The least excited ravens appeared to be the most proficient at supporting their weight, particularly if they had a well-developed hook on their upper mandible. The width of the branch they are gripping and the roughness of its surface would also be expected to affect their efficiency. There was no apparent relationship between age or body weight and hanging ability.—RICHARD D. ELLIOT, *Department of Biology, Acadia University, Wolfville, Nova Scotia, Canada B0P 1X0*. Accepted 16 July 76.

Spring migrant mortality during unseasonable weather.—For vernal migrating birds, premigratory lipid deposition has been theorized to have adaptive significance. Although some early-spring, short-range migrants may not increase lipid reserves significantly, most migrant birds undergo hyperlipogenesis coupled with increased cutaneous and subcutaneous adipose tissue deposition. The amount of lipid accumulated is a selective function of the distance to be covered, departure time, and flight load capacities of the bird (for review, see Berthold 1975) and should be sufficient to render the bird reproductively fit upon arrival at the breeding grounds.

Two periods of unseasonable cold and stormy weather in Utah during late April and mid-May 1975 caused mortality in spring migrant birds. Ligon (1968) reports a similar case in southeastern Arizona, Dence (1946) cites Tree Swallow mortality in New York, while Bull and Dawson (1968), and Skead and Skead (1970) cite spring migrant mortality in the southern hemisphere. As in the studies reported in the latter two papers, heavy snowfall accompanied the cold weather in Utah.

This study documents spring avian mortality with special reference to dry weight, lipid levels, muscle and gonad condition, and, in the case of the swallows, comparisons to live-trapped birds. A total of 569 individuals of 32 species were found dead, of which 136 individuals of 29 species were in good enough physical condition to be analyzed quantitatively (Table 1). Those not analyzed were primarily badly decomposed, partially eaten, or crushed by passing vehicles when they flocked to roads after snow covered the nearby ground.

Dead birds were collected between 30 April and 23 May 1975 at several locations in central Utah including the Provo Boat Harbor, Provo; Hobble Creek near Utah Lake; the cities of Holden, Kanosh, Nephi, and Mapleton; Palmyra Campground in Diamond Fork; Fish Springs Wildlife Refuge; and the Desert Experimental Range Station. For comparative purposes a small sample of swallows was collected live at Hobble Creek on 10 May 1975 between the periods of bad weather.

Immediately after collection birds were weighed, sexed, their gonads measured, and were then stored in a freezer in airtight plastic bags. Prior to lipid analysis stomach contents were examined. To obtain dry weights the birds were placed in a drying oven (78–80°C) until repeated weighings remained constant, usually 48–72 h. Whole body fat extraction was performed using the standard Soxlet apparatus with a solvent of petroleum ether. Wet and dry weights were obtained with triple beam balance while a Mettler balance was used to obtain lipid weights. Percent wet weight of the birds could not be accurate as the birds were dead for varying lengths of time before collection. Weather data were obtained through the courtesy of Dr. Ferron Anderson, Parasitology Weather Station at Brigham Young University.

Univariate statistical tests were made using a Hewlett-Packard 9810A desk calculator whereas multivariate tests were made on the IBM 360/75 computer at West Virginia University. For a description of the various multivariate statistical techniques used in the study see Morrison (1968) or Whitmore (1977).

The X values listed in Tables 1 and 2 are based on the Rogers and Odum (1964) equation for the relation between fat and nonfat weight in normal and stressed birds. They state that 0.2 g of fat per gram of dry weight nonfat tissue is present as tissue fat and can be utilized only at the expense of burning nonfat components. Birds with a body fat content less than this amount have to metabolize other tissues, such as muscle, to obtain the needed existence energy, and can be considered stressed. The X values were calculated by multiplying the nonfat weight of the bird by 0.2 thus giving the hypothetical amount of fat present in a bird just prior to being stressed, i.e. before having used all its available free lipid reserves.

