

## HEART WEIGHTS OF SOME ALASKAN BIRDS

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THE collection and interpretation of quantitative data relating to internal organs of birds have been largely overlooked by ornithologists until recently. Emphasis was placed for many years (and still is to a certain extent) upon morphological features. According to some investigators, the wisdom of weighing or measuring organs is questionable, especially when these raw data seemingly have no immediate practical value and supposedly clutter up the literature. Some of these data, when systematically collected (see Norris, 1961) with a view toward the solution of certain problems, have special value. Examples are spleen, liver, and thyroid weights amassed and studied as they relate to problems of reproduction, migration, and the like. As far as heart weights are concerned, the researches of Norris and Williamson (1955), Williamson and Norris (1958), Hartman (1954, 1955, 1961), Johnston and Williamson (1960), and others have yielded some important and interesting facts. It is now known, for example, that the size of a bird's heart is related to features such as total body weight, altitude, and activity.

Admittedly, much of the basic work in heart weight analyses has been done, but in spite of the compilations and comparisons contributed by the authors cited above (and others), refinements and further analyses are desirable. Hartman, for example, presented (1955) 1,340 heart weights of birds, many of which were tropical or subtropical forms. His data, together with those from arctic forms gathered in the present investigation, make possible a comparison of heart weights of birds over a broad geographic area. The analyses to follow compare and contrast some of the data from tropical and arctic forms, and also present heart weights (previously unpublished) from unusual North American birds and some Asiatic forms rare in North America. Finally, attention will be drawn to possible sex and age differences in species where large samples are available, and to certain variations in heart weight associated with seasons and/or fat deposition and migration.

From the end of May until late August 1960, I was part of a team of ornithologists studying birdlife on the arctic coast of North America at Cape Thompson, Alaska (latitude 68°06' N, longitude 165°46' W), under the auspices of the United States Public Health Service. The investigations were supported by the Division of Biology and Medicine of the Atomic Energy Commission (Agreement No. SF-54-373, environmental studies of Project Chariot). Heart weights recorded here were taken incidental to our main studies of avian populations and distribution, but, at the same time, we felt that there were real values to be gained in saving hearts from specimens taken for taxonomic or other purposes. Assisting in collecting hearts were Wayne Hanson, John Hines, Brina Kessel, Dale McCullough, Jerry Tash, Max Thompson, Francis S. L. Williamson, and Ernest Willoughby.

Most of the heart weights were obtained from birds fresh from the field, but some weights were taken after the heart had been preserved in 10 per cent formalin. Each heart was dried by blotting on absorbent paper, the vessels clipped off close to the heart, and the cavities emptied before weighing. Essentially the same method of obtaining weights was used as that discussed by Norris and Williamson (1955).

Heart weights from 567 individuals are given here. Seventy-seven species are represented, from eight orders and 21 families. The majority of these birds were collected within 10 miles of Cape Thompson along the sea coast or on the tundra at elevations ranging from sea level to about 700 feet. Most of the species are known to breed in the Cape Thompson region (Williamson et al., MS); generally speaking in the accounts to follow, those taken only in early June were migrating northward, whereas the birds taken only in August were migrating southward. Pertinent details concerning breeding, migration, and fat conditions are discussed under each species account or in the tables. The few species associated with the coniferous forest (*Pinicola*, *Canachites*, *Parus*, *Ixoreus*, *Perisoreus*, *Bombycilla*, *Vermivora*, *Picoïdes*, *Seiurus*, *Spizella*, and *Dendroica*) came from the Noatak River, about 100 miles east-southeast of Cape Thompson.

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#### DISCUSSION

*Comparisons with temperate forms.*—Heart and body weights from the Alaskan birds (Table 1) can in a general way be compared with Hartman's data (1955:227-234), but comparisons are usually possible only at the generic level.

*Gavia* spp. Probably all the loons from Alaska were migrants, although all three species breed in the Cape Thompson area. Uniformly, these loons had small heart ratios (0.90-1.22), the mean for the three species (eight birds) being 1.05. Hartman's figures of 1.10 and 1.33 for *G. immer* are within the range of expected interspecific variation.

*Phalacrocorax* spp. The two specimens of *pelagicus* reported here represented a local breeding population. Their heart ratios (1.13-1.14) were somewhat larger than those reported by Hartman (1955) for *auritus* (0.89) and *olivaceus* (0.67, 0.72). In a later paper (1961) Hartman gives an average of 0.91 for both of these latter species.

