



SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 144, NUMBER 2

DIMENSIONAL RELATIONSHIPS
FOR FLYING ANIMALS

By
CRAWFORD H. GREENEWALT
President, E. I. du Pont de Nemours & Co.



(PUBLICATION 4477)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION

April 6, 1962

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FOREWORD

Many of the data on the dimensions of flying animals are found in journals which are not readily accessible. Aside from Sotavalta's papers on insects, published within the past 15 years, the significant references are also many years old, harking back to an era when such studies were undertaken primarily to provide inspiration for the development of aircraft.

The literature is quite extensive for insects, for birds, and even for bats. Furthermore the results of the several investigations appear consistent among themselves, leading to the presumption that a reasonable degree of precision obtains for all the great mass of available data.

It seemed worthwhile first to bring these scattered sources together in one publication, and second to plot the various dimensions against each other to determine how well the principles of dimensional similarity hold for so diverse a collection of flying animals. The figures speak for themselves. The text has been added by way of summary and to point out certain anomalies which appear to provide exceptions to nature's usual sense of orderliness. The scientific names in the tables are given as they appeared in the original publications, in the belief that few identification difficulties will arise.

There is no claim to originality in what follows. I shall be quite content if it is useful, perhaps even stimulating, to entomologists and ornithologists.

CRAWFORD H. GREENEWALT

Greenville, Delaware
November 1960

DIMENSIONAL RELATIONSHIPS FOR FLYING ANIMALS

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President, E. I. du Pont de Nemours & Co.

For a dimensionally similar series of objects, animate or inanimate, a volume or a mass will be proportional to the cube, a surface to the square, of a linear dimension. If Alice, then, after sipping from the bottle labeled "Drink me," were reduced to one-third of her normal height, her surface would be one-ninth, her weight one twenty-seventh, of its original value. Or if we should plot Alice's weight and that of many other little girls, large and small, against let us say the length of their arms, we should find in logarithmic coordinates a straight line whose slope is 3, or in mathematical terms

$$W = cl^3$$

where W is weight, l is length of arm, and c a constant of proportionality.

For cats or for mice the result should be the same with, however, a different value for c , meaning simply that cats or mice are dimensionally similar within their families but not with each other, or for that matter with little girls.

BODY WEIGHT AND WING LENGTH

We turn now to figure 1 (all figures follow page 7), on which is plotted total weight against wing length for the entire array of flying animals. We see that for body weights ranging from less than 1 to more than 10 million milligrams, weight is roughly proportional to the cube of the wing length.

Insects show a much greater "scatter" than birds, evidence I suppose of nature's versatility in designing many models of animate aircraft at the lower end of the scale. The highest values of wing length per unit weight are found for the dragonflies and damselflies, for certain butterflies, and for such insect specialties as the craneflies and mosquitoes. Except for the dragonflies, these are rather poor fliers with low wing-beat rates. Lowest relative wing lengths are for the

bumble bees whose bulky, heavy bodies make one wonder how they can manage ever to become airborne. What might be called the "main sequence" of insects falls on a straight line well below that for the birds. One might expect this to mean a generally poorer flight performance, but this does not necessarily follow, since in appraising aerial ability one must also take wing-beat rate and muscle weight into account.

For birds, excluding for the moment the hummingbirds, the scatter is much less, particularly at the small end of the scale. In general the soaring birds have long wings, the gallinaceous birds short wings per unit of total weight. When one considers the aerodynamics of soaring this result might well have been expected.

Hummingbirds fall into a very special group, for here nature appears to have devised an unusual model, one in which weight is proportional to the 1.5 power of the wing length. This result is so unexpected that one might well question its validity. In figure 2 the hummingbird region is expanded, and I have plotted separately the two sets of available data. Their self-consistency leaves little room for doubt of the basic relationship. Hummingbirds cover only a small part of the roster of flying animals, and it should be noted that extrapolation of the hummingbird line either to larger or smaller body weights would lead to aerodynamic monstrosities. I can offer no rationale for the anomaly. Hummingbirds are excellent fliers, and it may be that their peculiar dimensional relationships contribute to this end.

One also sees that the hummingbirds are placed almost exactly in the center of the figure; hence they may represent a zone of transition between insects and other birds.

BODY WEIGHT AND WING AREA

Figure 3 shows the relationship between body weight and wing area. The results do not differ significantly from those in figures 1 and 2. Note again the much greater scatter for insects, the increasing scatter for birds as size increases, and the anomalous proportions for the hummingbirds. In figure 1, however, wing length for birds is in general greater per unit weight than for insects. Wing area, however, for the long-winged insects is considerably greater per unit weight than for the long-winged birds.

Figure 4 is an expansion of figure 3 for birds (excepting hummingbirds) with a differentiation in charting for selected bird families. We see that in general the birds of prey have the highest, ducks and gallinaceous birds the lowest, relative wing area. Aerial performance does not necessarily track relative wing area. Ducks, for example, are strong and competent fliers, making up for their small wing area by an unusually high wing-beat rate.

Note also that soaring birds, the albatross particularly, are not extraordinary in relative wing area, falling generally in line with the small passerines.

WING LENGTH AND WING AREA

Figure 5 shows the relationship for birds, figure 6 for insects. The birds fall into a very consistent pattern, but here the differences for soaring birds become more apparent. The albatross, for example, has a very long wing per unit area, as does the frigatebird and booby. This means simply that for soaring birds the wings are long and narrow, a condition essential for good aerodynamic stability, which does not require per se a large wing area.

In figure 6, the insects show their unusually large "scatter." We have models ranging from the long, narrow wing of the fruitflies and crane-flies to the broad stubby wings of the butterflies. The proportionality constant in the equation relating wing area with the square of the wing length varies through a factor of 5. For birds the variation is scarcely a factor of 2.

Figure 7 shows data for bats. One sees that these data are very self-consistent and that the constant of proportionality is quite close to that for birds. The flying model is similar, much more so than the appearance of the two classes of animals would lead one to expect.

WING SPREAD AND WING LENGTH

In virtually all ornithological handbooks the wing length as given is not the length of the whole wing, but that of what is called the "hand," viz, the distance from the wing tip to the first articulated joint. This practice arises out of the great difficulty in measuring total wing length or wing spread from bird skins, as compared with the relative ease of measuring the length of the "hand." Figure 8 shows Magnan's data on wing spread plotted against the measurements of the length of the "hand." It is essential here to use data from a single investigation since precise measurement of wing spread is greatly influenced by the technique of the particular observer. We see that the two hands average 62 percent of the wing spread. The "scatter" is not great, a tribute to Magnan's self-consistency.

WING AREA AND WING WEIGHT

In dimensional theory, the weight of the wing should be proportional to the cube of its length, or to the 1.5 power of its area. Figure 9 shows the relationship for insects and birds. We see that wing weight is proportional not to the 1.5 power, but to the 1.67 power of the wing area. Since we have previously shown wing area proportional to the square

of the wing length, we must conclude that wing *thickness* increases with the 1.34 power of the wing length and that the wings include a steadily increasing percentage of total weight as the size of the animal increases.

While we know little about the structural properties of bird and insect wings, it is reasonable to assume that if the thickness increased as the first power of the length, the angular deflection at the wing tip during, let us say, the downbeat would be constant. Since wing thickness actually increases as the 1.34 power of wing length, the angular deflection at the tip must decrease with increasing size (or weight) of the animal. This may be related to maintenance of aerodynamic efficiency with increasing size, but the argument is certainly not an obvious one.

It is even more extraordinary to note that the data for insects and birds fall on a continuous straight line. The materials of which the wings are constructed are totally different for the two classes; a ribbed chitinous membrane for the former and a complex structure of bone, muscle, and feather for the latter. It must, however, follow that the mean density of wings remains the same quite regardless of the material of construction.

It follows from the wing area-wing weight relationship that the weight of the wings will comprise a steadily increasing percentage of total body weight as the size of the flying animal increases. For the mosquito *Aedes aegypti*, weighing 1 milligram, Sotavalta's data show 0.2 percent of the total weight contained in the wings, whereas for the falcon *Gyps fulvus*, weighing over 7 kilograms, the wings, according to Magnan, are 22 percent of total weight.

WING-BEAT RATE AND WING LENGTH

There is good evidence¹ that the beating of the wings of flying animals can be described using the well-known theory for mechanical oscillators. This theory presumes a resonance frequency for beating wings which will be maintained regardless of changes in either external or internal wing loading. It follows then that wing-beat rate will be constant for a particular animal. The equation is as follows:

$$f^2 = \frac{Kbr^2}{I}$$

where f is the wing-beat rate, br^2 is proportional to the weight of the wing muscles, and I is the moment of inertia of the oscillating system, viz, the sum of the moment of inertia of the wings and the internal mo-

¹ Greenewalt, Crawford H., "The Wings of Insects and Birds as Mechanical Oscillators," Proc. Amer. Philos. Soc., vol. 104, No. 6, 1960.

ment of inertia of the wing muscles and whatever part of the skeleton vibrates with them. If we assume br^2 proportional to l^3 (or the weight of the animal) and I to l^5 (the product of wing weight and the square of a distance proportional to wing length) we see that the product fl should be constant for a dimensionally similar series of animals. We have seen, however, from figure 9 that for the whole roster of flying animals the weight of the wing varies with the 3.3 power of the wing length. Hence it should follow that the constant will be proportional to $fl^{1.15}$ not to fl .