Daily temperature, rain, and snowfall for 1970–75 during the two periods of avian mortality were tabulated. A multivariate analysis of variance (MANOVA) as well as a stepwise discriminant analysis were conducted to determine if 1975 was, in fact, significantly harsher than the previous 5 years (where no unusual mortality was recorded) and if so, which of the weather factors was most important in the difference. The results of the stepwise discriminant analysis indicated that the single variable most responsible for weather differences between the years was maximum temperature. The other variables, minimum temperature, rainfall, and snowfall also contributed to the differences but to a lesser degree. The results of the MANOVA (Approximate $F = 2.11$ with 20 and 190 degrees of freedom) indicate a significant difference in weather between the years at $P < 0.01$. To find out which of the individual years differ, a series

TABLE 1

MEANS (SD) ON MEASUREMENTS OF BIRDS FOUND DEAD AFTER UNSEASONABLE WEATHER[1,2]

Species	N	Wet wt.	Dry wt.	Lipid wt.	% Dry wt. lipid	Nonfat wt.	x[3]
Ash-throated Flycatcher (*Myiarchus cinerascens*)	2	22.8 (1.6)	7.5 (0.3)	0.275 (0.017)	3.7 (0.4)	7.23 (0.30)	1.40 (0.06)
Dusky Flycatcher (*Empidonax oberholseri*)	5	8.7 (0.9)	3.2 (0.3)	0.131 (0.014)	4.2 (0.7)	3.04 (0.27)	0.61 (0.05)
Western Wood Pewee (*Contopus sordidulus*)	2	9.6 (1.5)	3.7 (0.05)	0.146 (0.014)	4.1 (0.9)	3.50 (0.51)	0.70 (0.10)
Barn Swallow (*Hirundo rustica*)	8	12.8 (0.8)	4.3 (0.2)	0.167 (0.028)	3.9 (0.8)	4.10 (0.24)	0.82 (0.05)
Cliff Swallow (*Petrochelidon pyrrhonota*)	5	15.6 (0.7)	5.7 (0.4)	0.242 (0.026)	4.3 (0.5)	5.48 (0.41)	1.10 (0.82)
Violet-green Swallow (*Tachycineta thalassina*)	2	11.1 (0.3)	4.2 (0.0)	0.193 (0.033)	4.6 (0.8)	4.01 (0.03)	0.80 (0.01)
Tree Swallow (*Iridoprocne bicolor*)	7	13.9 (0.8)	5.1 (0.5)	0.251 (0.168)	4.7 (2.5)	4.87 (0.38)	0.98 (0.08)
Bank Swallow (*Riparia riparia*)	2	11.3 (0.3)	3.8 (0.5)	0.224 (0.71)	5.9 (1.1)	3.53 (0.42)	0.71 (0.08)
All Hirundinidae		13.4 (1.6)	4.8 (0.7)	0.212 (0.96)	4.4 (1.5)	4.54 (0.69)	0.91 (0.13)
Warbling Vireo (*Vireo gilvus*)	2	9.6 (0.1)	3.2 (0.1)	0.171 (0.020)	5.3 (0.4)	3.03 (0.12)	0.61 (0.02)
Orange-crowned Warbler (*Vermivora celata*)	6	7.3 (0.3)	2.7 (0.1)	0.142 (0.005)	5.3 (0.2)	2.53 (0.08)	0.51 (0.02)
Virginia's Warbler (*Vermivora virginiae*)	2	7.7 (0.8)	2.5 (0.2)	0.138 (0.008)	5.6 (0.2)	2.31 (0.20)	0.46 (0.04)
Yellow Warbler (*Dendroica petechia*)	5	7.7 (0.3)	2.8 (0.2)	0.148 (0.017)	5.3 (0.5)	2.63 (0.21)	0.53 (0.04)
Audubon's Warbler (*Dendroica coronata auduboni*)	11	9.7 (0.7)	3.6 (0.3)	0.173 (0.035)	5.0 (0.9)	3.41 (0.31)	0.68 (0.06)
MacGillivray's Warbler (*Oporornis tolmiei*)	9	8.8 (0.6)	3.2 (0.3)	0.133 (0.013)	4.2 (0.5)	3.00 (0.47)	0.60 (0.09)
All Parulidae		8.5 (1.2)	3.1 (0.5)	0.149 (0.028)	4.9 (0.7)	2.92 (0.52)	0.58 (0.10)
Western Tanager (*Piranga ludoviciana*)	14	23.9 (2.1)	9.0 (2.5)	0.415 (0.165)	4.6 (1.4)	8.53 (2.4)	1.71 (0.48)
Black-headed Grosbeak (*Pheucticus melanocephalus*)	5	39.2 (3.3)	14.5 (1.7)	0.826 (0.414)	5.5 (2.2)	13.71 (1.30)	2.74 (0.26)
Lazuli Bunting (*Passerina amoena*)	4	13.3 (2.4)	4.7 (1.2)	0.237 (0.054)	5.2 (1.1)	4.46 (1.21)	0.89 (0.24)
House Finch (*Carpodacus mexicanus*)	4	19.3 (3.1)	6.9 (1.4)	0.329 (0.154)	4.8 (1.9)	6.55 (1.38)	1.31 (0.28)
Green-tailed Towhee (*Chlorura chlorura*)	6	24.0 (4.2)	8.3 (1.5)	0.320 (0.74)	3.9 (0.4)	7.93 (1.48)	1.59 (0.30)
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	2	35.3 (3.7)	12.1 (1.0)	0.616 (0.146)	5.1 (0.8)	11.48 (0.84)	2.30 (0.17)
Lark Sparrow (*Chondestes grammacus*)	14	22.6 (3.6)	9.4 (1.5)	0.378 (0.104)	4.0 (0.9)	9.08 (1.43)	1.80 (0.29)
Gray-headed Junco (*Junco caniceps*)	5	17.0 (0.8)	6.2 (0.3)	0.285 (0.096)	4.6 (1.4)	5.90 (0.29)	1.18 (0.06)
Chipping Sparrow (*Spizella passerina*)	8	9.9 (1.2)	3.7 (0.4)	0.162 (0.032)	4.4 (0.5)	3.51 (0.40)	0.70 (0.08)