*Grus canadensis*. Although more heart weights were taken in Alaska than those mentioned by Hartman, the heart ratios of about 0.80-0.98 compare rather favorably with his values of 0.70 and 0.86.

*Charadrius* spp. The heart ratios of 1.52-1.64 from *semipalmatus* in Alaska are considerably larger than the values given by Hartman for *vociferus* (1.35) and *wilsonia* (1.27), but *semipalmatus* is a much smaller bird.

*Erolia* spp. For *melanotos*, the data from Alaska (1.50-1.78) approximate closely Hartman's figure of 1.70 though in his later paper (1961) values of 1.13 and 1.25 are

TABLE I  
BODY WEIGHTS AND HEART WEIGHTS OF SOME ALASKAN BIRDS

Species	Migratory <sup>1</sup> status	Fat <sup>2</sup> condi- tion	Body weight		Heart weight		Ht. wt./body wt	
			Mean	Extremes	Mean	Extremes	Mean	Extremes
<i>Gavia adamsii</i> 2 adF	PB	1	4,430	(4,303-4,557)	47.0	(46.3-47.7)	1.07	(1.02-1.11)
<i>Gavia arctica</i> 2 adM	MN	4	2,602.5	(2,185-3,020)	28.8	(26.7-30.9)	1.12	(1.02-1.22)
<i>Gavia arctica</i> 2 adF	MN	4	2,025.5	(1,870.6-2,180.3)	21.4	(19.1-23.8)	1.06	(1.02-1.09)
<i>Gavia stellata</i> 1 adM	MN	3	1,694		17.6		1.03	
<i>Gavia stellata</i> 1 adF	MN	3	1,472		13.3		0.90	
<i>Phalacrocorax pelagicus</i> 1 adM	B	1	2,030		23.2		1.14	
<i>Phalacrocorax pelagicus</i> 1 adF	B	1	1,509		17.1		1.13	
<i>Branta nigricans</i> 4 adM	MN		1,419.6	(1,398-1,440)	15.1	(13.3-16.7)	1.07	(0.93-1.19)
<i>Histrionicus histrionicus</i> 1 adM	MN	4	736.1		8.1		1.10	
<i>Histrionicus histrionicus</i> 2 adF	PB	4	536.2	(519.7-552.7)	7.3	(6.7-7.8)	1.35	(1.29-1.41)
<i>Polysticta stelleri</i> 1 adM	PB		823.3		8.5		1.03	
<i>Somateria mollissima</i> 1 adM	MN	4	2,750		25.8		0.94	
<i>Lampronetta fischeri</i> 3 adM	MN	1	1,367.6	(1,174-1,647)	13.0	(10.4-16.4)	0.95	(0.89-1.00)
<i>Melanitta deglandi</i> 1 adM	A	0	1,026.7		10.5		1.02	(emaciated)
<i>Canachites canadensis</i> 1 adM	PB		649.0		6.7		1.03	
<i>Lagopus lagopus</i> 5 adM	B, PB	0, 1	619.9	(586.5-634.1)	8.4	(7.1-9.1)	1.35	(1.21-1.44)
<i>Lagopus mutus</i> 3 adM	B, PB	1	508.1	(482.7-531.5)	9.4	(8.8-10.0)	1.85	(1.82-1.88)
<i>Grus canadensis</i> 3 adM	B, PB		3,434.0	(3,008-3,693.0)	30.3	(28.2-33.9)	0.87	(0.80-0.94)
<i>Grus canadensis</i> 2 adF	B, PB		2,799	(2,700-2,898)	25.9	(23.2-28.5)	0.92	(0.86-0.98)
<i>Charadrius semipalmatus</i> 3 adM	PB		42.5	(39.5-44.6)	0.68	(0.60-0.72)	1.59	(1.52-1.64)
<i>Charadrius semipalmatus</i> 1 adF	PB		45.6		0.72		1.58	
<i>Pluvialis dominica</i> 8 adM	B, PB, MS		146.7	(135.3-162.0)	2.31	(1.96-2.7)	1.57	(1.44-1.79)
<i>Pluvialis dominica</i> 4 adF	B, PB, MS		146.6	(134.5-158.6)	2.12	(1.90-2.27)	1.45	(1.39-1.55)
<i>Arenaria interpres</i> 4 adF	MS		94.9		1.54		1.62	
<i>Arenaria melanocephala</i> 1 adM		4	118.7		2.08		1.75	
<i>Arenaria melanocephala</i> 1 adF		4	124.5		2.24		1.80	
<i>Capella gallinago</i> 1 adM	PB	4	113.5		1.18		1.04	

