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College of Forestry, Wildlife and Range Sciences

ECOLOGY OF GREAT BLUE HERONS ON SILVER CREEK, IDAHO

FINAL REPORT TO
THE NATURE CONSERVANCY

NANCY M. WARREN
MAURICE G. HORNOCKER

JULY 1979

Forest, Wildlife and Range Experiment Station

University of Idaho

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Nancy M. Warren

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ABSTRACT

The population of Great Blue Herons at Silver Creek, Idaho, was studied intensively from May 1977 to August 1978. In both nesting seasons, the first eggs were laid during the end of March, and the first young hatched in the third week of April. Most young had fledged and left the heronry by the second week of July.

Nineteen nests were active in 1977, of which 14 fledged 47 young. In 1978, 25 nests were active, but only 5 fledged a total of 13 young. In both years, successful nests produced somewhat larger broods than those observed by other authors in colonies elsewhere. No significant differences were detected in nest success or brood size between nests with central and peripheral locations in the colony. The high nestling mortality in 1978 was probably due to disease or parasites, rather than starvation, predation, or human disturbance.

The Silver Creek nesting colony has been in existence for at least 40 years and apparently has remained relatively stable in numbers. Peak numbers of Great Blue Herons in the valley occurred during the nesting season, with a general dispersal observed after nesting. In the fall, groups of migrating herons were observed in the valley. Winter population counts fluctuated between 1 and 14 birds. Yearling birds were seen occasionally during the year.

Most observations of feeding herons were made in the tributaries. Loving Creek and the Silver Creek Preserve received regular use as standing-grounds during the fall and winter months. The majority of

observations (78%) were made in riparian zones, although groups of herons often used upland sites for resting areas.

Regurgitated pellets and fish remains were collected at the heronry. The pellets were composed primarily of small mammal fur (61% in 1977, 96% in 1978). The average length of fish prey was estimated to be 245 mm (9.6 in.) in 1977 and 224 mm (8.8 in.) in 1978. The sample was believed to over-represent large prey items. Sixty percent of identified fish remains were rainbow trout or brook trout, with 14% mountain whitefish and 26% nongame species.

Groups of herons were seen in every month of the year. Group sizes ranged from 2 to 34, with the largest average sizes observed in February, September, and October. Group size did not vary significantly at different times of the day, but more groups were seen during morning and mid-day than in the evening. Feeding herons were always solitary, and were occasionally observed to drive away intruding birds.

The selective advantage of colonial nesting was unclear. No evidence was found for the suggested advantages of social stimulation, predator defense, information about food locations, or use of limited nesting sites.

INTRODUCTION

Great Blue Herons (*Ardea herodias*) are the largest and most widely distributed of the North American herons. But despite their conspicuousness and broad distribution, few studies have been made of these birds until recently.

This study was conducted on Silver Creek, Idaho, where herons occur throughout the year. The study was planned to provide local baseline information on reproduction, food habits, and habitat use. In addition, behavior and social organization were observed throughout the year.

LITERATURE REVIEW

Nesting studies of Great Blue Heron colonies have been conducted by Werschkul et al. (1977) and Henny and Bethers (1971) in western Oregon; by Iven (1972), Pratt (1972, 1970), Page (1970), and Wilburn (1970) in California; by Lopinot (1950) in Illinois; by Edford (1976) in Ohio; and by McAloney (1973) and Vermeer (1969) in Canada. All provided information on nesting phenology and nesting success and identified mortality factors.

Breeding behavior has been documented by Mock (1976), Bent (1962), Meyerriecks (1960), and Cottrille and Cottrille (1958). Displays were described and their functions and evolution were discussed.

Alexander (1976), Ligas (1952), Kirkpatrich (1940), Cottom and Uhler (1937), and others have examined Great Blue Heron stomach contents and food items regurgitated by nestlings. Hibbert-Ware (1940) analyzed pellets regurgitated by Common Herons (*Ardea cinerea*) and discussed biases inherent in such analyses. Owen (1960) related nestling survival to food availability, and Krebs (1974) investigated the function of coloniality in relation to locating and utilizing food sources.

Palmer (1962) identified movement patterns by reviewing banding records. Henny (1972) used banding records to calculate the population dynamics of Great Blue Herons.

STUDY AREA

Field research was conducted in the area surrounding Silver Creek, in Blaine County, Idaho (Fig. 1). The area is located about 7 km (4 miles) south of Gannett, in sections 23, 24, 25, and 26 of T 1S, R 19E, Boise Meridian.

Silver Creek traverses an arid region dominated by big sagebrush (*Artemisia tridentata*). The valley bottomland is used for grazing cattle or for farming, with barley, hay, and potatoes being the principal crops produced.

Silver Creek is spring-fed, with 3 main tributary systems. The stream is famed for its trout fishery, although recently there has been some concern that its quality may be declining. The water remains open during the winter months, and the temperature and rate of flow are relatively constant throughout the year (Schweibert 1976). Because of this, the stream provides ideal habitat for numerous species of birds, including the Great Blue Heron.

A heron nesting colony is located on the western portion of the Nature Conservancy's Silver Creek Preserve. The Preserve is a 194-hectare (479-acre) tract, purchased by the Nature Conservancy in 1976. The nests are located in a grove of aspen (*Populus tremuloides*) trees, at a height of 15 to 18 meters (50 to 60 ft). Understory vegetation includes wild rose (*Rosa* spp.) and nettles (*Urtica* spp.).

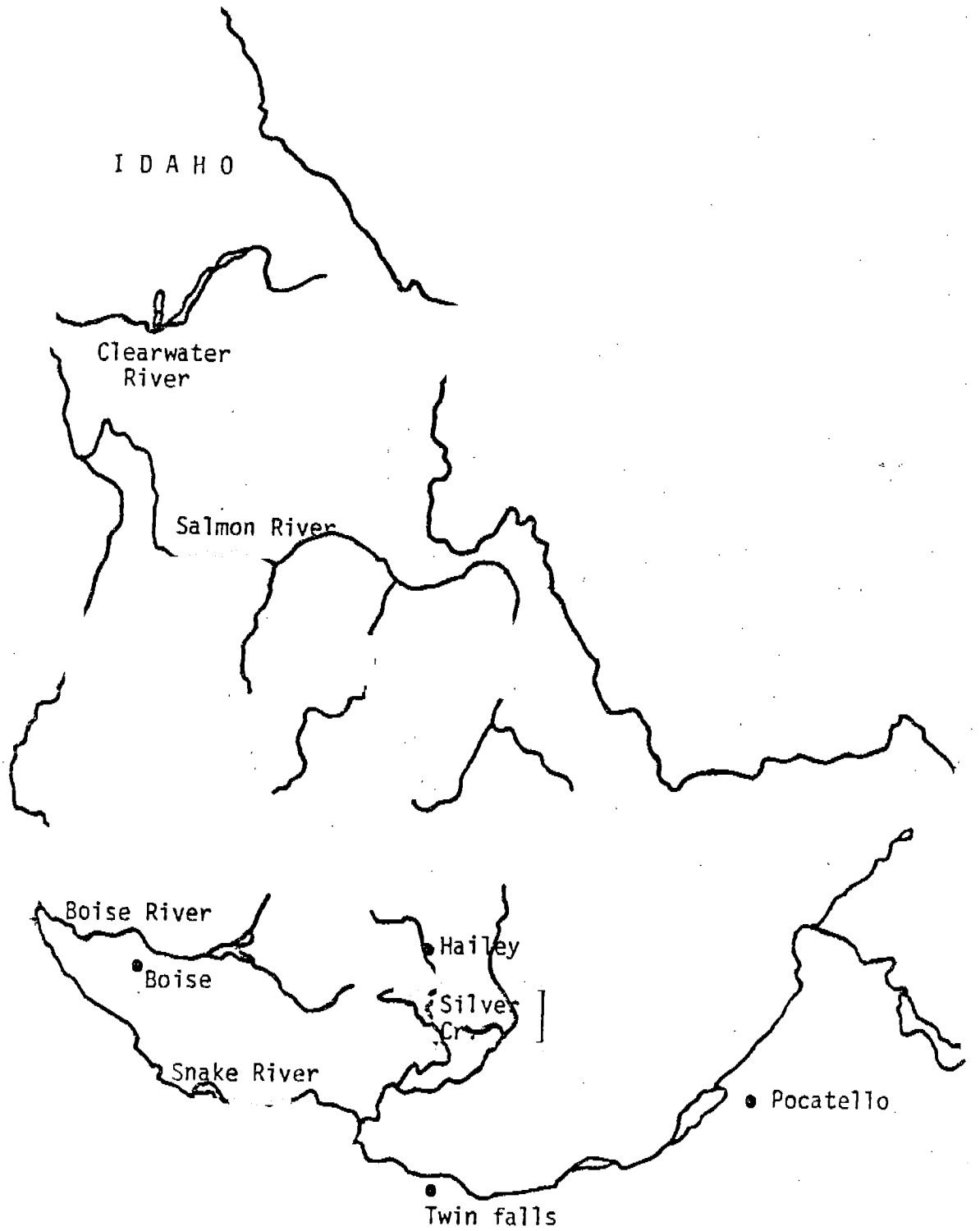

Fig. 1. Location map of Silver Creek, Idaho (from Wiley 1977).

OBJECTIVES

The objectives of the study were:

1. To document nesting phenology and success.

2. To ascertain the size and composition of the resident population throughout the year.

3. To obtain information concerning habitat use in the valley throughout the year.

4. To analyze food habits, with special reference to the rainbow trout (*Salmo gairdneri*) population.

5. To investigate the nature and function of behavior and social organization of Great Blue Herons throughout the year.

REPRODUCTION

Methods

An intensive study of the nesting colony was conducted in 1977 and 1978. In both years, nests were plotted and numbered from a vantage point along a road to the south of the heronry. Observations were made with a 20-60X spotting scope and 9 x 35 mm binoculars. Data were recorded for each nest at 1- to 3-day intervals.

In describing displays, terminology used by Mock (1976) was followed. No egg counts were made, as it was not possible to see into the nest cups. The number of young in a nest was counted during feedings, when all were active.

Nesting phenology was approximated and/or checked by backdating from the estimated age of the nestlings. Nestling age was estimated by identifying the following stages of development: able to stand and wald --3 weeks; left unattended by adults--3 to 4 weeks; wing exercising--4 weeks; able to climb out on branches near nest--5 weeks; capable of making short hop flights--7 weeks (Pratt 1970, Lopinot 1950). Incubation requires about 26 to 28 days, and about 17 days elapse between arrival in the colony and the onset of egg-laying (Pratt 1970, Vermeer 1969).

The study was planned for 2 seasons, to allow for comparison between years and to provide some indication of population trend. The first season of study was a year of severe drought; results from the 2 years were compared to evaluate the effect of the drought, if any, on behavior and productivity. Wilcoxon's two-sample test, modified for

unequal sample sizes by Mann and Whitney (Zar 1974), was used for this comparison of productivity. Results from both years were compared with results reported in the literature.

