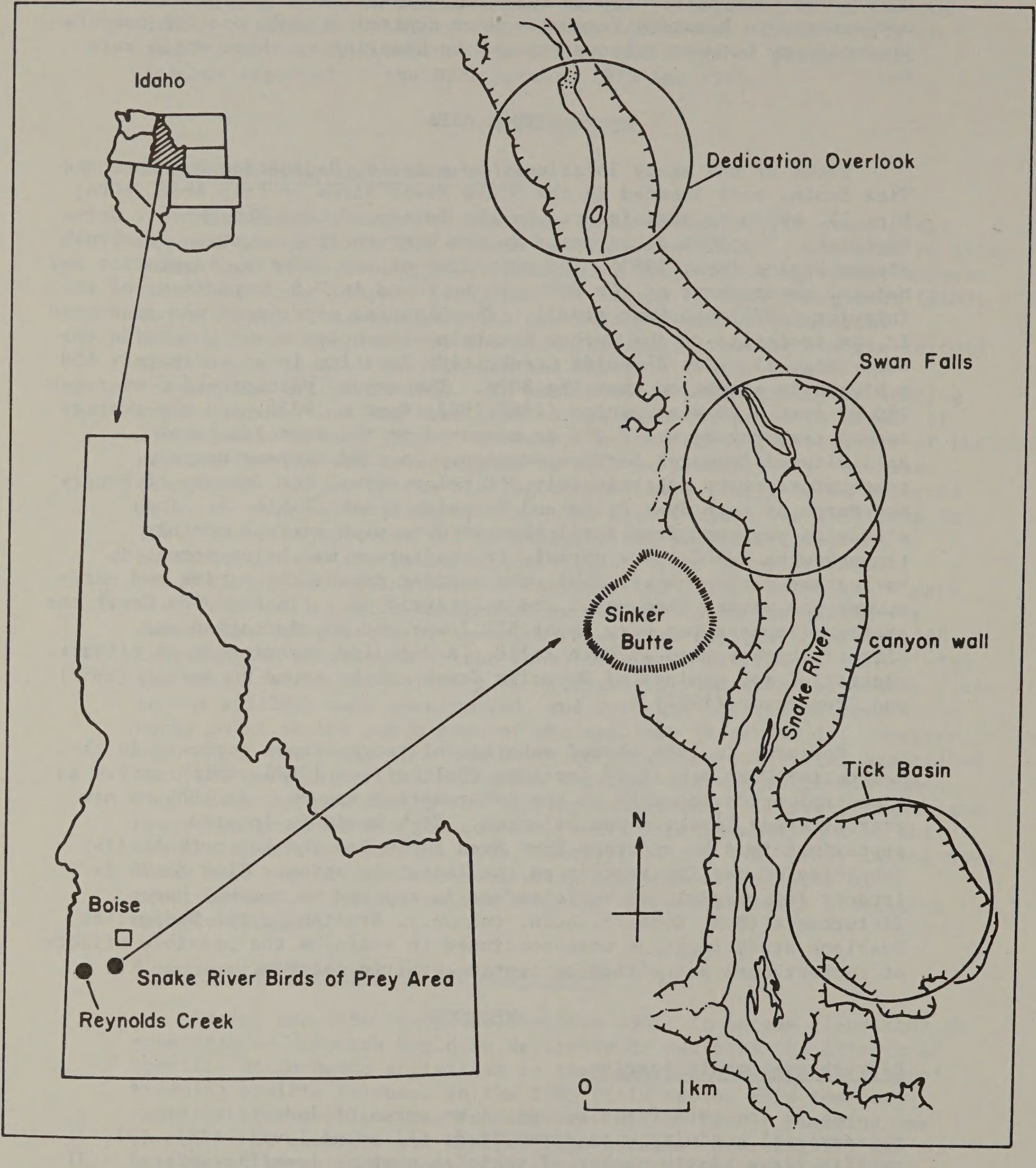

Fig. 1. Location of the study area.

Table 1. Weather information at Swan Falls and Reynolds Creek, January through June, 1985.

Swan Falls

Month	1985 Max (°C)	1985 Min (°C)	1985 Mean (°C)	1950–1980 Max (°C)	1950–1980 Min (°C)	1950–1980 Mean (°C)	1985 Precip. (mm)	1950–1980 Precip. (mm)
January	1.5	-9.4	-2.5	4.9	-3.6	0.7	6.5	22.3
February	4.7	-6.5	-0.9	9.5	-1.1	4.2	89.0	11.9
March	11.7	-1.6	5.1	14.3	1.0	7.7	14.7	15.0
April	23.6	5.9	14.7	19.7	4.6	12.2	8.2	22.3
May	27.3	9.1	18.2	25.5	9.2	17.2	30.0	25.6
June	33.7	13.3	23.5	30.1	13.4	21.8	9.2	22.6

Reynolds Creek

Month	1985 Max (°C)	1985 Min (°C)	1985 Mean (°C)	1964–1984 Max (°C)	1964–1984 Min (°C)	1964–1984 Mean (°C)	1985 Precip. (mm)	1962–1981 Precip. (mm)
January	0.3	-10.8	-5.3	2.9	-5.8	-1.5	2.0	36.0
February	2.8	-8.2	-2.7	6.0	-3.7	1.2	20.0	19.8
March	7.3	-4.7	1.3	9.2	-2.6	3.3	18.7	22.5
April	18.1	2.3	10.2	13.0	-0.2	6.4	14.5	25.3
May	21.4	5.3	13.4	19.1	3.9	11.5	47.2	22.0
June	26.5	5.2	15.9	24.0	8.0	16.0	7.5	32.5

determined only in the Swan Falls Dam and Dedication Overlook study locations. Sound levels were measured using an industrial noise dosimeter (Type 1954 Personal Noise Dosimeter, GenRad, Concord, Mass.). Sound level measurements (equivalent sound levels) were taken at the same locations as in the 1984 field season (Holthuijzen 1984; Fig. 3). Sampling intensity, however, was decreased from once every 6 days in 1984 to once every 10 days in 1985, until mid-May when construction started. Then, daily measurements ensued at the Swan Falls Dam weatherbox and at 3 blinds near Swan Falls Dam (Swan Dam North Side, Falcon Flats Fingers, and Ferry; Fig. 2).

Traffic flows were measured with traffic counters (Autocount Cumulative Counter, Highway and Traffic Data Systems, Golden River Corp., Rockville, Md) placed at (1) the Swan Falls access road, (2) 250 m upstream on the road parallelling the Snake River on the east bank, (3) 250 m downstream on the road parallelling the Snake River, (4) the road accessing the west side of the Snake River from Murphy, (5) the property line between BLM and IPC land downstream from the dam, (6) Priest Rapids, (7) Dedication Overlook, and (8) Three Poles Overlook (Fig. 2). Data were collected on a daily basis at all locations from late March through June, except at the traffic counter on the west side of the Snake River, which was checked every other day. In May a parking lot 400 m from the Dedication Overlook was constructed by the U.S. Army Reserves. The road leading to Dedication Overlook where the traffic counter was located was closed in late June. When this road was closed, the traffic counter was relocated to the entrance of the new parking lot. In late June and for the remainder of the year when weather permitted a weekly sampling interval was employed.

Heavy or excessively noisy machinery was recorded by observers in all study locations as in the 1984 field season (for details see Holthuijzen 1984).

In analyzing the traffic counter data, 2 periods were distinguished: (a) prior to 13 May when no construction took place, and (b) after 13 May when equipment was moved in. Traffic flows were calculated separately for weekdays and weekends because most recreational use of the Swan Falls area takes place during the weekends (Holthuijzen 1984). The 6 day work weeks during the first phase of the construction project (Appendix I) further complicated calculation of recreational traffic flows, particularly for Saturdays. Industrial traffic flows were calculated as follows. All traffic accessed the Swan Falls area along the Swan Falls access road. Recreational traffic flows directed either upstream or downstream were recorded at counters located 250 m upstream and downstream from Swan Falls Dam. Residential traffic flows remain relatively constant over time (Holthuijzen 1984). However, the residential traffic flow may have been slightly overestimated because some recreational vehicles would stop at Swan Falls Dam. Thus, construction traffic could be estimated by subtracting the recreational and residential traffic flows from the daily traffic flow entering the Swan Falls area along the Swan Falls access road.

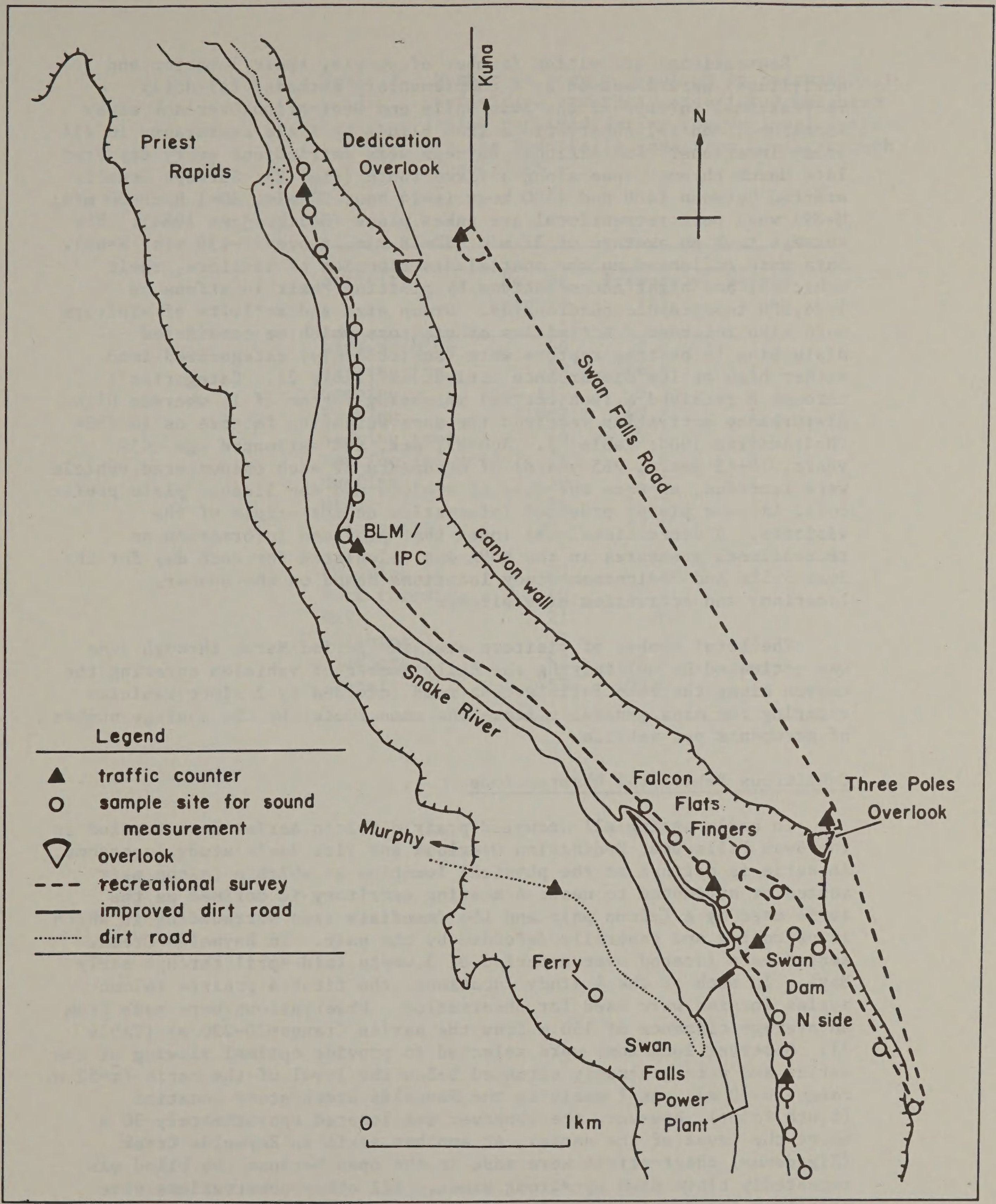

Fig. 2. Location of traffic counters, sample sites for sound measurements, and the recreational survey route.

Recreational activities (number of people, their location and activities) were assessed by 2 complementary methods: (a) daily recreational surveys of the Swan Falls and Dedication Overlook study locations, and (b) observations from blinds by field assistants in all study locations. Recreational surveys were carried out every day from late March through June along a fixed route (Fig. 2). Surveys usually started between 1400 and 1500 hour ($\bar{x}$=14 hour 30 min, SD=1 hour 20 min; N=89) when peak recreational use takes place (Holthuijzen 1984). The surveys took an average of 57 min (SD=18 min, range=27-139 min; N=86). Data were collected on the spatial distribution of visitors, their vehicles, and night accomodations by plotting their locations on 1:24,000 topographic quadrangles. Group size and activity of visitors were also recorded. Activities of visitors which we considered disturbing to nesting raptors were (subjectively) categorized into either high or low disturbance activities (Table 2). Categories 1 through 8 received a (subjective) weighting factor of 1, whereas high disturbance activities received the same weighting factors as in 1984 (Holthuijzen 1984; Table 7). Number, sex, and estimated age (<19 years, 19-65 years, >65 years) of occupants of each encountered vehicle were recorded, as were the type of vehicle and the license plate prefix code. License plates provided information on the origin of the visitors. A recreational use index that provided information on recreational pressures in the BOPA was calculated for each day for the Swan Falls and Dedication study locations based on the number, location, and activities of visitors.

The total number of visitors over the period March through June was estimated by multiplying the daily number of vehicles entering the canyon along the Swan Falls access road (divided by 2 since vehicles entering the area generally leave the same route) by the average number of occupants per vehicle.

Continuous Behavioral Observations

In early spring all occupied prairie falcon aeries were located in the Swan Falls Dam, Dedication Overlook and Tick Basin study locations. An aerie is defined as the physical location at which a falcon pair nested or attempted to nest. A nesting territory is defined as the aerie used by a falcon pair and the immediate area surrounding it which is patrolled and generally defended by the pair. In Reynolds Creek, aeries were located over a period of 3 weeks (mid-April through early May). In each of the 4 study locations, the first 4 prairie falcon aeries located were used for observation. Observations were made from an average distance of 150 m from the aeries (range=70-230 m) (Table 3). Observer locations were selected to provide optimal viewing of the aeries and were generally situated below the level of the aerie ($\bar{x}$=52 m, range=30-70 m). At 1 aerie in the Reynolds Creek study location (South Point), however, the observer was located approximately 30 m above the level of the aerie. At another aerie in Reynolds Creek (Zigadenus) observations were made in the open because the blind was repeatedly blown down by strong winds. All other observations were made from inside blinds or immediately next to the blinds.

Table 2. Number of people involved in recreational activities and their associated weighted value recorded during recreational surveys in the Swan Falls area from March through June, 1985.

Activity	No. of people	Frequency (%)	Weight
Birdwatching	66	2.7	1
Sightseeing	397	16.2	1
Camping	131	5.3	1
Fishing	1067	43.5	1
Boating (motor)	60	2.4	1
Boating (no motor)	15	.6	1
Outfitter	50	2.0	1
Other	606	24.7	1
Subtotal	2392	97.4	
Shooting	23	.9	3
Rock throwing	10	.4	2
ORV	21	.8	2
Climbing	7	.3	2
Subtotal	61	2.4	
Total	2453	100.0	

Table 3. Distances (m) from blinds and blasting points to prairie falcon aeries and modes of access to observation and blasting points.

Site	Distance blind to aerie (m)		Distance blasting point to aerie (m)	Mode of access
	1984	1985		
Three Poles	200	170	-	walking
Swan Dam N Side	225	190	-	walking
Ferry	140	146	-	walking
Falcon Fl.Fingers	250	177	-	walking
Priest Rapids I	250	230	-	walking;motorbike
Camera	-	137	-	motorbike;walking
PF I	155	-	-	motorbike;walking
PF II	190	173	-	motorbike;walking
Priest Upper	170	160	-	walking
Tick City	-	125	-	walking
Tick II	-	182	-	walking
Tick III	-	105	-	walking
Tick IV	-	135	-	walking
Halfway	-	70	125	walking
Trail	-	105	140	walking
Zigadenus	-	150	120	walking
South Point	-	137	125	walking
Mean	198	150	127	

Observational methods were the same as those used during the 1984 field season (Holthuijzen 1984). Observations started 30 min before sunrise and were terminated 30 min after sunset. An entire day was chosen as a sampling unit to avoid sampling problems related to daily behavioral cycles of the falcons (Altmann 1974; Fraser 1984). Each aerie was observed once every 6 days. An average of 13 (SD=1.5) days of observation were conducted at each aerie (range=10-15 days). Observations at an aerie were carried out by 2 observers working in 2 shifts of equal lengths (5-8 hours) to avoid observer fatigue and ensure data quality. Observers were systematically rotated through all observed aeries to minimize observer bias.

Observations started during the last week in March at the 3 BOPA study locations and in mid-April at Reynolds Creek. They continued until chicks were 35 days of age (early to late June). At each aerie an average of 1.6 (SD=1.2) days (range=0-4 days) of observations were made during pre-incubation, 5.4 (SD=1.6) days (range=4-6 days) during incubation, and 6.0 (SD=1.4) days (range=1-7 days) during brood-rearing. This amounted to an average of 193.4 (SD=22.1) hours (range=145-221 hours) per aerie and totalled 3087 hours for all aeries combined (Table 4). Unfamiliarity with the location of traditional aeries, difficult terrain, and unfavorable weather conditions in Reynolds Creek resulted in prolonged search efforts to locate the aeries. Consequently, observations started later and the total number of hours of observation in Reynolds Creek was lower than for any of the other 3 study locations.

At 1 aerie (North Point) in the Reynolds Creek area, observations were discontinued in favor of another aerie (Zigadenus) because falcons did not continue using the aerie frequented earlier in the season. The Ferry pair at the Swan Falls study location lost their chicks early during brood-rearing, but the nesting season had already progressed too far to shift observations to another aerie.

The nesting season was divided into 3 stages: pre-incubation, incubation and brood-rearing (see Holthuijzen 1984). Hatching dates were based on the estimated ages of chicks observed using a photographic aging key (Moritsch 1983). Laying dates were calculated based on a 34-day incubation period (Burnham 1983).

Separate records were collected for the male and female falcon forming a pair. Sex was determined in part by behavioral observations, such as position of the birds during copulations (reverse mountings have not been observed in prairie falcons (Evans 1982)), and food begging by the female. Individual variation in plumage pattern, and the larger body size of the female as compared to the male were also used for sex determination. Finally, a stylized drawing was made of the facial pattern and body of each bird. They were used as quick references by the observers. For each sex, behavioral information was collected continuously on the time (min) spent on pre-defined activities (Table 5 and Appendix II). The frequency and time at which patrols; copulations; prey deliveries, caches, and retrievals; and perch relocations occurred during an observation day were also recorded for each sex. Interactions between the territorial pair, conspecifics,

Table 4. Time spent observing prairie falcons during the 1985 nesting season.

Area	No. aeries	No. days	No. hours
Swan Falls	4	50	737
Dedication	4	56	831
Tick Basin	4	56	831
Reynolds Creek	4	45	688
Total	16	207	3087

Table 5. Behavioral categories used in continuous observations on prairie falcons during the 1985 nesting season.

Time period/day	Frequency/day	Plots
perching	patrol	perching distance to scrape
preening	aggressive encounter	
incubating	copulation	patrolling routes
brooding	prey delivery	
nest visit	prey caching	
flight-in-canyon	prey retrieval	
flight-out-of-canyon	re-location	
feeding (adult/chick)		

other birds and mammals were classified as aggressive, non-aggressive, or defensive interactions (Appendix II). Panoramic photographs taken of the section of the cliff where the aerie was located were used to map perching locations, patrolling routes, and encounters between the residential pair and other birds or mammals. Data on chick behavior were not collected because the chicks generally could not be observed inside the aeries.