TABLE I (Continued)

Species	Migratory <sup>1</sup> status	Fat <sup>2</sup> condi- tion	Body weight		Heart weight		Ht. wt/body wt	
			Mean	Extremes	Mean	Extremes	Mean	Extremes
<i>Numenius phaeopus</i> 2 imM 1 imF	MS MS	1 1	320.8 377.3	(296.5-345.0)	4.3 4.3	(3.3-5.3)	1.41 1.14	(1.28-1.54)
<i>Heteroscelus incanum</i> 1 adM	B		101		1.6		1.58	
<i>Calidris canutus</i> 9 adM 1 adF	MS(?) MS	4 4	135.0 142.5	(106.2-147.8)	2.2 2.2	(1.79-2.40)	1.63 1.54	(1.42-1.75)
<i>Erolia acuminata</i> 2 imF	MS	2	51.2	(49.3-53.0)	0.86	(0.81-0.90)	1.68	(1.53-1.83)
<i>Erolia melanotos</i> 3 adM 1 adF	PB PB		57.4 54.2	(40.8-69.5)	0.97 1.1	(0.61-1.24)	1.67 2.03	(1.50-1.78)
<i>Erolia bairdii</i> 1 imM 1 imF	MS MS		34.3 42.1		0.55 0.66		1.60 1.57	
<i>Erolia alpina</i> 1 adM 1 imM	PB MS	1 1	46.5 47.2		0.91 0.81		1.96 1.72	
<i>Limnodromus scolopaceus</i> 1 imM 2 imF	MS MS		103.0 103.2	(101.6-104.8)	2.06 1.77	(1.63-1.91)	2.0 1.71	(1.60-1.82)
<i>Ereunetes pusillus</i> 1 adM 1 imM 3 adF	PB MS PB		20.6 19.3 24.5		0.39 0.32 0.43		1.89 1.66 1.81	
<i>Ereunetes mauri</i> 5 adM 4 imM 2 adF 1 imF	B, PB MN, MS MN, MS MN, MS	4 4 4 4	23.8 23.0 25.6 24.2	(21.5-27.0) (21.0-24.6) (25.5-25.6)	0.42 0.39 0.44 0.43	(0.39-0.45) (0.30-0.44) (0.39-0.48)	1.79 1.67 1.70 1.78	(1.56-1.95) (1.43-1.79) (1.52-1.88)
<i>Tryngites subruficollis</i> 1 imM	MS	4	69.5		0.86		1.24	
<i>Limosa lapponica</i> 2 adM 5 imM 2 adF 5 imF	PB MS MS MS	4 4 4 4	243.3 218.8 308.5 250.6	(240.3-246.3) (195.5-240.7) (297.2-319.8) (206.8-268.2)	3.85 3.54 4.35 3.79	(3.8-3.9) (3.0-3.86) (4.2-4.5) (3.2-4.17)	1.58 1.62 1.41 1.52	(1.58-1.58) (1.37-1.74) (1.31-1.51) (1.23-1.69)
<i>Crocethia alba</i> 1 imM 3 imF	MS MS	2 2	48.5 48.7	(43.4-53.5)	0.71 0.76	(0.70-0.87)	1.46 1.57	(1.42-1.66)
<i>Phalaropus fulicarius</i> 2 adF 10 imM 1 ad F 6 imF	MS MS MS MS	1 1 1 1	44.6 33.3 55 36.6	(43.7-45.5) (29.6-39.0)	0.80 0.55 1.0 0.56	(0.79-0.80) (0.45-0.66)	1.79 1.64 1.82 1.54	(1.76-1.81) (1.47-1.90)
<i>Lobipes lobatus</i> 2 imM 2 adF 1 imF	MS MS MS	1 2 1	25.9 43.1 28.6	(25.2-26.7) (38.7-47.5)	0.48 0.70 0.56	(0.43-0.52) (0.57-0.83)	1.83 1.61 1.96	(1.71-1.95) (1.47-1.75)

TABLE 1 (Continued)