In figure 10 we have plotted all available data for wing-beat rate against the corresponding wing length. We see that there is a limiting boundary line which does indeed have the slope 1.15. Unfortunately the data for birds are quite limited. I have obtained measurements for hummingbirds and for a few small passerines using high-speed cinematography, and Meinertzhagen gives data for a number of large birds whose wing frequencies are sufficiently low to permit visual counting. Even for insects there are insufficient data to show conclusively whether the slope 1.15 is characteristic also for particular families or genera of insects, or whether in these limited ranges a slope of 1.0 obtains. Figure 12 would appear to give some support to the latter hypothesis. Here we have placed the insects in four arbitrarily selected groups with decreasing values for fl assumed to be constant. It is seen that in quite general terms the various genera appear to fall on lines for which the slope is unity.

Whatever the proper exponent for l (and for a particular genus it makes little difference) the product fl appears to define the flying ability of the animal. This would place the fruitflies at the bottom of the list, with butterflies not much better. The best fliers would appear to include many of the Hymenoptera, certain Diptera genera, and a few Coleoptera. The birds in general seem to be more proficient fliers than the insects, with the hummingbirds at least equal to the best in both groups.

The hummingbirds again appear to be anomalous, but the data are not good enough to establish quantitative relationships with sufficient precision. Figure 11 is an expansion of the hummingbird region. The best fit for the data appears to be a line whose slope is 1.25 and this slope correlates well with what one would expect from the other dimensional relationships for the family.

It is to be hoped that many more data for birds will become available in order that these relationships can be more precisely established. Ideally, of course, one should have data on wing length, wing weight, muscle weight, and wing-beat rate for each specific individual. Here

we have had to assume muscle weight proportional to body weight, which is true only in the most general terms.

MUSCLE WEIGHT

In figure 13 we show the weight of the large pectoral muscle plotted against total weight for birds. The large pectoral muscle powers the downbeat of the wings, and so is the prime source of energy for flight. We see that for the entire procession of birds, from a tiny kinglet to a mute swan, the large pectoral averages 15.5 percent of the body weight with very little "scatter" on either side of the mean.

In figure 14 the weight of the large pectoral muscle is plotted against the weight of the wing. Here the scatter is considerably greater and the wing weight increases with the 1.1 power of the muscle weight. Body weight, on the other hand, increases with the first power of muscle weight. The rationale here is based on the data presented in figure 9. We recall that wing weight increases more rapidly than body weight, and since muscle weight is directly proportional to body weight it must also increase more rapidly than the weight of the muscle.

Figure 15 shows the weight of the small pectoral muscle (which powers the upbeat) plotted against body weight. Here we find the same proportional relationship that existed for the large pectoral muscle, but a far greater scatter from the mean. In general the gallinaceous birds have relatively large small pectorals; for soaring birds and birds of prey the small pectoral is a much lower percentage of body weight. The explanation is not readily apparent. Gallinaceous birds are relatively poor fliers, but it is hard to say why this should be associated with a relatively large small pectoral.

In figure 16 the weights of the two pectoral muscles are plotted against each other. We see that on the average the large pectoral has 10 times the weight of the small pectoral. The scatter from the mean is considerable, owing of course to the variability in relative weight of the small pectoral muscle.

The relative muscle weights provide the best available evidence for the presumption that for ordinary birds power for flight is provided wholly by the downbeat of the wings. If we make the reasonable assumption that power output is proportional to the weight of the muscle we see that the small pectoral can provide no more than 10 percent of the power required for flight. Since power must be expended merely to lift the wings, the contribution of the small pectoral muscle to flight may well be considerably less than this percentage.

For hummingbirds the situation is quite different. Large and small pectorals account for 25 to 30 percent of total weight as compared with

an average of 17 percent for ordinary birds. Hence one would expect hummingbirds to be relatively more powerful fliers. The ratio of the weights of the two muscles for hummingbirds is roughly 2 as compared with 10 for ordinary birds. One can then safely assume that both up-beat and downbeat contribute power for flight. This is also what one would expect from the pattern of the wing beat seen in high-speed moving pictures.

In figure 17, total muscle weight is plotted against body weight for insects. We see the usual scatter typical of dimensional data for insects. However, for many insects, notably the Neuroptera, Diptera, and Hymenoptera, total muscle weight is roughly the same percentage of body weight as is found for birds. For the butterflies, however, the musculature is very light, correlating with their poor flight performance.

Admittedly these same data could have been presented in many different ways. No attempt has been made, aside from figure 4, to subdivide the insects and birds into families and genera. Such an effort might well be fruitful, but the data collected here are probably not sufficiently precise to permit more than the broadest generalization. It is possible that relationships such as these will be of significance in taxonomic investigations both for insects and birds. It is to be hoped that someone will find the rather tedious investigations worth the effort.