In each year, nests were subjectively divided into 2 groups, classified as "central" or "peripheral" with respect to relative location within the colony. Productivity of the 2 groups was compared for each year. Wilcoxon's two-sample test was used as before to test for differences between the groups.

Carcasses of dead birds were collected and frozen. Autopsies were performed by Dr. Eric Stauber of the University of Idaho Veterinary Science Department.

Results

Phenology

In 1977, nesting activities had begun before my first visit on 15 March. Of the 17 nests in the trees, a maximum of 15 was occupied at any given time. At least 9 of these nests were occupied by pairs.

All of the displays described by Mock (1976) were observed. Single birds were engaged in aggressive displays such as Arched Neck, Forward, and Supplanting; paired birds were engaged in nest-building and repair activities, and pair-bond strengthening displays such as Stretch and Bill-Clappering. Copulation was observed on 2 nests.

Hatching dates were estimated to extend from 17 April to 13 May for most nests; one nest, probably a second attempt, hatched young on 1 June. The first juvenile flight apparently occurred on 13 June, and the second on 19 June. By 6 July, all nests were empty except 2. By

17 July, the heronry was deserted, with young birds no longer returning to roose or to be fed.

In 1978, the nests were first visited on 8 February by a total of 17 birds. The birds exhibited the brilliant soft-parts coloration characteristic of the early breeding season (Meyerriecks 1960). Frequent Circle Flights and Supplanting were observed, and 2 pairs were engaged in Bill Duel and Bill-Clappering displays, typical of early pair formation. After 10 February, the heronry was deserted.

On 23 and 24 February, 2 Golden Eagles (*Aquila chrysaetos*) were seen standing on 2 of the nests. By the morning of the 27th, 21 herons had returned to the colony. Thirteen nests were attended, with pairs at 2 of the nests. The remaining nests were held by single birds; 6 of these had a second bird perched nearby. After 1 March, the nests were attended continuously, except on the afternoon of 13 March, when a Bald Eagle (*Haliaeetus leucocephalus*) was observed perched in the heronry.

Copulation was observed between 16 March and 18 April. Hatch dates were believed to extend from 20 April to 19 May. The first flight away from a nest was observed on 19 June, and the second apparently was on 22 June. Only one nestling still remained in the colony by 5 July.

In both years, hatch dates occurred during the same period. By 5 May, 69 and 70 percent of the nests had hatched eggs in 1977 and 1978, respectively. The peak of hatch occurred earlier in 1977 (Fig. 2). The late nest hatching eggs on 1 June 1977 was probably a second attempt; 3 other late nesters did not hatch eggs. There were no second attempts in 1978, and only 2 nests failed to hatch eggs.

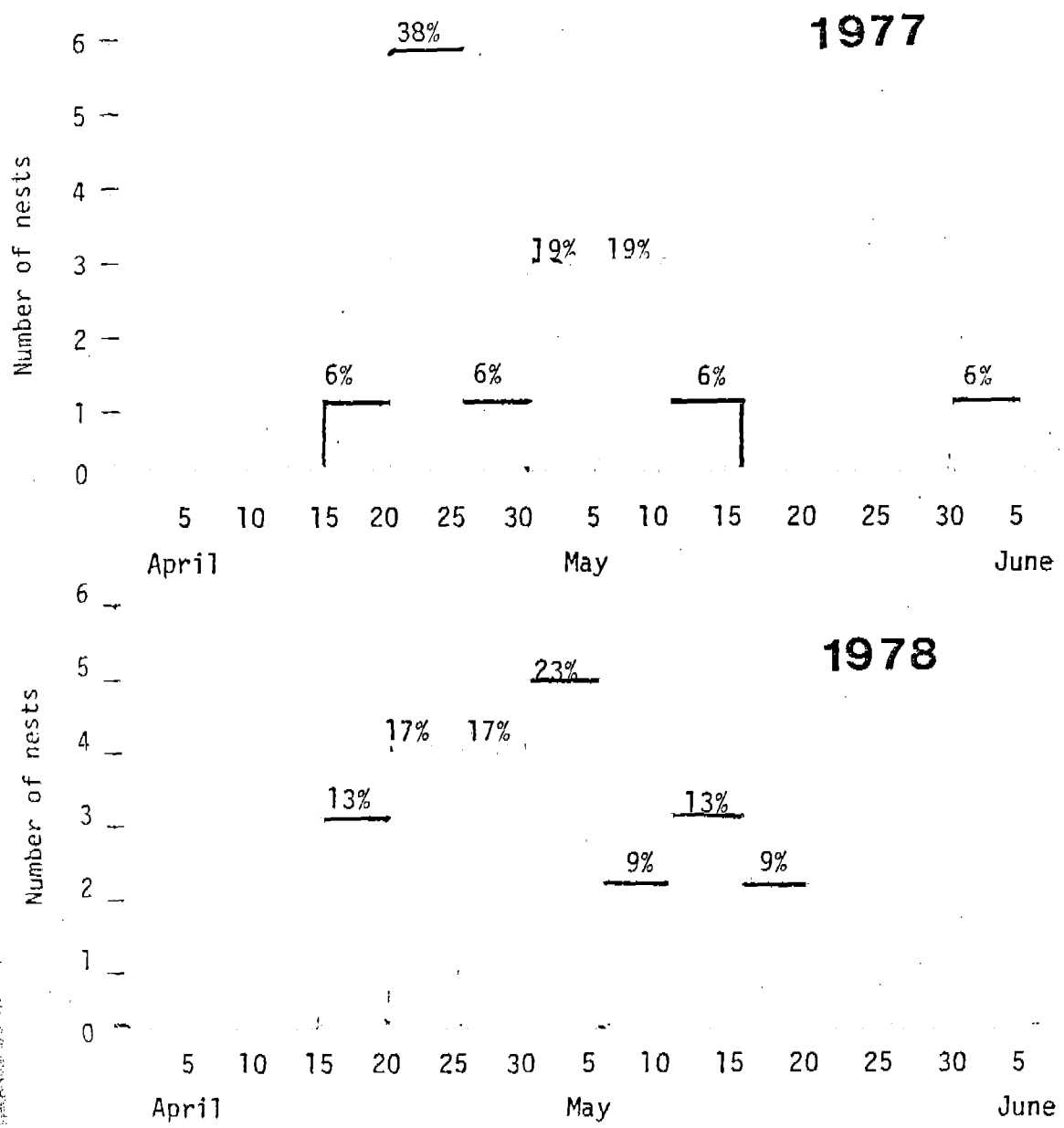

Fig. 2. Hatch chronology at Silver Creek, Idaho, in 1977 and 1978.

Reproductive Success

Rates of Success. There were 15 known first nesting attempts and 4 probable second attempts in 1977, of which 14 successfully fledged young. The number of young fledged from a nest varied from 2 to 5 (Table 1). A total of 47 young were fledged, for averages of 2.5 fledglings per breeding pair and 3.4 fledglings per successful nest.

Table 1. Fledging success at Silver Creek, Idaho, in 1977 and 1978

No. fledged	Number and percent of nests	
	1977	1978
0	5 (26%)	20 (80%)
1	0	1 (4)
2	4 (21)	2 (8)
3	4 (21)	1 (4)
4	3 (16)	0
5	3 (16)	1 (4)
	n = 19	n = 25
	$\bar{x}$ = 2.5	$\bar{x}$ = 0.5

In 1978, there were 25 active nests, an increase in colony size by about 32 percent. Of these, only 5 successfully fledged young. The number of young fledged from the nests varied from 1 to 5 (Table 1). A total of 13 young were fledged in 1978, for averages of 0.5 per breeding pair and 2.6 per successful nest.

The difference between years in average numbers fledged per breeding pair was highly significant ($u = 377.5$, $P < 0.001$). This

difference was probably due largely to the marked change in the number of nest failures. In 1977, about 74 percent of all nests were successful; in 1978, only 20 percent of the nesting attempts were successful. When nest failures were excluded, there was no significant difference in average brood size between years ($u = 47.5$, $P > 0.20$).

Nesting success rates were compared with reports from other nesting colonies in the United States and Canada (Table 2). The percentage of nests that were successful in 1977 did not differ from the range reported by these authors ($\chi^2 = 10.455$, $0.25 < P < 0.50$); in 1978, the percentage of successful nests differed significantly from rates reported elsewhere ($\chi^2 = 58.3$, $P < 0.001$).

Great Blue Herons lay clutches of 3-7 eggs, with 5 being most common (Palmer 1962). The eggs hatch asynchronously, and results of several studies indicate that generally only the largest members of a brood survive to fledging. Pratt (1972) reported only one nest successfully raising 4 young to fledging in 4 years of study (cumulative total of 217 nests observed); no instances of fledging 5 or more young were recorded. Similar results were reported by Henny and Bethers (1971), Page (1970), Wilburn (1970), and Vermeer (1969).

In this study, however, 3 nests (16 percent of all or 21 percent of successful nests) were found to have fledged 5 young in 1977; in the next year, when only 5 nests were successful, one of these fledged 5 young. For this reason, the average number fledged by successful nests in 1977 was higher than other reported rates (see Table 2), while the number per active nest did not differ appreciably. In 1978, the number fledged per successful nest did not differ from

Table 2. Comparison of nesting success rates reported for Great Blue Heron colonies

Source	No. nests	No. fledged per nest	No. nests successful	No. fledged per successful nest
This study	19	2.5	14	3.4
	25	0.5	5	2.6
Edford 1976[a]	1348	2.26	--	---
	134	1.93	--	---
Henny & Bethers 1971	55	2.04	43	2.61
Ives 1972	136	1.7	116	2.0
McAloney 1973	38	2.84	35	3.09
Page 1970	--	---	31	1.87
Pratt 1972	50	1.5	34	2.2
	62	1.7	50	2.1
	55	2.0	48	2.3
	50	1.5	38	1.9
Vermeer 1969	11	2.2	--	---
Werschkul et al. 1977[a]	161	---	--	2.7
	33	---	--	2.2
	88	---	--	2.53
	86	---	--	2.58
	97	---	--	2.18
Wilburn 1970	22	2.63	19	3.05
	19	2.26	18	2.39

[a]Reports of different colonies. All others are reports from a single colony for one or more years.

the results of other studies, even though the unusually large number of nest failures resulted in a very low average number per active nest. None of the other studies which were continued for more than one breeding season exhibited the dramatic change in success between years that I observed (Edford 1976, Pratt 1972, Wilburn 1970).

Central and peripheral nests were compared in both years. In 1977, 10 central nests fledged an average of 3 young each, while 9 peripheral nests peripheral nests fledged an average of 1.8; in 1978, 13 central nests fledged an average of 0.9 young, and 12 peripheral nests fledged 0.1. No significant difference was detected in nest success relative to nest location in either year (1977: $u = 65$, $0.10 < P < 0.20$; 1978: $u = 97.5$, $P > 0.20$).

The unsuccessful nests were then excluded from the samples. In 1977, 8 central and 6 peripheral nests were successful; central and peripheral nests fledged averages of 3.8 and 2.7 young per nest, respectively. There was no statistically significant difference in brood size of the nests ($u = 38$, $P = 0.10$). In 1978, only 5 nests were successful; 1, which fledged 1 young, was classed as peripheral and 4, fledging 2 to 5 young each, were considered to be central. Because of the small sample size, no further tests were performed.