Species	Migratory <sup>1</sup> status	Fat <sup>2</sup> condi- tion	Body weight		Heart weight		Ht. wt./body wt	
			Mean	Extremes	Mean	Extremes	Mean	Extremes
<i>Stercorarius pomarinus</i> 1 adM	MN	4	710.2		7.3		1.03	
2 adF	MN	4	775.5	(741-810)	8.2	(8.1-8.3)	1.06	(1.00-1.12)
<i>Stercorarius parasiticus</i> 5 adM	MN		406.3	(371.8-440.2)	6.12	(5.1-7.5)	1.50	(1.35-1.70)
2 adF	MN		456.7	(416.8-496.6)	6.35	(6.2-6.5)	1.41	(1.25-1.56)
<i>Stercorarius longicaudus</i> 5 adM	B, PB	2, 4	285.4	(272.3-301.4)	3.6	(3.3-4.3)	1.28	(1.19-1.46)
1 imM	B, PB		271		2.8		1.03	
2 adF	B, PB		332.7	(323.8-341.5)	3.6	(3.3-3.9)	1.09	(0.97-1.20)
<i>Larus hyperboreus</i> 6 adM	B, PB	2, 4	1,529.9	(1,466.4-1,624.4)	14.3	(13.1-16.2)	0.93	(0.85-1.10)
7 adF	B, PB	2, 4	1,284.6	(1,164.6-1,490.1)	11.6	(10.5-14.9)	0.91	(0.83-1.00)
1 subadM			1,225.1		9.9		0.81	
7 subadF			1,190.1	(747.3-1,470)	11.4	(6.6-14.1)	0.95	(0.88-1.02)
<i>Larus canus</i> 1 subadM	A		400.5		4.7		1.17	
<i>Rissa tridactyla</i> 4 adM	B		495.1	(466.4-545.0)	5.2	(5.0-5.7)	1.06	(1.03-1.09)
2 juvF			47.5	(41.5-53.4)	0.49	(0.44-0.54)	1.04	(1.01-1.06)
2 adF	B		434.0	(380.4-487.6)	4.1	(3.6-4.6)	0.95	(0.94-0.95)
<i>Xema sabini</i> 2 adM	MN		188.2	(174.8-201.5)	2.2	(2.0-2.4)	1.17	(1.14-1.19)
1 adF	MN		169.1		2.2		1.30	
<i>Sterna paradisaea</i> 3 adM	P, PB		102.3	(100.1-103.5)	1.40	(1.35-1.44)	1.36	(1.30-1.44)
3 adF	P, PB		104.8	(96.5-117.0)	1.54	(1.25-1.70)	1.47	(1.30-1.68)
1 imM			68.0		99.0		1.46	
<i>Uria aalge</i> 4 adM	B	1	929.8	(865.0-1,032.0)	8.6	(7.4-9.6)	0.92	(0.83-1.02)
4 adF	B	1	911	(855-970)	8.9	(8.2-9.4)	0.98	(0.90-1.04)
<i>Uria lomvia</i> 25 adF	B	1	887.1	(747.3-1,046.0)	8.8	(7.8-10.0)	0.99	(0.86-1.10)
18 adM	B	1	956.5	(837.0-1,060.0)	9.54	(7.9-11.6)	1.00	(0.87-1.23)
<i>Cephus columba</i> 1 adM	B		490.0		7.5		1.53	
1 adF	B		502.2		6.8		1.35	
<i>Brachyramphus brevirostre</i> 1 adF	B		203.9		3.11		1.53	
1 juvM	B		35.7		0.50		1.40	
2 adM	B		251.1	(236.0-266.1)	2.94	(2.68-3.19)	1.18	(1.01-1.35)
<i>Aethia cristatella</i> 1 adM	A	0	216.6		2.3		1.06	

TABLE 1 (Continued)