[1] Weights expressed in grams.
[2] Six species: Horned Lark (*Eremophila alpestris*), Rough-winged Swallow (*Stelgidopteryx ruficollis*), Rock Wren (*Salpinctes obsoletus*), Mountain Bluebird (*Sialia currucoides*), Wilson's Warbler (*Wilsonia pusilla*), and Brewer's Sparrow (*Spizella breweri*) only had one specimen each and therefore means and standard deviations could not be calculated.
[3] Hypothesized amount of lipid (in grams) in unstressed birds based on equations in Rogers and Odum (1964).

TABLE 2

MEANS (SD) OF MEASUREMENTS OF BIRDS COLLECTED LIVE DURING EARLY MAY 1975[1,2]

	N	Wet wt.	Dry wt.	Lipid wt.	% Dry wt. lipid	Nonfat wt.	x[3]
Barn Swallow (*Hirundo rustica*)	3	19.4 (1.7)	8.6 (1.4)	2.910 (0.974)	33.4 (5.6)	5.66 (0.50)	1.13 (0.10)
Tree Swallow (*Iridoprocne bicolor*)	7	20.7 (1.4)	8.9 (1.0)	2.579 (0.823)	28.5 (6.9)	6.27 (0.39)	1.25 (0.08)

[1] Weights expressed in grams.
[2] One species, Rough-winged Swallow (*Stelgidopteryx ruficollis*) had only one specimen and, therefore, mean and standard deviation could not be calculated.
[3] Hypothesized amount of lipid (in grams) in unstressed birds based on equations in Rogers and Odum (1964).

of Hotelling T^2 tests were computed, which showed that 1975 had a significantly ($P < 0.025$) harsher climate than any of the preceding 5 years.