Causes of Mortality. Of the 5 unsuccessful nests in the first year of study, 3 were abandoned before the eggs hatched, both downy nestlings disappeared from or died in the fourth nest, and both nestlings in one nest were killed by a nocturnal predator. The first 4 were probably second attempts. One nestling fell from its nest and was killed, apparently during a wind storm.

In 1978, 2 of the unsuccessful nests were blown down by strong winds during a storm. Three nests were abandoned during incubation; one of these failures was believed to be linked with the death of an adult, killed upon collision with a power line near the heronry. The remaining 15 nests suffered mortality of their entire broods. The number of nests and fledglings lost are shown for each mortality factor in Table 3.

Table 3. Causes of nestling mortality and nest loss in 1977 and 1978 at Silver Creek, Idaho

Cause	1977		1978	
	No. nests	No. young	No. nests	No. young
Abandoned in incubation	3	uk	3	uk
Windstorm	0	1	2	0
Predation	1	2	0	0
Died in nest--cause unknown	1	2	15	37[a]

[a]Number of young in 14 nests only; the number in the remaining nest could not be determined because of obscuring foliage.

Pratt (1970) observed most nestling mortality in the third or fourth week after hatching and suggested that competition for food was probably greatest during this stage of development. Similarly, Owen (1960), studying 3 colonies of the closely related Common Heron, found that most partial brood losses occurred after the first and before the

fourth week after hatching; for this and other reasons, he attributed differences in nestling survival to food availability.

On Silver Creek, however, age at death in 1978 ranged from 3 to 7 weeks after hatching, with a mean and median of about 6 weeks. Approximate dates of and ages at death of nestlings in 1978 are summarized in Table 4. In all of these nests, the entire brood was lost, in contrast to Pratt's and Owen's observations.

Table 4. Approximate dates of and ages at death of nestlings in nests hatching young in 1978

Nest No.	No. of young	Date of death	Age at death (weeks)
102	1	6/22	6
104	uk[a]	6/1	4
106	3	7/3,4	7
107	2	6/24	6
108	2	5/29	3
110	2	6/10	5
112	1	6/16	7
118	4	5/27	5
119	3	6/8	7
120	3	6/15-24	7
121	4	6/10	6
122	3	6/11	6
123	3	5/27	4
124	3	6/15	6
125	3	6/15-20	6

[a]Nest obscured by foliage--estimates based on adult activities.

A bucket truck was brought into the colony to facilitate banding and marking of some nestlings on 25 May and 4 June of 1978. I was concerned that this activity may disrupt the colony and reduce nest success. Nestling mortality was first observed 2 days after the first banding visit, but was not a result of desertion as feeding visits were recorded for those nests on 26 May. Nestling losses continued until 4 July. The banding was conducted in the central part of the colony, and 4 of the 5 successful nests were centrally located. For these reasons, the high mortality rate was not believed to be related to the banding.

The pattern of mortality suggested that disease or parasites may have been the cause. No carcasses were recovered from the nests because of the risk of causing premature fledging of nestlings in nearby nests. The carcasses of 2 fledglings dying of other causes were autopsied, but did not yield any further clues.

Instances of mortality after fledging were documented in both years. Three carcasses of juvenile birds were recovered during late summer of 1977; all apparently were killed upon collision with fences or power lines. In 1978, one fledgling was recovered, apparently having been killed upon collision with a power line near the heronry.

Discussion

After the initial occupation of the nests and before egg-laying, sudden flights of all or most of the herons out of the colony have been recorded (Pratt 1970, Cottrille and Cottrille 1958). Other than these brief absences, other studies have implied that the nests were attended

continuously (Edford 1976, Mock 1976, Ives 1972, Lopinot 1950, Miller 1943).

However, this was not the pattern observed on Silver Creek. I observed heronry occupation, territory defense, and pair formation followed by total absence from the heronry for 17 days, then re-occupation and resumption of breeding activities. Meyerriecks (1960) reported that cold weather and high winds may inhibit courtship. However, weather was probably not the cause of colony abandonment in this case. Snow fell immediately prior to first occupation of the nests and again on the morning when the nests were reoccupied.

Dates of nesting were quite similar in 1977 and 1978. In both years, the first eggs were laid around the end of March, and the first young hatched around the third week of April. Most young had fledged and left the heronry by the second week of July.

No clear trend in population size was apparent from the 2 years of study. Nesting success was unusually high in 1977, with brood size of successful nests much higher than rates reported for other colonies. Several authors have pointed out that usually only the largest 2 or 3 members of a brood survive to fledging and have suggested that brood size is adjusted to the food supply in this way (Pratt 1970, Owen 1960). Apparently the herons had little difficulty in securing enough food for their offspring, as 6 of the successful nests (43%) fledged 4 or 5 young. In 1978, the number of breeding birds increased, but 80 percent of the nests failed.

The drought conditions of 1977 did not appear to affect reproductive success adversely. In the Silver Creek aquifer, stream volume

was lower than average during 1977, but declined to even lower levels in 1978, one year after drought conditions occurred (Thurow 1979).

Henny (1972) estimated that, in the northern United States, 1.9 young Great Blue Herons must be fledged per breeding pair to maintain a stable population. On Silver Creek, productivity in 1977 (2.5 fledged per pair) exceeded this minimum, but productivity in 1978 (0.5 per pair) fell far short of it. Further observations will be needed to assess the status of the population.

Great Blue Herons are single-brooded, but will lay a second (or third) clutch if the first is lost (Palmer 1962, Miller 1943). On Silver Creek, renesting attempts did not contribute to productivity of the population, as none of the nests thought to be second attempts was successful. Edford (1976) also reported zero success of late nesting attempts in Ohio.

POPULATION SIZE AND COMPOSITION

Methods

To gain information on historical heron use in the area, some long-time local residents were interviewed. They were asked whether they had any information as to how long the heronry had been in existence and whether in their opinion the local heron population had changed appreciably in size over recent years.

Aerial counts of Great Blue Herons in the Silver Creek valley were conducted once or twice each month, from September 1977 to August 1978. A Cessna 172 of Piper Cherokee was used, with the same pilot on all but 2 of the flights. We flew about 75 meters (250 ft) above the ground, at about 75 miles per hour. We flew over each tributary in succession, serpentine fashion, and then followed Silver Creek down as far as its confluence with the Little Wood River. One observer recorded the number and location of birds seen in and along the creeks, while the second observer scanned fields and stream sections as necessary.

Ground survey data, collected from July 1977 through July 1978, were used to augment the aerial population data. I completed 3 ground searches each week--one in the morning (before 1100 hours), one at midday (1100 to 1600 hours), and one in the evening (after 1600 hours). These surveys were conducted from a car and by foot, using hillsides and prominences for viewing when possible.

In months when all ground searches were not completed, an average value was computed and assigned as the missing value. An

overall average and median was then derived for each month. The average numbers observed on ground searches and aerial counts each month were compared.

To gain more information about dispersal of young birds after fledging, nestlings were banded, color-marked, and radio-instrumented. A bucket-truck was used to gain access to the nests. Three nestlings in 2 nests were successfully banded and marked at about 4 weeks of age; a second visit for banding had to be aborted because of imminent premature fledging of 6-week-old nestlings in one of the target nests. The nestlings were banded with a standard U.S. Fish and Wildlife Service band and marked with square Herculon markers attached above the tibiotarsal joint. Radio transmitters were assembled and attached as recommended by Dunstan (1972).

Age composition of the population was recorded while conducting ground searches and monitoring reproduction. Subadult birds were recognized by their plumage, which is characterized by short occipital and scapular plumes, general gray coloration, and lack of a distinct black shoulder patch (Palmer 1962).

Results

Historical information about the Great Blue Heron population must be treated cautiously, as most observations have been casual and non-systematic. But these data are useful in establishing the presence or absence of herons in the valley, and some observers can provide insight into relative abundance over the years.

A large heronry, reportedly comprised of several hundred nests, was located on the Big Wood River near Bellevue until about 50 years

ago, when it was destroyed by shooting birds and cutting down nest trees. Another heronry was located on the Big Wood River about 50 km (30 mi) south of Bellevue, south of State Highway 20. That heronry was destroyed when the trees were logged for a mill in Bellevue. A colony of about 25 to 20 nests, referred to as the Statton Crossing heronry, is now located near Highway 20, north of the old heronry and about 13 km (8 mi) west of the Silver Creek heronry. The Silver Creek colony apparently has existed in its present location for at least 45 years.

Les Bushby, a ditch-rider in the valley since the 1930's, stated that the heronry had probably remained fairly stable since then, varying between 18 and 22 nests each year (pers. comm. 1978). In the 2 seasons of this study, colony size increased from 19 to 25 nests, close to the range reported by Mr. Bushby. However, most local residents expressed the belief that the heron population has increased noticeably in recent years. This would appear to be a misconception.

Herons occupied the Silver Creek valley throughout the year. However, population numbers fluctuated considerably over the year (Fig. 3).

In July 1977, ground surveys were initiated. Only 13 observations of herons were made in 15 searches during July and August. Fledging of nestlings began on 13 June 1977, and by 17 July the heronry was deserted. A general post-breeding dispersal occurred, with virtually all of the herons leaving the valley.