Species	Migratory <sup>1</sup> status	Fat <sup>2</sup> condi- tion	Body weight		Heart weight		Ht. wt/body wt	
			Mean	Extremes	Mean	Extremes	Mean	Extremes
<i>Fratercula corniculata</i> 4 adF	B		602.2	(543.7-664.7)	6.1	(5.6-6.4)	1.02	(0.96-1.14)
<i>Lunda cirrhata</i> 1 adM	B	1	836.6		8.5		1.02	
1 adF	B	1	741.3		6.8		0.92	
<i>Picoides tridactylus</i> 2 adM	PB	1	55.0	(53.6-56.5)	0.68	(0.66-0.70)	1.24	(1.23-1.24)
<i>Eremophila alpestris</i> 1 adM	PB		43.0		0.50		1.16	
<i>Perisoreus canadensis</i> 3 adM	PB	0	75.8	(72.5-78.0)	0.73	(0.70-0.75)	0.96	(0.91-1.01)
2 imM	PB	0	75.2	(74.6-75.8)	0.69	(0.67-0.71)	0.92	(0.88-0.95)
3 imF	PB	0	69.6	(66.8-72.3)	0.64	(0.58-0.72)	0.93	(0.83-1.08)
<i>Parus cinctus</i> 1 adM	PB	1	12.8		0.22		1.72	
1 imM			13.0		0.19		1.46	
1 adF	PB	1	12.0		0.15		1.25	
1 imF			12.0		0.19		1.58	
<i>Parus hudsonicus</i> 1 imM	PB	1	12.9		0.24		1.86	
1 adF			10.8		0.19		1.76	
<i>Ixoreus naevius</i> 1 adM	PB		86.6		1.02		1.18	
1 imM			68.7		0.77		1.12	
<i>Hylocichla minima</i> 1 adF	PB		31.1		0.35		1.12	
1 imF			30.5		0.39		1.28	
<i>Oenanthe oenanthe</i> 1 adM	PB		23.2		0.35		1.51	
14 imM	MS	1, 4	25.4	(22.9-27.7)	0.36	(0.29-0.44)	1.42	(1.27-1.73)
8 imF	MS	1, 4	25.5	(23.3-28.1)	0.36	(0.31-0.41)	1.41	(1.12-1.61)
<i>Luscinia svecica</i> 2 imM	MS	4	19.9	(18.8-21.0)	0.31	(0.30-0.31)	1.52	(1.43-1.60)
8 imF	MS	4	19.3	(16.4-21.0)	0.27	(0.22-0.30)	1.40	(1.20-1.59)
<i>Phylloscopus borealis</i> 5 adM	B, PB, MS	4	11.0	(9.1-13.2)	0.18	(0.14-0.23)	1.59	(1.38-1.82)
6 imM	B, PB, MS	4	10.5	(10.0-11.3)	0.16	(0.15-0.17)	1.54	(1.42-1.62)
2 adF	B, PB, MS	4	9.6	(8.1-11.1)	0.15	(0.12-0.17)	1.50	(1.48-1.53)
6 imF	B, PB, MS	4	10.4	(9.3-11.4)	0.15	(0.13-0.17)	1.49	(1.14-1.72)
<i>Motacilla flava</i> 11 adM	B, PB, MS	3, 4	18.2	(16.1-20.4)	0.27	(0.22-0.33)	1.50	(1.36-1.84)
10 imM	B, PB, MS	3, 4	18.6	(17.4-20.2)	0.27	(0.24-0.29)	1.44	(1.22-1.61)
12 adF	B, PB, MS	3, 4	16.7	(15.3-18.3)	0.25	(0.21-0.28)	1.49	(1.28-1.73)
11 imF	B, PB, MS	3, 4	17.9	(16.1-20.9)	0.25	(0.31-0.29)	1.40	(1.24-1.68)
<i>Anthus spinoletta</i> 1 adM	B, PB	0, 1	21.8		0.35		1.61	
1 adF	B, PB	0, 1	19.2		0.27		1.41	
1 imF			17.5		0.26		1.49	
<i>Anthus cervinus</i> 2 adM	B, PB		25.0	(20.6-23.0)	0.33	(0.32-0.33)	1.49	(1.39-1.60)
1 adF	B, PB		21.8		0.32		1.28	

TABLE 1 (Continued)