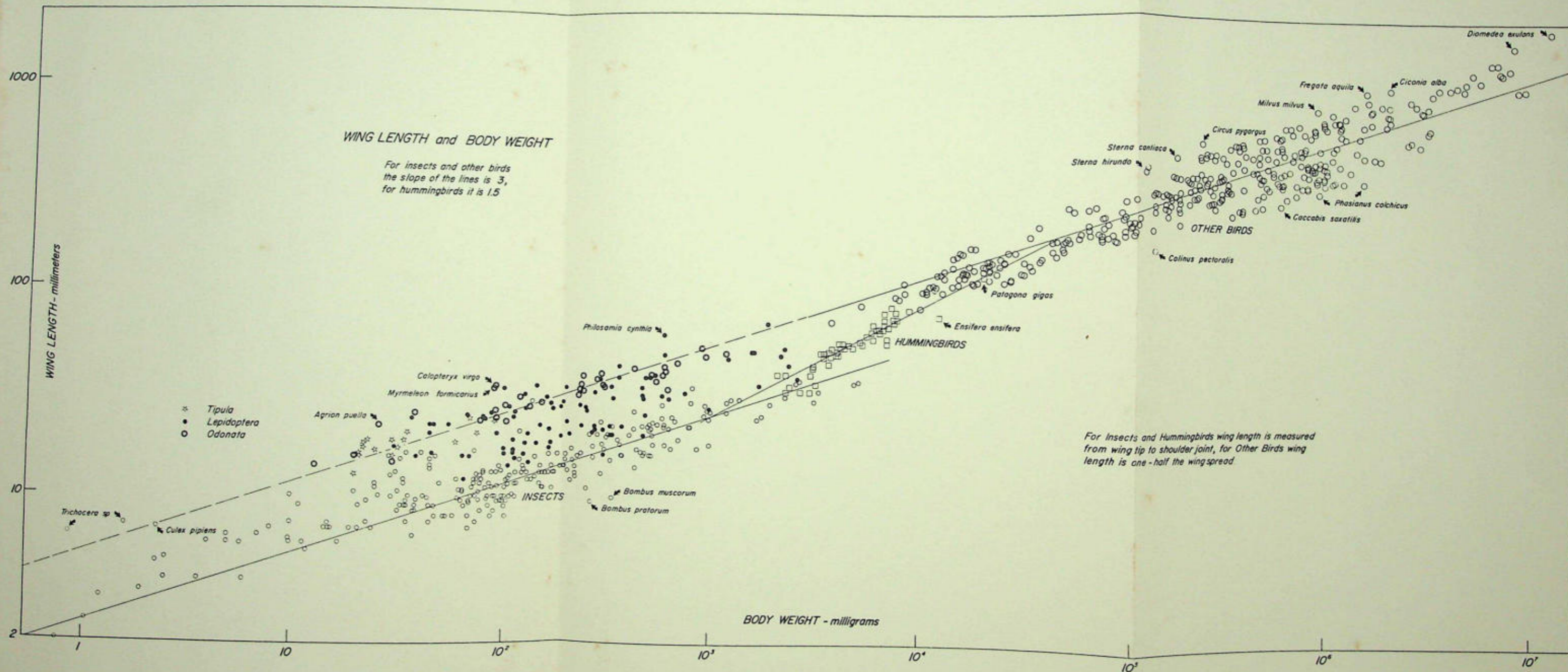


FIG. 1

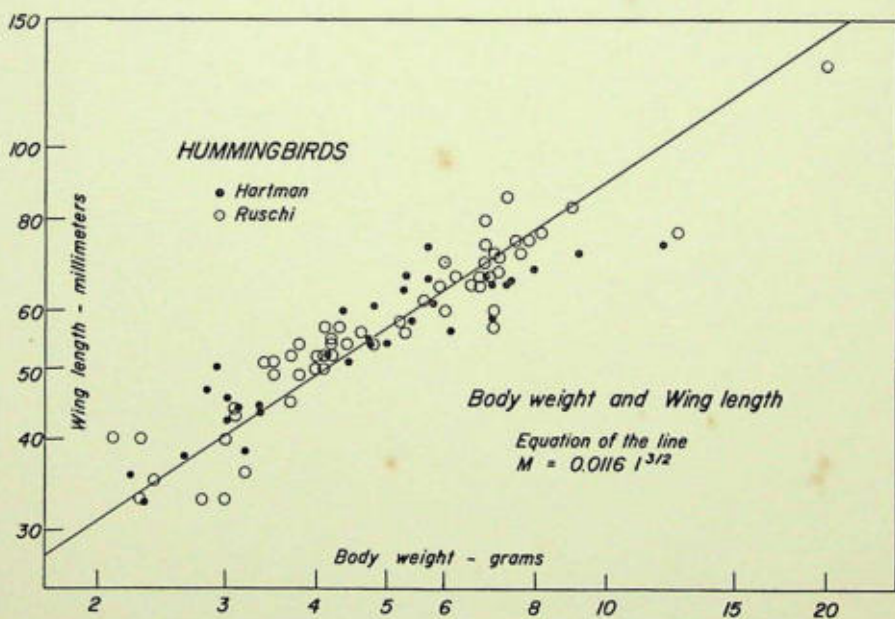


FIG. 2

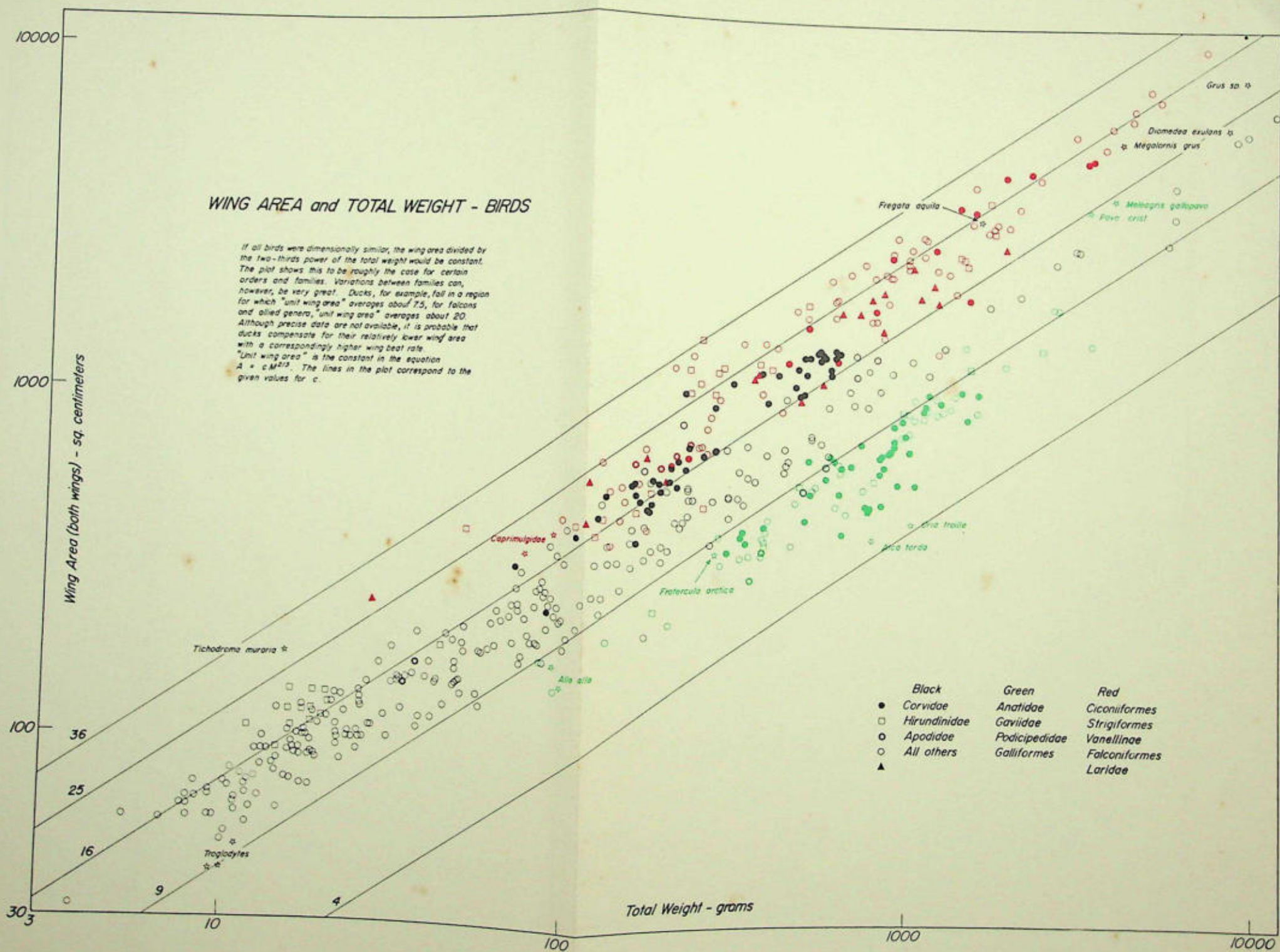


FIG. 4

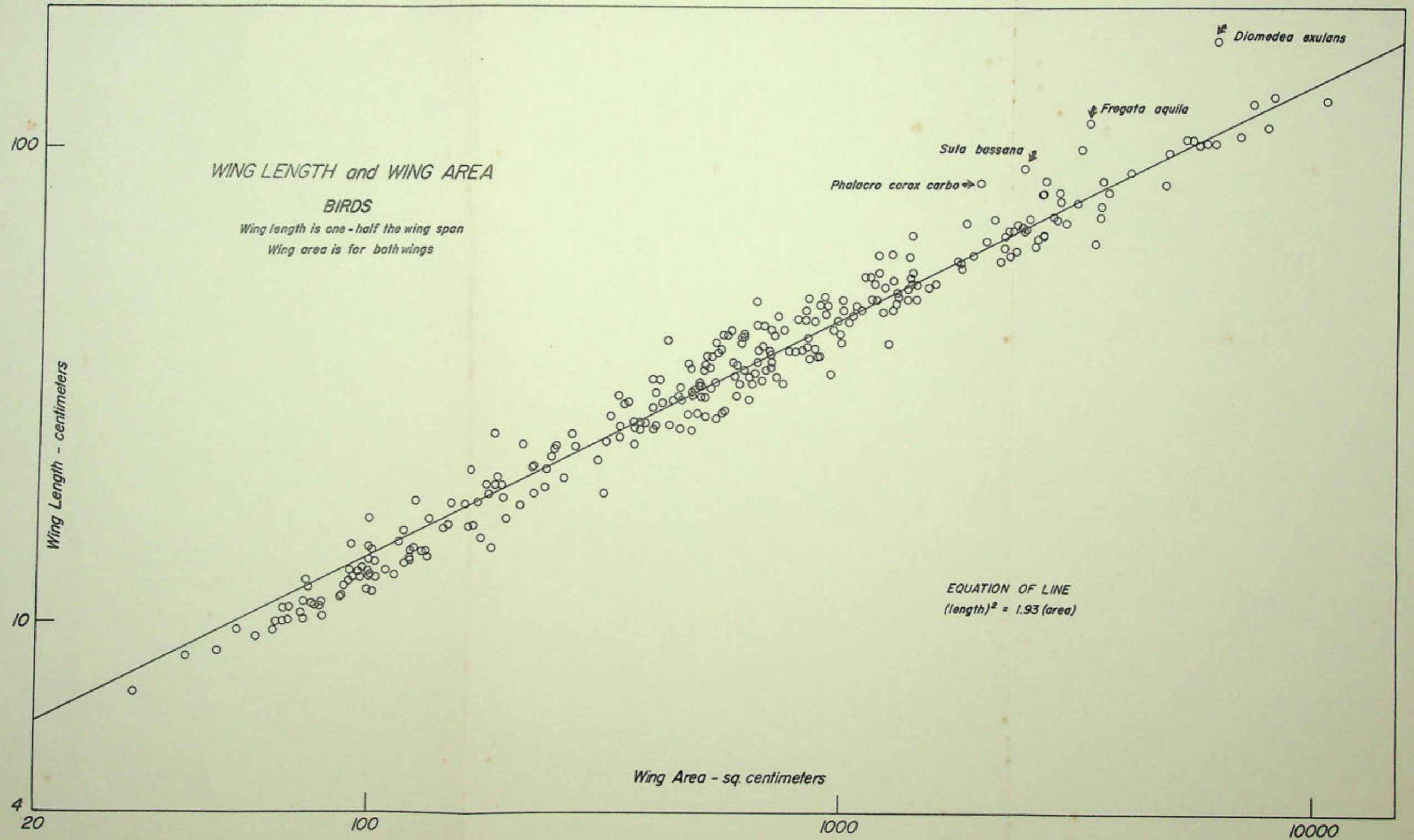


FIG. 5

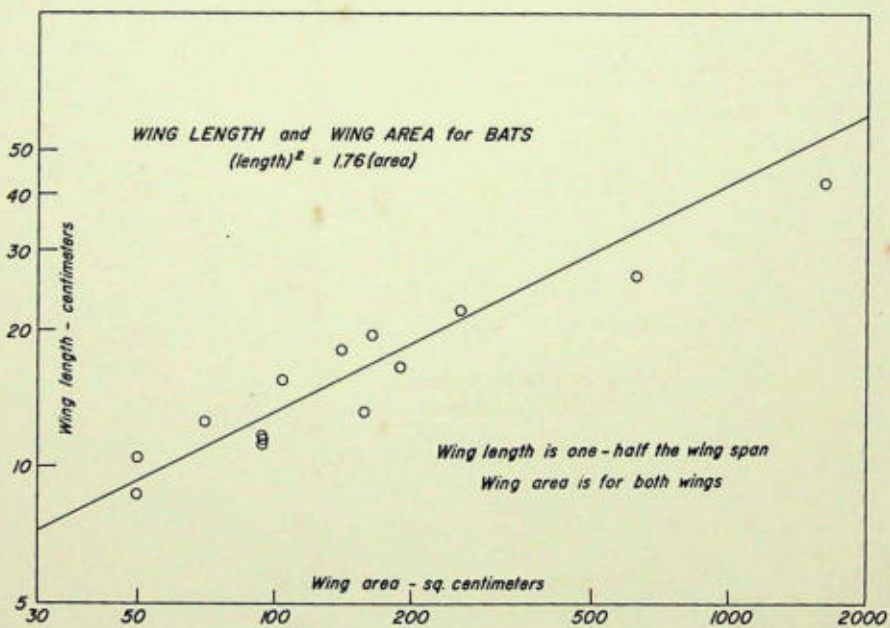


FIG. 7

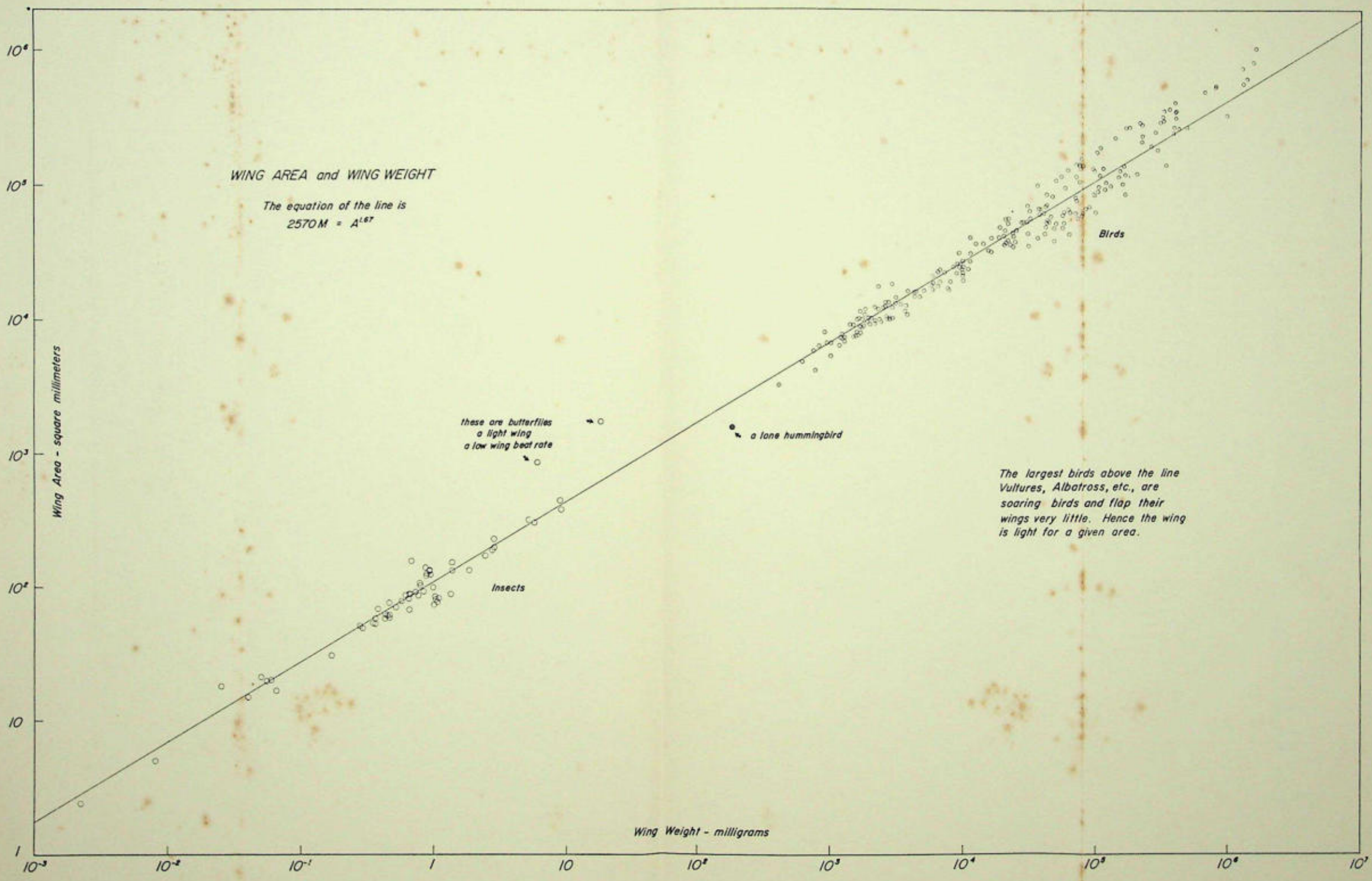


FIG. 9

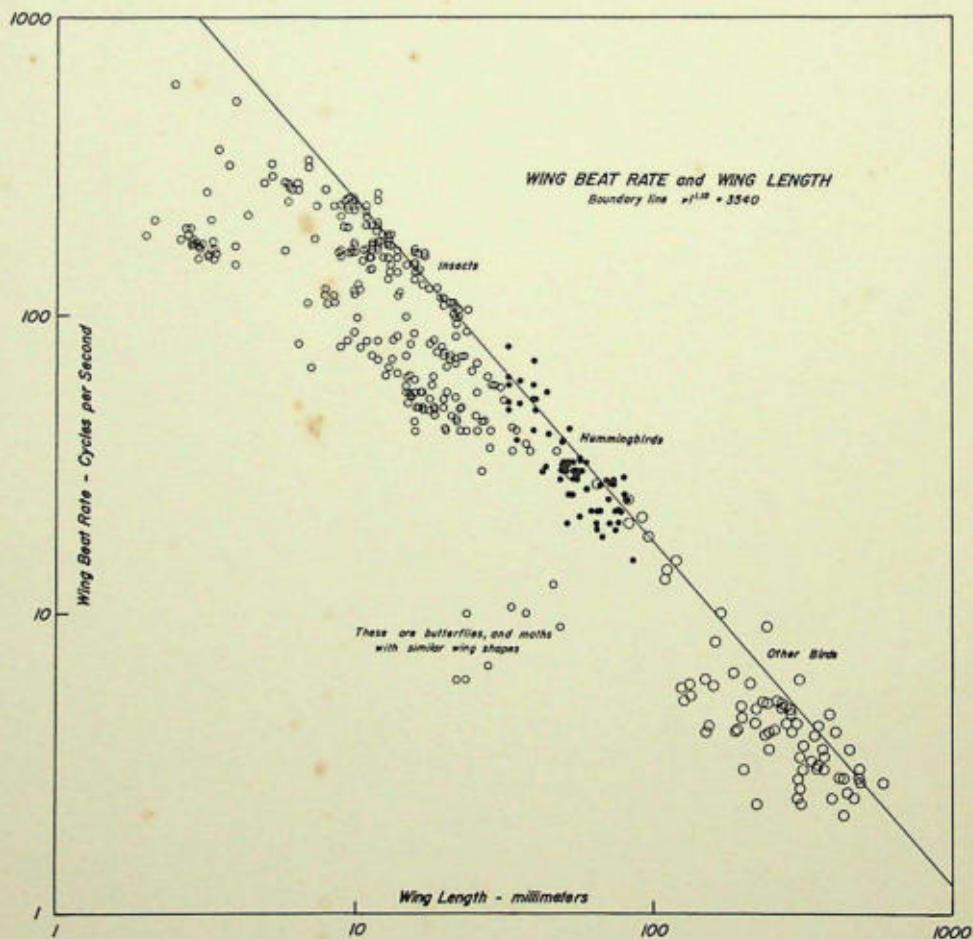


FIG. 10

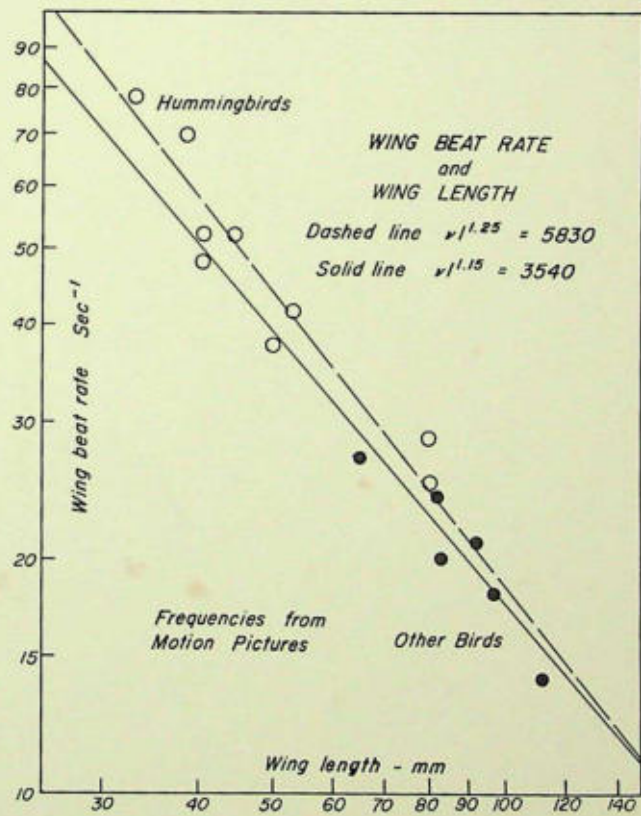
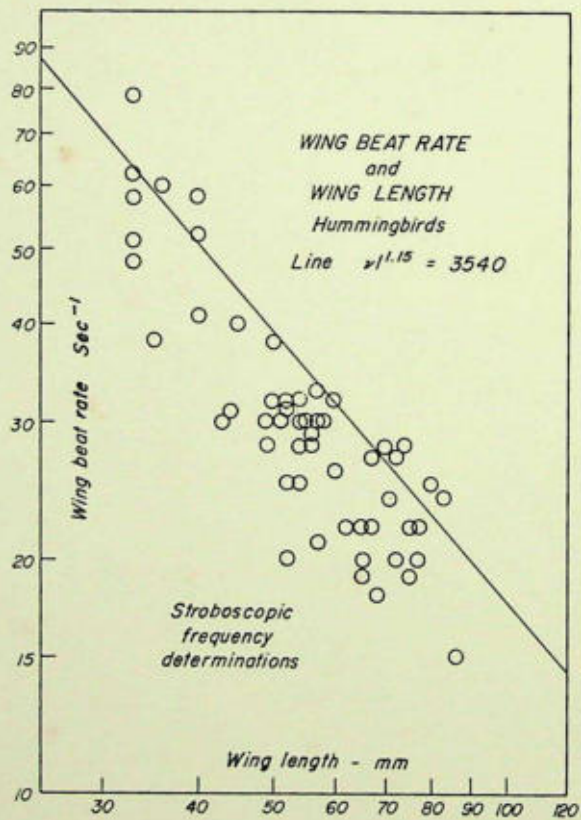


FIG. 11