Initial qualitative analysis of the birds showed some striking features. Most birds had highly atrophied pectoralis and latissimus dorsi muscles, yet in most cases the gonads were of normal breeding size. Evans (1970) suggests that some muscle protein is metabolized during migration in Common Redpolls (*Acanthis flammea*), but Berthold (1975) states that there is not enough evidence to warrant the same conclusion for all migrants. All birds examined had empty stomachs. During the harsh weather many instances of cannibalism and scavenging were noticed with live birds eating the remains of dead ones. These included: Green-tailed Towhees eating dead Green-tailed Towhees, Song Sparrows, various warblers and flycatchers, and a Horned Lark; Rufous-sided Towhees eating dead Rufous-sided Towhees, Green-tailed Towhees, Western Tanager, and Horned Larks; and Mourning Doves (*Zenaida macroura*) eating dead towhees and flycatchers. One instance of active predation was observed when a Rufous-sided Towhee attacked and began to eat a living Green-tailed Towhee that was too weak to fly. Based on muscle condition, quantitative fat analysis, and stomach content, we assume that the birds either starved to death or froze when available energy reserves could not satisfy the metabolic demands imposed by dropping temperature.

Comparisons of gonad measurements between live captured birds and starved birds were made using the Hotelling T^2 statistic. Neither the gonads of the male nor the female live-caught swallows were significantly different from those of the starved swallows (males: $T^2 = 5.50$ with 2 and 19 d.f. females: $T^2 = 0.42$ with 2 and 12 d.f.). It is interesting that the birds did not metabolize their gonads during periods of environmental and physiological stress, but apparently used muscle protein to increase energy supplies. Two explanations for this are possible. First, the biochemical pathways required to metabolize gonadal tissues may be more complex and less productive than those using the flight muscles, but this may not be the case as the gonads are reabsorbed prior to fall migration. The second possible explanation is that saving the gonads, even up to the point of near death, may have adaptive value if the weather changes suddenly and the opportunity to reproduce arises.

Comparing the other measured characters between live and starved swallows showed the live captured birds to have significantly ($P < 0.001$) heavier dry weights ($t = 11.14$), lipid weights ($t = 12.72$), % dry weight lipid ($t = 18.16$), and nonfat weights ($t = 5.65$). Percent dry weight lipid for the starved birds ranged from 2.3 to 9.8 ($\bar{x} = 4.58, s = 1.15$), well under the values for migrants reported by King and Farner (1965). The nonfat weight differences are consistent with the above observation that the muscles appeared atrophied in the starved birds. The observed fat levels were found to be significantly ($P < 0.001$) larger than the hypothesized x values in the live-captured birds ($t = 5.78$) and lower than hypothesized in the starved birds ($t = 15.64$). This indicated that the live captured birds were well above the stress levels hypothesized by Rogers and Odum (1964) and that the starved birds were well below the stated stress level.

Several hypotheses to explain why some birds starved while others did not are possible. As the amount of fat deposited prior to migration is directly related to the distance to be covered (for review, see Berthold 1975) it might be stated that those birds that did not starve in Utah had farther distances to travel than those that did starve, and their larger available fat reserves enabled them to survive the periods of stress. Another possibility is that the live captured birds were in a different migratory wave than the starved birds and arrived after the inclement weather. One final possibility is that those that survived were simply behaviorally and physiologically more fit.

Finally, it would seem difficult for an animal to evolve mechanisms enabling it to survive during periods of unpredictable stress, such as unseasonable weather, as this factor is not constant. One such response that could be adaptive is the migratory wave phenomenon. Originally hypothesized to be related to the amount of available food (Dolnik and Blyumental 1967) migratory waves could also have evolved in response to other environmental factors, such as weather. Short periods of inclement weather would remove members of one wave but not those of each succeeding wave.