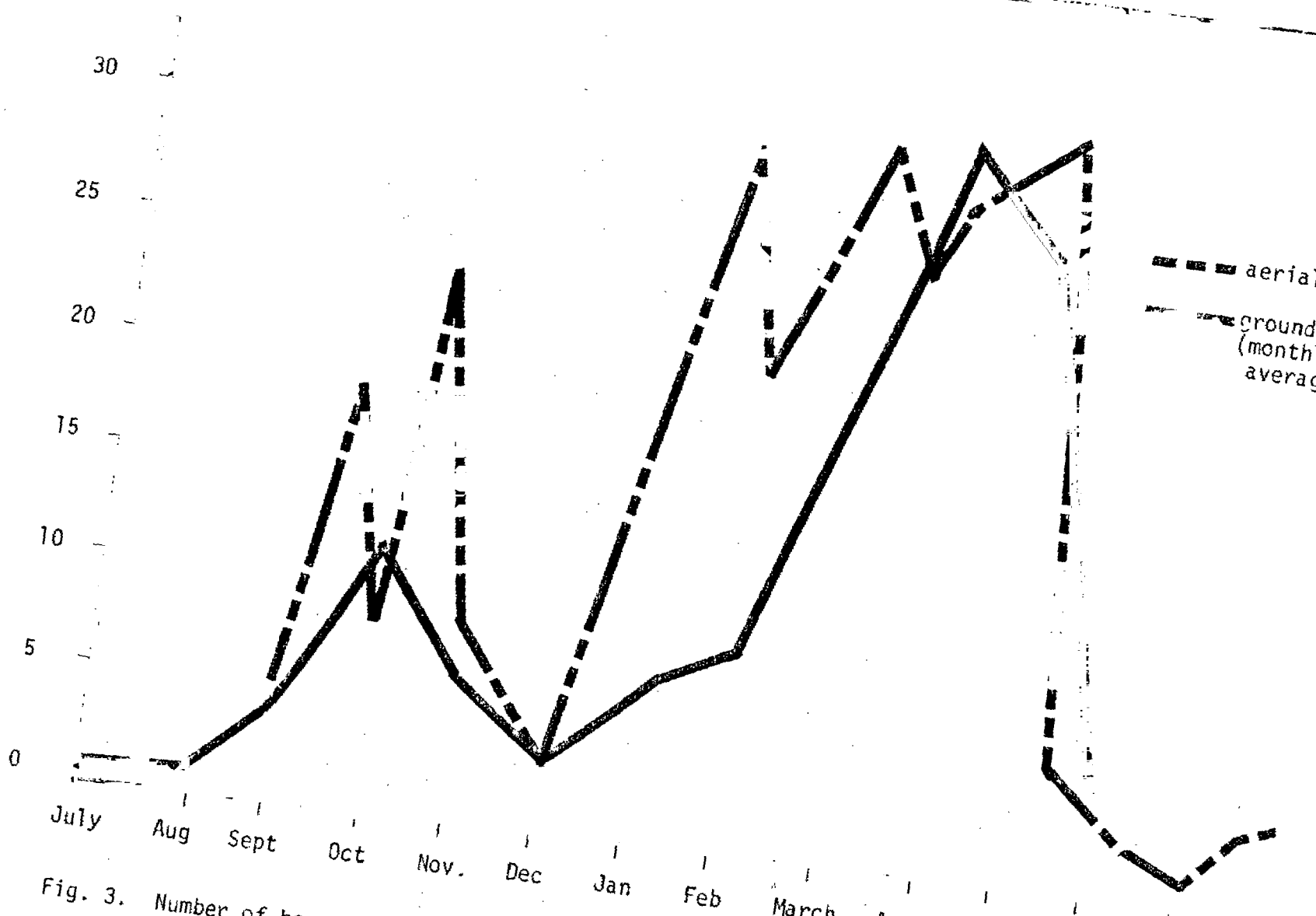

Fig. 3. Number of herons counted on aerial and ground searches from
at Silver Creek, Idaho.

I began making aerial counts in September. Both adults and subadults reappeared in the valley in that month, with the second aerial count totaling 18 individuals.

In October, several large groups of up to 34 herons were seen, standing in open plowed fields. These birds were believed to be migrants.

During the winter months of November and December, population size fluctuated, varying from 1 to 14 counted. The overall trend was a decline in the number of herons using the valley over these 2 months.

Only one aerial count was completed in January, and because of unfavorable weather and scheduling difficulties, it was made at the very end of the month. The count of 30 on that flight was much higher than ground search totals during the month, and is probably more typical of the breeding population than the wintering population. If this count is excluded, the average number of adults seen in all other ground surveys was 6.8, with a median of 6 and range of 2 to 13.

In late January and early February, an influx of herons was noted. The nests were first occupied and defended on 8 February. Eventually 25 nests were active, for 50 breeding individuals. However, survey totals never equaled the number of breeding birds; some birds were leaving the valley.

By the end of May, 16 nests were still active in 1978; only 6 were active by 30 June. The unsuccessful birds apparently moved out of the valley, as the number of individuals seen dropped off markedly during June. Numbers remained low in July and August, once again indicating the occurrence of a post-breeding dispersal.

Of the marked, radio-instrumented nestlings, one died in its nest 2 weeks after banding; one fell from its nest at 5 weeks of age, was fed and kept alive for 4 weeks, then was killed, apparently by an avian predator; and one survived to fledging. The surviving bird was monitored for 30 days after fledging. For the first 8 days after its first extended flight, it remained in the valley and continued to return to the nest to be fed. Then the bird moved and could not be located in the Silver Creek valley or along the Big Wood or Little Wood Rivers. An aerial search was conducted, and the bird was located northwest of Magic Reservoir on Poison Creek, about 20 km (12 mi) west of the Silver Creek heronry. The bird remained in this area for 16 days, then moved again and could not be relocated.

Yearling birds visited the heronry occasionally in both years. These individuals generally perched near various nests in the colony and sometimes followed adult birds flying into or out of the heronry. The largest number of yearlings seen in the colony at one time was 4, on 6 June 1977. Five other observations in 1977, made between 31 May and 14 June, were of only 1 or 2 subadults at one time.

In 1978, I was present for the entire breeding season, and yearlings were observed throughout the season. One yearling was observed in mid-January, perched in the heronry trees with 2 adults. In February, a subadult was seen on 3 different days in the same location away from the heronry. Yearlings were seen in the heronry on 8 additional days in 1978: once in late March, 3 times in April, twice in May, and twice in June. Between 1 and 3 individuals were present each time.

Discussion

The size of Common Heron colonies has been found to remain relatively constant over a period of years (Lack 1954), with the mechanism regulating numbers presumably being behavioral (Owen 1959). The size of the Great Blue Heron nesting colony on Silver Creek apparently has remained relatively stable, despite the destruction of 2 nearby colony sites.

Owen (1959) suggested that immature birds may explore breeding areas for vacancies to return to and occupy in subsequent years. At Silver City, subadult birds were observed occasionally throughout the breeding season. They frequently were threatened by adults or nestlings when they approached the nests closely, but were never driven out of the colony by other birds.

In analyzing banding records of Great Blue Herons, Henny (1972) and Palmer (1962) found evidence of a post-breeding dispersal in which the birds moved in all directions, followed by a later southward migration. In Europe, Olsson (1958) found a similar pattern in the Common Heron and suggested that the dispersal was caused by a shortage of food due to the sudden increase in population size after breeding. If this is the ultimate cause, the proximate cause must be a behavioral impetus, since both adults and subadults moved out of the valley, leaving available habitat unused.

DISTRIBUTION AND HABITAT USE

Methods

Data from ground searches and aerial counts were used to identify the pattern of habitat use in the valley. Ground surveys provided data on activities engaged in and habitats used; aerial data were used to adjust the distribution data.

The number of birds seen during morning, mid-day, and evening ground searches were compared. A one-way analysis of variance was computed to test for statistical differences in the numbers counted during different times of the day.

Numbers observed in each stream section were tabulated by activity and for each season. These data were weighted by the proportional number of all possible ground surveys that were completed.

To adjust for possible biases due to uneven coverage of the valley on ground searches, the data were adjusted using aerial count data. The ground surveys nearest the date of each aerial survey for the same time of day were selected. Coefficients were calculated for each of the 9 valley sections, based on the proportional numbers seen on 16 aerial and 16 ground surveys. These were applied to ground search data, and percentage use of the stream sections was then calculated for months and seasons.

Areas used by birds observed on ground surveys were described using the following categories of plant community structure: trees, riparian shrub, riparian emergent, riparian meadow, upland shrub,

upland prairie, cropland, or plowed fields. Additional information, such as water depth, substrate, and flow or distance to water, and height and type of perch was estimated and recorded.

Results

There was no significant difference in the numbers seen during morning, mid-day, and evening surveys for weeks when no surveys were missing ($F = 0.441$, $P > 0.50$).

The coefficients of visibility and the area each pertains to are shown in Fig. 4. Visibility from the ground was quite uneven.

Over the year, the Silver Creek Preserve and Loving Creek were used most frequently, with 44 and 22 percent of adjusted observations, respectively. When only observations of feeding herons were included, the distribution favored the tributaries in the upper end of the valley, with most observations being made on Cain-Chaney Creeks (31%) and Grove-Wilson Creeks (28%).

Distribution data for each season indicate that shifts in distribution occurred during the year (Table 5). During the fall, the greatest concentrations of herons were on Loving Creek (42%), but none of these birds were presumed to be feeding. Instead, the area surrounding Loving Creek was used as a gathering ground. During the fall, feeding birds favored the Cain-Chaney (36%) and Grove-Wilson (23%) tributaries. Use of lower sections (18%) was higher than during other times of the year.

During the winter months, most observations again were on Loving Creek (50%). The Loving Creek area continued to receive heavy use as a standing ground, although the groups tended to shift from the

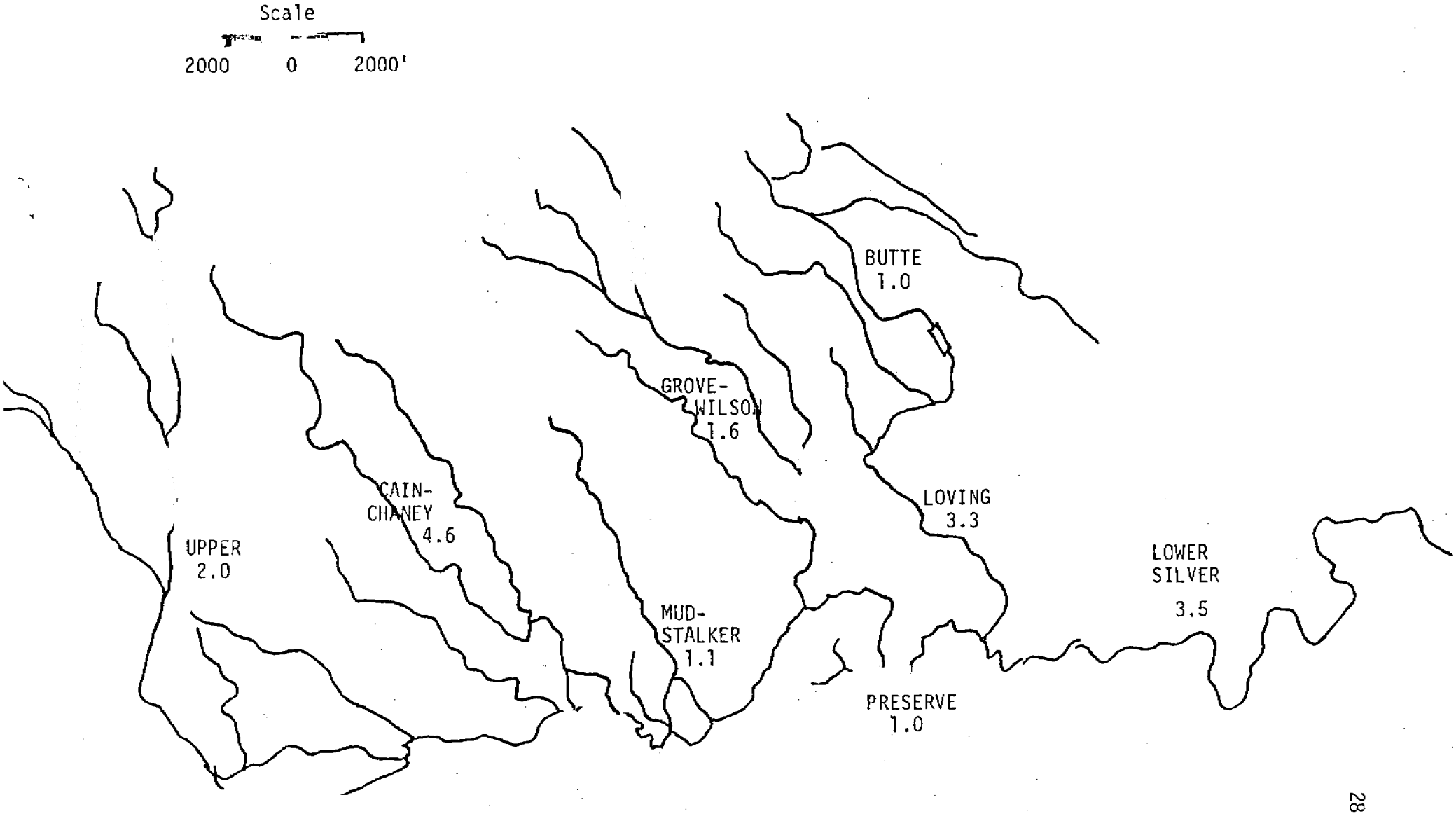

Fig. 4. Coefficients of visibility applied to ground survey data, based on comparison with distributions recorded on aerial surveys of the Silver Creek valley.