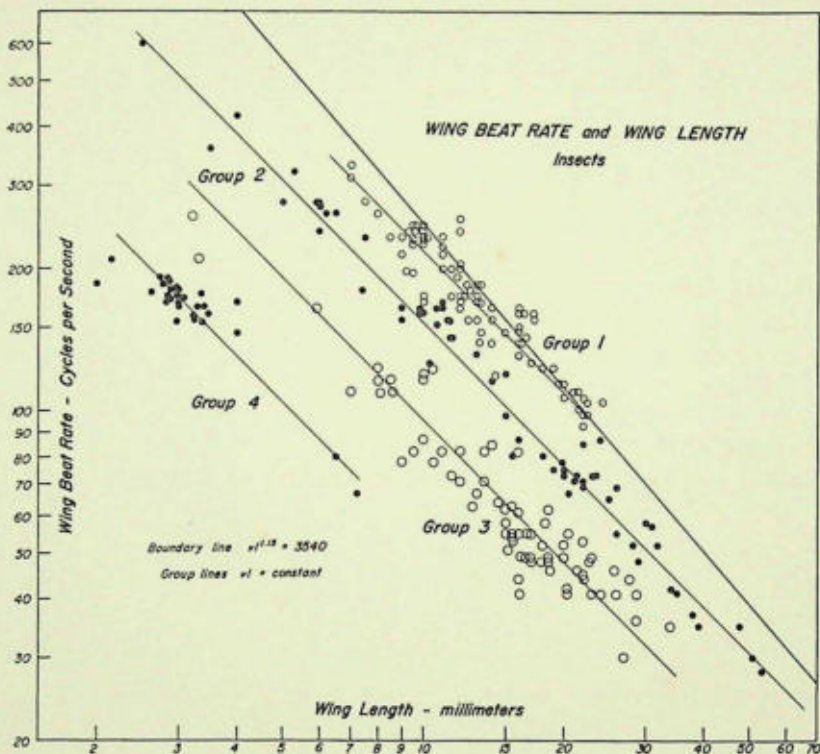


FIG. 12—Wing-beat rate and wing length for insects

GROUP 1

HYMENOPTERA

ACULEATA

Vespa
Megachile
Anthidium
Psithyrus
Bombus
Apis

COLEOPTERA

Cetonia
Potosia

DIPTERA

NEMATOCERA
Chironomus
BRACHYCERA
Tabanus
Neotamus
Bombylius
Volucella
Eristalis
Helophilus

GROUP 2

LEPIDOPTERA

Hemaris
Chaerocampa
Deliphila
Sphinx
Aegeria
Cossus

HYMENOPTERA

SYMPHYTA

Trichiozoma
Sirex
ACULEATA
Camponotus
Andrena
Eucera
Ammophila

HEMIPTERA

ODONATA

Aeschna

COLEOPTERA

Creophilus
Amphimallon
Melolontha
Trichius
Saperda
Cerambycidae
Macroglossum
Gcotrupes

DIPTERA

NEMATOCERA
Aedes
Culicidae
Anopheles
Theobaldia
BRACHYCERA
Calliphora

GROUP 3

LEPIDOPTERA

Acronycta
Agrotis
Sora
Charax
Hadena
Hydroecia
Xylina
Poecilocampa

HYMENOPTERA

SYMPHYTA

Diprion
ACULEATA
Colletes
TEREBRANTIA
Amblyjoppa
Colichneumon
Opheltes
Paniscus
Enicospilus
Ophion
Agrypon