Behavioral Reactions of Prairie Falcons to Blasting

Commonly observed behaviors of falcons (perching, incubating and brooding) were recorded continuously from a maximum of 30 min prior to a blast to a maximum of 30 min after a blast. The readjustment time was defined as the period it took for falcons to resume the behavior they had been engaged in immediately before the blast. Only observations when the birds were in the nesting territory at the time of the blast were included in analyses.

Blasting Procedures

Experimental blasting began as soon as the aeries of the falcons were located in Reynolds Creek. Blasts were conducted on a rock facing the aerie at an average distance of 127 m (range=120-140 m; Table 3). The falcons were exposed to the noise produced by the air blast and the accompanying shock wave. We used 167 g of Kinestik (Kinepak Inc., Lewisville, Texas) for each electrically detonated explosion. Post-season tests indicated that sound levels equalled those produced by 500 g of dynamite (t-test, $t=0.05$, $df=14$, $P=0.95$). Each aerie was exposed to a blasting sequence of 3 blasts a day at 3 hour intervals, which was repeated every other day. The blasting sequence was carried out at about the same time each blasting day and continued until the chicks were 35 days of age. Each aerie was exposed to an average of 90 ($SD=2$) blasts over an average period of 62 days (Table 6).

Observer Disturbance of Prairie Falcons

The possible effect of an observer on the prairie falcon pairs under observation was evaluated by comparing behavior of falcons before and during the approach of observers to blinds generally during the mid-day shift. We assumed that this was probably the time when the falcons were most likely disturbed by observers; in the morning the observers arrived at the blinds before sunrise and in the evening they left after sunset, when the birds generally were roosting. Data were usually collected from outside the blinds from early May through the remainder of the nesting season. A change in behavior of a falcon under observation during the approach of an observer was considered a reaction to an approaching observer.

Data Analysis

A similar approach was taken in data analysis as with the 1984 data (Holthuijzen 1984). Comparisons of prairie falcon behaviors in the 4 study locations were conducted on the basis of the approximate developmental stage of either eggs or chicks (i.e., pre-incubation

Table 6. Number of blasts per aerie and average time of blasting (hours and min) in Reynolds Creek, 1985.

Blast no.	Aerie			
	Halfway	Trail	Zigadenus	South Point
1	8:46±33	7:20±40	8:56±54	7:59±30
2	11:49±38	10:22±43	11:57±57	11:01±36
3	14:53±41	13:20±40	14:55±61	14:06±38
Total blasts	90	91	87	92
Blasting days	30	31	29	31

stage, days -15, -9, -3; incubation stage, days 3, 9, 15, 21, 27, 33; brood-rearing stage, days 39, 45, 51, 57, 63 and 69).

For each aerie, observation day and sex the total amount of time engaged in pre-defined behaviors was calculated. Direct comparisons of behaviors expressed in absolute time (min) among study locations cannot be made since the daily observation period increased during the study period from approximately 12 to 16 h. Therefore, the percentage of the daily observation time spent on each behavior was calculated per aerie and sex. Percentage data were subjected to an arcsine-square root transformation to stabilize the variance and to conform the data to the normality assumption which is required for parametric tests (Sokal and Rohlf 1981). The frequency at which specific behaviors occurred for each developmental day was calculated per aerie and sex.

Two disturbance variables were evaluated for their possible effects on behaviors of adult prairie falcons: (1) daily number of visitors in the Swan Falls and Dedication Overlook study locations, weighted by their activities (Table 2), and (2) daily traffic flows. The total number of visitors (weighted by their activities) recorded in the Swan Falls and Dedication Overlook study locations was used as a variable for daily visitor use in both study locations. Daily traffic flows for the Swan Falls study location were approximated using traffic flows measured at the Swan Falls access road and for the Dedication Overlook study location at the border between BLM and IPC land (Fig. 2). Sound level measurements were not used because these values remained relatively constant over time in both study locations. Also, construction did not start until late May which precluded the usefulness of sound measurements as a disturbance variable. Information on heavy or excessively noisy machinery passing through both areas could not be used because it has not yet been automated. However, because the use of heavy machinery did not take place until late May this information may not be of great relevance.

Factor analyses were conducted with behavioral data on male and female falcons expressed as percentages of the total observation time per day (e.g., percent of day perching and preening), or number of occurrences per day (e.g., patrols, copulations) and disturbance variables. Iterative principal factor analysis was used. The basic factor matrix was rotated using an oblique rotation (promax) to seek a simple structure and to describe each factor with a minimum number of variables (Dillon and Goldstein 1984). Oblique rotation was chosen because factors are isolated regardless of the degree of correlation among factors. In orthogonal rotation only uncorrelated factors can be isolated. Factor analysis was carried out for exploratory, not confirmatory resasons, to investigate possible associations among disturbance variables and behaviors of the falcons. A short explanation of common factor analysis is found in Appendix VII.

Differences in behaviors of either male or female prairie falcons among study locations were investigated using stepwise discriminant analysis.

All statistical analyses were carried out using the Statistical Analysis System (SAS Institute Inc. 1982). Variation is expressed as standard deviations, except when otherwise indicated. Tests were evaluated at the 0.10 level of significance.

RESULTS

Disturbance

Sound levels

Sound levels were highest along the Swan Falls access road (49.6±9.5 dB; N=62), followed by sound levels upstream and downstream from Swan Falls Dam (47.2±10.0 dB; N=166) and the Dedication Overlook study location (47.0±9.9 dB; N=148). However, none of these locations differed significantly (ANOVA, F=1.66, df=2 and 373, P=0.19). There was no change in sound levels over time either along the Swan Falls access road, around Swan Falls Dam, or in the Dedication Overlook study location (significance level regression coefficients $0.12<P<0.63$).

Sound levels at the Official Weather Box of the National Weather Service averaged 57.9 (SD=9.1; N=15) dB over the period 27 March through 20 June when construction took place. In blinds at Falcon Flats Fingers, Swan Road North Side, and Ferry aeries, equivalent sound levels averaged 77.8 (SD=20.8; N=5) dB, 53.0 (SD=11.1; N=3) dB, and $<$20 dB, respectively (N=2). Sound levels measuring $<$20 dB near Swan Falls Power Plant, and at blinds at Falcon Flats Fingers, and Swan Dam North Side were not included in the above calculations (N=3, 2, and 4, respectively). The high equivalent sound levels at Falcon Flats Fingers may be caused by the configuration of the cliff at this site which may funnel and thereby reinforce sound levels. However, possible sound measurement equipment malfunctioning make the usefulness of the data questionable.

Traffic Flows

Prior to construction, weekday traffic averaged 113.9 vehicles/day, and weekend traffic averaged 301.6 vehicles/day (Table 7). During construction (including Saturdays), weekday traffic flows increased to 258.5 vehicles/day and averaged 405.2 vehicles/day on Sundays. Three Poles Overlook attracted a consistently higher (1.5 times) volume of traffic than the Dedication Overlook. Traffic flows to Dedication Overlook remained relatively constant over time, in spite of construction of a parking lot by the U.S. Army Reserves. Recreational traffic flows downstream were on the average 2.8 times higher than upstream. An average of 22.6(±16.0)% of the total traffic flow into the Swan Falls area passed the Priest Rapids counter (Fig. 2). These visitors may have continued to Halverson Lake, although this could not be substantiated because traffic flows were not monitored beyond Priest Rapids. Prior to 13 May a considerable percentage of the visitors going downstream concentrated in the area between Swan Falls Dam and BLM land. After 13 May a larger percentage of visitors ventured farther downstream. This may have been caused by 2 factors: (a) the area between Swan Falls Dam and BLM land was saturated, i.e.,

Table 7. Traffic flows (vehicles/day) estimated in the Swan Falls area from March through June, 1985.

	Prior to construction						During construction					
	Weekday			Weekend			Weekday			Weekend		
Location	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Swan Rd	113.9	63.5	45	301.6	134.6	19	258.5	91.8	37	405.2	57.5	6
Dedication	10.1	7.8	41	29.7	20.2	17	17.2	14.5	37	34.7	13.1	6
Three poles	12.8	8.4	38	56.9	21.1	16	21.6	14.3	37	49.8	16.8	6
Local	74.4	52.6	45	167.0	123.6	19	74.4	-	-	74.4	-	-
Construction	-	-	-	-	-	-	151.3	85.5	37	0.0	-	-
Upstream	8.2	6.0	45	32.7	17.0	19	10.9	9.2	37	27.3	13.1	6
Downstream	33.3	23.7	45	101.9	53.6	19	21.9	24.2	37	48.9	39.4	6
IPC/BLM	10.4	9.9	41	35.9	22.4	17	15.8	14.0	37	62.7	6.2	6
Priest Rapid	7.7	6.5	41	20.6	15.9	17	6.0	5.8	37	20.0	11.9	6
Swan Rd W S	2.0	2.0	18	4.4	4.0	11	3.0	2.0	37	4.7	2.7	6

there were only a limited number of parking spaces available which filled up due to the large influx of visitors, and (b) prime fishing shifted downstream (S. Addington, pers. commun.). Traffic flows on the west bank of the river were negligible compared to those on the east bank (Table 6). Traffic flows on the east bank of the Snake River averaged 179.1 vehicles/day on weekdays and 326.5 vehicles/day on weekends over the period March through June.

Recreational Survey

Only 2.4% of the visitors were involved in what we considered high level disturbance activities, with shooting as the main activity (0.9%), followed by off-road vehicle use (0.8%). Fishing (43.5%) was the main low level disturbance activity followed by the category "other" activities (24.7%; predominantly people driving in vehicles) and sightseeing (16.2%). Only 2.7% of the visitors were actively involved in bird watching. Most vehicles carried Idaho plates (94.4%); the majority from Ada (68.5%) and Canyon (15.7%) counties (Table 8). Out-of-state license plates comprised 5.6% of all recorded vehicles (14 states), with those bordering Idaho contributing the highest percentages of out-of-state plates: Utah 36.2%, Oregon 22.4% and Washington 10.3% (Table 8).

There were an average of 2.1 (SD=2.3; N=1181) persons per vehicle (Table 9), including 1.6 adults/vehicle, 0.4 children/vehicle and 0.1 persons older than 65 yr/vehicle. Sixty-five percent of all visitors were males. The number of visitors entering the BOPA over the period March through June was estimated at 15,000 for weekdays and 9,000 for weekends, totalling 24,000 visitors (rounded to the nearest 1,000). This represents a 2.4-fold increase from the same period in 1984 (Holthuijzen 1984). However, in both 1984 and 1985 residential and construction traffic was included in the figures. Additional traffic counters in 1985 made it possible to obtain estimates on local and construction traffic flows. When the total traffic flow into the Swan Falls area was corrected for construction and residential traffic a more realistic visitor number was calculated. The number of visitors was estimated at 3,000 and 5,000 for weekdays and weekends, respectively, totalling 8,000 visitors entering the BOPA from March through June in 1985.

Associations Between Disturbance and Behavior Variables

When behavioral data expressed in percentages were analyzed, 4 factors were extracted for female and 5 for male falcons (Table 10). Three of these factors extracted for the female were common factors (i.e., with at least 2 significant loadings per factor) and the remaining 1 was unique (i.e., with only 1 significant loading per factor). Three common factors were obtained for the males, and the remaining 2 were unique. None of the common factors extracted for either the male or the female showed associations between disturbance and behavioral variables.

The first common factor for the male falcon indicated presence of the bird either inside or outside the canyon. Association between

Table 8. Origin of vehicles based on license plates recorded during the recreational surveys in the Swan Falls area from March through June, 1985.

County	Number of cars	% of total	State	Number of cars	% of total
Ada	672	68.5	California	3	5.6
Canyon	154	15.7	Colorado	3	5.1
Boise	19	1.9	Michigan	1	1.7
Twin Falls	17	1.7	Missouri	2	3.4
Owyhee	14	1.4	North Dakota	1	1.7
Valley	12	1.2	Nebraska	1	1.7
Adams	12	1.2	New Mexico	1	1.7
Elmore	11	1.1	New York	2	3.4
Other counties	(28)	1.7	Oklahoma	1	1.7
			Oregon	13	22.4
			Texas	2	3.4
			Utah	21	36.2
			Washington	6	10.3
			Wisconsin	1	1.7
Subtotal	980	94.4	Subtotal	58	5.6

Table 9. Number of persons in vehicles recorded during recreational surveys in the Swan Falls area from March through June, 1985.

Occupant	Mean	SD	N
Adult	1.6	2.0	1181
Retired	0.1	0.5	1181
Child	0.4	0.9	1181
Total	2.1	2.3	1181
Male	1.3	1.5	1181
Female	0.7	1.2	1181

Table 10. Factor matrix for disturbance parameters and behaviors of male and female prairie falcons (behaviors expressed as percentages of total observation time/day), field season 1985.

	Male					Female			
	Factor Loadings					Factor Loadings			
Variables	I	II	III	IV	V	I	II	III	IV
People	0.08	0.80	-0.05	-0.19	-0.10	<0.01	0.97	0.01	0.07
Traffic	0.21	0.71	0.04	-0.21	0.04	0.20	0.59	-0.08	0.07
Perching	-0.04	-0.27	-0.15	0.90	-0.24	0.73	0.05	0.34	0.02
Preening	-0.52	-0.23	-0.25	0.03	-0.05	-0.07	0.09	-0.20	0.91
Incubation/ brooding	-0.67	0.01	-0.21	-0.56	-0.32	-0.86	<0.01	-0.77	0.30
Canyon flight	0.15	-0.03	<-0.01	0.27	0.90	0.55	0.03	0.13	-0.03
Out-of-canyon	0.91	0.22	-0.28	-0.01	0.14	0.29	-0.06	0.93	-0.20
Out-of-sight	0.12	0.04	0.99	-0.08	<-0.01	0.45	0.17	0.06	-0.09
Perched out-of-sight	-0.36	0.01	-0.19	0.02	-0.05	-0.01	-0.04	-0.08	0.01

traffic flows and the number of visitors counted during during recreational surveys was shown in the second common factor. This is not surprising because these 2 variables were highly correlated (Appendix II). The remaning common factor indicated an association between behaviors in the aerie (incubation or brooding) and out of the aerie (perching). The 3 common factors for the females provided similar results. The first and third common factor presented an association between behaviors inside versus outside the aerie. Again, traffic flows and number of visitors were associated (second factor).

Five factors were extracted for both male and female falcons for behavioral data expressed in frequencies (Table 11). Four common factors were found for the male as well as the female; the remaining factors were unique. Again, disturbance variables were not associated with any of the behavioral variables. Associations were found between the 2 disturbance variables (first and second common factor for males and females, respectively). Behaviors expressing territorial behavior (patrolling and aggression) were associated (second and fifth factor for male and female, respectively). The third common factor for the male also may express territorial behavior, because aggressive behavior was associated with relocations and flights in the canyon; activities that may suggest a higher than usual level of excitement. The remaining (fifth) common factor for males suggested typical pre-incubation behavior; the falcons copulated frequently and inspected potential aeries. The first and third common factor for the female may express the relationship among behaviors associated with prey deliveries. Prey deliveries were associated with flights in the canyon and repeated relocations. Prey may be delivered directly to the aerie by either the male or the female, or to the female by the male. This may explain extraction of 2 common factors for the female expressing similar behavioral associations. In conclusion, factor analyses showed absence of association between behavioral and disturbance variables.

<u>Behavioral Differences of Falcons Among the Study Locations</u>

Although differences were found for some behaviors expressed as percentages among the 4 study locations, discrimination was poor as exhibited by the consistently low average squared canonical correlation coefficients (ASCC) ($0.09 < ASCC < 0.12$, for the "best" models; Table 12). Canonical correlations are analogous to ordinary simple correlation coefficients. Thus, ASCC values close to 1 would suggest substantial differences in behaviors among the 4 study locations and values close to 0 minor differences. The low ASCC values found for behaviors of the falcons among the 4 study locations suggested that differences in behaviors of the falcons in the 4 study locations were minor. Similar results were found when the above analyses were carried out with behavioral data based on frequencies (Table 13). Again, differences were found for some behaviors, but discrimination among breeding groups of falcons could not be detected ($0.10 < ASCC < 0.15$; Table 13).

A separate analysis was conducted with behavioral data collected at the Ferry aerie in the Swan Falls study location, failing shortly after hatching of the eggs. Behaviors of both sexes of falcons at the Ferry aerie were compared with behavioral observations recorded in the

Table 11. Factor matrix for disturbance parameters and behaviors of male and female prairie falcons (behaviors expressed as number of occurrences/day), field season 1985.

	Male					Female				
	Factor Loadings					Factor Loadings				
Variables	I	II	III	IV	V	I	II	III	IV	V
People	0.68	-0.02	-0.01	-0.11	-0.06	-0.07	0.65	-0.12	0.02	0.06
Traffic	0.85	-0.11	0.11	-0.20	-0.06	0.13	0.87	0.03	-0.02	-0.04
Patrolling	-0.09	0.92	0.16	0.09	0.04	0.01	0.13	-0.11	-0.01	0.31
Aggression	0.12	0.36	0.53	0.26	-0.08	0.08	0.01	0.03	-0.03	0.97
Copulation	<-0.01	-0.09	-0.10	0.16	0.47	0.02	-0.01	0.05	0.99	-0.03
Canyon-flight	-0.01	0.01	0.77	0.28	0.10	0.51	0.12	0.47	-0.01	0.19
Relocation	-0.20	0.11	0.41	0.96	0.30	0.61	-0.05	0.53	0.04	0.07
Nest visits	-0.09	0.15	0.15	0.20	0.75	0.91	0.03	0.29	0.01	0.02
Prey delivered	-0.03	-0.23	0.11	0.03	0.11	0.36	-0.06	0.94	0.05	0.02

Table 12. Stepwise discriminant analysis to evaluate differences in behaviors (expressed as percentages of total observation time/day) among prairie falcon pairs in the 4 study areas for incubation and brood-rearing stages, field season 1985.

	Incubation						Brood-rearing					
	Male			Female			Male			Female		
Behavior	R^2	F	P	R^2	F	P	R^2	F	P	R^2	F	P
Perching	0.08	2.62	0.05	0.04	1.23	0.30	0.16	5.91	<0.01	0.09	3.30	0.02
Preening	0.02	0.58	0.62	0.24	8.89	<0.01	0.20	7.72	<0.01	<0.01	0.11	0.94
Incubation	0.01	0.40	0.75	0.03	0.88	0.45	-	-	-	-	-	-
Brooding	-	-	-	-	-	-	0.03	1.16	0.01	0.01	0.35	0.79
Canyon flight	0.05	1.60	0.19	0.04	1.16	0.32	0.14	5.03	0.08	0.08	2.67	0.05
Out-of-canyon	0.14	4.46	<0.01	0.08	2.63	0.05	0.05	1.77	0.03	0.03	1.06	0.36
Out-of-sight	0.12	3.92	0.01	0.13	4.10	<0.01	0.06	2.24	0.06	0.06	2.10	0.10

ASCC male (incubation)=0.04 ("best" model ASCC=0.12)
ASCC male (brood-rearing)=0.08 ("best" model ASCC=0.12)
ASCC female (incubation)=0.06 ("best" model ASCC=0.09)
ASCC female (brood-rearing)=0.03 ("best" model ASCC=0.09)

Table 13. Stepwise discriminant analysis to evaluate differences in behaviors (expressed as counts/day) among prairie falcons in the 4 study areas for the incubation and brood-rearing stages, field season 1985.