Table 5. Seasonal distribution of Great Blue Herons in the Silver Creek valley, Idaho (percentage by season for each activity in parentheses)

Section	Activity	Fall	Winter	Spring	Summer
Upper Stalker Cr.	All	4 (1)	0	8 (3)	0
	Feeding	2 (3)	0	6 (5)	0
	Non-feed	2 (1)	0	2 (1)	0
Cain-Chaney Cr.	All	47 (9)	9 (2)	42(15)	51(30)
	Feeding	28(36)	9(11)	33(26)	42(55)
	Non-feed	19 (4)	0	9 (1)	9(10)
Mud-Stalker Cr.	All	20 (4)	13 (3)	13 (4)	22(13)
	Feeding	6 (8)	8(10)	10 (8)	7 (9)
	Non-feed	14 (3)	5 (1)	3 (1)	15(16)
Grove-Wilson Cr.	All	117(22)	98(24)	68(24)	40(23)
	Feeding	18(23)	30(28)	38(30)	15(20)
	Non-feed	99(22)	68(21)	30 (4)	25(26)
Butte Cr.	All	7 (1)	1 (1)	11 (4)	8 (5)
	Feeding	2 (3)	1 (1)	4 (3)	4 (5)
	Non-feed	5 (1)	0	7 (1)	4 (4)
Loving Cr.	All	224(42)	205(50)	65(23)	7 (4)
	Feeding	0	7 (9)	10 (8)	0
	Non-feed	224(49)	198(60)	55 (7)	7 (7)
Silver Creek Preserve	All	20 (4)	64(16)	615(71)	8 (5)
	Non-nest			39(13)	
	Feeding	8(10)	18(23)	11 (9)	1 (1)
	Non-feed	12 (3)	46(14)	604(82)	7 (7)
Silver-Martin Br.	All	98(18)	14 (3)	35(12)	14 (8)
	Feeding	14(18)	0	7 (6)	7 (9)
	Non-feed	84(18)	14 (4)	28 (4)	7 (7)
Martin Br-lower	All	0	7 (2)	7 (2)	21(12)
	Feeding	0	7 (9)	7 (6)	0
	Non-feed	0	0	0	21(22)
n =	All	537	411	864	171
	Feeding	78(15)	80(19)	126(15)	76(44)
	Non-feed	459(25)	331(81)	738(85)	95(56)

open fields used in the fall to shrubby areas near the confluence of Loving and Silver Creeks. Feeding birds tended to favor the Grove-Wilson tributary (38%) and the Silver Creek Preserve (23%).

During the spring months, the Silver Creek Preserve assumed most importance (71%) because of heron concentration at the nests. If only observations of herons away from the nests are included, then Loving and Grove-Wilson Creeks received most use (23 and 24%, respectively). Feeding birds concentrated in the Grove-Wilson (30%) and Cain-Chaney (26%) Creek systems.

In the summer, the Cain-Chaney and Grove-Wilson areas received most use by herons away from the nesting colony (30 and 23%, respectively). Feeding birds were also observed most often in these drainages (55 and 20%).

Use of plant communities is shown in Table 6; 5 individuals were flying when seen and could not be tied to a particular area. The majority of observations were made in riparian areas (78%) rather than upland sites (22%). The greatest number of observations were made in trees (60%) and plowed fields (13%); these 2 types were frequently used by groups of herons, particularly during the breeding season and the fall and winter months, respectively. Solitary birds were most often observed in riparian zones, particularly shrubby areas (43%).

Some specific sites were of special importance to the herons. The Loving Creek Ranch, particularly the fields along Loving Creek north of the Silver Creek Preserve and the field west of Wilson Creek south of Highway 20, received heavy use as resting areas. In addition, the

Table 6. Observations of Great Blue Herons in plant communities along Silver Creek, Idaho

Community	Number & percentage of all observations	Number & percentage of single birds
Trees	817 (60)	11 (4)
Riparian-shrub	161 (12)	112 (43)
Riparian-emergent	34 (2)	30 (12)
Riparian-meadow	48 (4)	42 (16)
Upland-shrub	25 (2)	2 (1)
Upland-prairie	45 (3)	22 (8)
Upland-crop	54 (4)	19 (7)
Upland-plowed	178 (13)	19 (7)
	n = 1367	n = 259

shrubby area in the central portion of the Silver Creek Preserve received frequent use by herons during the winter months.

Feeding herons were observed most frequently in slow-flowing sections of the streams (71%) rather than in pools (10%) or riffles (19%). Water depth of areas used ranged from about 8 to 45 cm (3 to 18 in.). Most feeding herons were observed in areas with a substrate predominantly of silt (60%) compared to areas with a gravel substrate (40%).

Discussion

The tributaries were of most importance as feeding areas for Great Blue Herons. Preliminary data from the Idaho Fish and Game Department's study of Silver Creek for the period 28 May-30 September 1978 indicated that most anglers (65%) fished in lower sections of the creek, with only 12.5% of angler observations in the tributaries

(Thurow 1979). Anglers may be causing some displacement of herons, as feeding birds tended to utilize lower sections more frequently in the fall and winter than during the spring and summer.

Resting areas had several characteristics in common: they were generally open, with good visibility, located in areas with little disturbance (i.e., closed to duck hunting), and were located near groves of trees. During the fall, plowed fields were most frequently used; during the winter, the herons gathered along shrubby areas, possibly for the thermal cover they provided.

FOOD HABITS

Methods

Regurgitated pellets, dropped food fragments, and food regurgitated by nestlings were collected from under the nests. The heronry was visited about once every 2 weeks to obtain food items, from mid-May until all young were fledged. In 1978, nylon netting was placed under some of the nests to facilitate collection of food remains. In addition, stomachs of recovered carcasses were examined.

Pellets, comprised of indigestible portions of food, were weighed and measured and their composition was recorded. Fish fragments were occasionally dropped from the nests; fish length was estimated for spinal fragments by using the ratio of the proportional number of vertebrae to fragment length. A reference collection of fish was developed to aid in species identification of skeletal fragments and fish scales.

One nestling fell from its nest when about 4 weeks old. Although it survived, it was injured, apparently damaging tissues around the hallux of its right foot. To study food intake, I provided food for the bird for 4 weeks.

Heron distribution was compared with data obtained by the Idaho Department of Fish and Game concerning fish availability in different sections of the stream. This and other information was used to evaluate the impact of heron predation on the Silver Creek fishery.

Results

One hundred fifty-two regurgitated pellets were collected in the 2 years. The pellets ranged in size from 18 to 134 mm in length (averaging 56 mm), and from 9 to 54 mm in diameter (averaging 27 mm). Weights varied from 1 to 38 grams, averaging about 15 grams.

Regurgitated pellets do not provide an accurate record of the diet of Great Blue Herons. Because digestion is quite complete, fish and amphibian remains are grossly under-represented (Hibbert-Ware 1940). However, analysis of the pellets provided information concerning other sources of food and their relative importance over time.

In 1977, the majority of all pellets (61%) were composed primarily of small mammal fur. Twenty-six percent contained primarily plant material, 13% were primarily feathers, and 1% were primarily fish remains (scales). In 1978, nearly all pellets (96%) were composed primarily of small mammal fur, with the remaining 4% primarily plant material.

Most pellets contained undigested matter from more than one course (Table 7). Small mammal remains occurred in the largest proportion of pellets in every month except July 1977, when plant matter was recorded in a slightly larger number of the pellets. In 1977, birds occurred in about 20 percent of all pellets in June and July but were never recorded in pellets in 1978. Avian prey species appeared to be shore birds and waterfowl. It has been suggested that plant matter is taken more frequently when the diet is primarily fish or amphibians, to provide roughage (Lowe 1954). Plant material seemed to be taken more frequently as breeding progressed. Plant matter included mostly

Table 7. Percentage occurrence of prey items in pellets regurgitated by Great Blue Herons at the nesting colony

Month	Type of prey					
	Mammal	Bird	Insect	Fish	Plant	Grit
1977						
May	38%	0	12	6	21	23
June	38	20	2	4	28	8
July	32	22	0	12	34	0
1978						
May	66	0	16	0	16	3
June	37	0	30	5	19	9
July	42	0	31	4	19	4

barley seedheads and some grass blades and twigs. Identified insect remains included terrestrial species such as ladybugs and dragonflies and aquatic species such as caddisflies and aquatic beetles. The aquatic insects, along with snails and grit, were probably ingested indirectly, as stomach contents of fish that were eaten.

A total of 62 fish skeletal or anatomical fragments were collected. These were not believed to be a representative sample of fish taken by herons, however. Larger items would be both more durable and easier to find. Also, nestlings usually swallowed food whole, except that larger items were sometimes pecked at and shared between siblings, thus providing greater opportunity for these fragments to be dropped from the nests. Because of these factors, larger individuals and species would be over-represented.

The size of prey was estimated using the size and number of vertebrae relative to the number of vertebrae in a complete spine (R.L. Wallace, pers. comm.). In 1977, the estimated lengths varied from 168 to 344 mm (6.6 to 13.5 in.), averaging 245 mm (9.6 in.). In addition, a pelvic fin of a bridgelip sucker (*Catostomus columbianus*) and 2 fish skins were collected in 1977. One of the skins was the caudal portion of a whitefish (*Prosopium williamsoni*); the second was the entire skin of a rainbow trout that was approximately 305 mm (12 in.) in length. In 1978, estimated lengths were smaller, ranging from 64 to 300 mm (2.5 to 11.8 in.), averaging 224 mm (8.8 in.).

The majority of collected and identified fish bones were Salmonids (74%), with 60% rainbow trout or brook trout (*Salvelinus fontinelis*) and 14% mountain whitefish. The remainder were non-game species.

Only one recovered heron carcass still had its digestive tract intact; the others had been scavenged. The stomach of the necropsied heron, a juvenile female, contained only insect remains.

Food presented to the injured nestling ranged in size from 50 to 280 mm (2 to 11 in.) total length. The maximum size eaten was 240 mm (9.5 in.). The amount of food eaten each day varied from 153 to 454 grams (5.4 to 16 oz); the average amount eaten per day was 301 grams (10.6 oz). An adequate food supply was provided; all of that provided was eaten on only 9 of the 29 days.