HEMIPTERA

ODONATA

Sympetrum
HETEROPTERA
Mesocerus
Carpocoris
Dolycoris

COLEOPTERA

Aphodius
Dermestes
Pachyta

BLATTARIA

Periplaneta

DIPTERA

NEMATOCERA
Tipula
Pachyrrhina
Limnobia
Simulium
BRACHYCERA
Musca
Chrysops

GROUP 4

HYMENOPTERA

TEREBRANTIA

Nemeritis

DIPTERA

NEMATOCERA
Trichocera
BRACHYCERA
Drosophila

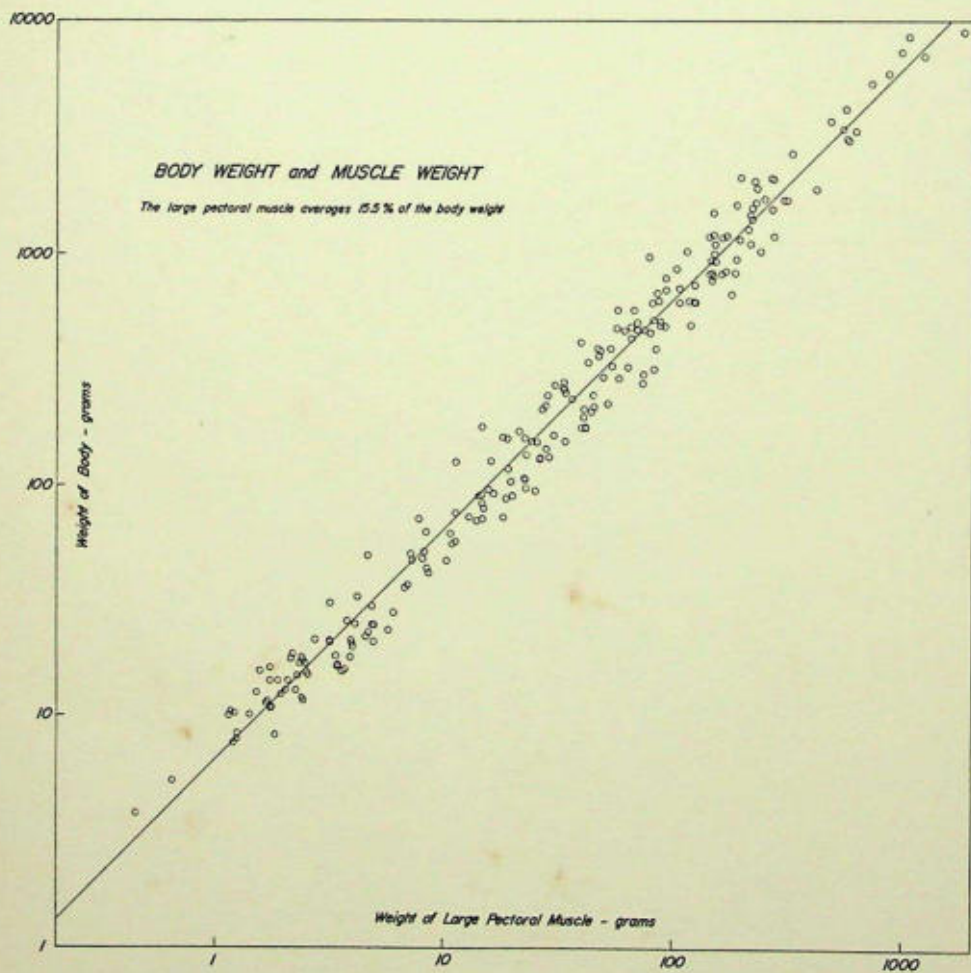


FIG. 13

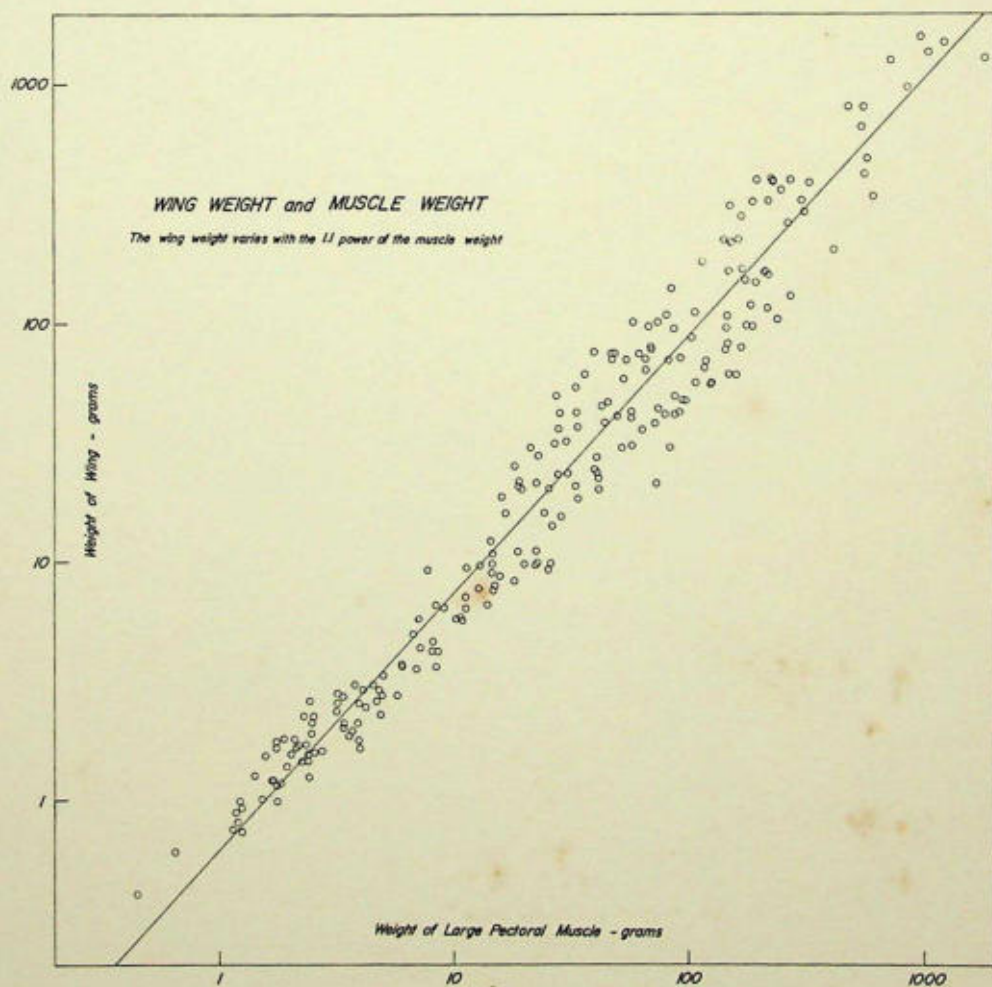


FIG. 14

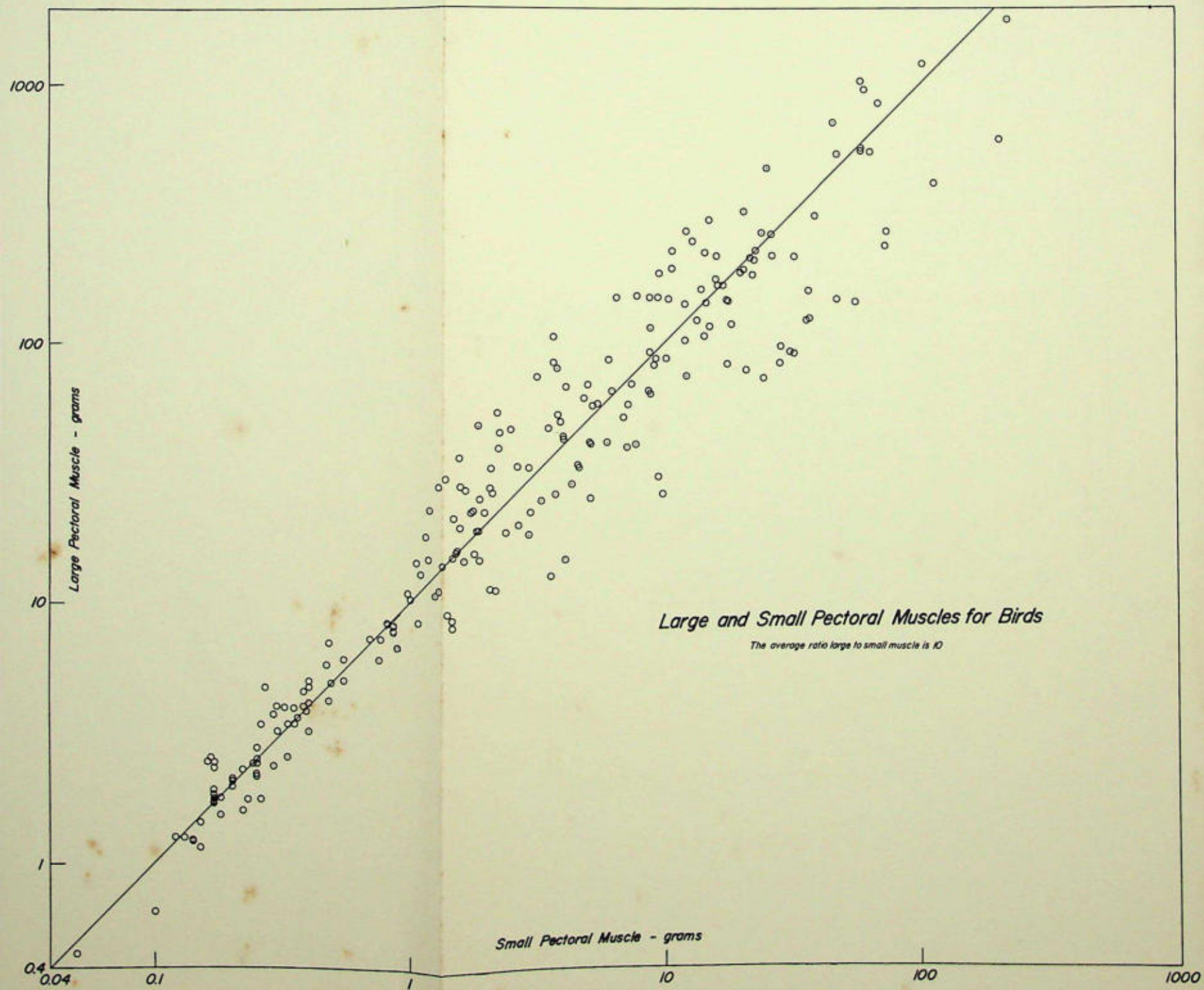


FIG. 16

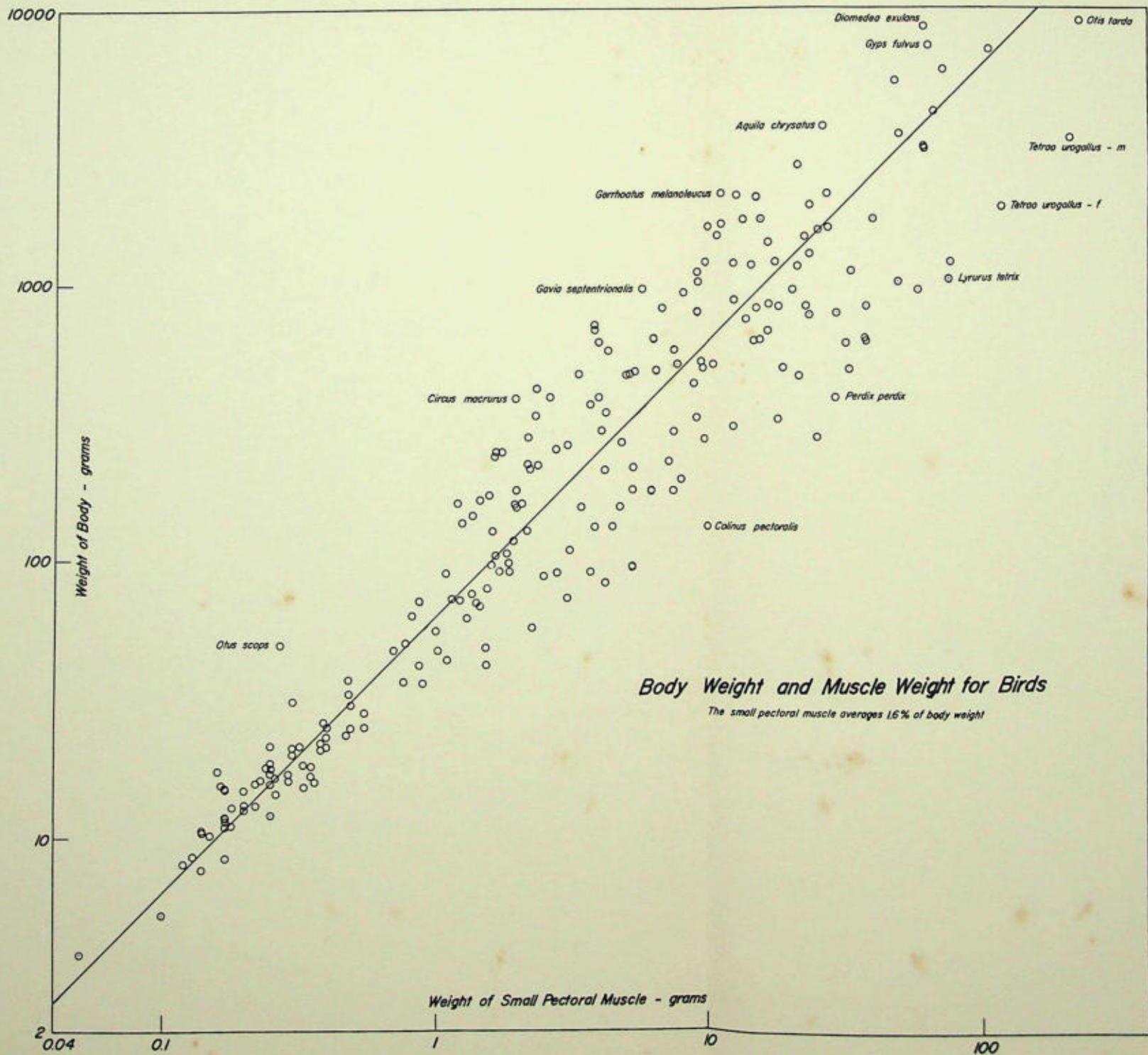


FIG. 15

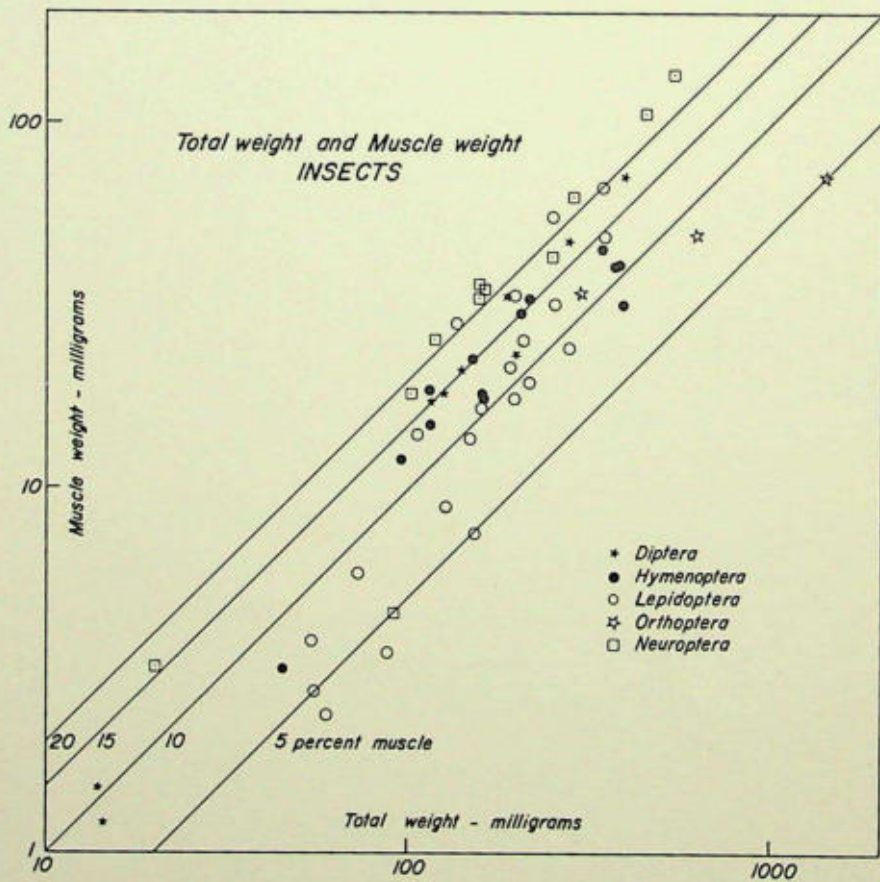


FIG. 17

METHODS EMPLOYED IN OBTAINING DATA FOR TABLES 1-3,
FROM O. SOTAVALTA*Wing frequency:*

All papers—"Flight tone": Sotavalta has the gift of perfect pitch and made nearly all his measurements by the "acoustic" method. He reports a possible error in his determinations of -5 to +1 percent. Data are given which show his "acoustic" method to be in close agreement with direct stroboscopic measurements.

Total weight:

1947—Weights determined using "in most cases" a balance with a sensitivity of ± 1 mg. after exposure of the insect to HCN vapor for 10 to 15 seconds.

1952 }
1954 } As above, but with a more accurate balance.

Wing length:

All papers—Measured using a common millimeter rule with an accuracy of $\pm \frac{1}{2}$ to 1 mm. Distance is the "direct distance from the wing tip to the articular point."

Wing area or total sustaining surface:

1947—Measured by tracing the contour of the entire insect with spread wings on millimeter cross-section paper, "the wings then being fresh in their assumed striking position straight aside." This gives the "total sustaining surface."

1952—Measured as above but here the area of all wings alone was measured. This gives true "wing area" of all wings.

Wing weight:

1952—Weighings made on a microchemical balance with an accuracy of 1 microgram. For very small wings, several were weighed together and the average weight computed.

1954—As above but with a torsion microbalance of 5 micrograms sensitivity.

Moment of inertia of wings:

1952 } Determined by summation of the weights of small wing slices multiplied
1954 } by the square of the distance of the slice from the articular point.