	Incubation						Brood-rearing					
	Male			Female			Male			Female		
Behavior	R^2	F	P	R^2	F	P	R^2	F	P	R^2	F	P
Nest visits	0.03	1.06	0.37	0.03	0.91	0.44	0.06	2.10	0.10	0.16	2.37	0.12
Patrolling	0.10	3.08	0.03	0.02	0.77	0.51	0.10	3.57	0.01	0.21	0.77	0.38
Aggression	0.09	2.84	0.04	0.15	4.96	<0.01	0.08	2.71	0.04	0.05	4.64	0.03
Copulation	0.01	0.30	0.82	0.17	0.49	0.69	0.07	2.46	0.06	0.07	0.10	0.74
Relocation	0.01	0.46	0.70	0.09	2.91	0.03	0.19	7.21	<0.01	0.16	0.01	0.88
Feeding adult	0.05	1.69	0.17	0.09	2.88	0.04	0.09	3.06	0.03	0.04	2.24	0.14
Feeding chick	-	-	-	-	-	-	0.04	1.46	0.22	0.03	1.00	0.32
Prey deliveries	0.09	2.81	0.04	0.03	1.14	0.35	0.08	2.68	0.05	0.01	0.06	0.80
Prey cached	0.12	3.89	0.01	-	-	-	0.02	0.68	0.56	-	-	-
Prey retrieved	0.06	1.85	0.14	0.01	<0.01	0.99	0.10	3.57	0.01	<0.01	0.17	0.91

ASCC male (incubation)=0.04 ("best" model ASCC=0.15)
ASCC male (brood-rearing)=0.06 ("best" model ASCC=0.10)
ASCC female (incubation)=0.05 ("best" model ASCC=0.14)
ASCC female (brood-rearing)=0.07 ("best" model ASCC=0.10)

control group (Tick Basin) using stepwise discriminant analysis as outlined above. In general, no substantial differences were found in behaviors between the Ferry and the Tick Basin aeries for either of the sexes (0.15<ASCC<0.63; Appendix IV). Further investigation of the behavioral repertoire of the Ferry pair compared to the Tick Basin pairs failed to reveal apparent deviations from "normal" behavior. For example, percent incubation per day averaged 44.6(±15.1)% for the Ferry female and 59.2(±13.3)% for the Tick Basin females; for the male at Ferry incubation averaged 45.6(±8.2)% compared to 36.9(±13.0) for the male falcons at Tick Basin (Appendix V).

Behavioral Responses of Prairie Falcons to Blasting

Readjustment Time

The average readjustment time of falcons to blasting was 1.86±3.20 min (N=180) (Table 14). Readjustment times were not significantly different among the 4 aeries or between sexes (ANOVA, F=0.83, df=3 and 145, P=0.48, and F=1.06, df=1 and 145, P=0.30, respectively). However, the readjustment time was shorter for the brood-rearing stage (1.53±1.64 min; N=79) than for the incubation stage (2.12±4.0; N=101) (ANOVA, F=5.98, df=78 and 100, P<0.0001; Table 14).

The reaction to blasting was further evaluated by type of pre-blasting behavior, i.e., perching (N=100), incubating (N=64), brooding (N=11), preening (N=2), flight-in-canyon (N=5), and feeding (N=3) compared to post-blast behavior (Fig. 3). Perched birds usually reacted to blasting by a short flight in the canyon (78%), followed by perching, but many (21%) remained perched after the blast. Incubating birds continued incubating (43.7%), briefly sat up and continued incubating (20.3%), or made a short flight in the canyon (2.7±2.8 min; N=23), and returned to the aerie and resumed incubation (36%). Brooding falcons continued brooding in 9 of 11 instances (81.8%). In the 2 remaining instances the brooding falcons flew out of the aerie (18.2%) but returned within minutes (3.5±0.7 min) and resumed brooding. Preening birds (N=2) remained perched or flew off and circled in the canyon. Flying birds (N=5) either perched after the blast (N=1), continued flying (N=2), or disappeared out of view (N=2). In 3 instances the birds were feeding when blasting took place; they either temporarily discontinued feeding, flew off and circled in the canyon, or flew off and disappeared out of view.

Habituation

Habituation is here defined as the waning of a response to a repeated activity (Marler and Hamilton 1966). Readjustment time regressed on day of the nesting season decreased over time (b=-0.02, $P(|t|>1.66)=0.09$), which may suggest habituation (Fig.4). On a daily basis habituation could not be detected for readjustment times among either the 3 sequential blasts or between breeding stages (2 way-ANOVA, F=2.49, df=2 and 146, P=0.08; F=1.80, df=1 and 146, P=0.18, respectively).

Table 14. Readjustment time (min) of prairie falcons to blasting in Reynolds Creek, 1985.

Stage	Mean	SD	N
Incubation	2.12	4.01	101
Brood-rearing	1.53	1.64	79
Overall	1.86	3.20	180

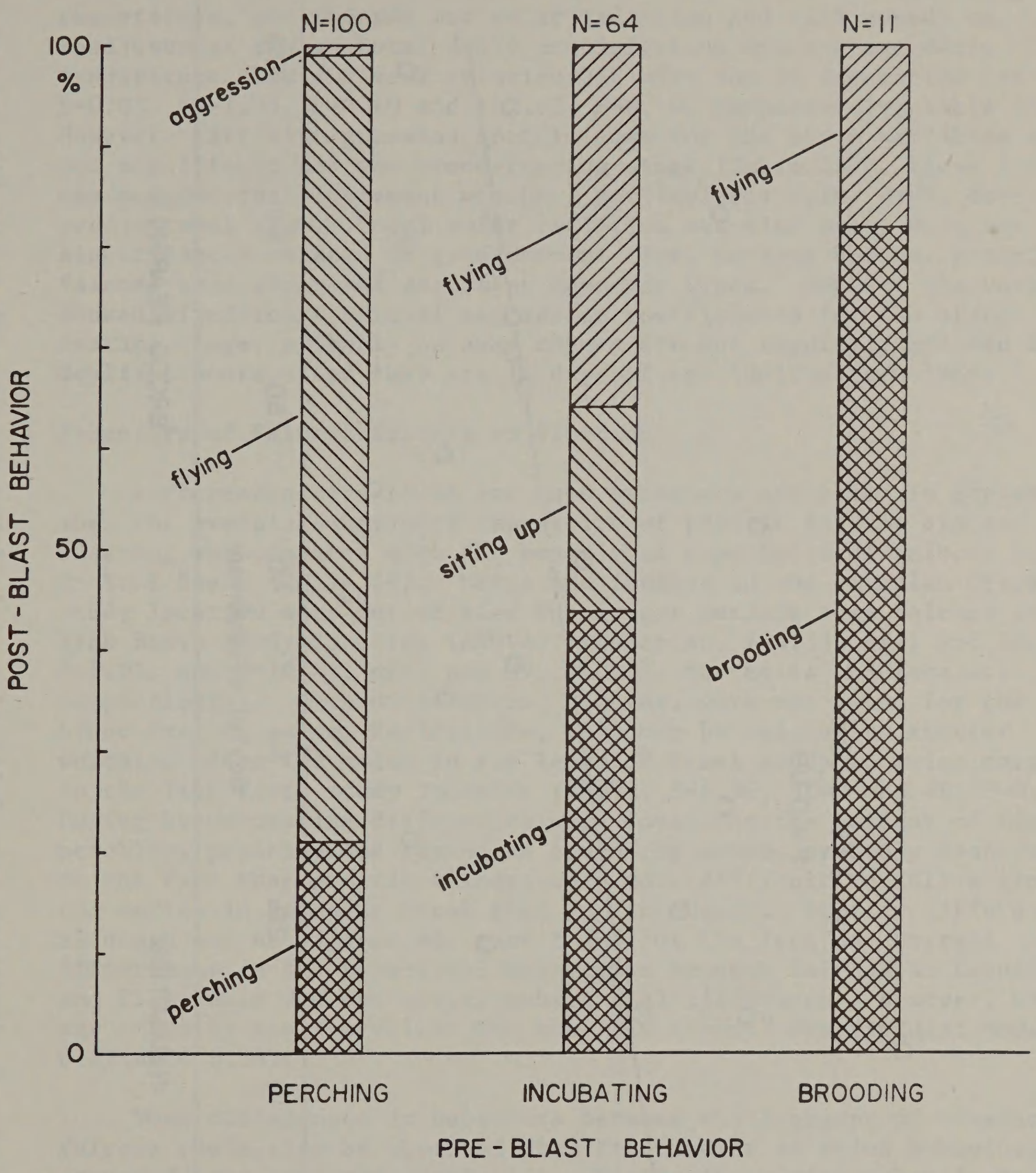

Fig. 3. Behavioral responses to experimental blasting by prairie falcons which were either perched, incubating, or brooding prior to blasts in the Reynolds Creek study location.

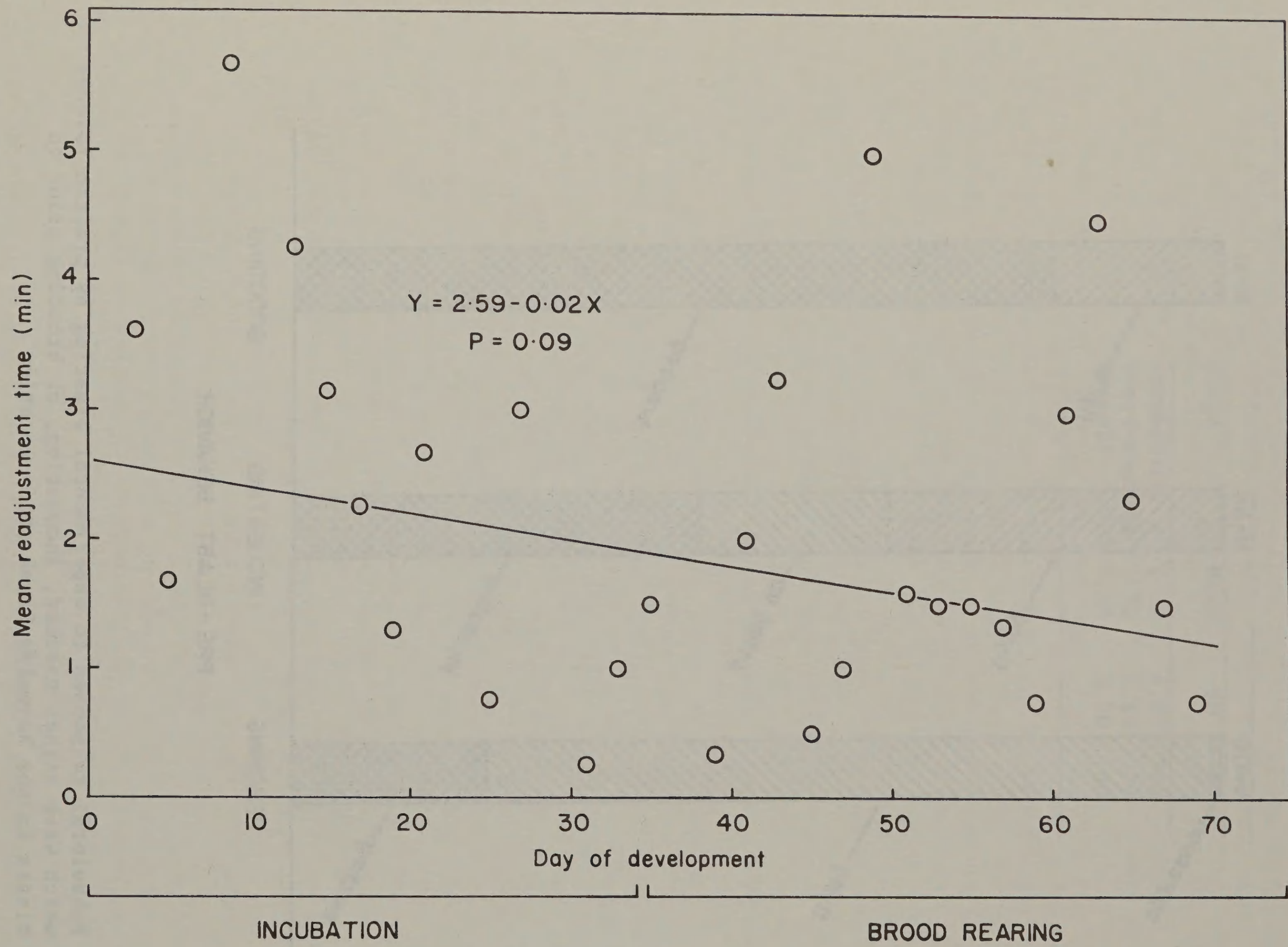

Fig. 4. Readjustment time (min) of prairie falcons regressed on the time period over which the falcons were exposed to blasting.

Weather

The possible effect of weather conditions on readjustment time was investigated by regressing day of incubation or brood-rearing and major weather variables (i.e., total daily precipitation, average daily temperature, and indexes for solar radiation and wind speed) on readjustment time. Total daily precipitation and average daily temperature showed a weak relationship with day of incubation (t=-2.09, P=0.03, t=-1.65, P=0.10 and t=1.62, P=0.10, respectively; Table 15). However, partial regression coefficients for the above variables were not significant for the brood-rearing stage (Table 15). These results may suggest that inclement weather, particularly rainy days, decreases readjustment time. Total solar radiation and wind speed were not significantly related to readjustment time, perhaps because prairie falcons used sheltered aeries at Reynolds Creek. None of the variables showed significant partial regression coefficients for the brood-rearing stage, probably because chicks are not regularly brooded during daylight hours after they are 14 days of age (Holthuijzen 1984).

Behaviors of Falcons Exposed to Blasting

Differences were found for some behaviors expressed in percentages when the overall behavioral repertoire of prairie falcons exposed to blasting was compared with the behavioral repertoire of falcons nesting in Tick Basin (Table 16). Males and females in the Reynolds Creek study location were out of view for longer periods than falcons in the Tick Basin study location (ANOVA, incubation, F=4.53, df=1 and 39, P=0.03, and F=10.42, df=1 and 39, P<0.01, for males and females, respectively). Such differences, however, were not found for the brood-rearing stage. Furthermore, this may be related to shorter perching times for males in the Reynolds Creek study location compared to the Tick Basin study location (ANOVA, F=4.96, df=1 and 49, P=0.03). During brood-rearing differences were found for the percent of time perching, preening and flying in canyon by males, probably also related to the fact that prairie falcons were more difficult to follow around the aeries in Reynolds Creek than in Tick Basin. Similar differences, although not as pronounced, were found for the females. Overall differences in the behavioral repertoire between falcons in Reynolds and Tick Basin did not reveal substantial differences, however, which was shown by the low values for the ASCC ("best" discriminant models 0.21 < ASCC < 0.36).

Some differences in behaviors between the 2 groups of breeding falcons could also be observed when frequencies at which behaviors occurred were compared (Table 17). During incubation males in Reynolds Creek patrolled less frequently and engaged in fewer aggressive interactions with other birds or mammals than males in Tick Basin (F=4.41, df=1 and 30, P=0.04, and F=5.80, df=1 and 39, P=0.02, respectively). Such differences were not found for the females.

During brood-rearing the frequency of aggressive interactions was lower for both males and females in Reynolds Creek than for falcons nesting in Tick Basin (F=6.55, df=1 and 49, P=0.01, and F=4.64, df=1 and 49, P=0.03, respectively). These differences were relatively

Table 15. Multiple regression analysis relating readjustment time of prairie falcons to blasting, day of incubation or brood-rearing and weather variables, calculated separately for the incubation and brood-rearing stages.

Variable	Incubation			Brood-rearing		
	Estimate[1]	t(b=0)	P>|t|	Estimate	t(b=0)	P>|t|
Intercept	-3.53	-0.82	0.41	-0.69	-0.35	0.72
Day	-0.08	-2.09	0.03	<-0.01	-0.25	0.80
Precipitation	-32.77	-1.65	0.10	0.68	0.05	0.95
Average temp.	0.08	1.62	0.10	0.03	0.91	0.36
Solar radiation	0.002	0.72	0.47	<-0.01	-0.20	0.84
Wind speed	0.01	1.31	0.19	<0.01	1.03	0.30

[1] Partial regression coefficient

Table 16. Stepwise discriminant analysis to evaluate differences in behaviors (expressed as percentages of total observation time/day) between prairie falcons in the control (Tick Basin) and treatment areas (Reynolds Creek) for incubation and brood rearing-stages, field season 1985.

	Incubation						Brood-rearing					
	Male			Female			Male			Female		
Behavior	R^2	F	P	R^2	F	P	R^2	F	P	R^2	F	P
Perching	0.11	4.96	0.03	<0.01	0.17	0.67	0.08	4.34	0.04	0.08	4.46	0.03
Preening	0.03	1.11	0.29	0.05	2.37	0.13	0.10	5.59	0.02	<0.01	0.43	0.51
Incubation	<0.01	0.05	0.82	<0.01	0.05	0.81	-	-	-	-	-	-
Brooding	-	-	-	-	-	-	0.04	2.54	0.11	0.02	0.97	0.32
Nest visit	0.05	2.29	0.13	-	-	-	<0.01	0.02	0.88	0.03	1.97	0.16
Flying	<0.01	0.01	0.91	<0.01	0.13	0.71	0.09	4.95	0.03	0.09	4.90	0.03
Out-of-canyon	0.01	0.70	0.40	0.04	1.85	0.18	<0.01	0.44	0.51	<0.01	0.21	0.64
Out-of-sight	0.10	4.53	0.03	0.21	10.42	<0.01	0.03	1.75	0.19	0.02	1.28	0.26

ASCC male (incubation)=0.112 ("best" model ASCC=0.359)
ASCC male (brood-rearing)=0.131 ("best" model ASCC=0.168)
ASCC female (incubation)=0.210
ASCC female (brood-rearing)=0.090 ("best" model ASCC=0.250)

Table 17. Stepwise discriminant analysis to evaluate differences behaviors (expressed as counts/day) between prairie falcons in the control (Tick Basin) and treatment areas (Reynolds Creek) for incubation and brood-rearing stages, field season 1985.

	Incubation						Brood-rearing					
	Male			Female			Male			Female		
Behavior	R^2	F	P	R^2	F	P	R^2	F	P	R^2	F	P
Nest visits	0.06	2.84	0.09	-	-	-	<0.01	<0.01	0.96	0.04	2.37	0.12
Patrolling	0.10	4.41	0.04	0.02	0.86	0.35	0.04	2.36	0.13	0.01	0.77	0.38
Aggression	0.12	5.80	0.02	0.05	2.06	0.15	0.11	6.55	0.01	0.08	4.64	0.03
Copulation	0.02	0.85	0.36	0.03	1.43	0.23	<0.01	0.18	0.66	<0.01	0.10	0.74
Relocation	<0.01	0.30	0.58	0.04	1.63	0.20	0.14	8.36	<0.01	<0.01	0.01	0.88
Feeding adult	<0.01	<0.01	0.94	<0.01	0.24	0.62	0.06	3.51	0.06	0.04	2.24	0.14
Feeding chick	-	-	-	-	-	-	0.04	2.19	0.14	0.02	1.00	0.32
Prey deliveries	<0.01	0.07	0.78	0.02	1.05	0.31	0.02	1.05	0.31	<0.01	0.06	0.80
Prey cached	0.08	3.52	0.06	<0.01	0.23	0.63	<0.01	0.21	0.64	0.10	5.82	0.01
Prey retrieved	<0.01	<0.01	0.99	<0.01	<0.01	0.97	0.11	6.56	0.01	<0.01	0.09	0.75

ASCC male (incubation)=0.129 ("best" model ASCC=0.370)
ASCC male (brood-rearing)=0.145 ("best" model ASCC=0.361)
ASCC female (brood-rearing)=0.106 ("best" model ASCC=0.268)

minor, however, indicated by the low ASCC values (ranging from <0.01 to 0.37).

Behavioral Responses of Prairie Falcons to Observers

Behavioral data collected on prairie falcons while observers approached blinds were used to answer 3 specific questions: (1) did prairie falcons respond to approaching observers, i.e., did behavioral changes take place and which were those behavioral responses?, (2) did different modes of approach (i.e., walking or a combination of riding on a motorbike and walking) elicit different responses?, and (3) did the distance the blinds were placed affect the behavior of the birds during approach of an observer? A change in behavior of a falcon under observation during the approach of an observer was considered a reaction to the observer. An exception was made for those instances when birds changed their behavior from perching to preening which was not considered a response to an approaching observer. In general, falcons showed little or no observable response to an approaching observer (no response in 156 out of 172 instances, or 90.7%; Table 18). Responses between male and female falcons were not different (χ^2=0.15, df=1, $P(\chi^2>0.15)>0.25$). Changes in behavior that were recorded may not necessarily have been related to the approaching observer, e.g., a change from preening to perching, or a nest exchange (Table 19).