Species	Migratory <sup>1</sup> status	Fat <sup>2</sup> condi- tion	Body weight		Heart weight		Ht. wt/body wt	
			Mean	Extremes	Mean	Extremes	Mean	Extremes
<i>Bombycilla garrula</i>	1 adM 1 adF	2 2	50.0 53.5		0.70 0.84		1.40 1.57	
<i>Vermivora celata</i>	1 imF	MS(?)	9.0		0.12		1.33	
<i>Dendroica coronata</i>	1 adF 2 imF	2	13.9 13.0 (11.5-14.4)		0.17 0.17 (0.16-0.18)		1.22 1.32 (1.25-1.39)	
<i>Dendroica striata</i>	1 imM	MS(?)	13.5		0.17		1.26	
<i>Seiurus noveboracensis</i>	1 imM	MS(?)	16.6		0.22		1.33	
<i>Wilsonia pusilla</i>	1 imM 3 imF	MS MS	8.0 7.6 (7.2-8.2)		0.12 0.10 (0.10-0.11)		1.50 1.31 (1.22-1.39)	
<i>Pipicola enucleator</i>	3 adM 3 adF	1, 2 1, 2	60.2 (58.3-62.8) 59.5 (58.8-60.1)		0.83 (0.80-0.85) 0.86 (0.77-0.91)		1.38 (1.34-1.43) 1.45 (1.28-1.55)	
<i>Acanthis</i> sp.	18 adM 8 adF	0, 1 0, 1	13.2 (11.7-14.5) 14.3 (11.8-16.6)		0.24 (0.21-0.28) 0.24 (0.22-0.27)		1.81 (1.47-2.12) 1.67 (1.46-1.95)	
<i>Passerculus sandwichensis</i>	16 adM 3 imM	0, 1 0, 1	18.3 (15.4-21.1) 19.0 (18.7-19.4)		0.29 (0.23-0.31) 0.25 (0.23-0.26)		1.56 (1.32-2.01) 1.30 (1.23-1.34)	
<i>Spizella arborea</i>	2 adM 1 imM	0, 1 0, 1	19.4 (15.9-25.6) 16.9 (16.7-17.1)		0.27 (0.25-0.29) 0.22 (0.22-0.22)		1.39 (1.09-1.76) 1.30 (1.29-1.32)	
<i>Zonotrichia leucophrys</i>	8 adM 1 juvM 9 adF	1, 2 1, 2	19.4 (19.0-19.8) 18.4 27.3 (25.3-29.2) 28.0		0.24 (0.21-0.27) 0.24 0.33 (0.29-0.38) 0.28		1.24 (1.06-1.42) 1.30 1.19 (1.06-1.37) 1.00	
<i>Zonotrichia atricapilla</i>	1 adM	1	24.8 (20.8-26.9)		0.29 (0.24-0.34)		1.19 (0.94-1.35)	
<i>Passerella iliaca</i>	1 adM	A	35.2		0.49		1.39	
<i>Calcarius lapponicus</i>	47 adM 21 adF 2 imM 2 imF 1 juvF	A B, PB B, PB 0, 1, 2, 3 0, 1, 2, 3 0, 1, 2, 3	40.5 27.3 (24.0-30.5) 27.3 (23.5-32.5) 28.9 (28.3-29.4) 25.5 (24.7-26.3) 18.5		0.59 0.43 (0.33-0.51) 0.40 (0.30-0.53) 0.51 (0.44-0.57) 0.38 (0.37-0.38) 0.27		1.46 1.59 (1.25-1.88) 1.48 (1.14-2.11) 1.76 (1.50-2.01) 1.48 (1.41-1.54) 1.46	
<i>Plectrophenax nivalis</i>	2 adM 1 adF	B, PB B, PB	34.3 (29.5-39.1) 32.0		0.56 (0.54-0.58) 0.45		1.66 (1.48-1.83) 1.41	

<sup>1</sup> Migratory status: B, breeding; PB, probably breeding; MN, migrating northward; A, accidental; MS, migrating southward.<sup>2</sup> Fat condition: 0, no fat; 1, a little fat; 2, moderately fat; 3, fat; 4, very fat.

given. Other species of *Erolia* (*acuminata*, *bairdii*, and *alpina*) had moderately large hearts ranging from 1.53–1.96.

*Larus* spp. Hartman's figures for *atricilla* range from 0.73–0.98. In the present study, heart ratios of *hyperboreus* and *canus* ranged from 0.81 to 1.17, and for other gull genera (*Rissa* and *Xema*), similar values were obtained.

*Sterna* spp. Interestingly enough, *paradisaea* from Alaska had heart ratios of 1.30–1.68, but for three other species, Hartman reported much lower values (1.04–1.34).

*Parus* spp. For three species Hartman gave values of 1.30–1.58, whereas in Alaska, for two other species, heart ratios ranged from 1.25 to 1.72 and 1.76 to 1.86.

*Hylocichla* spp. *H. minima* in Alaska had heart ratios from 1.12 to 1.28, whereas *guttata* and *fuscescens* reported by Hartman had values of 1.21–1.61.

*Dendroica coronata*. The three heart ratios from Alaska ranged between 1.22 and 1.39. Hartman's average for 10 birds was 1.29.

*Wilsonia pusilla*. Hartman's figure of 1.05 for this species in Panama and a later value (1961) of 1.18 differ significantly from the values of 1.22–1.50 found in Alaska.

*Passerculus sandwichensis*. Hartman's average of 1.46 does not seem to differ greatly from Alaskan values (averages of different groups ranging from 1.30–1.56).

*Spizella* spp. The values of 1.06–1.46 of *arborea* from Alaska tend to be greater than those given by Hartman for *passerina* (1.03–1.32) and *pusilla* (1.29), but sample sizes were small.