Nine species of fish occur in Silver Creek and its tributaries (Thurow 1979). They include rainbow trout, brown trout (*Salmo trutta*), brook trout, mountain whitefish, bridgelip sucker, redside shiner

(*Richardsonius balteatus*), longnose dace (*Rhinichthys cataractae*), Wood River sculpin (*Cottus leiopomus*), and Utah chub (*Gila atraria*). Thurow (1979:18) presented electrofishing data showing species composition in various stream sections and in the tributaries; these data are reprinted in Table 8. There is evidence that smaller classes and species of fish were under-represented by the electrofishing, but his data indicate species presence or absence and relative abundance between sections.

Foraging herons were observed most often in Stalker Creek (42% of observations, adjusted with coefficients of visibility); their most abundant (and presumably most available) prey species would be rainbow trout, dace, whitefish, and suckers. The Grove-Wilson tributaries accounted for 28% of adjusted observations of herons; most abundant prey species in these creeks would be rainbow trout and brook trout. Ten percent of feeding herons were observed in the Silver Creek Preserve section; the most abundant prey there would be rainbow trout, whitefish, and suckers. The remaining 20 percent of feeding herons were observed in lower sections, where suckers were the most abundant species, and in Loving Creek, where rainbow trout and suckers were the most plentiful fish.

Fish movement could affect vulnerability of fish to heron predation. Thurow (1979) provided information on seasonal migration patterns. Both spring and fall-spawning races of rainbow trout exist in Silver Creek; all tributaries were used for spawning areas. The tributaries provide rearing areas for juvenile trout, with Grove and Wilson Creeks being particularly important. In 1977, many juvenile

Table 8. Species composition of fish captured by electrofishing in Silver Creek and its tributaries in 1976 (from Thurow 1979)

Species	Stalker	Grove	Wilson	Loving	Silver 1[a]	Silver 2[b]	Silver-lower
Rainbow trout	53%	83%	43%	49%	47%	27%	13-26%
Brook trout	8	12	46	0.2	2	1	0-0.5
Brown trout	0	0	0	0	0	0	0-7
Whitefish	12	3	0	0.6	32	4	0.1-1
Sucker	11	0.5	1	35	15	60	33-49
Dace	14	0.1	0.5	15	3	3	11-19
Sculpin	1	1	10	0.1	0.2	0	0
Shiner	0	0	0	0	0	3	7-35
Chub	0	0	0	0	0	0	0-0.2

[a]Silver Creek Preserve section (fly-fishing only regulations).

[b]Below Preserve to Martin Bridge.

rainbows moved into Silver Creek in July (Francis 1977); these probably were trout reared in the tributaries. Mountain whitefish spawned in Grove and Wilson Creeks in November. Except for spawning, wild trout generally remained within 1.6 km (1 mi) of the location where they were captured.

In different seasons of the year, 69 to 90 percent of herons observed feeding were seen in the tributaries (Table 9). Heaviest use of the tributaries occurred in the summer, when use of Stalker Creek increased. Grove and Wilson Creeks were used most heavily in the November to January period. Use of Silver Creek for feeding was lowest from May through July.

Table 9. Percentage of observations of feeding herons in 3 tributary systems and 2 sections of Silver Creek in different seasons of the year

Location	Seasons			
	Aug-Oct	Nov-Jan	Feb-Apr	May-Jul
Stalker Creek	46%	21%	39%	65%
Grove-Wilson Creeks	23	38	30	20
Loving Creek	3	10	11	5
Silver Creek Preserve	10	22	9	1
Lower Silver Creek	18	9	11	9

Discussion

To evaluate the impact of predation, the amount of biomass required per day by a heron and the number of herons present were assessed. In addition, selectivity in terms of species and/or relative size influences the effects on prey populations. (Selection based on prey vigor could not be evaluated.)

Alexander (1976) estimated that Great Blue Herons eat 454 to 680 grams (16 to 24 oz) of fish per day, while Lower (1954) reported that 341 grams (12 oz) per day would maintain a Common Heron in good health. The average amount eaten by the young bird I cared for was 301 grams (10.6 oz). In 1977, with a maximum of 53 young and 30 adults in the colony at one time, and assuming that each heron required about 340 grams of food, a peak total of 28 kg (67 lb) of food would be consumed by the colony per day. In 1978, 27 kg of food per day would have been required when numbers were at a peak (50 young and 30 adults).

Although 38 to 50 adult birds nested in the colony on Silver Creek in the 2 years, only a proportion of them hunted in the valley. The maximum number of herons seen feeding in the valley at one time was 16, on 3 March 1977. During the winter months, a maximum of 14 birds were found in the valley.

While herons did take large fish from Silver Creek, the average sizes taken were probably smaller than indicated by food-fragment analysis. The apparent decrease in prey size in 1978 as compared with 1977 may have been simply a result of the improved method for collecting food items.

Except for spawning fish, wild trout in Silver Creek seldom moved far. Since anglers and herons used different sections of the stream for the most part, competition between them was probably minimal. Spawning fish, however, would become more vulnerable to heron predation when they moved into shallower waters; herons and anglers would compete directly for these individuals.

SOCIAL ORGANIZATION

Methods

The social organization of Great Blue Herons was documented throughout the year on Silver Creek. The degree of sociality during the year, winter behavior, and the function of coloniality were investigated.

Groups of herons were recorded and described in conjunction with gathering data on distribution and habitat use throughout the year. Because a few of the aerial and ground searches could not be completed, the data were weighted to allow comparisons to be made. Weighting adjusted the data to the maximum of 14 surveys per month (2 aerial and 12 ground). Size and age composition of all groups seen were recorded, and the numbers and sizes of groups seen were tested for differences between months, seasons, and time periods of the day. Locations and habitats selected by groups were noted and compared between months and seasons.

Behavior of herons during the winter months was observed from a hillside above feeding and resting areas, using binoculars and a spotting scope. Activity patterns and interactions between individuals were recorded.

Potential positive and negative effects of colonial nesting on population productivity were evaluated. Possible disadvantages include the increased potentials for spreading diseases, attracting predators, and raising unrelated young; advantages could include social stimulation, communal predator defense, and shared information about food sources.

Most information was obtained in conjunction with monitoring reproductive success. The "information center" theory was evaluated by observing flights in and out of the heronry for a total of 15 hours each week (from 0600 to 1200 hours). In 1977, both arrivals and departures were recorded, to gauge peak periods of activity (i.e., nest relief and/or feeding of nestlings). Arrivals elicited greeting responses (vocal, visual, and tactile) from the attending mate and/or the nestlings, and therefore were easily detected. In 1978, only departures were recorded, in order to obtain better data on flight direction and destination. These data were analyzed to determine whether individuals followed each other to feeding grounds, whether the individual birds from a particular nest favored certain directions and/or sites, and whether directional shifts occurred. Mean angular direction and angular dispersion were calculated and used as shown by Batschelet (1965).

Results

Sociality

On Silver Creek, groups were observed in every month of the year except in July 1977. Only adults were present in November and December; mixed-age groups occurred occasionally throughout the remainder of the year.

A majority of all heron sightings made away from the heronry were of single birds, except in the months of October, November, and December (Table 10). A greater number of groups were seen away from the heronry during the fall and winter seasons than in the spring and summer.

Table 10. Number and percentage of herons observed singly or in groups away from the heronry from August 1977 to July 1978 at Silver Creek, Idaho (weighted data)

Month	Total No.	No. of singles	No. in groups
August	23	19 (83%)	4 (17%)
September	70	40 (57)	30 (43)
October	180	30 (17)	150 (83)
November	101	28 (28)	73 (72)
December	44	23 (52)	21 (48)
January	141	56 (40)	85 (60)
February	94	49 (52)	45 (48)
March	54	42 (78)	12 (22)
April	51	40 (78)	11 (22)
May	61	40 (66)	21 (34)
June	38	23 (61)	15 (39)
July	12	9 (75)	3 (25)

Group sizes ranged from 2 to 34, with monthly averages varying from 2 to 8 (Table 11). The largest average group sizes were observed in February, coinciding with the arrival of breeding birds in the colony, and in September and October, a period of dispersal and fall migration.

In all seasons, more groups were usually seen during morning and mid-day surveys than in the evening (Table 12). Although the number of groups varied with the time of day, there was no significant difference in the size of groups seen during morning, mid-day, and evening searches over the 12-month period ($F = 2.02$, $k = 2.11$, $0.50 > P > 0.20$).

Over the year, groups were observed in decreasing order of frequency in plowed fields, riparian areas, upland meadows and croplands,

Table 11. Sizes of groups of Great Blue Herons observed throughout the year at Silver Creek, Idaho, away from the heronry

Month	No. groups	Size range	Mean size	Median size
July	0	--	--	--
August	2	--	2	2
September	4	2-14	8	8
October	21	2-34	7.1	5
November	11	2-14	6.1	3
December	8	2- 9	4.1	4
January	12	2-10	3.7	3
February	8	2-16	8.1	7
March	6	2- 3	2.2	2
April	4	2- 3	2.3	2
May	4	2- 8	3.8	2.5
June	4	2- 7	3.8	4
July	3	--	3	4

Table 12. Number of groups seen on ground surveys during each season of the year (data weighted to account for missing surveys)

Season	Time of day of survey		
	Morning	Mid-day	Evening
Fall (Aug-Oct)	11	5	4
Winter (Nov-Jan)	8	12	5
Spring (Feb-Apr)	6	6	5
Summer (May-Jul)	4	5	1

and upland shrubby areas (Fig. 5). A Kolmogorov-Smirnov goodness of fit test (Zar 1974) showed they were not evenly distributed between habitats ($D = 0.172$, $0.01 < P < 0.02$).

In most cases, the herons stood in loose flocks with their necks drawn down onto their shoulders. Few overt interactions between members of a group were noted.

Reports of a courtship dance in the Great Blue Heron are few in number, except from Florida (Meyerriecks 1960). I did not observe dancing; however, the Superintendent of the Idaho Fish and Game Department's Hayspur Fish Hatchery recounted an observation that he and his wife made of heron dancing in 1978 (Leland Batchelder, pers. comm.).

Winter Behavior

During the winter, the pattern of heron activity generally was one of forming and/or rejoining a group between feeding forays. The flocks varied in size from 2 to 14 individuals in the winter; foraging herons were always solitary.

Groups usually formed in upland sites, although occasionally they were seen in shrubby areas along the stream bank. When in groups, the herons were inactive, often standing on one leg and sometimes tucking their heads under their wings.

Certain stretches of the stream were regularly utilized by foraging herons. Individuals spaced themselves out, so that each could forage alone in a section of stream at least 250 m (270 yd) long. Aggressive interactions were observed when one bird flew or waded into the vicinity of another. When this occurred, one of the birds would chase the other away and then circle back to the area. Nearby herons

Table 12. Number of groups seen on ground surveys during each season of the year (data weighted to account for missing survey).