With 1 exception, none of the blinds were accessed along a route which took the observer closer to the aerie than distances at which the blinds were located. At 1 aerie (Tick City) the observer came closer than the distance from the blind to the aerie (135 m), but was shielded from view by a ridge until the observer reached the bottom of the canyon. In 1985, 13 out of 16 blinds were accessed by foot; the remaining 3 were accessed by motorbike, and walking the last 30-100 m (Table 1). Responses from the birds did not differ among means of access to the blinds, either by walking, or a combination of riding and walking (χ^2=0.19, df=1, $P(\chi^2>0.19)>0.25$; Table 20). The behavior of the falcons when approached was apparently not affected by the distance at which observations were conducted, as was suggested by the non-significant (negative) relationship between the percent of approaches which elicited a behavioral response and the distance from the blinds to the aerie ($t=-1.71$, $P(|t|>1.71)=0.11$, $R^2=0.17$). Thus, the data did not support the hypothesis that observer approaches may have influenced the behavior of the falcons.

The question remained whether the observed changes in behavior could be considered "normal" or a response to observer activity. This was investigated by examining the distribution of behavioral changes through time. A function was developed from the total number of behavioral changes per observation day recorded from May through June. This function fitted a Poisson distribution function (χ^2=30.24, $P(\chi^2>30.24)>0.99$) (Table 21). Based on this function it can be expected that 13.1% of all behavioral changes will occur in the time interval between 0 and 7.5 minute (Table 21). Observers were in view of the falcons during an observer exchange approximately 8 min. Thus, the 9.3% behavioral change which was found conformed to the expected rate of behavioral change.

Table 18. Behavioral change (%) observed in prairie falcons upon approach of a blind by an observer.

Sex	No change	Change	N
Male	91.9 (57)	8.1 (5)	62
Female	90.0 (99)	10.0 (11)	110
Both sexes	90.7 (156)	9.3 (16)	172

Table 19. Behavioral reactions of prairie falcons upon approach of a blind by an observer.

Activity	No change	Change in Behavior
Perching	68	2 (flight-in-canyon)
Brooding	28	1 (flight-in-canyon)
		1 (perching)
Preening	22	2 (flight-in-canyon)
		2 (perching)
Incubating	11	1 (flight-in-canyon)
Flight-in-canyon	9	1 (aggression)
		2 (flight-out-canyon)
Feeding chick	6	0
Relocation	4	1 (perching)
Aggression	3	1 (flight-out-canyon)
		1 (perching)
		1 (aggression)
Out of view	3	0 (perching)
Feeding adult	2	0
Total	156	16

Table 20. Behavioral change (%) observed in prairie falcons upon approach of a blind by an observer using different modes of transportation. N denotes the number of approaches.

Transport	No change	Change	N
Motor biking and walking	92.5 (37)	7.5 (3)	40
Walking	90.2 (119)	9.8 (13)	132
Overall	90.7 (156)	9.3 (16)	172

Table 21. Frequency distribution of the number of behavioral changes per hour in prairie falcons over the period May through June, 1985.

x_i	f_i	$P(x_i)$	F_i	X_i
0	1	0.009	2.0	0.5
1	17	0.04	9.0	7.1
2	35	0.10	22.6	6.8
3	46	0.15	33.9	4.3
4	36	0.18	40.7	0.5
5	38	0.17	38.4	<0.1
6	19	0.13	29.4	3.7
7	13	0.09	20.3	2.6
8	12	0.05	11.3	<0.1
>8	9	0.08	18.3	4.7

N=226, $\bar{x}$=4.7 changes/hour, SD=2.3 changes/hour ($P(D>0.089)<0.01$, i.e non-normal distribution).

$\chi^2 = 30.24$
$\chi^2_{1,225} = 163.79$, thus distribution is Poisson distributed.
$P(X_i>6)=0.131$, thus 13.1% of the behavioral changes can be expected to occur in the time interval $0<T<7.5$ min.

Productivity and Occupancy

Productivity, i.e., the number of chicks reaching 30 days of age or more per aerie, was similar among the 4 study locations (Kruskal-Wallis χ^2=2.85, df=3, P(χ^2>2.85)=0.41) (Table 22). Comparison of productivity between the 1984 and 1985 breeding seasons failed to show differences (t-test, t=-1.09, df=27, P(|t|>1.09)=0.28). Hatching dates also were not different among the 4 study locations (Kruskal-Wallis χ^2=4.94, df=3, P(χ^2>4.94)=0.17, Table 22). On the average, chicks in Reynolds Creek hatched latest (Julian day 138±6.5) and falcons at Swan Falls earliest (Julian day 128±6.2). Hatching dates were not different between the 1984 and 1985 nesting seasons (Wilcoxon 2-sample test z=-0.429, P(|z|>0.429=0.66).

In the Dedication Overlook study location 7 of 8 nesting territories which were occupied every year from 1976 to 1978 were used in 1985 (Appendix VI). Overall occupancy rate was 58% as in 1984 (Holthuijzen 1984).

In the Swan Falls study location the Swan Road Turn nesting territory was not occupied; this nesting territory has been vacant at least 1 other time between 1973 to 1984 (occupancy data not available for 1975, 1980, and 1981 (Appendix VI). The Balls Basin Powerline nesting territory was vacant again in 1985. Occupancy rate in the Swan Falls area was 66.7% in 1985 as compared to 83% in 1984 (Holthuijzen 1984).

Behavior of Falcons During the Breeding Season

Daily Behavioral Repertoire

Both males and females spent a considerable amount of time perching during the pre-incubation stage, females more so than males (45.6±18.3 and 22.0±13.2%, respectively; Table 23). A few days prior to egg-laying the female was largely inactive and spent much of the day (45.6±18.3%) perched near the aerie (egg-laying lethargy; Newton 1979), or inside the aerie (an average of 19.9% of the time). Little time was spent flying, and the male supplied most of the food. The female incubated an average of 60.6(±14.8)% of the day and the male 35.5(±14.9)%. Females spent longer periods outside the canyon during incubation (11.8±14.6% of the day) compared to the pre-incubation stage (3.5±6.3% of the day), although considerable variation existed among pairs. During brood-rearing the males almost doubled the time outside the canyon (from 26.0 to 51.6% of the day), whereas females did most of the brooding during the first 2 weeks.

Generally, the female was observed during incubation and brood-rearing as the last bird on the aerie at dusk. The male generally was observed at a roost or flew out of view and was assumed to be roosting. Thus, it was likely that the female probably incubated the eggs or brooded the small chicks during the night as was found in the 1984 nesting season (Holthuijzen 1984). Similar observations were made by Ratcliffe (1980) on peregrine falcons. Females brooded an average of 23.4% of the day and males 2.6%. Females gradually increased the time

Table 22. Productivity of prairie falcons in the 4 study locations, 1985.

Location	No. chicks	Hatching date	Julian date
Swan Falls			
Swan Dam Three Poles	4	05/07	127
Swan Dam North Side	4	05/09	129
Ferry	0	05/17	137
Falcon Flats Fingers	4	05/02	122
Mean	3.0±2.0		128.7±6.2
Dedication Overlook			
Priest Rapids I	4	05/18	138
Camera	4	05/10	130
PF I	5	-	-
PF II	5	05/02	122
Priest Upper	5	05/10	130
Dedication Point	1	-	-
Mean	4.0±1.5		130.0±6.5
Tick Basin			
Tick City	4	05/16	136
Tick II	4	05/06	126
Tick III	1	05/13	133
Tick IV	5	05/09	129
Mean	3.5±1.7		131.0±4.4
Reynolds Creek			
Halfway	5	05/10	130
Trail	4	05/17	137
Zigadenus	2	05/26	146
South Point	<3	05/19	139
Mean	3.25±1.5		138.0±6.6

Table 23. Behavioral time allocation (behaviors expressed as proportions of total daily observation time) for male and female prairie falcons (16 pairs) during (A) pre-incubation, (B) incubation, and (C) brood-rearing.

A. Pre-Incubation

	Male				Female			
Behavior	Mean	SD	Range	N	Mean	SD	Range	N
Perching	22.0	13.2	0.6-59.7	26	45.6	18.3	1.8-74.3	26
Preening	5.7	4.9	0.0-17.7	26	8.6	5.6	0.0-26.0	26
In scrape	4.1	7.6	0.0-29.2	26	19.9	20.8	0.0-65.2	26
Flight-in-canyon	1.8	1.7	0.0- 6.5	26	1.2	1.7	0.0- 8.0	26
Out-of-canyon	39.7	17.1	2.2-69.1	26	3.5	6.3	0.0-23.0	26
Out-of-view	10.0	13.2	0.0-61.3	52	6.0	9.1	0.0-60.4	52

B. Incubation

	Male				Female			
Behavior	Mean	SD	Range	N	Mean	SD	Range	N
Perching	7.8	7.3	0.0-45.0	86	8.9	8.2	0.0-50.0	86
Preening	7.6	5.8	0.0-22.1	86	7.0	5.6	0.0-26.0	86
Incubating	35.3	14.9	0.0-75.9	86	60.6	14.8	16.4-99.6	86
Flight-in-canyon	1.1	1.0	0.0- 5.0	86	0.8	1.1	0.0- 6.2	86
Out-of-canyon	26.0	15.7	0.0-67.9	86	11.8	14.6	0.0-68.4	86
Out-of-view	9.8	12.2	0.0-69.6	172	4.0	7.2	0.0-41.2	172

C. Brood-rearing

	Male				Female			
Behavior	Mean	SD	Range	N	Mean	SD	Range	N
Perching	13.9	9.4	0.0-42.8	95	24.7	17.8	0.9-82.9	95
Preening	5.1	4.8	0.0-20.8	95	4.7	4.4	0.0-22.6	95
Brooding	2.6	5.9	0.0-36.8	95	23.4	32.4	0.0-90.8	95
Flight-in-canyon	1.6	1.2	0.0- 7.0	95	1.5	1.5	0.0- 6.4	95
Out-of-canyon	51.6	17.8	0.0-89.2	95	24.5	23.5	0.0-76.2	95
Out-of-view	11.2	14.8	0.0-97.0	190	6.7	10.6	0.0-59.0	190

spent outside the canyon during brood-rearing, averaging 24.5% of the day over the entire period.

Aggression

The number of aggressive interactions was significantly affected by study location, breeding stage and nesting pair (ANOVA, $F=13.74$, $df=1$ and 395, $P<0.01$; $F=10.74$, $df=1$ and 395, $P<0.01$; and $F=8.36$, $df=15$ and 395, $P<0.01$), but not by sex ($F=1.18$, $df=1$ and 395, $P=0.27$). The largest number of aggressive interactions per day, both intra- and interspecific, occurred in the Dedication Overlook study location (4.2±4.0; N=112), followed by Tick Basin (3.6±3.9; N=112), Swan Falls (3.4±3.0; N=100), and Reynolds Creek (1.6±1.6; N=90). The number of aggressive interactions was lowest for falcons nesting at Reynolds Creek compared to the other study locations (Duncan multiple range test, $P<0.05$). This may be due to lower breeding densities of prairie falcons and other raptors in Reynolds Creek. As the incubation stage progressed females spent increasingly longer periods incubating; they were particularly tenacious in their incubation activities just before the estimated hatching date (day 33). Consequently, they spent less time outside the aerie and were less frequently involved in territorial defense. The presence of newly hatched (or hatching) chicks apparently triggered a sharp increase in territorial defense activities by the male (Fig. 5). The males also rapidly increased the number of prey deliveries per day to the aerie; also, the percent of time spent outside the canyon increased (51.6%). This may account for the continued decline in aggressive interactions during brood-rearing. The number of aggressive interactions gradually increased again towards the end of the brood-rearing stage and peaked at day 69. This may be related to fledging of chicks from the observed aeries as well as from other nearby nesting territories.

Prey Delivery Rates

The total number of prey items delivered per day to the aerie by each sex was calculated as the number of prey items brought to the aerie either freshly killed or retrieved from caches subtracted by the number of prey items cached per day in the nesting territory (Fig. 6). Low numbers of prey items were brought to the aerie by both sexes during both the pre-incubation and incubation stages. Males supplied some, but not all of the prey items to the females during this period. Then, during brood-rearing the number of prey deliveries increased dramatically and levelled off after the chicks were about 4 weeks old (Fig. 6). Females spent significantly shorter periods of the day outside the canyon when the numbers of prey items delivered to the aerie by the male increased (partial $b=-35.3$, $t=-2.56$, $P(|t|>2.56)=0.01$). However, day of the nesting season prior to brood-rearing did not affect the females' presumed hunting activities (partial $b=0.98$, $t=1.25$, $P(t>1.25)=0.21$).

The average number of prey items delivered to the aerie per day significantly increased with brood size, as estimated by the number of chicks older than 21 days (partial $b=1.0$, $t=4.27$, $P(t>4.27)=0.0001$),

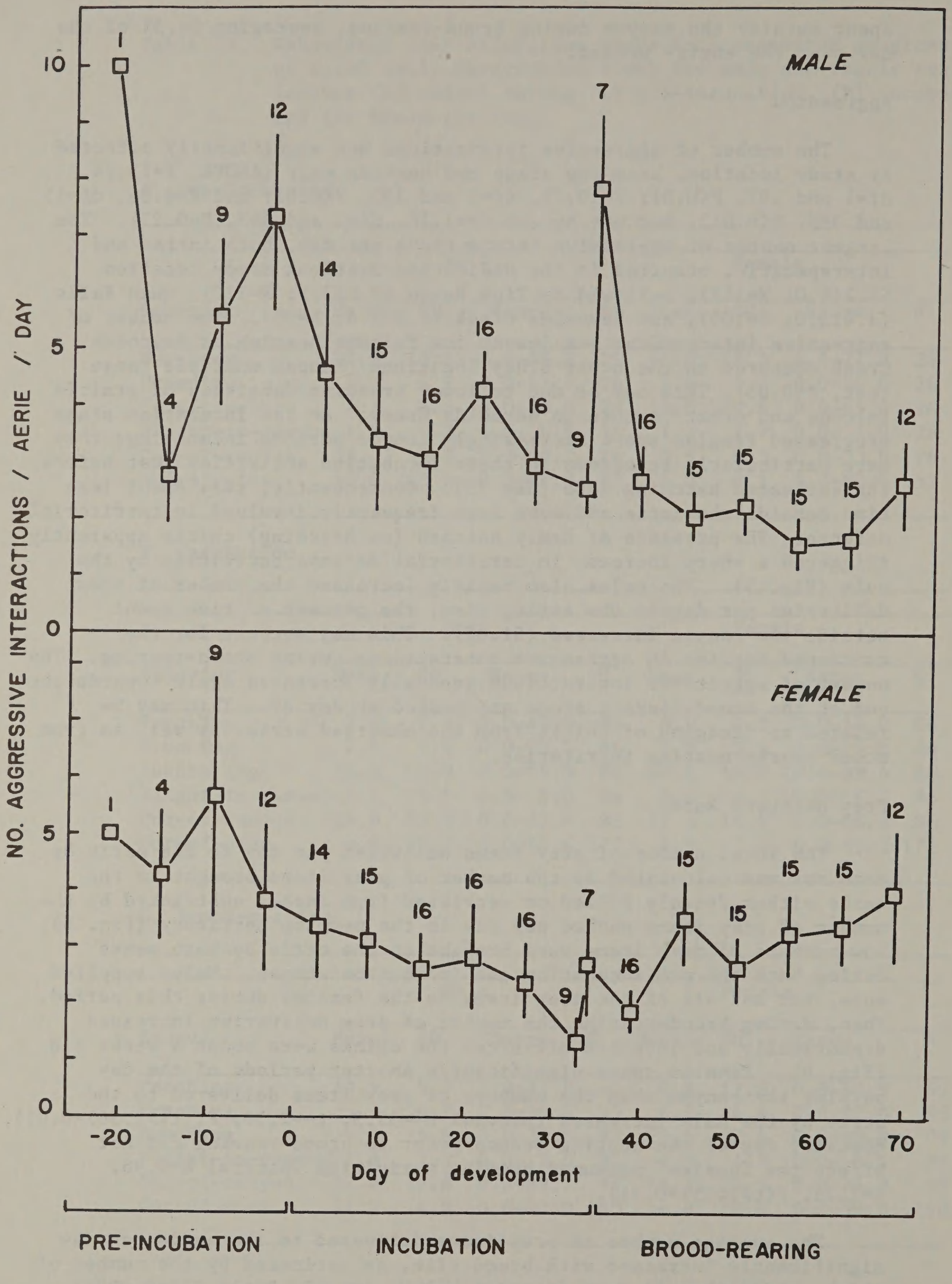

Fig. 5. Number of aggressive interactions per day by both sexes of priaire falcon pairs during the nesting season.

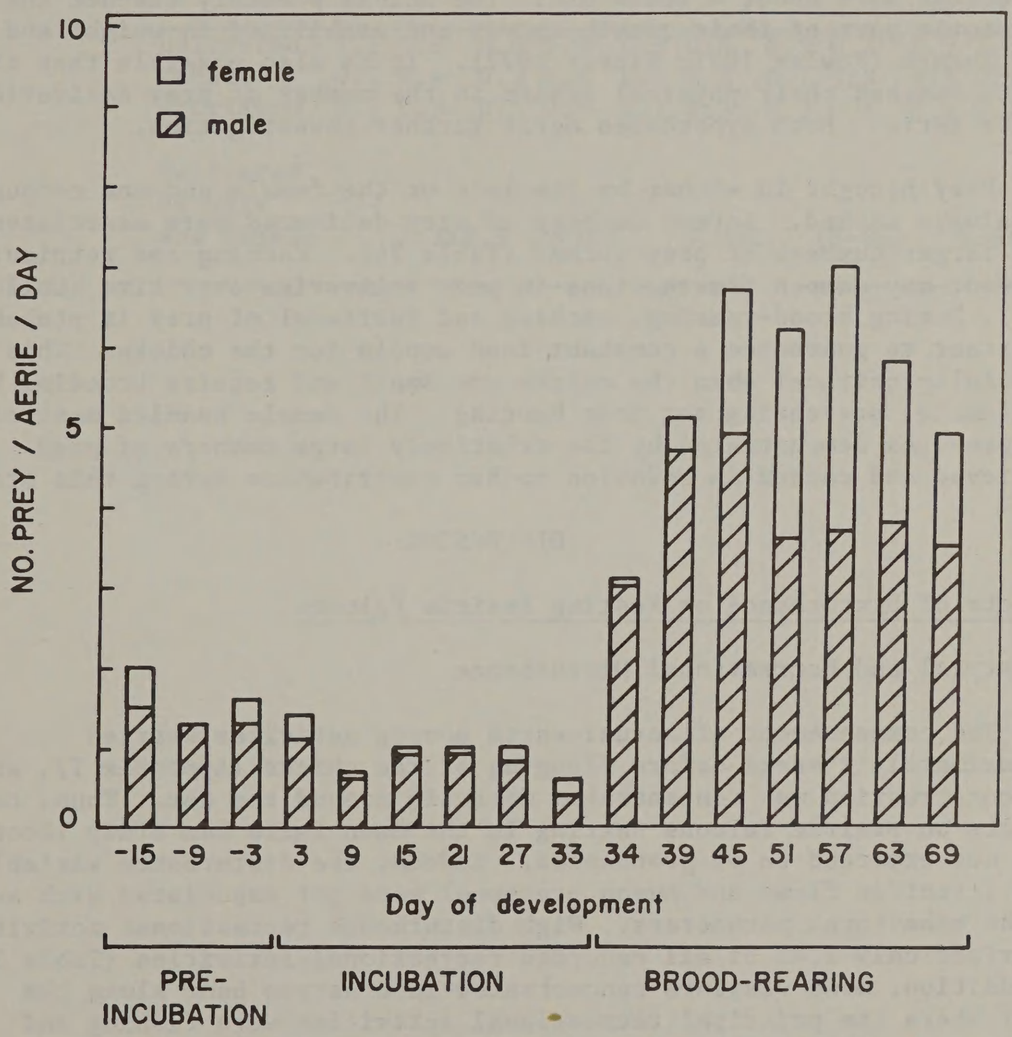

Fig. 6. Number of prey items delivered to the aerie per day by both sexes of prairie falcons during the nesting season.

but not with average age of the brood (partial b=0.02, t=1.31, P(t>1.31)=0.19).