We thank C. M. White, J. R. King, G. C. West, and R. L. Smith for reading an earlier draft of this paper. Their comments have been most helpful. We also thank C. D. Jorgensen, Chairman, Department of Zoology, Brigham Young University for supplying the needed funds for equipment.

Literature Cited

BERTHOLD, P. 1975. Migration: Control and metabolic physiology. Pp. 77–128 *in* Avian biology (D. S. Farner and J. R. King, Eds.). New York, Academic Press.

BULL, P. C., AND D. G. DAWSON. 1970. Mortality and survival of birds during an unseasonable snow-storm in South Canterbury, November 1967. Notornis 16: 172–179.

DENCE, W. A. 1946. Tree Swallow mortality from exposure during unseasonable weather. Auk 63: 440.

DOLNIK, V. R., AND T. I. BLYUMENTAL. 1967. Autumnal premigratory and migratory periods in the Chaffinch (*Fringilla coelebs coelebs*) and some other temperate-zone passerine birds. Condor 69: 435–468.

EVANS, P. R. 1970. The physiology and nutrition of Lesser Redpoll during moult and autumn migration. 15th Intern. Ornithol. Congr.: 97–98.

KING, J. R., AND D. S. FARNER. 1965. Studies of fat deposition in migratory birds. Ann. New York Acad. Sci. 131: 422–440.

LIGON, J. D. 1968. Starvation of spring migrants in the Chiricahua Mountains, Arizona. Condor 70: 387–388.

MORRISON, D. F. 1968. Multivariate statistical methods. New York, McGraw-Hill Book Co.

ROGERS, D. T., AND E. P. ODUM. 1964. Effect of age, sex and level of fat deposition on major body components in some wood warblers. Auk 81: 505–513.

SKEAD, D. M., AND C. J. SKEAD. 1970. Hirundinid mortality during adverse weather, November 1968. Ostrich 41: 247–251.

WHITMORE, R. C. 1977. The use of multivariate statistics in ecology and wildlife biology. Proc. Inst. Nat. and Environ. Res. Workshop in Quant. Ecol. Univ. of New Hampshire.

ROBERT C. WHITMORE, JAMES A. MOSHER, AND HERBERT H. FROST. *Department of Zoology, Brigham Young University, Provo, Utah 84602. Present address first author: Division of Forestry, West Virginia University, Morgantown, West Virginia 26506. Present address second author: Appalachian Environmental Laboratory, Frostburg, Maryland 21532.* Accepted 16 July 76.

Survival of a Blue Jay with a malformed bill.—On 12 December 1970, a Blue Jay (*Cyanocitta cristata*) with a badly malformed bill came to my feeding tray in Wilton, Connecticut. The upper mandible was thin, shortened, and bent upward; also it curved to the left, as shown in Figs. 1B and 1C. The bird had no difficulty in feeding on grain or suet, having adequately adapted to its infirmity. It scooped up seeds by tilting its head to the right and scraped at the suet with its lower mandible, using an upward thrust of the head.

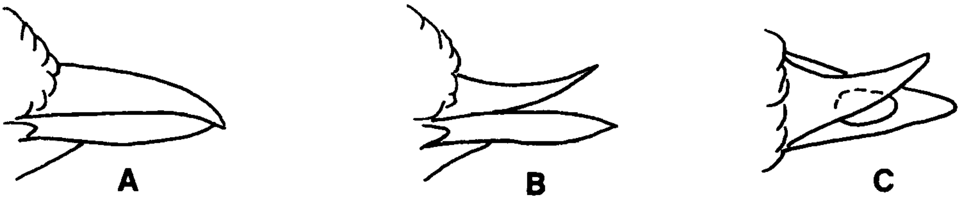

Fig. 1. Malformed Blue Jay bill. A, Normal shape, after Ridgway (1887, Manual of North American birds: Plate C,1.); B, malformed, side view; C, malformed, top view showing seed in normal lower mandible.