Season	Time of Day of Survey		
	Morning	Mid-day	Evening
Fall (August-October)	11	5	4
Winter (November-January)	8	12	5
Spring (February-April)	6	6	5
Summer (May-July)	4	5	1

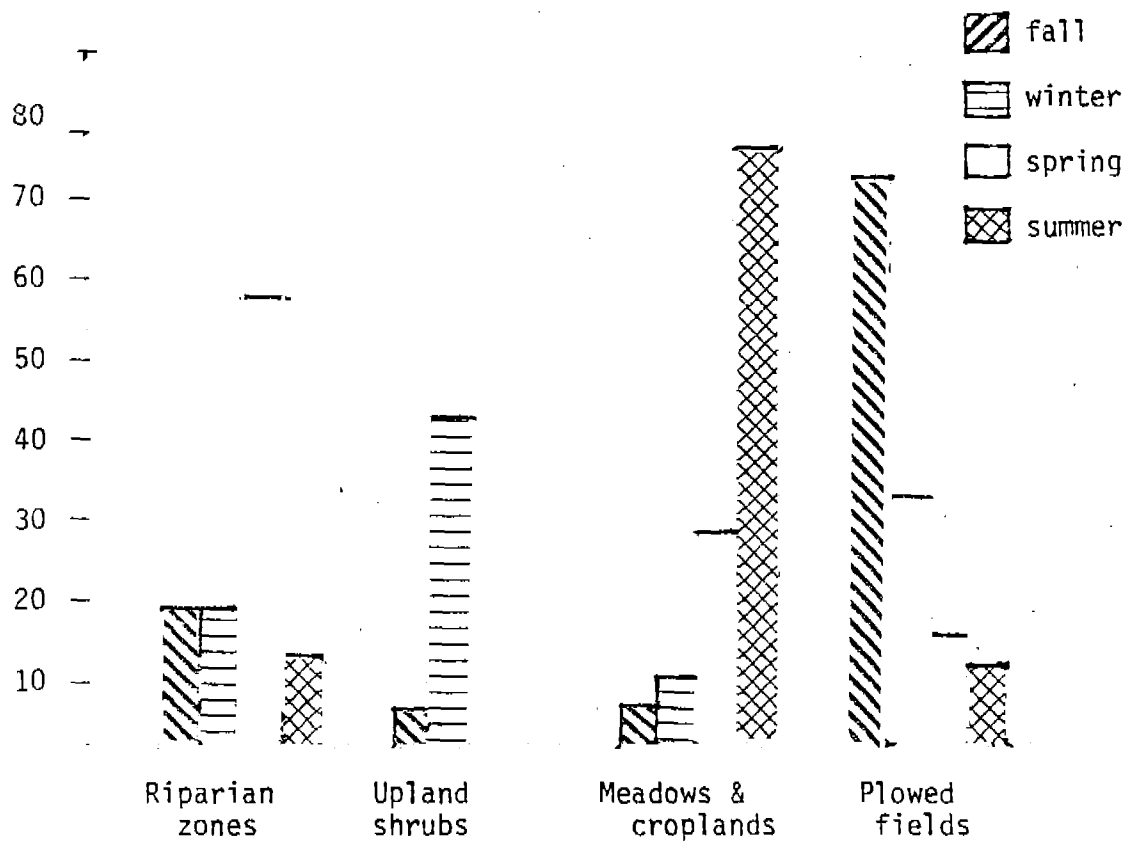

Fig. 5. Percentage of groups seen using various habitats on Silver Creek in each season of the year.

would join the chase when the others passed through their areas. Usually, the resident bird drove off the encroaching heron; one time, a heron flew in and chased a heron that had been feeding and standing in an area for over an hour.

Coloniality

One disadvantage of colonial nesting is the increased risk of disease or parasite outbreaks (Emlen and Demong 1975). Conditions in a heron colony are very favorable to their culture and transmission, and a severe outbreak could result in nestling failure of most or all of the nests--affecting the entire local population.

This was very nearly the case on Silver Creek in 1978, when only 5 of the 25 nests succeeded in fledging young. Losses of entire broods suggest disease or parasite overload, rather than starvation, which usually results in only partial brood loss. However, 4 of the 5 successful nests were located in the central, most densely populated portion of the colony. Other environmental factors besides crowding may have been operating.

Heronries may attract predators, as they typically are quite odorous, and young herons are very noisy when begging for food. Once a colony was discovered, a predator could return and raid many, or all, of the nests.

In 1977, 2 nestlings in one nest were apparently killed by a nocturnal predator. These were about 4 weeks old, and had appeared to be healthy. In 1978, none of the nests showed signs of predation, although most carcasses of young that died in the nest were scavenged.

A third potential disadvantage of colonial nesting is the possibility of nestlings moving into another nest. The additional young would increase the stress on the foster parents, who would have to provide more food for them (Emlen and Demong 1975).

I observed one such nest-switching in 1977, when a nestling from a brood of 3 apparently joined a brood of 5. I discovered the exchange after it had occurred; my observations indicated that the newcomer met little aggression from the other nestlings. All 6 nestlings were fed during the next 2 weeks, until they fledged.

Darling (1938) first observed that large colonies were more closely synchronized and more productive than those that were smaller; social stimulation was suggested as the factor responsible for this phenomenon. The theory predicts that pairs nesting during periods of peak activity would be most productive, since they would receive most stimulation; it also predicts that the more centrally located nests would be more productive than the peripheral ones.

In 1977, early nests and those hatching eggs mid-way during the month-long hatch period (first attempts only) were most productive (Table 13). In 1978, 3 of the 6 nests hatching eggs before 25 April and 2 of the 5 nests hatching eggs after 10 May were successful. None of the 12 nests hatching eggs between 25 April and 10 May were successful. However, centrally located nests were not found to be either more successful or more productive in the 2 years, as previously discussed.

Reduced predation has been cited as a factor with selective value for improving productivity of colonial nesters (Lack 1968). Predation losses would be reduced by having more individuals on the

Table 13. Number of young fledged from nests hatching eggs in 1977, in relation to hatch chronology

Hatch date	Nest number	Number fledged
4-17	3	4
4-21	2	5
4-21	13	4
4-22	6	3
4-22	4	3
4-23	1	3
4-24	9	4
4-27	7	5
5-03	8	4
5-03	19	2
5-04	17	2
5-06	10	2
5-06	14	3
5-06	16	2
5-13	18	0
6-01	5	0[a]

[a]Second nesting attempt.

alert and then, when an approaching predator was detected, by joining together as a group to defend the nests.

Great Blue Herons do not exhibit any anti-predator behavior such as mobbing; on the contrary, they are most likely to flee at the appearance of potential predators, leaving the nests unprotected. At Silver Creek, Bald Eagles (*Haliaeetus leucocephalus*), Golden Eagles (*Aquila chrysaetos*), and humans elicited this response, while Red-tailed Hawks (*Buteo jamaicensis*), Rough-Legged Hawks (*Buteo lagopus*), Marsh

Hawks (*Circus cyaneus*), and Great Horned Owls (*Bubo virginianus*) were ignored.

Ward and Zahavi (1973) suggested that anti-predator adaptations were secondary, with the primary benefit of coloniality being derived from increased efficiency in locating unevenly distributed food supplies. If food is ephemeral, unpredictable, and unevenly distributed, then individuals could benefit by taking advantage of the searching power of the entire group in locating food. Thus a nesting colony or communal roost could serve as an information center by providing unsuccessful individuals with the opportunity to follow successful birds to food sources. This theory also predicts that central nests would be more productive than peripheral nests, since central birds would have more opportunities for following neighbors to good feeding areas (Krebs 1976).

In the Silver Creek valley, the largest number of Great Blue Herons observed feeding in close proximity was only 2 individuals. This occurred in less than 1% of all observations of feeding herons. Herons leaving the valley, however, could have followed each other to food sources. I received one report of about 10 herons gathering and feeding at the Richfield Canal (16 km southwest of the heronry) when it was closed off in August (L.J. Francis, pers. comm.).

Visits to and flights out of the heronry were concentrated into peak periods. The number of feeding visits recorded in 1977 showed definite peaks between 0600 and 0800, and between 1800 and 1900 hours (Fig. 6). The percentage of departures in each hour was more evenly distributed in 1978 than in 1977 (Fig. 7). More observations were made

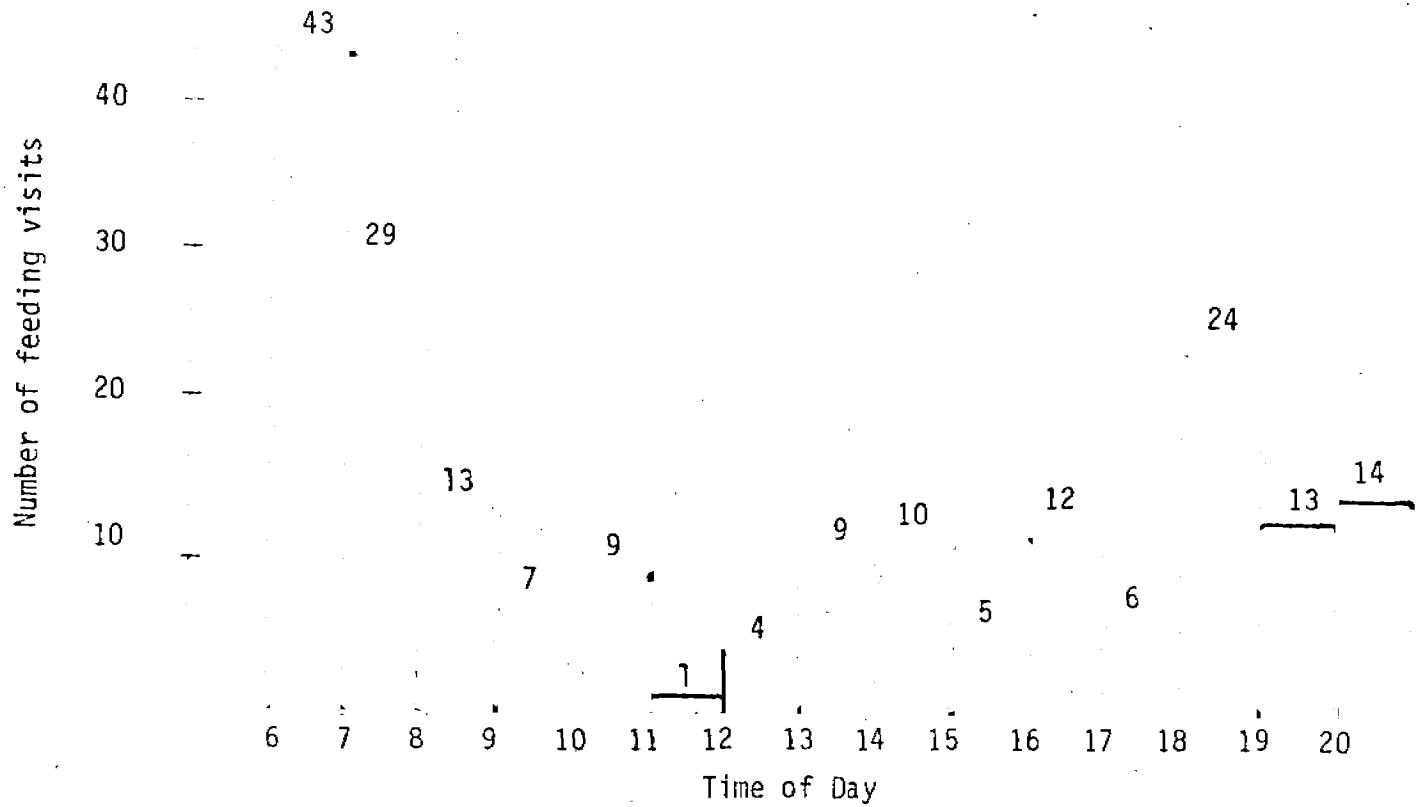

Fig. 6. Number of feeding visits at various times of the day in 1977.