During brood-rearing males increased the number of prey items delivered to the aerie up to 5-fold when compared to pre-brood-rearing stages (Fig. 6). Females apparently hunted throughout the nesting season evidenced by prey taken to the nesting territory or other signs of hunting. The number of prey items the females delivered to the aerie increased considerably after the chicks were approximately 2 weeks old and averaged about 25-45% of all delivered prey items (Fig. 6). The distribution of the average number of prey deliveries in the 1985 nesting season was very similar to the 1984 nesting season (Holthuijzen 1984). In both seasons prey deliveries levelled off after the chicks were about 4 weeks old. The chicks probably reached the asymptotic part of their growth curve, and stabilized in weight and food intake (Fowler 1931; Sitter 1977). It is also possible that the adults reached their physical limits in the number of prey deliveries to the aerie. Both hypotheses merit further investigation.

Prey brought in either by the male or the female and not consumed was always cached. Larger numbers of prey delivered were associated with larger numbers of prey cached (Table 24). Caching and retrieving behavior may dampen fluctuations in prey deliveries over time (Collopy 1977). During brood-rearing, caching and retrieval of prey is probably important to guarantee a constant food supply for the chicks. This is especially critical when the chicks are small and require brooding by the female, preventing her from hunting. The female handled most of the prey, as demonstrated by the relatively large numbers of prey retrieved and cached in relation to her contribution during this stage.

DISCUSSION

Effects of Disturbance on Nesting Prairie Falcons

Industrial and Recreational Disturbance

The commencement of actual earth moving activites started approximately 2 weeks before fledging of the chicks (Appendix I), and all construction was concentrated directly around the dam. Thus, the effects on prairie falcons nesting in the Swan Falls Dam study location were not expected to be pronounced. Indeed, the disturbance variables (i.e., traffic flows and human presence) were not associated with any of the behavioral parameters. High disturbance recreational activities comprised only 2.4% of all recorded recreational activities (Table 2). In addition, most visitors concentrated in a narrow band along the river where the principal recreational activities were fishing and sightseeing (59.7%; Table 2). Measures of construction and recreational activities may not have represented the disturbances to which prairie falcons may react. However, the behavioral repertoire of prairie falcons nesting in the Swan Falls and Dedication Overlook areas was not significantly different from those nesting in the control study location. This may suggest that the nesting falcons did not react to other disturbance variables, not measured in this study.

Table 24. Number of prey items delivered to the aerie, cached and retrieved per day in the nesting territory by both sexes of prairie falcons during the nesting season.

Prey category	Pre-incubation				Incubation				Brood-rearing			
	Male		Female		Male		Female		Male		Female	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Delivered	1.3	0.9	0.0	0.0	0.9	0.8	0.0	0.2	3.9	2.0	1.7	1.7
Cached	0.2	0.4	0.3	0.6	0.1	0.3	0.1	0.3	0.2	0.4	0.9	1.1
Retrieved	0.1	0.3	0.5	0.8	0.1	0.3	0.2	0.4	0.3	0.7	1.0	1.1
Delivered by male and female	1.3±0.9 (N=26)				0.9±0.7 (N=86)				5.6±2.4 (N=95)			

Several investigators have found evidence that nesting raptors (gyrfalcons, Falco rusticolus, peregrine falcons, Falco peregrinus, and ferruginous hawks, Buteo regalis) disturbed during the nesting season may successfully raise young, but may not re-use the same nesting territory in future years (Fyfe and Olendorff 1976; Platt 1977; Ratcliffe 1980; White and Thurow 1985). Abundance of prey may counteract the effects of disturbance (Newton 1979). Prey abundance has been found to affect the physical condition of the adults and their energy expenditure to secure prey, thereby affecting breeding condition and survival of their chicks (van der Zande and Verstrael 1985; White and Thurow 1985). Townsend ground squirrels (Spermophilus townsendii), the main prey species of the prairie falcon, reach high densities in the BOPA except in years of extreme drought (USDI 1979). The generally high prey densities in the BOPA compared to other areas may make prairie falcons breeding in the BOPA less susceptible to disturbance than in other areas.

Five traditional nesting territories are located along the newly constructed access road to Swan Falls Dam (Appendix VI). Four of these nesting territories were occupied in 1984 and 3 were occupied in 1985. Assessment of occupancy of these nesting territories over the period 1976-1978 when complete surveys were carried out showed that only 4 of the 5 nesting territories were occupied every year. The remaining nesting territory was vacant for 2 years (Appendix VI). Thus, the observed vacancy rate of nesting territories along the Swan Falls access road in 1984 was the same as vacancy rates over the period 1976-1978, but occupancy rates in 1985 were slightly lower. Therefore, the effects of road construction on prairie falcon occupancy are still unclear.

Productivity in the Swan Falls study location was lower in 1985 (3.0±2.0 chicks per aerie; N=4) than in 1984 (3.6±0.9 chicks/aerie; N=5), largely because of nesting failure of the Ferry nesting territory during early brood-rearing. Inspection of this aerie approximately 1 week after abandonment revealed small pieces of eggshell and some down. Human disturbance on the west side of the river was minimal and was unlikely to be a factor in the failure. The Ferry falcons established their aerie relatively late compared to the other falcon pairs in the Swan Falls area (Table 22), but otherwise behaviors of the pair did not differ from nesting pairs at Tick Basin (Appendix V and VI). The Ferry aerie was located behind a boulder and did not possess a protective overhang, which may have made it more vulnerable to avian predators. The aerie may also have been accessible to mammalian predators, particularly the bobcat (Lynx rufus). Open aeries suffer much higher predation rates than protected ones (90% higher egg loss; Ogden and Hornocker 1977). Aggression between the Ferry prairie falcon pair and a pair of red-tailed hawks (Buteo jamaicensis) that nested approximately 50 m from the falcon's aerie sometimes involved both the male and the female falcon. Temporary absence of the adult birds coupled with a predation-prone aerie may have facilitated predation on the small chicks.

Productivity in the Swan Falls area was within the range of productivity figures reported for prairie falcons in the BOPA over the period 1973-1979 (USDI 1979).

Experimental Blasting

Several investigators (Fyfe and Olendorff 1976; Harmata et al. 1978) reported that sudden loud sounds (e.g., slamming doors of vehicles 100-150 m from the aerie) disturbed nesting prairie falcons and that extended periods of loudness may even cause desertion. In contrast, we found that readjustment time of falcons exposed to experimental blasting was short, averaging less than 2 min (Table 14). Also, overall behavioral repertoire and productivity of falcons nesting in Reynolds Creek was similar to pairs exposed to minimal human disturbance nesting in the BOPA.

The frequency of behavioral reactions of prairie falcons to blasting did not differ between the incubation and brood-rearing stages (χ^2=0.272, df=1, P(χ^2>0.272)=0.602), although readjustment time decreased. Thus, it appears that prairie falcons may habituate to blasting (Fig. 4).

Historical use of the Reynolds Creek study location by prairie falcons has been documented for several years. However, detailed historical nesting data are available for only 1 year (M.N. Kochert, pers. commun.). The Reynolds Creek study location is remote from major population centers and difficult to access, even by foot. Cattle ranching is the main human activity. Thus, habituation to high levels of human activity by falcons nesting in the Reynolds Creek study location was not likely to have taken place in the recent past and certainly not to the levels of experimental blasting the birds were exposed to in 1985.

Considerable individual intra- and interspecific variation is exhibited by raptorial species with respect to human disturbance, sometimes stratified along age groups and geographical areas (Newton 1979; Fraser 1984; White and Thurow 1985). Some individuals can tolerate considerable levels of disturbance, as exhibited by a pair of prairie falcons that was exposed to intensive coal mining activities, including blasting and heavy equipment operations within 75 m of the aerie (Platt, cited in Bednarz 1984). These falcons returned to the same general area for 3 consecutive years following mining activities although they were not successful in producing chicks, probably due to adverse weather conditions. Likewise, species considered sensitive such as peregrine falcons have nested successfully near active excavation areas where dynamite blasts occurred regularly (Pruett-Jones et al. 1980; Haugh 1982; White and Thurow 1985). Other species, such as ferruginous hawks were very sensitive to simulated sound levels and in some cases abandoned their nests (White and Thurow 1985). In this study, however, incubating prairie falcons did not flush in 64% of the blasting instances, although in 20% of the cases the birds sat up and looked out to locate the source of disturbance before settling back on the eggs (Fig. 4). Similar observations were made with nesting peregrines disturbed by humans (Ratcliffe 1980).

We suggest that inclement weather conditions may decrease readjustment time. Cold and rainy days may have motivated the incubating falcon to sit tightly as was found for incubating peregrines (Ratcliffe 1980). Daily average wind speed and total sunshine did not affect readjustment time significantly, perhaps because of the generally sheltered aeries used by the prairie falcons.

In conclusion, behavior and productivity of prairie falcons exposed to blasting were apparently not affected by high intensity blasting. However, the long-term effects on occupancy and productivity of aeries which were exposed to blasting will not be known until at least 2 more nesting seasons when these aeries (and those not exposed to blasting) are monitored for occupancy and productivity.

Observer Disturbance

Investigators apparently did not affect the behaviors of prairie falcons by approaching observation blinds, or by different modes of access (Table 20). This is not surprising in light of the results of other studies. Nesting prairie falcons were observed by Sitter (1983) from blinds placed between 2 and 160 m from the aeries. The falcons under observation were very tolerant of activities of the observers and the blinds and would often resume normal activities within minutes after construction of a blind (Sitter 1983). Furthermore, each aerie under observation was entered by a researcher every fourth day to collect pellets. This apparently did not interfere with the nesting activities of the falcons because all but 1 of the studied aeries successfully fledged chicks. Steenhof and Kochert (1982) compared success rate of breeding prairie falcons disturbed early, with those of pairs found early but not disturbed before young were 4 days old. They found that success rates of pairs disturbed early did not differ significantly from those disturbed later. This may suggest that prairie falcons do not easily abandon their reproductive effort once they have small chicks. Alternatively, because prairie falcons use cavities, nestlings may be less affected by potential thermal stress than nestlings on open ledges.

Recreational Pressures on the Birds of Prey Area

Traffic flows along the Swan Falls access road increased approximately 2.4 fold in 1985 compared to the same period (March through June) in the previous year. The increase in traffic flows along the Swan Falls access road from 1984 through 1985 may be partly attributed to (1) improved access to the canyon along the Swan Falls access road reconstructed in 1984, (2) increasing popularity of the Swan Falls area for recreation over the past 10 years, and (3) closure of the road during late fall 1983 and early winter 1984 (A.R. Ansell, pers. commun.). The total traffic volume along the Swan Falls access road increased, as did traffic flows continuing downstream from Swan Falls Dam (1.7-2.4-fold). Upstream traffic flows remained at about the same level as in 1984 (Table 7). Number of persons per vehicle was lower in 1985 (2.1) than in 1984 (3.7). The total number of people entering the BOPA over the period March through June excluding resident and construction traffic was estimated at 8,000. In 1984 the number of visitors was estimated at 10,000 (Holthuijzen 1984). However, the 1984 estimate was not corrected for residential and construction traffic flows and may be considered somewhat inflated. Although the number of visitors to the Swan Falls area probably doubled in 1985, the number of high disturbance activities was relatively small (61 regulatory violations, or 2.4% of all recorded activities; Table 2). This may reflect the stepped-up patrolling by BLM personnel. The increasingly larger numbers of people recreating in the Swan Falls area may also be reason for concern. The road pattern, particularly downstream from Swan Falls Dam appeared to have become more braided, littering increased (including even an abandoned car), and the riparian vegetation has suffered from indiscriminant cutting for fire wood. Environmental degradation downstream from Swan Falls Dam is likely to continue if recreation use remains unregulated. This is compounded by the slow rate of revegetation as is witnessed by the old Oregon wagon trail.

Breeding Biology of Prairie Falcons

The behavioral repertoire of prairie falcons during the 1985 breeding season (Table 23) was very similar to behaviors observed in 1984 (Holthuijzen 1984; Table 15). Females were ususally inactive during the pre-incubation stage and spent up to 74% of the day time perched near the aerie, preening, or out-of-view inside the aerie. Inactive behavior several days prior to egg-laying has been described as pre-laying lethargy (Newton 1979). Females incubated on the average 60.6% of the daytime and males 35.5%. This is in close agreement with estimates for wild peregrine falcon males (30-50% at mid-incubation; Ratcliffe 1980) and captive breeding male peregrine falcons (Cade in Ratcliffe 1980). Female prairie falcons usually incubated during the night as do peregrine falcons (Ratcliffe 1980). It was assumed that falcons were most likely involved in hunting activities when they were outside the canyon. This assumption is supported by (1) falcons flying out of the canyon commonly returned with prey or showed signs (e.g., bulging crop, blood on talons or breast) that they had caught prey, and (2) time spent outside the canyon by falcons in this study compares favorably with estimates on radio-tagged prairie falcons nesting in the BOPA which spent time away from the canyon and were believed to be hunting most of the time (Dunstan 1976).

Males provided most, but not all, prey during incubation. Based on the above assumptions we suspect that females often hunted while males incubated. Similar observations were made on prairie falcons by Haak (1984) and on peregrines (Ratcliffe 1980). Brooding was carried out mainly by the female prairie falcon; males generally brooded for short periods ($\bar{x}$=2.6% of the day). Male prairie falcons, like peregrine falcons, may be too small to adequately cover the nestlings and seem to be less eager to brood (Ratcliffe 1980; Hovis et al. 1985). Brooding in prairie falcons rapidly decreased over time, and after they were 14 days of age, chicks were generally not brooded during the day as also was observed for peregrine falcon chicks (Enderson et al. 1973; Hovis et al. 1985).

The number of aggressive interactions during the 1984 nesting season increased during the nesting season and levelled off during the last 2 weeks of brood-rearing (Holthuijzen 1984; Fig. 8). In 1985 aggressive interactions decreased during pre-incubation and incubation, then increased during the brood-rearing stage (Fig. 5). Aggressive interactions by the male peaked immediately after hatching. These observations do not agree with Sitter's (1983) observations that aggression decreased over the nesting season, only to peak when the chicks fledged.

Newly hatched chicks may have triggered the male's increased hunting activities, which was expressed in a three-fold increase in prey items delivered immediately after the estimated hatching date. Similar observations were made during the 1984 nesting season (Holthuijzen 1984; Fig. 10). Likewise, hatching eggs or newly hatched chicks motivated male peregrine falcons and ospreys (Pandion haliaetus) to sharply increase their prey deliveries (Newton 1979; Ratcliffe 1980; Van Daele and Van Daele 1982). Female prairie falcons hunted throughout the brood-rearing stage, although hunting time varied considerably among females during the first 2 weeks of brood-rearing. Females increased their hunting efforts considerably after the chicks were about 14 days of age. Similar observations have been made for other raptors, although considerable variation occurs among individuals (Newton 1979).

FUTURE RESEARCH AND RECOMMENDATIONS

Monitoring of the behavior and productivity of nesting prairie falcons will continue over the period that construction activities will take place at Swan Falls (1984-1987). Recreational use of the Swan Falls area has increased continuously over the past 10 years, and this trend is likely to continue in coming years (A.R. Ansell, pers. commun.). In addition, access to the canyon has been improved by construction of the Swan Falls access road in 1984. Therefore, possible effects of recreational activities on prairie falcons will be monitored over the coming years, because recreation is likely to be a major source of potential disturbance to nesting raptors in the future.

The number of prairie falcon pairs observed in the Swan Falls and Dedication Overlook study locations will be increased if possible. The recreational surveys provided baseline data on visitors, their activities, and location; they will be continued in future years.

Blasting will be discontinued in the Reynolds Creek area. Occupancy and productivity of all aeries in the Reynolds Creek area will be monitored over the coming nesting seasons.

Regular patrols by BLM personnel in the BOPA appeared to be successful in influencing behavior of visitors as was suggested by the low number of regulatory violations compared to 1984. These patrols should be continued if possible. Also, there is an increasing need for information by visitors. The importance of the BOPA on a national and international level would certainly justify presence of BLM personnel. The most challenging task in future years in the BOPA will be people management to safeguard this important natural resource.

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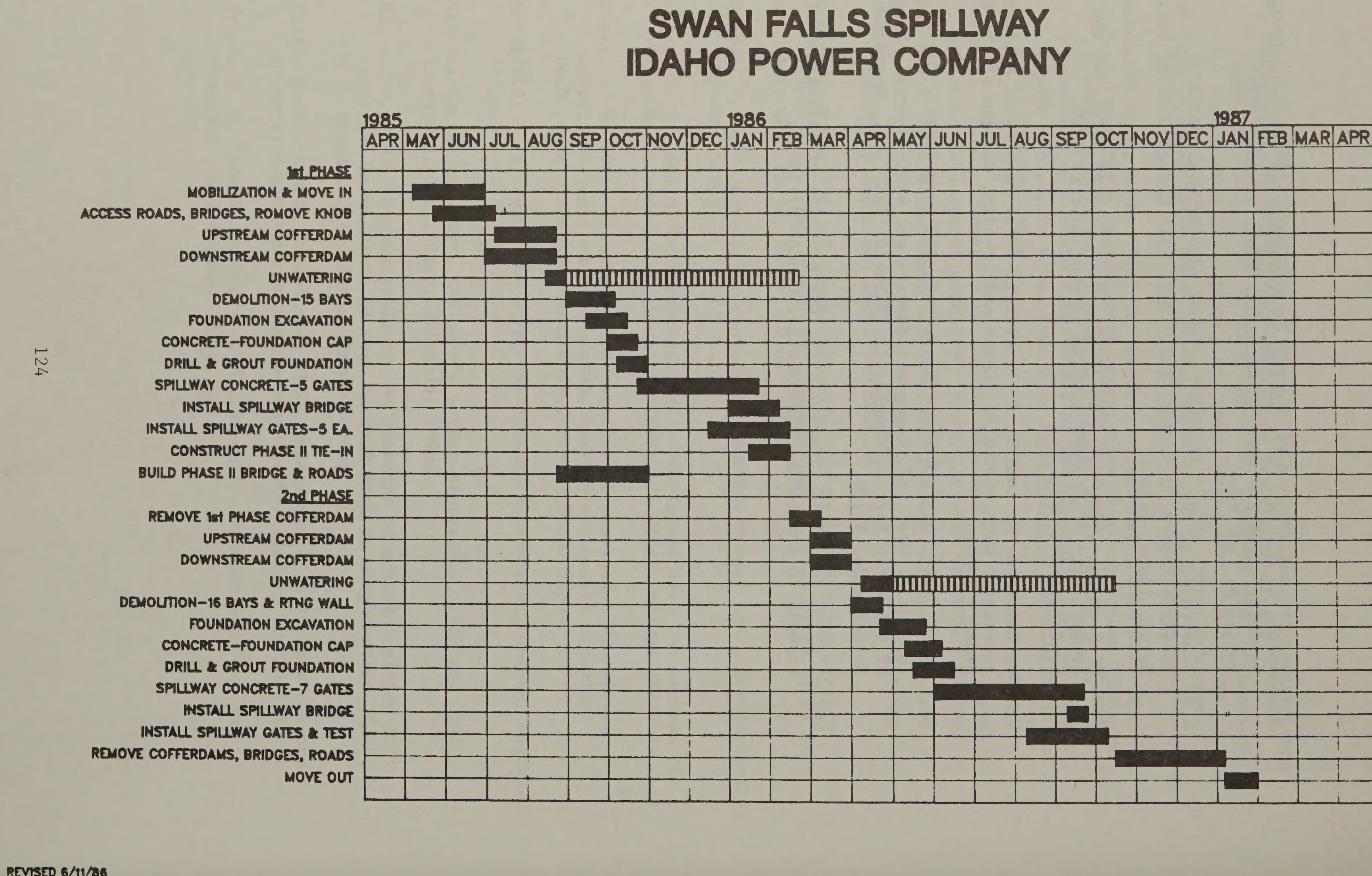
APPENDIX I. Construction schedule for the Swan Falls Dam spillway 1985-1987.