*Zonotrichia* spp. The two species from Alaska had greater heart ratios (0.94–1.39) than did another two species (0.84–1.00) reported by Hartman.

Recognizing the many possible sources of error involved by comparing Hartman's data with mine (interspecific comparisons, different breeding conditions, seasonal variations, and the like), in a very general way arctic species tend to have larger hearts than do more southerly species in the same genus from temperate and tropical regions. Many years ago Parrot (1893), Rensch (1948), and others proposed this latitudinal difference, but there were few supporting figures because many authors failed to cite specific collecting localities. In addition to the comparisons made here with Hartman's figures, Norris and Williamson (1955) have provided some further comparable figures from California. Their heart ratios for lowland specimens of *Zonotrichia leucophrys* and *Passerella iliaca* are significantly less than the values obtained from Alaskan birds. Some of these differences might be due to body weight alone, but until more regional weights are available quantitatively (see, for example, Norris and Johnston, 1958), it seems that latitude, per se, does play a role in affecting heart weight in birds.

*Sex and age differences.*—For some species enough heart weights were available to warrant statistical comparisons of two sex or age groups. Thus, standard *t* tests (see Simpson, Roe, and Lewontin, 1960:176) were used to compare the heart ratios between adult males and adult females in the following species: *Pluvialis dominica*, *Uria lomvia*, *U. aalge*, *Motacilla flava*, *Acanthis* sp., *Zonotrichia leucophrys*, *Passerculus sandwichensis*, *Calcarius lapponicus*, and *Larus hyperboreus*. Similar comparisons were made between



immature males and immature females in *Motacilla flava*, *Oenanthe oenanthe*, and *Phalaropus fulicarius*. In none of these statistical comparisons were the differences between sexes significant at either the 5 per cent or 1 per cent level. Thus, the data from these Alaskan species taken on their breeding grounds bear out the early contention of Hartman (1955:223–224) that between sexes in birds heart weights are generally similar.

More recently, however, Hartman (1961:17) has found significant sexual differences in heart weight in 19 species, most of which were tropical forms. In these, the male's heart was the larger. Nineteen species, nevertheless, represent only a small proportion of the 360 species surveyed in his paper. So, from all the data now available on bird heart weights, it appears that any differences attributable to sex are relatively unimportant.

Additional comparisons by *t* tests were made between the following: adult vs. immature males in *Phylloscopus borealis* and *Motacilla flava*; adult vs. subadult females of *Larus hyperboreus*; adult vs. immature females of *Motacilla flava*; and, for *Calcarius lapponicus*, adult males taken in June were compared with adult males taken in July, and a similar comparison using adult females taken in these two months. As before, no significant differences were found at the 5 or 1 per cent levels. At least in the few species used in these comparisons, it can be concluded that (1) adult and immature heart weights are similar and (2) in *Calcarius* heart weights are not significantly different between adults taken at the onset of the breeding season and those taken at or immediately after the completion of breeding.

*Flight habits.*—Although total body weight is probably the foremost factor influencing heart size in birds, it seems likely from the data presented by other authors and in Table 1 that heart size is related also to flight habits. Species which habitually fly only short distances have small hearts. Hartman (1955, 1961) has alluded to the fact that tinamous, known for their poor flying abilities or habits, have extremely small hearts (0.1–0.2), as do Turkeys (*Meleagris gallopavo*) (0.40), Bobwhite (*Colinus virginianus*) (0.39), Spruce Grouse (1.0), and Willow Ptarmigan (1.3). These are all species which typically walk or run more frequently than they fly. Many aquatic birds which generally dive for food also have small hearts: in Table 1, observe the heart values for loons (ca. 1.05), cormorants (1.1), eiders (ca. 1.0), murrens (0.9), and puffins (1.0). Although the size of these birds certainly influences heart size, the data suggest that flying requires more energy and hence a larger heart than either walking or diving in birds.

Similarly, one can find a good case for soaring or gliding flight when compared with a more active, flapping flight. Among falconiform birds Hartman (1955:227) gave heart ratios of  $< 0.7$  for most of the vultures and buteos, whereas two species of falcons had ratios of  $> 1.3$ . In the present

work, the jaegers and gulls generally have small hearts. Although jaegers are capable of swift, flapping flight, they frequently soar and/or glide as do the gulls for which data are available here.

All these data relate to activity among birds, and it is of particular interest to call attention to Bowman's careful investigation (1961:80-86) of the Galápagos finches. The heart ratios of nine species of geospizines varied between 0.54 and 0.69, among the smallest such values known for passerines. The small hearts are correlated with foraging activities and flight: the smallest, most active species had the largest heart, and the species with the largest heart had the strongest and most rapid flight. Bowman's data point up a need for more information on bird activity as it is related to heart size in birds.