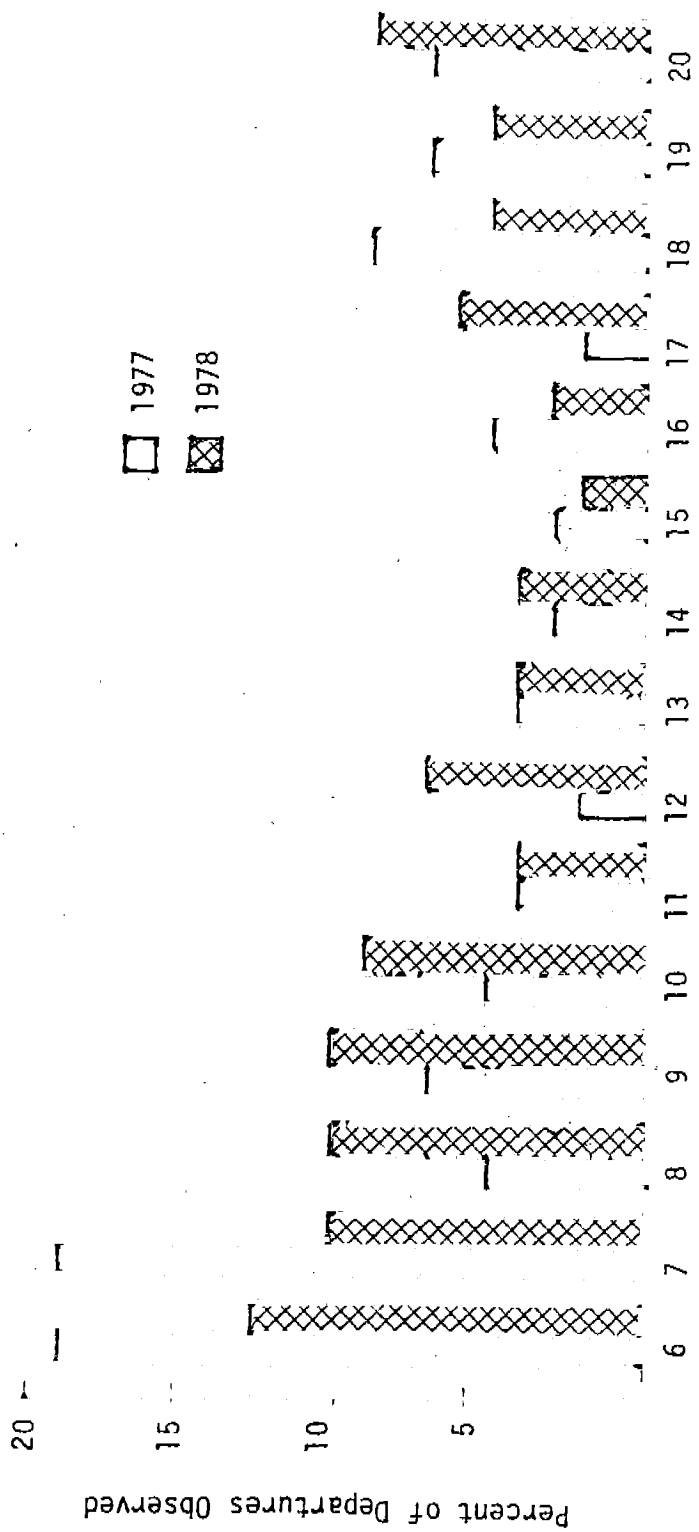

Fig. 7. Percent of departures from the heronry at different times of the day in 1977 and 1978 (weighted data).

in 1978, when observations were recorded throughout the nesting season; in 1977, observations were made only from 24 May to 6 July.

Silver Creek herons commonly followed each other to resting areas and to nest-material gathering sites. However, I observed only 2 instances when herons appeared to have been following each other onto feeding grounds. One of these observations was of a subadult bird following an adult out of the heronry. The second was of 2 adults; after flying about 1 km (0.6 mi) away from the heronry, in different directions, the second bird appeared to veer and then follow the first heron.

Flight observation data for 8 weeks in 1978 showed slight shifts in mean direction, but ranges of directions overlapped considerably (Table 14). Mean direction of flights from individual nests showed considerable variation. In 1977, mean directions varied from 8 to 51 degrees; in 1978, means ranged from 225 to 35 degrees. Individuals from some nests exhibited a great deal of variability while others consistently were observed flying in particular directions.

Herons from 6 nests were known to have flown out of the valley. Fifty-four percent of observed flights terminated within the Silver Creek valley, with 26 percent having unknown destinations.

Discussion

Sociality

Meyerriecks (1960) described Great Blue Herons as solitary to semisocial outside of the breeding season. Krebs (1976) stated that they are variable in both feeding behavior and in nesting, depending

Table 14. Mean direction and angular dispersion of flights out of the Silver Creek heronry for 8 weeks in 1978

Week	Range of directions	Mean direction	Dispersion
1	280-75°	358°	57°
2	225-70	323	52
3	210-70	344	47
4	220-60	305	59
5	260-45	300	48
6	250-80	37	59
7	260-80	360	60
8	240-80	314	65

upon local conditions. On Silver Creek, while the herons did not feed in groups, they were not solitary. Groups were formed away from the heronry in every month of the year; these were inactive groups. Thus, a good description of Silver Creek herons would be that of solitary feeders using communal roosts, and nesting colonially.

There may be a delay in initiating courtship in both migratory and sedentary populations. Mock (1976) observed more than 100 herons standing in a group for 4 days before ascending to the nesting trees in Minnesota; he believed they were "merely waiting for environmental conditions to permit colony occupation and nesting." Similarly, in a migratory population of Michigan, Cottrille and Cottrille (1958) found that some time was spent standing or preening in the heronry trees prior to courtship. In a sedentary population of Florida Bay, there was a delay in occupying the breeding area during which time a dancing ground was utilized (Meyerriecks 1960).

A similar pattern has been described for the Common Heron in Europe. In sedentary populations of Great Britain, dancing has been observed before colony occupation (Lowe 1954). Dancing is not known to occur in the migratory populations of continental Europe.

On Silver Creek, there was a long delay (19 days) between the initial occupation of the nests and the onset of breeding. Dancing reportedly occurred during this period.

Both migratory and sedentary populations may assemble on gathering grounds, if conditions are not conducive to occupation of the nests. It is possible that dancing may occur only during a prolonged period on a standing ground, which would be a more likely occurrence in a sedentary population.

Winter Behavior

Palmer (1962) reported that Great Blue Herons are generally solitary during the winter months and may defend feeding territories; Meyerriecks (1960) described them as solitary to semisocial outside the breeding season. On Silver Creek, feeding areas were defended, but herons were not solitary away from the feeding grounds.

Krebs (1976) explained phenotypic variations in heron social organization as responses to local conditions. Where food was dispersed and defendable, herons were territorial; where food occurred in unpredictable clumps, herons foraged socially. Zahavi (1971) demonstrated that the social organization of wintering Wagtails (*Motacilla alba*) could be altered by modifying the distribution of the food supply.

Coloniality

Disease and parasites have not been found to be serious problems in other Great Blue Heron populations. However, on Silver Creek, 80% of the nests failed to fledge young in 1978, under circumstances suggesting that mortality was related to disease.

Nest-switching probably happens only infrequently; Beetham's (1910) observation was the only account that I found in the literature. It seems unlikely that this would be an important factor affecting the success of tree-nesting colonial birds.

The fact that central nests were abandoned less frequently than peripheral nests could be used to show that coloniality improved productivity by providing social stimulation. However, this pattern is inconclusive, as it could also be used as evidence that coloniality has advantages in reducing predation or in providing information about food sources. It has also been shown in other species that differences in success relative to nest location may be the result of differences in age or quality of the birds (Coulson 1971).

Lack (1968) and others have concluded that, in many colonial-nesting species, the primary advantage conferred may be predator defense. However, herons do not exhibit any antipredator behavior, even though some colonies, particularly those of the smaller Ardeids, can suffer considerable nest predation (Jenni 1969, Kahl 1963). I found only one instance of nest predation in 2 years of study. Other studies of Great Blue Herons have not found predation to be a significant problem (Werschkul et al. 1977, Pratt 1972, Page 1971), although

Krebs (1976) observed several instances of egg predation by Ravens (*Corvus corax*) in one colony.

Krebs (1976), studying a coastal population of Great Blue Herons, concluded that colonial nesting was of benefit to the birds in locating food; he reported that flights out of the colony were synchronized, with neighbors tending to follow each other, and that herons feeding in groups had a higher foraging efficiency than solitary feeders. However, on Silver Creek, there was no indication that the colony functioned as an information center to enhance exploitation of food supplies, since social foraging was not observed.

Coloniality would be selected for if nesting habitat were in short supply. On Silver Creek, other suitable nesting trees are present, although none is in as close proximity to water.

No conclusive evidence was obtained to demonstrate the adaptive advantage of colonial nesting in herons. Krebs (1976) suggested that herons may have a tendency to colonial nesting, which will prevail as long as there is no disadvantage, even in areas where they feed solitarily.

RECOMMENDATIONS FOR MANAGEMENT OF GREAT BLUE HERONS ON SILVER CREEK

No trend was apparent in population size over the 2 years. Nesting productivity should be monitored annually. The number of nests should be counted in early April, and the number of young in each nest should be recorded around the first of May, June, and July.

During March and early April, excess human disturbance can cause nest abandonment or embryo mortality. At all times during the nesting season, visits should be made only during clear, warm weather, and adults should not be kept off the nests for prolonged periods.

While preserving the heronry is of fundamental importance, feeding areas must also be protected. The tributaries are particularly important feeding areas, and any protective measures, such as purchasing scenic easements, would be of benefit to the heron population. All steps that can be taken to enhance the long-term productivity of Silver Creek will help ensure the continuing presence of Great Blue Herons.

On the Preserve, patches of shrubs in upland areas should be preserved, and additional areas should be developed where possible. These sites, providing both thermal cover and visibility at the edges, are important for herons and other wildlife species during the winter months. There is very little of this habitat available in the valley at present and it continues to be reduced.

Many local residents do not understand the role of the Great Blue Heron in the Silver Creek community. An information program could be developed to remedy this situation.

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