APPENDIX II. Definition of behavioral categories used in continuous behavioral observations on prairie falcons.

Feeding: feeding young, feeding adult.

Resting/sleeping/perching: inactively perching, no head or body movements.

Preening: cleaning, oiling, positioning feathers.

Flying-in-canyon: flying within sight in or above the canyon.

Flying-out-of canyon (hunting): flying out of sight out of the canyon; this category was used when the bird left the canyon and returned with prey or showed other indications that the bird had hunted.

Copulation: male alights on the females back; contact of the cloacas.

Incubation: lie posture covering the eggs.

Brooding: sheltering the chicks.

Unattended: eggs or chicks are left unattended by adults.

Nest visit: adult entering the scrape for less then 1 min.

Prey delivery: delivery of prey item to the nest site territory

Prey species: abbrevation common name, or in case prey cannot be identified to species level, category (mammal, bird, reptile, or other).

Inter- and intraspecific interactions

Vocalization: alarm call, lowest level of aggression.

Aggressive: stooping, chasing, following of intruder.

Non-aggressive: mutual display, soaring, no overt aggression.

Defensive: avoidance, flying directly away.

APPENDIX III. Pearson's product-moment correlation coefficients between the total number of visitors and traffic flows measured measured daily in the Swan Falls area from March through June, 1985.

Variable	Traffic counter						
	Swan Rd	Dedic	3 Poles	Upstr	Dwnstr	IPC/BLM	Pr Rapid
Visitors[1]	.58	.47	.82	.85	.68	.79	.66
Swan Rd		.53	.70	.58	.38	.68	.49
Dedic			.61	.47	.46	.47	.34
3 Poles				.81	.64	.71	.60
Upstr					.68	.70	.69
Dwnstr						.65	.70
IPC/BLM							.78

1). Number of visitors counted during the daily recreational survey

APPENDIX IV (A & B). Stepwise discriminant analysis to evaluate differences in behaviors during the incubation stage (expressed in (A) percentages of total observation time per day, and (B) frequencies per day) between the Ferry falcon pair and the falcon pairs nesting in Tick Basin, 1985.

A

	Male			Female		
Behavior	R^2	F	P	R^2	F	P
Perching	0.01	0.44	0.51	0.29	9.94	<0.01
Preening	0.02	0.56	0.45	0.29	9.93	<0.01
Incubating	0.03	0.92	0.34	0.12	3.28	0.08
Canyon flight	<0.01	0.22	0.64	0.03	0.95	0.33
Flight-out-canyon	<0.01	0.14	0.70	<0.01	0.07	0.78
Out-of-view	0.15	4.31	0.04	0.08	2.23	0.14

ASCC (male)=0.15 ("best" model ASCC=0.15)
ASCC (female)=0.29 ("best" model ASCC=0.63)

B

	Male			Female		
Behavior	R^2	F	P	R^2	F	P
Nest visit	0.01	0.13	0.71	-	-	-
Patrolling	0.01	0.34	0.56	0.05	1.40	0.24
Aggression	0.01	0.26	0.61	0.02	0.61	0.44
Copulation	0.01	0.20	0.56	0.01	0.42	0.51
Relocation	0.09	2.52	0.12	0.19	5.92	0.02
Feeding adult	0.13	3.59	0.07	0.03	0.93	0.34
Prey deliveries	<0.01	0.12	0.72	-	-	-
Prey cached	0.03	0.92	0.34	-	-	-
Prey retrieved	0.17	5.04	0.03	-	-	-

ASCC (male)=0.17 ("best" model ASCC=0.17)
ASCC (female)=0.19 ("best" model ASCC=0.19)

APPENDIX V (A & B). Behavioral time allocation during incubation (behaviors expressed as proportions of total daily observation time) for (A) the male and (B) the female prairie falcon nesting at Ferry and likewise for the prairie falcon pairs nesting in Tick Basin, 1985.

A

Behavior	Ferry male				Tick Basin males			
	Mean	SD	Range	N	Mean	SD	Range	N
Perching	8.4	5.4	2.4-15.9	6	11.7	10.8	0.2-44.9	20
Preening	11.2	6.5	3.8-18.8	6	8.6	6.3	0.0-22.9	20
Incubating	45.6	8.2	34.2-55.7	6	36.9	13.0	16.8-59.7	20
Flight-in-canyon	0.9	0.7	0.1- 1.6	6	1.1	1.2	0.1- 5.0	20
Flight-out-canyon	23.1	6.1	14.7-29.3	6	21.3	13.6	0.0-43.5	20
Out-of-view	3.8	3.9	0.0-11.7	12	8.8	11.4	0.0-49.2	40

B

Behavior	Ferry female				Tick Basin females			
	Mean	SD	Range	N	Mean	SD	Range	N
Perching	21.0	15.7	7.2-50.0	6	8.0	6.3	0.1-22.3	20
Preening	13.0	7.2	8.0-26.0	6	5.2	4.5	0.0-16.0	20
Incubating	44.6	15.1	16.4-61.0	6	59.2	13.3	35.1-81.8	20
Flight-in-canyon	0.4	0.3	0.0- 0.9	6	0.9	1.1	0.0- 4.8	20
Flight-out-canyon	16.2	6.4	8.2-24.4	6	21.1	17.9	0.0-50.6	20
Out-of-view	0.8	2.0	0.0- 6.9	12	2.0	3.3	0.0-14.7	40

APPENDIX VI. Occupancy of prairie falcon nesting territories in the Swan Falls and Dedication Overlook study locations from 1973 to 1984.

Nesting territory	Year 73	74	75	76	77	78	79	80	81	82	83	84	85
Swan Falls													
Balls Basin Powerline[4]	2	-	2	41	41	41	41	-	2	1	1	1	1
Falcon Flats Fingers[4]	2	-	-	42	41	3	1	1	2	2	2	41	41
Ferry	2	-	-	41	2	1	-	1	2	-	1	41	42
Swan Dam Road Turn[4]	2	41	-	41	3	2	2	-	-	1	41	41	1
Swan Dam North Side[4]	2	-	41	41	41	41	2	41	-	2	3	41	41
Swan Dam Three Poles[4]	-	41	2	41	1	1	42	2	2	41	41	41	41
Dedication Overlook													
Beecham	2	41	-	-	2	1	2	-	1	1	1	1	1
Beecham Gate	-	-	41	3	-	41	2	41	2	2	2	1	1
Beecham Gate Dwnstream	-	-	2	3	-	1	1	1	1	1	1	1	1
Camera	41	-	41	3	42	3	41	41	41	41	2	41	41
Dedication Point	2	-	3	3	2	2	41	2	41	2	41	41	41
Dedication Site	2	41	41	2	3	2	2	41	3	41	42	1	1
PF I	2	2	41	41	41	2	1	1	2	42	41	41	41
PF II	2	-	41	41	41	2	1	42	2	2	1	41	41
Priest Lower	2	41	41	1	1	2	2	-	-	2	-	1	1
Priest Rapids I	2	2	2	3	2	41	2	1	2	-	-	42	41
Priest Rapids II	-	-	2	3	2	2	2	2	-	41	-	3	3
Priest Upper	2	41	41	41	41	41	2	2	41	41	2	41	41

1) Unpublished data Bureau of Land Management, Birds of Prey Research Project, Boise.

2) Coding occupancy: 1=vacant
   2=occupied undetermined breeding
   3=breeding undetermined success
   41=breeding successful
   42=breeding unsuccessful

3) Only in the years 1976, 1977, and 1978 the 2 study locations wer completely surveyed and were used to calculate occupancy rates.

4) Nesting territories located along the Swan Falls access road.

APPENDIX VII. Common factor analysis

This appendix provides a short introduction to (common) factor analysis. Child (1973) and Dillon and Goldstein (1984) present detailed, but still readable, overviews of factor analysis.

Factor analysis is one particular statistical method belonging to the family of multivariate analyses. Multivariate analysis can simply be defined as the application of methods that deal simultaneously with large numbers of variables. Factor analysis is a data reduction technique. By investigating the interrelationships among variables, it attempts to define a new set of variables (i.e., factors) fewer in number than the original variables which express that which is common among the original variables. In other words, factor analysis tries to uncover common dimensions or factors that link together the seemingly unrelated variables and consequently provides insight into the underlying structure of the data. A factor can be defined as a number of variables which have a great deal in common. Related variables are discovered by using the technique of correlation. The next step after extracting the common factors is to identify what these factors represent. Therefore, the highest loadings per factor taken into consideration. These factor loadings should be greater than $|\pm 0.30|$. However, the same variable may load significantly on several common factors. Interpretation of factors would be much simpler by having a minimum number of significant loadings of a particular variable on the common factors, and to maximize the loadings with negligible values. Thus, one seeks a simple structure which can be achieved by factor rotation, i.e., the structure of common factors is rotated around the geometrical origin. Two groups of rotations can be discerned (a) orthogonal, and (b) oblique rotations. In orthogonal rotation the orthogonal structure of common factors is rotated around the origin. In oblique rotation the common factors are rotated independently so that they are not perpendicular to one another after rotation. Communality estimates are no longer applicable, because the factor loadings are not invariant under oblique transformations.

TITLE: Feeding Ecology of the Common Barn-Owl in the Snake River Birds of Prey Area.

INVESTIGATOR: Carl D. Marti, Department of Zoology, Weber State College, Ogden, Utah 84408.

OBJECTIVES:

1. Determine food habits and other food niche parameters of nesting common barn-owls (*Tyto alba*).

2. Determine food niche variation (a) among sites and (b) among years.

3. Determine the barn-owl's position in the raptor feeding guild.

INTRODUCTION

Field studies for this project began in 1978 and have continued through 1985. All data were obtained in the Snake River Birds of Prey Area (BOPA) which is described in U.S. Dep. Inter. (1979). Analysis and subsequent statistical treatments were done at Weber State College, Ogden, Utah. Reports on previous years are also available (Marti 1979, 1981, 1982, 1983, 1984).

This report describes field activities and preliminary analysis for 1985 data. Dietary trends for 1978 through 1985 are also summarized.

ANNUAL REPORT

Three visits were made to the BOPA to collect data in 1984: 26-28 April, 25-27 May and 30 June to 2 July. Twenty-six samples of regurgitated pellets were collected from 15 sites (Table 1). A summary of prey content of these pellets is in Table 2.

Figure 1 presents dietary trends for the major barn-owl prey genera over 8 consecutive years. *Microtus* has been the most numerous prey in every year. Two genera, *Dipodomys* and *Mus* have shown a directional pattern of decreasing importance in the diet. The other three genera have fluctuated but without long-term direction.

PLANS FOR 1986

Two or three trips to the BOPA are planned for the spring/summer of 1986. The primary objective is to continue collecting food habits data for the analysis of long-term predation trends by barn-owls.

ACKNOWLEDGMENTS

I thank Michael Kochert, Karen Steenhof, John Doremus, Lenny Young and all of the Snake River Birds of Prey Research staff for a variety of

Table 1. Collection sites for common barn-owl food habits data in the BOPA, 1985.

Mary's
Kitten's
Jensen Cliff
Wildhorse Butte
Castle Rock (2 sites)
Lower Lower Black Butte (2 sites)
Upper Lower Black Butte (4 sites)
Chattin Hill
Fence Corner
Road End

Table 2. Total prey identified for the common barn-owl in the BOPA, 1985.

Prey Species	Number	Percent Number
MAMMALS		
Antrozous pallidus	2	tr.
Sorex vagrans	67	1.2
Mus musculus	296	5.3
Peromyscus spp.	788	14.2
Reithrodontomys megalotis	196	3.5
Onychomys leucogaster	2	tr.
Neotoma lepida	11	0.2
Neotoma cinerea	4	0.1
Microtus montanus	3,176	57.1
Perognathus parvus	345	6.2
Dipodomys ordii	186	3.3
Thomomys townsendi (juvenile)	394	7.1
unidentified leporids (neonate)	9	0.2
BIRDS		
Callipelpa californica	1	tr.
Columba livia	1	tr.
Cistothorus palustris	1	tr.
Sturnus vulgaris	6	0.1
Passer domesticus	3	tr.
unidentified icterid	11	0.2
unidentified medium bird	20	0.4
unidentified small bird	39	0.7
Unidentified scorpion	1	tr.
TOTALS	5,559	100.0

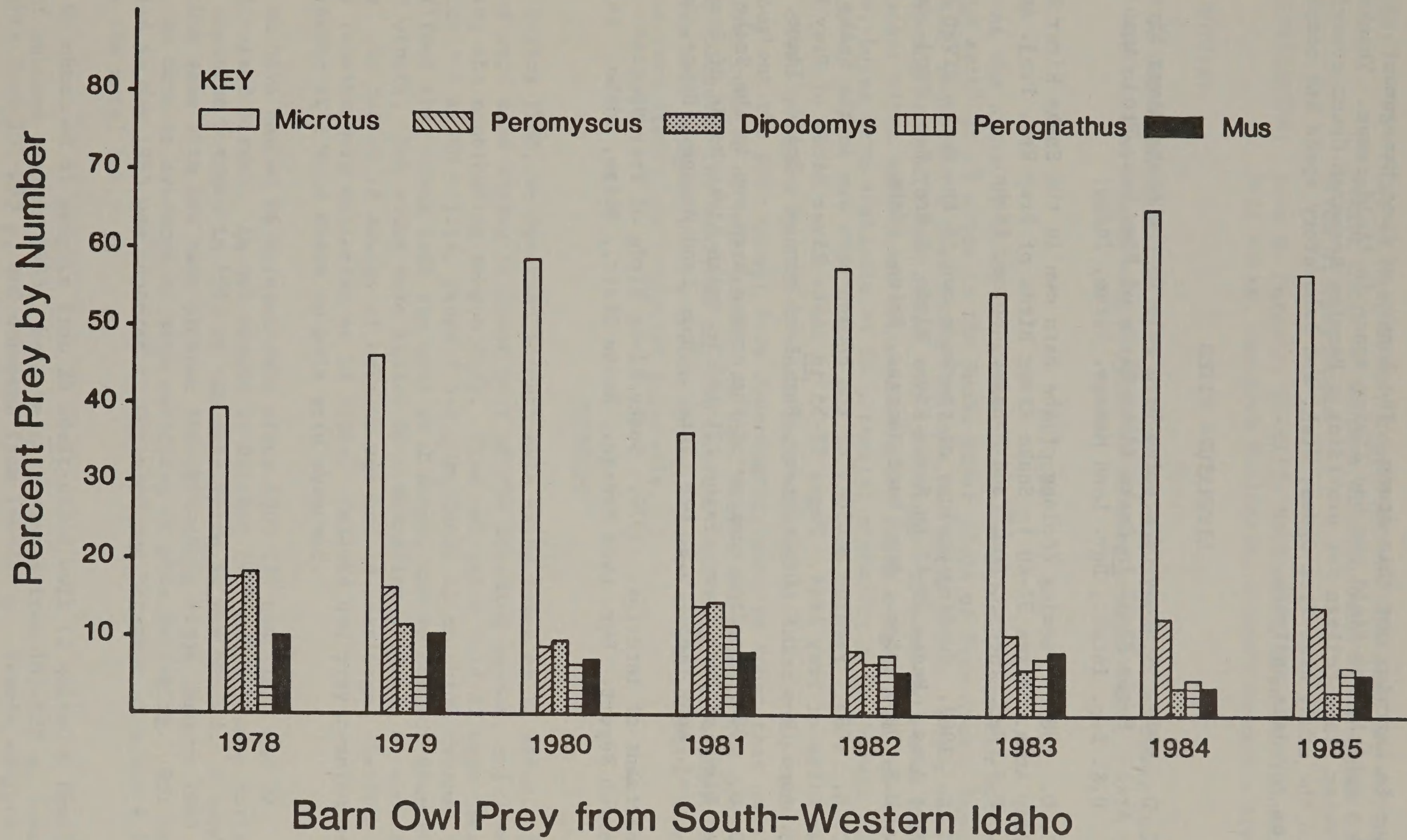


Fig. 1. Eight-year summary of major barn owl prey from the Snake River Birds of Prey Area, Idaho.

assistance in carrying out this study. The Bureau of Land Management provided a vehicle for field use and living space in field camps. Thanks also to Weber State College for providing a Faculty Research Grant covering travel to the study area from Ogden, Utah, and laboratory space and computer facilities for data analysis.

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U.S. Department of Interior. 1979. Snake River Birds of Prey Special Research Report. Bur. Land Manage., Boise Distr., Boise, Idaho. 142 pp.

TITLE: Use of Nest Boxes, Reproduction, Food Habits, and Annual Weight Cycle of Western Screech-Owls in the Snake River Birds of Prey Area.

INVESTIGATORS: John H. Doremus, Wildlife Biologist, Bruneau Resource Area
Jeff Marks, Research Biologist, Cascade Resource Area

OBJECTIVE:

To determine patterns of nest box use, reproductive success, food habits, and annual weight cycle of western screech-owls.

METHODS

At the start of 1985, nest boxes were available to western screech-owls (Otus asio) at 19 sites in the Snake River Birds of Prey Area. Each site usually contained 2 nest boxes (Doremus and Marks 1984). Boxes were removed in spring at 2 of these sites, and in 3 cases the same owls used boxes at adjacent sites (distances between occupied boxes ranged from 180-400 m). Thus, boxes were available at 14 potential sites for screech-owls throughout 1985.

Sites occupied by screech-owls were visited at least once each month throughout the year except from June-August, when we found that owls usually roosted outside of nest boxes. At each visit, all pellets and prey remains were collected for analysis of food habits. All owls were banded, and adults were weighed with a Pesola spring balance at each visit. Unoccupied sites were visited at irregular intervals.

RESULTS

During 1985, we observed screech-owls using boxes at 11 sites. Eight sites were used during at least part of the breeding season, and 3 were used during the nonbreeding season only. Five owl pairs laid 22 eggs (mean clutch = 4.4, SD = 1.14, range = 3-6), at least 15 of which hatched. We confirmed that young left the nest at 2 sites, and we suspect that they did at 2 others. The young were killed by a mammalian predator at the remaining site. We banded 16 adults of unknown age and 14 nestlings. Pellets and prey remains were collected at 12 sites. Pellets and prey remains were also collected at 1 site where no owls were observed.

We have banded 66 screech-owls since 1980 (34 nestlings and 32 adult-sized birds). An owl banded in October 1983 and not seen during 1984 was captured 3 times in 1985 at the site where it was banded. A second owl at this same site has been present intermittently since January 1984. Thus far, we have no evidence of mate switching or site switching. One nestling banded in May 1985 was captured in November and December at a box 4.4 km from its natal box.

We obtained 61 weights from 23 adult-sized owls (5 males, 6 females, and 12 of unknown sex) in 1985. Male weights ranged from 169-222 g, female weights from 191-295 g, and unknowns from 166-280 g. Female weights peaked during egg-laying (late March-early April), whereas male weights were relatively constant (Table 1). A presumed female that we did not weigh during the nesting season weighed 280 g in December (795-43966; Table 1).

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Doremus, J. H., and J. S. Marks. 1984. Use of nest boxes, reproduction and food habits of western screech-owls in the Snake River Birds of Prey Area. Pages 131-132 in Snake River Birds of Prey Research Project Annual Report. U.S. Dep. Inter., Bur. Land Manage., Boise District, Idaho. 141pp.

Table 1. Weights of adult western screech-owls in the Snake River Birds of Prey Area in 1985. Only owls with 3 or more weights are reported.