*Heart weights of ptarmigan.*—Ever since Strohl reported (1910) on ptarmigan heart weights from Europe, his work has been quoted widely as evidence that at least some birds residing at high altitudes have larger hearts than others residing at lower altitudes. Strohl's data were for *Lagopus alpinus* (= *L. mutus*) taken at 2,000-3,000 meters elevation in the Alps and *L. lagopus* taken at 600 meters over the north plains of the continent. Heart weights of *mutus* were 16.30 grams/1,000 grams body weight, and of *lagopus*, 11.08 grams/1,000 grams. These heart weight differences were therefore attributed to the altitudinal differences. Later, Stieve (1934 *vide* Hartman, 1961) compared heart sizes in these two species and found the differences to be interspecific.

At Cape Thompson these two species were sympatric in the years 1959-61. Heart ratios for birds taken in 1960 are given in Table 1. When these values for adult males are converted to weights comparable to those given by Strohl, *mutus* has a heart weight of 18.5 grams/1,000 grams body weight and *lagopus*, 13.5 grams/1,000 grams. Since both species were collected together at elevations ranging from near sea level up to about 500 feet, the data from Alaska strongly suggest that heart weight differences between these two ptarmigan are not due to altitudinal differences. Rather, heart weight differences seem more related to body weights. Especially is this relationship clear when additional body weights (all adults collected between 1959 and 1961) between the two species are compared. From Table 2 it is plain that *lagopus* in northern Alaska is considerably larger than *mutus*.

Interspecific heart weight differences in these ptarmigan—at least from the overwhelming data from Alaska—should be attributed to body weight differences and not altitude. This does not, of course, negate or minimize intraspecific differences due to altitude as clarified by Norris and Williamson (1955) for other species.

*Fat condition.*—The relationship between fat condition and migratory

TABLE 2  
BODY WEIGHTS OF TWO SPECIES OF PTARMIGAN FROM NORTHERN ALASKA

	Number	Body weight in grams	
		Average	Extremes
Willow Ptarmigan ( <i>Lagopus lagopus</i> )			
adult male	20	649.5	563.1-752.0
adult female	6	588.4	533.5-683.7
Rock Ptarmigan ( <i>Lagopus mutus</i> )			
adult male	20	509.3	465.0-552.5
adult female	6	464.1	427.5-500.8

status shown in Table 1 is apparent because most migrating individuals fell into the higher fat classes and, conversely, individuals taken while breeding or probably breeding were, on the average, much less fat. Whereas great masses of abdominal and/or subcutaneous fat might affect the heart weight : body weight ratio, my own observations of such obese birds have also shown considerable fat deposits associated with the heart, but pericardial fat deposits are usually removed before weighing.

In addition to the specimens taken for heart weights, others were collected and frozen for quantitative lipid studies (Johnston, MS). These species were *Calcarius lapponicus*, *Ereunetes mauri*, *Acanthis* sp., *Pluvialis dominica*, and *Sterna paradisaea*. The average body lipid content of the first four of these species (ten specimens each) ranged between 5.3 and 7.4 per cent of the total body weight. Ten specimens of *Sterna* had an average body lipid content of only 11.3 per cent. From these and other unpublished data it does not seem likely that such low lipid values could significantly affect the heart weight : body weight ratio in these species.

#### SUMMARY

Five hundred sixty-three individuals of 77 species were taken near Cape Thompson, Alaska, in the summers of 1960 and 1961. For each of these birds, total body weight, heart weight, and the heart weight : body weight ratio are presented.

By comparing these data with those compiled by Hartman for tropical and subtropical birds, it is concluded that arctic species tend to have larger hearts.

No significant intraspecific sex or age differences were detected.

Heart size is related to body activities: species which spend much time foraging on the ground (regarded as "poor fliers"), those which generally dive for food in water, and soaring birds have smaller hearts than their counterparts which are more active fliers.

The sympatric Willow and Rock Ptarmigan have significantly different heart ratios, but, contrary to earlier beliefs, this difference is attributed to body size rather than altitude.

Body lipids of four breeding species (*Calcarius*, *Acanthis*, *Pluvialis*, and *Ereunetes*) amounted to < 10 per cent of the total weight; in another species (*Sterna*), this value was about 11 per cent. In at least these species, it is believed that the heart ratio is not significantly affected by lipid deposits.

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