Band no.	Sex	Date	Weight (g)
795-43998	F	23 March	246
		21 April	227
		18 May	201
795-43990	F	24 February	237
		10 March	238
		23 March	241
		21 April	241
		18 May	200
		28 May	191
		16 November	236
		9 December	218
795-43996	M	23 March	178
		21 April	187
		16 November	170
		9 December	209
795-43995	F	10 March	219
		23 March	275
		21 April	256
795-43992	F	24 February	220
		23 March	257
		21 April	249
795-43963	M	27 January	184
		10 March	169
		16 November	180
		9 December	176
795-43964	F	17 February	239
		10 March	261
		23 March	295
		21 April	240
		27 October	209
		9 December	227
		29 December	240
795-43965	M	27 January	185
		17 February	207
		23 March	188
795-43966	F?	24 February	245
		28 September	218
		16 November	230
		9 December	280
		29 December	198

TITLE: Use of Nest Boxes by American Kestrels in the Snake River Birds of Prey Area.

INVESTIGATORS: Karen Steenhof, Associate Research Leader
Deana Ramirez, Data Transcriber
John Doremus, Wildlife Biologist, Bruneau Resource Area

OBJECTIVES:

1. Determine occupancy of 20 nest boxes erected in the Snake River Birds of Prey Area.

2. Ascertain food habits of American kestrels nesting in boxes in the Birds of Prey Area.

3. Mark any nestling or adult kestrels encountered while working on the first 2 objectives to accumulate baseline data for possible future studies on kestrel population dynamics.

INTRODUCTION

American kestrels (Falco sparverius) are known to nest on cliffs in the Snake River Birds of Prey Area (BOPA), but little is known about their densities, food habits, or breeding biology. Information on kestrel food habits in the BOPA is needed to complete analyses of food-niche characteristics of the raptor guild and to assist managers in evaluating certain management actions (e.g., insect control programs). Kestrels are known to nest in boxes that are especially designed for them (Bent 1938). Kestrels are difficult to study in the canyon because most of their natural nesting cavities are inaccessible. This study was initiated to provide an opportunity to gather information on kestrels in the BOPA.

Idaho Power Company discontinued their use of a 46 kV power line in the BOPA in the winter of 1983-84. The line extends from Highway 67 near Chattin Hill northwest to the substation near Swan Falls and runs parallel to the north rim of the canyon (Fig. 1). In the fall of 1984, Idaho Power Company removed the line and poles but left every 4th pole standing. Approximately 80 poles were left along the 36 km (22.6 mile) stretch.

METHODS

Twenty nest boxes constructed of rough fir (Fig. 2) were placed on 20 of the 80 remaining power poles in the BOPA on 28 February 1985. Boxes were erected approximately 1 mile (0.6 km) apart and were placed approximately 2.75 m (9 feet) from the ground. All boxes faced east. The dominant shrub species surrounding each box was determined by visual inspection (Table 1.). Vegetation along the line consists of mostly shadscale (Atriplex confertifolia) and winterfat (Ceratoides lanata). All nest boxes were checked on 10 May, 3 June, and 23 July. One box with a confirmed nesting attempt was re-visited on 29 July. No boxes were visited during suspected incubation

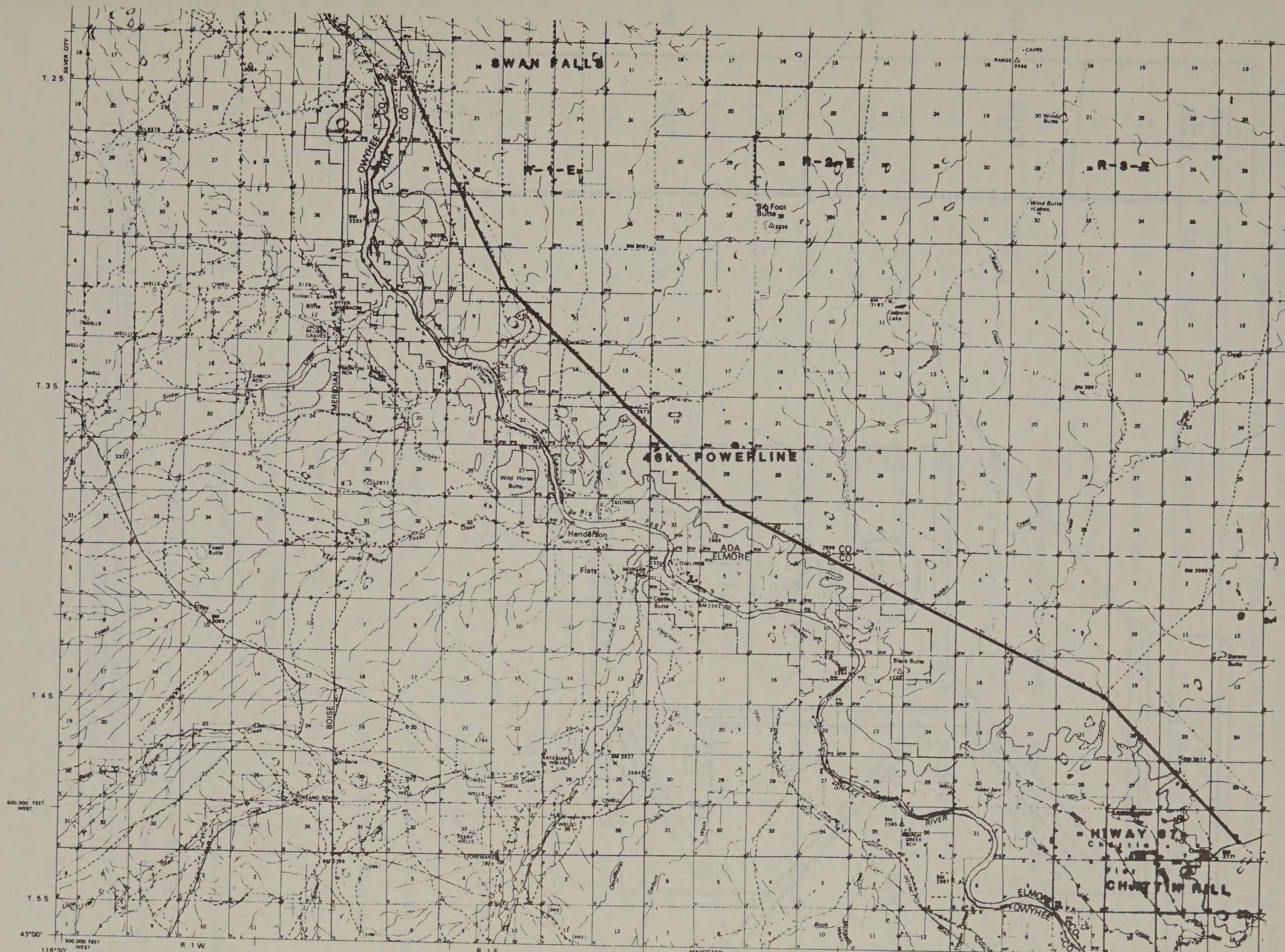

Fig. 1. Location of 46 kV power line.

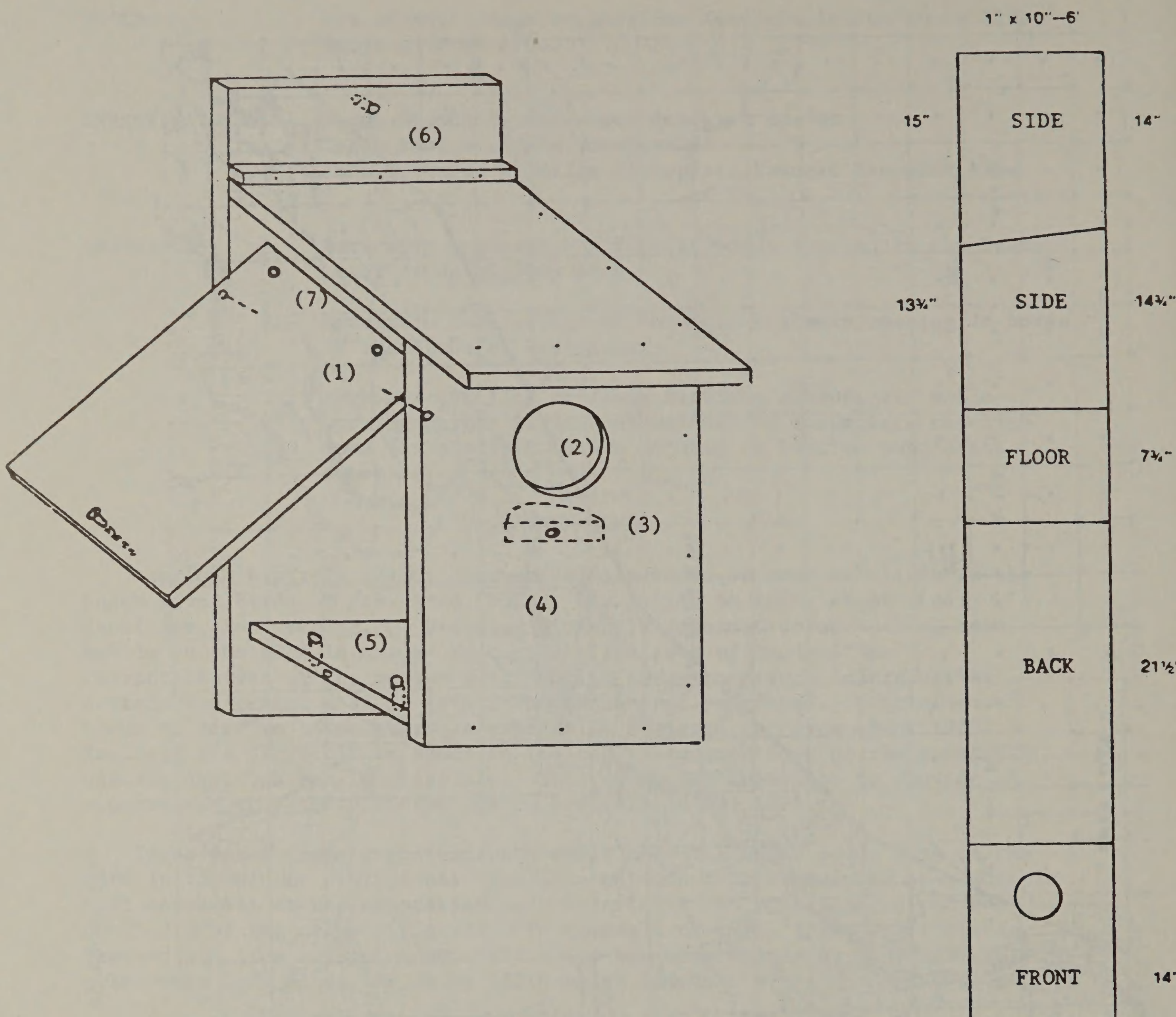

Fig. 2. Dimensions and design of the kestrel nest boxes erected in the BOPA, 1985.

Table 1. Description of nest box locations, as measured travelling east on the power line right of way from Swan Falls to Chattin Hill.

Box #	Miles From Last Box	Vegetation	Description
1	0.3*	sage/grass	Pole 24
2	1.0	winterfat	
3	1.0	cheatgrass/winterfat	Old Firebreak
4	1.0	winterfat	
5	1.1	winterfat	Pole 95
6	1.0	winterfat	near road intersection
7	1.1	winterfat	
8	1.0	winterfat/shadscale	near Sungoddess Draw
9	0.8	shadscale/hopsage	
10	1.2	shadscale	Pole 182
11	0.9	shadscale	by road to Spoon
12	0.9	winterfat/shadscale	Pole 214 Power line Draw
13	1.1	shadscale	by BM marker-West Cabin Draw
14	0.9	shadscale	Pole 249 near Cabin Platform
15	1.0	shadscale	near Black Butte
16	1.0	shadscale	near Black Butte
17	1.1	sage/shad/winterfat	
18	1.0	sage/shad/winterfat	
19	1.1	shadscale	West of Feedlot Draw
20	1.9	shadscale	2.2 mi West of Grand View Highway

* Measured from first gate east of Swan Falls Turnoff

mounted on a broomstick. The hole stuffer was inserted in the nest box entrance to trap any adult birds in the box. The investigator climbed to the nest box using a ladder and inspected the box contents. Nests of European starlings (Sturnus vulgaris) were removed to keep boxes suitable for nesting by kestrels.

RESULTS

Three of the 20 boxes were used by birds for nesting in 1985. Two boxes were used by European starlings, and 1 was used by kestrels. One box was destroyed by lightning between 10 May and 3 June. Four of the 80 poles burned during a 7 July fire, but no poles containing boxes burned.

Kestrels were first observed in the vicinity of Box 16 on 3 June, but the box was empty on that date. On 23 July, the box contained 4 nestlings estimated to be 3 weeks of age. Age of the nestlings suggests that eggs had been laid on 6 June and hatched on 5 July. These dates are 45 days later than average dates recorded for kestrels in the canyon from 1977-1982 and they are 10 days later than average dates reported in literature (Craig and Trost 1979, Bloom and Hawks 1983). Interestingly, young hatched within 2 days of a range fire that burned 5895 ha surrounding the box. All 4 nestlings were healthy on both 23 and 29 July. Weights of the 2 female and 2 male nestlings are shown in Table 2. On both dates young appeared to have been fed just prior to our check. Adults were present on both days when we arrived. Prey remains and pellets were collected for analysis of food habits.

Nesting starlings were first observed in Box 1 on 10 May. At that time the nest with eggs was destroyed and removed. The nest had been rebuilt and had 5 nestlings on 3 June. Starling eggs were first found in Box 7 on 3 June. The nest and eggs were destroyed, and no further starling activity was recorded.

DISCUSSION

Nesting boxes have been effective in attracting kestrels in several areas including Colorado (Stahlecker and Griese 1979), Iowa (Andrews 1986), and California (Bloom and Hawks 1983), but few studies have evaluated the success of nesting box programs for kestrels in shrubsteppe environments.

In 1985, only 1 of 20 boxes in this study was used for nesting by kestrels. Kestrel occupancy rates in our study area (5%) were lower than first year occupancy rates reported by other studies (Table 3). The reasons for these differences are unclear. Comparisons of occupancy rates in the 2nd year may suggest some factors influencing reduced occupancy rates. Other studies have shown additional increases in use of boxes after the first year.

The laying and hatching dates in this study are later than those dates recorded for canyon nests in the BOPA and for nest boxes in other locations. It is possible that the nesting attempt in our study was a re-nesting effort. Other possible reasons for very late nesting could be local weather conditions (Roest 1957) or prey availability.

Table 2. Weights and sexes of 4 nestling kestrels banded in the Snake River Birds of Prey Area, 1985.

Band Number	23 July Weight	29 July Weight	Sex
1433-86701	125g	127g	F
1433-86702	107g	120g	M
1433-86703	115g	118g	F
1433-86704	105g	112g	M

Table 3. Comparison of first year occupancy rates in other studies of kestrel nest box use.

Location	# Boxes Out	# Occupied 1st Year	% Occupancy	Habitat	References
SW Idaho	20	1	5%	Shadscale/ Winterfat	This Study
Eastern Idaho	7	3	43%	Cottonwood Trees	(Craig & Trost 1979)
California	71	14	20%	W. Juniper/ Big Sage	(Bloom & Hawks 1983)
Wyoming/ Montana	42	22	52%	Sagebrush/ Wheatgrass	(Dahmer et al. 1984)
Wisconsin	50	16	32%	Meadows/ Buildings	(Hamerstrom et al. 1973)
Iowa	20	8	40%	Interstate Corridor	(Andrews 1986)
Colorado	25	12	48%	Shortgrass Prairie	(Stahlecker & Griese 1979)
Oregon	217	87	40%	Riparian	(Henny et al. 1983)

PLANS FOR NEXT YEAR

Pellets and prey remains will be analyzed to provide information on American kestrel diets in the BOPA. We will continue to monitor occupancy of the 20 nest boxes in 1986. In addition, if time and funds permit, we will erect boxes in other habitats in or near the BOPA. A comparative study of the 2 groups should provide further insight on food habits and occupancy rates.

ACKNOWLEDGMENTS

We would like to express special thanks to Scoutmaster Allan Lynch and Scout troop #151 who built and painted the kestrel boxes.

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TITLE: Occupancy and Breeding Success of Long-eared Owls and Northern Harriers in the Snake River Birds of Prey Area.

INVESTIGATORS: John H. Doremus, Wildlife Biologist, Bruneau Resource Area
Carla Schroer, Volunteer Technician, Bruneau Resource Area

OBJECTIVES:

1. To monitor occupancy of long-eared owls in riparian areas on public land within the Snake River Birds of Prey Area.

2. To compare occupancy and breeding success of long-eared owls and northern harriers in areas near high recreational areas with those in undisturbed areas.

METHODS

Traditional long-eared owl nesting sites in riparian areas on public lands in the Snake River Birds of Prey Area (BOPA) were searched from a boat and on foot in early April. The term "nesting site" is used synonymously with the terms "nesting territory" or "nesting area" which are defined as the confined locality containing nests where no more than 1 pair has ever bred at 1 time (Steenhof 1986). Some sites were revisted in mid-May.

Eleven traditional long-eared owls nesting sites and 11 northern harrier sites were selected prior to the nesting season. All sites selected were occupied at least once between 1980 and 1984. Six owl sites were in areas considered to have moderate to high human use, and 5 were in areas considered to have low or no human use (Table 1). These areas were searched for owls in early April and again in mid-May. Northern harrier nesting sites were observed during courtship, incubation and brood-rearing. Four were in areas considered to have moderate to high human disturbance, and 7 were in an area considered to have little or no human disturbance (Table 1). Nesting sites were observed from a motor vehicle or ground observation post at a distance from potential nests that ranged from 30 to 500 m.

Pairs that showed no evidence of laying eggs were considered nonbreeding. Pairs were considered successful if they raised 1 or more young to 80% of the age of first sustained flight (i.e.,24 days old for harriers and 28 days for long-eared owls) (Marks 1980, Steenhof 1986).

RESULTS

Long-Eared Owl Monitoring

Seventy-two traditional nesting sites were searched at least once, and 19 were occupied by at least 1 owl. Of these, 10 contained breeding pairs. Of the remaining 53 traditional sites 9 were confirmed vacant; however, the remaining 44 were only visited once in April, and although no owls were seen at these sites, vacancy could not be confirmed because they lacked follow-up visits. Assuming that these sites were vacant, the number of occupied long-eared owl sites has greatly declined since the last complete surveys when Marks (1980, 1981) reported 64 and 41 occupied territories in 1980 and 1981 respectively for the BOPA. High river flows may have contributed to the low occupancy in 1985. Marks (pers. commun.) believes long-eared owls avoid nesting over open water.

Monitoring Areas of Recreational Use

Long-eared Owls

Of the 6 sites in moderate to high human use study area, only Tom Draw was occupied in 1985. Tom Draw contained only 1 pair prior to 1985 but had 2 breeding pairs and 1 lone bird in 1985. One of the breeding pairs failed, and the other had 15-20 day old young at the last visit.

All 5 sites in the control area were occupied in 1985, and 4 pairs laid eggs. One successfully fledged 3 young, and 2 were unsuccessful. The remaining pair was incubating on 3 April and again on 22 May. This may have been prolonged incubation of the first clutch (Marks 1983) or normal incubation for a second clutch in the same nest.

Northern Harriers

Of the 4 nesting territories in the high human use study area, 3 were occupied, and 2 pairs (66.7%) successfully fledged young. The remaining pair failed to breed. The vacant territory was subjected to heavy cattle use which allowed fisherman to wade through the cattail marsh where harriers had nested previously.

All 7 traditional territories in the control area were occupied, and 4 of these pairs (57.1%) were successful. Although breeding status of the remaining 3 pairs could not be determined, they failed to produce young.

Table 1. Long-eared owl and northern harrier nesting territories selected for human use monitoring, 1985.

Species	High Human Use	Low Human Use
Long-eared Owl	Tom Draw Crane Falls Lake Crane Falls Sturgeon Cabin Draw Cabin GE Draw Cellar Hole	Rye Patch Tree Rye Patch tree D.S. Fossil Creek I Fossil Creek II Fossil Creek III
Northern Harrier	Tom Draw Crane Falls Lake Cabin Sugar	Strike Dam Strike Dam Marsh Strike Dam Marsh Yellow Strike Dam Marsh Brown Strike Dam Marsh Green Strike Dam Marsh North Strike Dam Marsh West

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TITLE: Abundance of Black-tailed Jack Rabbits and Kangaroo Rats in the Snake River Birds of Prey Area.

INVESTIGATORS: John Doremus, Wildlife Biologist, Bruneau Resource Area
Carla Schroer, Volunteer Technician, Bruneau Resource Area

OBJECTIVE:

To monitor jack rabbit population changes in the Snake River Birds of Prey Area.

ANNUAL SUMMARY

Black-tailed jack rabbit (*Lepus californicus*) density in the Birds of Prey Area averaged 0.02 rabbits/ha in 1985. This value represents a continuing decline in jack rabbit density.

METHODS

Black-tailed jack rabbits were surveyed along 10 spotlight transects (Smith and Nydegger 1985) which run through major cover types within the study area. Each transect was sampled 3 times from mid-May to mid-June totalling approximately 547 km. Data were analyzed using the computer program "TRANSECT" (Burnham et al. 1980). The locations of all kangaroo rats (*Dipodomys ordii*, *D. microps*) sighted during the jack rabbit survey were also recorded.

RESULTS

The overall annual density index declined between 1984 and 1985 to the lowest level ever recorded since surveys began in 1977 (Table 1). An even grater decline was observed in big sagebrush types (Table 2) which comprise the best jack rabbit habitat in the area (Smith and Nydegger 1985).

The number of kangaroo rats seen per unit effort (Table 3) varied from 0 to 0.5 animals/km depending on cover type. These values have decreased sharply since 1984.

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Table 1. Annual density estimates of black-tailed jack rabbits from spotlight transects in the Birds of Prey Area, 1977-1985.

Year	Number of Rabbits Observed	Density Index[a] (N/ha)	95% Confidence Interval	Coefficient of Variation
1977	218	0.16	0.14-0.18	6.68
1978	103	0.17	0.13-0.21	10.09
1979	701	0.49	0.46-0.53	3.84
1980	807	0.48	0.43-0.53	4.98
1981	870	0.52	0.49-0.56	3.44
1982	282	0.14	0.12-0.16	6.05
1983	192	0.12	0.11-0.14	7.36
1984	59	0.05	0.04-0.07	13.41
1985	55	0.02	0.02-0.03	13.50

[a] Calculated using the Exponential Power Series estimator in program TRANSECT (Burnham et al. 1980).

Table 2. Annual density estimates of black-tailed jack rabbits from spotlight transects in big sagebrush within the Birds of Prey Area, 1977-1985.

Year	Number of Rabbits Observed	Density Index[a] (N/ha)	95% Confidence Interval	Coefficient of Variation
1977	60	0.23	0.18-0.29	13.01
1978	54	0.67	0.48-0.85	14.45
1979	412	0.79	0.71-0.86	5.03
1980	455	0.75	0.68-0.82	4.76
1981	466	0.95	0.86-1.04	4.75
1982	163	0.29	0.24-0.34	7.96
1983	137	0.33	0.28-0.37	6.63
1984	36	0.13	0.06-0.19	26.70
1985	25	0.04	0.03-0.06	20.03

[a] Calculated using the Exponential Power Series estimator in program TRANSECT (Burnham et al. 1980).

Table 3. Number of kangaroo rats seen per unit of effort (N/km) on the spotlighting transects within selected cover types, Snake River Birds of Prey Area, 1984 and 1985.

Cover Type	1984 Number/km	1985 Number/km
Big sagebrush	0.65	0.50
Big sagebrush/winterfat	1.59	0.50
Big sagebrush/shadscale	1.23	0.38
Winterfat	0.71	0.36
Shadscale	0.56	0.04
Shadscale/winterfat	0.25	0.11
Greasewood	1.81	0.00
Grass	0.46	0.48
All cover types pooled	0.67	0.39

TITLE: The Occurrence of Vesicular-Arbuscular Mycorrhizae Associated with Artemisia tridentata var. wyomingensis within Burned Areas of the Snake River Birds of Prey Area.

INVESTIGATOR: Marcia Wicklow-Howard, Biology Department, Boise State University

COOPERATOR: Boise State University

OBJECTIVE:

To determine the effects of fire on vesicular-arbuscular mycorrhizae in the Snake River Birds of Prey Area.

ABSTRACT

Soils from 1981, 1983, and 1985 burn sites and an unburned site within the Snake River Birds of Prey Area were collected. All sites were vegetated primarily with Artemisia tridentata var. wyomingensis (big sage) which is dependent upon vesicular-arbuscular mycorrhizae (VAM) for its healthy growth. These soils were investigated using pot culturing methods to determine if they contained active VAM fungal propagules. The results from pot cultures inoculated with the 1981 and 1893 soils showed that fungal propagules were present and actively infected 100% of the roots. With the 1985 burn soils, infection was much lower; only 50% of the roots from the pot cultures became infected. Most abundant were the spores of Glomus microcarpus, while spores of the genus Gigaspora were found in many of the soils.

INTRODUCTION

Wildfires have become an increasingly common occurrence within the Snake River Birds of Prey Area. Over the past 10 years, 37% (90,000 acres) of the sagebrush dominated rangeland has burned; and 80% (72,000 acres) of this burned in the past 5 years.

Artemisia tridentata var. wyomingensis (big sage) is the dominant variety of sagebrush present. After a burn, the previously sagebrush-dominated area is revegetated by Artemisia and invading non-native grasses, particularly cheat grass (Bromus tectorum). After each fire more Artemisia is replaced by cheat grass, and eventually the area may be completely overrun by cheat grass. Cheat grass burns very quickly and therefore is hard to control. Repeated fires within these cheat grass-dominated regions result in a ripple effect. The fire burns the cheat grass and a zone of previously undisturbed Artemisia surrounding it. With each consecutive fire, these areas increase in size and more Artemisia is lost.

The big sage community supports high densities of black-tailed jack rabbits (Lepus californicus). Jack rabbits are the main prey of golden eagles (Aquila chrysaetos), and research has shown a strong relationship between eagle productivity and jack rabbit abundance (U.S. Dep. Inter. 1979). The severe decline in jack rabbit numbers in recent years is thought to have been facilitated by the extensive loss of Artemisia habitat. There are concerns that the large loss of Artemisia may continue to maintain low jack rabbit numbers and resulting golden eagle numbers.

A positive solution to the problem is to revegetate these areas with the big sage soon after a burn, before the non-native grasses take a stronghold. The purpose of this study was to determine if VAM fungi, which are essential for the healthy growth of Artemisia, are present and remain active in soils after experiencing a recent burn.

MATERIALS AND METHODS

Soil samples, taken to depths of 15 cm, were collected from the rhizosphere of Artemisia tridentata var. wyomingensis within 4 different sites on 29 October 1985. The first collection site was from an unburned control area vegetated primarily with big sage. The remaining 3 sites were vegetated primarily with the big sage before experiencing a burn in 1981, 1983, or 1985. Three plots from each site were randomly selected.

Soil samples were used as inoculum for pot cultures the day after collection. For each plot, 2 pot cultures were inoculated, resulting in 6 pot cultures for per site. An equal amount of inoculum soil was mixed with 500 g of sterilized, sandy garden soil. One control from each plot, in which the inoculum soil was sterilized as well, was prepared. All were then planted with seeds of sudan grass (Sorghum vulgare var. sudanense) that had been surface sterilized with 1% $AgNO_3$. Pot cultures were watered, and received 16 hours of light, daily.

The sudan grass was harvested 3 months after planting the seeds. Roots were remove with approximately 50 g of soil. This soil was washed from the roots using a strong stream of distilled water, and collected in a 2 liter beaker for wet sieving; a procedure in which VAM spores are isolated. Roots were fixed in FAA for later work.

Soil within the 2 liter beaker was allowed to settle for 20 to 30 sec. The water was then decanted over 2 stacked sieves. The top sieve had a 420 um mesh and the bottom sieve a 45 um mesh which is smaller than the diameter of most VAM spores. This was repeated 2 times.

Material accumulating on the top sieve was washed thoroughly by a strong stream of distilled water. Material collected on the 45 um sieve was washed into a 15 ml glass centrifuge tube for sucrose centrifugation. The material centrifuged at 2000 RMP for 4 min. The water was carefully decanted and discarded. The soil pellet was then suspended in cold (5° C) 1.5 M sucrose and centrifuged again at 2000 RMP for 4 min. The sucrose, containing suspended fungal propagules, was decanted over medium grain filter paper which was examined for the presence of VAM spores using a dissecting microscope.

Following the procedure of Phillips and Hayman (1970), sudan grass roots fixed in FAA were cleared and stained with trypan blue, which specifically stains the fungal symbiont. The roots were then examined, using the light microscope, the 1 or more of the following fungal propagules: vesicles, arbuscules, and tightly coiled hyphae called peloton. These structures are unique to VAM fungi, therefore their presence is indicative of a VAM infection.

RESULTS AND DISCUSSION

VAM spores were found within the filtrate of all soil samples, including controls, pointing towards possible contamination. However, only 1 of the 12 control soils had infected sudan grass roots (Table 1), suggesting that sterilization of the soils inactivated, but did not disrupt or destroy spores.

The VAM spore occurring most frequently in all soil filtrates was identified as the asexual chlamydospore of Glomus microcarpus. The spore is smooth, globose hyaline to light yellow, and approximately 50 mm in diameter. It is attached singly to a hyphal extension.

A large spore with a suspensor-like bulb attached to its base was found. Several narrow outgrowing hyphae radiated from the bulb with the uppermost growing up and around the surface of the spore but never fusing with it. This spore fit the description of the azygospores of the genus Gigaspora, another VAM fungus.

Table 1 shows the incidence of VAM infection within sudan grass roots. The results from pot cultures inoculated with the 1981 and 1983 soils show that fungal propagules were present and actively infected 100% of the roots. With the 1985 burn soils, infection was much lower. Only 50% of the sudan grass roots from the pot cultures became infected.

Also investigated was the incidence of VAM infection within Artemisia tridentata var. wyomingensis roots from 2 1985 burn sites. One site experienced fire of low intensity, while the other a fire of higher intensity. 67% of roots from the low intensity burn were infected, while only 18% of roots from the higher intensity burn were infected (Table 2).

The preceding data suggest that VAM fungi are affected more adversely by a high intensity burn and that they recover from a burn within at most 2 years, and possibly 1. However, after 2 years have passed, these areas are often highly invaded by cheat grass which is not dependent upon mycorrhizae. Therefore, areas experiencing a low intensity burn in which the mycorrhizae are not significantly reduced, should be revegetated that same year before cheat grass invasion. In high intensity burn areas in which mycorrhizae are significantly reduced, revegetation programs should begin 1 to 2 years after the fire, giving the mycorrhizal fungi time to recover and increase in numbers. In this case, steps would have to be taken to eradicate the cheat grass before reseeding.

This research took the initial steps in understanding the effects of fire upon vesicular-arbuscular mycorrhizae. Further research is necessary to determine the effects of different fire intensities on spore survival and, in addition, how rapidly fungal spores will reinvade the area.

Table 1. VAM infection of sudan grass roots from pot cultures.

Soil Plots	Unburned	1981 Burn	1983 Burn	1985 Burn
1a	+	+	+	–
1b	no plant	no plant	+	–
2a	+	+	+	+
2b	no plant	+	+	+
3a	+	+	+	+
3b	+	+	no plant	–
Control 1	–	+	–	–
Control 2	–	–	–	–
Control 3	–	–	–	–

Table 2. Percent mycorrhizal infection of <u>Artemisia tridentata</u> roots following fire.

Type of Disturbance to Root	Slide 3 % of Infection	Slide 2 % of Infection	Slide 3 % of Infection	Total % of Infection
Low intensity burn	10/10 = 100%	0/10 = 0%	10/10 = 100%	67%
High intensity burn	5/10 = 50%	0/10 = 0%	0/10 = 0%	18%

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TITLE: The Formation of Vesicular-Arbuscular Mycorrhizae in Natural Plant Communities of the Snake River Birds of Prey Area.

INVESTIGATOR: Marcia Wicklow-Howard, Biology Department, Boise State University

COOPERATOR: Boise State University

OBJECTIVE:

To identify the relationships between vesicular-arbuscular mycorrhizae and plant species in the Snake River Birds of Prey Area.

INTRODUCTION

A survey of native Idaho desert shrubs and their associated vesicular-arbuscular mycorrhizae (VAM) is being conducted in the Snake River Birds of Prey Area. In order to better understand which VAM fungi are associated with individual plant species, a spore isolation study is underway.

METHODS

The basic procedure for spore isolation and quantification is taken from Daniels and Skipper (1982). Soil and fine roots were collected from plants at the study sites. The soil was wet-sieved through a 106 micrometer sieve, and the material on the sieve washed into a beaker. The solution was decanted several times in order to remove the material which floated (i.e., fungal spores). The plants and the amount of soil used are presented in Table 1.

The roots and the sieve materials were used to inoculate pots of sterile soil. These were then planted with Sorghum vulgare var. sudanense (Piper) Hitch. After 4 months soil cores were removed from the pots and sieved for VRM spores. Roots were removed from the sudan grass and stained for the presence of fungal structures.

RESULTS

The results from the pot cultures are presented in Table 2. Arbuscules, vesicles, and spores were observed in the sudan grass roots. Spores were also observed attached to hyphae that had grown out from the roots. The spores ranged in size from 200-400 micrometers and were terminal asexual chlamydospores of the species Glomus microcarpus.

LITERATURE CITED

Daniels, B. A., and H. D. Skipper. 1982. Methods for the recovery and quantatative estimation of propagules from soil. Pages 29-36 in N. C. Sclenck, ed. Methods and principles of mycorrhizal research. Amer. Phytopathological Society Minn. 244pp.

Table 1. Plant species and soil quantities.

Plant	Site	Volume (ml)	Weight (g)
Artemisia tridentata var. wyomingensis	1	400	443
Artemisia spinescens	1	400	423
Gutierrezia sarothrae	2	400	505
Chrysothamnus nauseosus	7	400	565
Tetradymia glabrata	2	350	388
Atriplex spinosa	1	400	409
Atriplex confertifolia	4	400	392
Tetradymia canescens	7	400	476
Atriplex nutallii	3	375	367
Atriplex confertifolia	7	375	374
Chrysothamnus nauseosus	7	400	469
Gutierrezia sarothrae	2	400	466
Tetradymia glabrata	2	400	480
Artemisia spinescens	1	300	540
Artemisia tridentata var. wyomingensis	1	200	357

Table 2. Mycorrhizal spores isolated from soils associated with desert plants.

Plant	Site	Dates Roots Collected From Desert	Structures Found in Pot Cultures: Vesicles	Arbuscules	Spores	Coiled Hyphae
Tetradymia glabrata	2	2/18/84	+	-	+	-
Tetradymia glabrata	2	4/27/84	+	-	-	-
Tetradymia canescens	7	2/18/84	+	+	-	+
Artemisia tridentata var. wyomingensis	1	2/18/84	+	+	+	+
Artemisia tridentata var. wyomingensis	1	4/27/84	+	-	-	-
Artemisia spinescence	1	2/18/84	+	-	+	-
Artemisia spinescence	1	4/27/84	+	-	+	+
Chrysothamnus nauseosus	7	2/18/84	+	-	+	-
Chrysothamnus nauseosus	7	4/27/84	-	-	-	-
Gutierrezia sarothrae	2	2/18/84	-	-	-	-
Gutierrezia sarothrae	2	4/27/84	-	-	-	-
Atriplex confertifolia	7	2/18/84	+	-	+	-
Atriplex confertifolia	4	4/27/84	-	-	-	-
Atriplex canescens	3	4/27/84	-	-	-	-
Atriplex spinosa	1	2/18/84	+	-	+	+
Control		--	-	-	-	-

TITLE: Vegetation Monitoring in the Snake River Birds of Prey Area.

INVESTIGATORS: Ray Aguilar, Range Conservationist, Bruneau Resource Area
Randy Trujillo, Wildlife Biologist, Bruneau Resource Area
John Doremus, Wildlife Biologist, Bruneau Resource Area
Raul Morales, Wildlife Biologist, Owyhee Resource Area
Carla Schroer, Volunteer

OBJECTIVE:

To monitor changes in vegetation in the Birds of Prey Area as related to livestock grazing and wildfires.

ANNUAL SUMMARY

All 5 livestock exclosures and 4 of 8 fire study plots were sampled in 1985.

METHODS

Exclosures

The 5 livestock exclosures established in 1981 were sampled as specified in the Birds of Prey Exclosure plan. Techniques in use on each exclosure included paired 40-sample (10-m spacing) Daubenmire transects (Daubenmire 1959, 1970), 1/300-acre ($13.49m^2$) density plots (Asherin 1973), $1\text{-}m^2$ stem or trend plots, and photographic documentation. In 1985 an additional sampling method, nested frequency plots (80-samples, 2 per m^2 at 10-m spacing) (U.S. Dep. Inter. 1983), was initiated.

Ground squirrel hole count transects (U.S. Dep. Inter. 1979) were conducted within and outside of each exclosure. A record of all flora and fauna seen was kept by field personnel.

Fire Study Plots

Three new paired study plots were established in 1983, as controls to supplement the 5 pairs established in 1982. Control pairs were placed at the Big Sagebrush spring/fall exclosure, Winterfat exclosure, and the Shadscale exclosure. Like the previously established study plot pairs, each plot consisted of 3 permanently marked 100-ft (30.5 m) transect lines in a radial arrangement with a common origin. Each plot consisted of 2 of these radial triads. One triad of each pair was located inside the respective exclosure to prevent livestock grazing; the other was located adjacent to, but outside the exclosure fence.

Four of 8 fire plots were sampled in July 1985. Sampling of fire plot #4 (CELA exclosure) and Fire plot #6 (CELA control) was prevented when an excessive amount of malathion was sprayed directly on fire plot #4 during grasshopper spraying operations by the Animal and Plant Health Inspection Service. Monitoring crews were directed to remain clear of the area until the Environmental Protection Agency's investigation was complete. Fire plot

#7 (ATCO control) was burned in June 1985, and will have to be re-established in 1986. Fire plot #8 was not monitored in 1985 as a result of an oversight by Bruneau personnel.

The exclosure which contains fire plot #1 was entered during 1985 and used as a holding corral for livestock. The ground was heavily trampled and a majority of the vegetation was removed. As a result the data from this plot will not be comparable to that of prior years. Future data collection from this sample site will only be comparable to the 1985 data. All fire plots which were not sampled in 1985 will be sampled in 1986.

Sixty canopy coverage estimates (Daubenmire 1959) were obtained on each triad (20 per line) at 5-ft intervals. Twelve 1/300-acre (13.49 m2) circular plots (Asherin 1973) were used on each triad to record plant density. Each line was photographed. The frequency of occurrence for each species was also calculated for each triad.

RESULTS

Exclosures and Fire Study Plots

Precipitation for the spring of 1985 was lower than average for the area encompassing the five exclosures (U.S. Dep. Commerce 1985). Annuals were short in vertical stature and perennials appeared to be stressed. The growing season appears to have been shorter than normal due to lack of precipitation.

After 1985 data had been recorded the shadscale exclosure burned. All sample sites were burned. The southern portion of this exclosure has burned within the past few years affecting both 400-m transects lines(40-sample, 10-m spacing Daubenmire transects).

All data collected on the exclosures and fire study plots are located in the Birds of Prey Exclosure binder at the Boise District, Bureau of Land Management, Boise, Idaho. The 5 base years of data (1981-1985) will be analyzed in the spring of 1986 to determine the effectiveness of the sampling techniques. A report will be produced by January 1987.

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