TABLE 1.—DATA FROM O. SOTAVALTA, ACTA ENTOMOLOGICA FENNICA, PT. 4 (1947)

	Wing- beat rate sec-1	Body weight mg.	Wing length mm.	Total sustaining surface mm. ²
LEPIDOPTERA :				
<i>Papilio machaon</i>	5.5	369	43	2,064
" " (on a flower)	5	610	49	2,810
" " (fixed)	9	610	49	2,810
<i>Pieris napi</i>	6	47	22	686
<i>Gonepteryx rhamni</i>	6.7	168	28	1,128
<i>Vanessa antiopa</i>	10	495	38	2,030
<i>Hemaris fuciformis</i>	85	241	22	440
<i>Chaerocampa elpenor</i>	58	642	30	780
" "	57	480	31	770
" " <i>porcellus</i> ♂	71	308	21	426
" " " ♀	71	383	22	477
" " " ♀	65	496	25	589
" " " ♀	67	272	20.5	462
" " " ♀	69	334	22	520
<i>Deilephila gailii</i>	52	765	32	934
<i>Sphinx ligustri</i> ♂	30	1,645	51	2,057
" " ♀	28	2,288	53	2,360
" " <i>pinastri</i> ♂	42	477	34	934
" " " ♂	37	520	38	1,041
" " " ♂	35	550	39	1,287
<i>Acronycta auricoma</i> ♀	58	217?	15	278
<i>Agrotis occulta</i>	30	252	27	830
<i>Sora rubricosa</i>	44	125	16	...
" "	55	165	17	...
<i>Charaeeas graminis</i> ♂	71	65	12	246
<i>Hadena lateritia</i>	45	332	22	...
" " <i>monoglypha</i>	53	280	22	572
<i>Hydroecia fucosa</i>	61	100	16	307
<i>Xylina ingrca</i>	49	210	20	...
<i>Catocala fraxini</i>	12.5	1,235	47	2,710
<i>Geometra papilionaria</i>	10	80	24	716
<i>Aegeria apiformis</i> ♂	87	310	16	...
" " ♀	75	485	20	...
<i>Cossus cossus</i> ♂	44	997	27	...
" " ♀	37	2,645	38	1,694
" " ♀	41	1,730	35	1,326
HYMENOPTERA :				
<i>Symphyta</i>				
<i>Diprion</i> sp.	123	68	8	...
<i>Trichiosoma lucorum</i>	73	265	20	...
<i>Sirex gigas</i> ♀	69	440	26	...
<i>Aculeata</i>				
<i>Camponotus herculeanus</i> ♀	73	120	15	...
<i>Ammophila sabulosa</i> ♀	143	86	11.5	...
<i>Vespa vulgaris</i> ♀	165	224	14	166
" " ♀	175	70	10	80
<i>Colletes cunicularius</i>	117	107	10	...
<i>Andrena vaga</i> ♂	132	154	13	137
<i>Eucera longicornis</i> ♀	170	150	11.5	...
<i>Megachile lagopoda</i> ♂	214	153	11	...
" " ♂	214	155	11	...
" " ♀	205	214	12	...
" " ♀	175	136	12	...

TABLE 1.—continued

	Wing- beat rate sec-1	Body weight mg.	Wing length mm.	Total sustaining surface mm. ²
HYMENOPTERA, Continued				
<i>Aculeata</i> , Continued				
<i>Megachile ligniseca</i> ♀	233	115	10	...
" <i>rotundata</i> ♀	277	38	6.5	...
<i>Anthidium manicatum</i> ♂	233	171	11	...
" " ♀	233	90	8.5	...
" " ♀	196	104	9.5	...
<i>Psithyrus rupestris</i> ♀	123	541	18	361
" <i>bohemicus</i> ♀	123	715	19	...
<i>Bombus hortorum</i> ♂	139	195	14	217
" " ♀	131	533	16	262
" " ♀	127	450	17	368
" " ♀	147	337	15	...
" <i>equestris</i> ♀	262	58	8	...
" <i>hypnorum</i> ♀	150	485	16	...
" " ♀	139	380	16	308
" <i>agrorum</i> ♀	170	225	13	192
" <i>lapidarius</i> ♀	165	537	16	284
" " ♀	161	534	16	270
" " ♀	161	487	16	...
" <i>ruderarius</i> ♀	185	302	13	210
" <i>pratorum</i> ♀	233	101	9	90
" <i>lucorum</i> ♀	147	520	16	...
" " ♀	161	487	16.5	...
<i>Apis mellifica</i> ♀	233	85	9	86
" " ♀	225	99	10	...
" " ♀	225	97	9.5	...
" " ♀	230	100	9.5	...
" " ♀	230	99	10	...
" " ♀	240	98	10	...
" " ♀	247	94	9.5	...
" " ♀	247	101	10	...
" " ♀	214	65	9	...
" " ♀	230	91	10	89
<i>Terebrantia</i>				
<i>Amblyjoppa proteus</i>	82	165	16	...
<i>Coelichneumon comitator</i>	123	32	10.5	...
<i>Opheltes glaucopterus</i>	52	95	20	...
"	55	120	20.5	...
<i>Paniscus opaculus</i>	78	20	10.5	...
" "	78	22	10.5	...
" "	71	45	13.5	...
<i>Enicospilus ramidulus</i> ♀	73	25	11.5	...
" " <i>merdarius</i> ..	82	25	11	...
<i>Ophion luteus</i>	64	45	14	141
" "	55	45	15	...
" "	55	48	15.5	...
" "	55	35	16	...
<i>Agrypon anxium</i>	78	11	9	49
HEMIPTERA:				
<i>Heteroptera</i>				
<i>Mesocerus marginatus</i>	120	85	10	...
<i>Carpocoris purpureipennis</i>	117	74	10	...
<i>Dolycoris baccarum</i> ♂	116	48	8	84

TABLE 1.—continued

	Wing- beat rate sec-1	Body weight mg.	Wing length mm.	Total sustaining surface mm. ²
HEMIPTERA, Continued				
<i>Odonata</i>				
<i>Aeschna juncea</i>	35	958	48	2,180
COLEOPTERA:				
<i>Creophilus maxillosus</i>	98	200	15	...
<i>Geotrupes stercorarius</i>	85	810	22	520
" "	87	1,000	24	684
" "	73	690	23.5	...
" "	73	540	23	...
<i>Aphodius subterraneus</i>	117	32	8.5	...
" <i>finetarius</i>	82	35	9.5	...
<i>Amphimallon solstitialis</i>	75	364	19	...
" "	80	306	18	...
<i>Melolontha hippocastani</i>	58	1,220	29	965
<i>Trichius fasciatus</i>	116	170	14	...
<i>Cetonia aurata</i>	98	512	22	425
" "	107	478	22	...
" "	104	521	22.5	...
" "	101	437	21.5	...
" "	98	611	22.5	...
" "	114	323	19.5	...
" "	107	338	20	...
" "	93	478	22	...
<i>Potosia cuprea metallica</i>	110	521	21	...
" " "	114	534	20	...
" " "	110	529	21.5	...
<i>Dermestes lardarius</i>	110	21	7	...
<i>Pachyta quadrimaculata</i>	85	151	14	...
" "	82	126	13.5	...
" "	82	74	12	...
<i>Saperda carcharias</i>	55	1,010	26	...
" "	55	1,220	26	800
DIPTERA:				
<i>Brachycera</i>				
<i>Tabanus tropicus</i> ♀	165	131	12	...
" " ♀	185	81	13	...
" " ♀	156	88	13	...
" <i>bromius</i> ♀	156	78	12.5	...
<i>Neotamus cyanurus</i>	170	42	10	...
<i>Bombylius maior</i> ♂	255	60	12	...
" " ♀	240	79	12	100
" " ♀	230	36	10	65
" " ♀	170	75	12	...
<i>Volucella pellucens</i>	147	200	15	...
" "	156	125	14	...
<i>Eristalis oestracea</i>	200	101	11	...
" "	200	83	11	...
" "	200	116	11.5	...
" "	200	104	12	...
" "	170	174	13	...
" <i>tenax</i>	175	165	13	160
" " (same specimen)	161	150	13	160
" " " "	139	130	13	160

TABLE I.—concluded

	Wing- beat rate <i>sec-1</i>	Body weight <i>mg.</i>	Wing length <i>mm.</i>	Total sustaining surface <i>mm.²</i>
DIPTERA, Continued				
<i>Brachycera</i> , Continued				
<i>Helophilus trivittatus</i>	222	89	11	...
<i>Drosophila funebris</i>	170	6	4	...
<i>Nematocera</i>				
<i>Tipula excisa</i> ♂	49	32	17	145
" <i>lateralis</i> ♂	67	32	13	75
" <i>scripta</i> ♀	52	59	18	...
" <i>selene</i> ♀	49	90	23	...
<i>Pachyrrhina analis</i>	62?	14?	18.5	...
" <i>lineata</i>	87	10	10	...
<i>Limnobia quadrimaculata</i>	55	29	15.5	...
<i>Culicidae</i> sp. ♂	523	2.5	4	10
" " ♀	277	5	6	...
" " ♀	277	2.5	5	...
" " ♀	262	5	6.5	...
" " ♀	270	5	6	...
<i>Anopheles maculipennis</i> ♀	240	4	6	16
<i>Theobaldia alaskaensis</i> ♀	233	10	7.5	...
<i>Chironomus plumosus</i> ♂	311	13	7	24
" " ♂	330	8	7	29
" " ♂ (<i>s. sp.</i>) ..	494	8	7	29

TABLE 2.—DATA FROM O. SOTAVALTA, ANN. ZOOL. SOC. "VANAMO,"
VOL. 15, NO. 2 (1952)

	Wing- beat rate sec-1	Body weight mg.	Wing length mm.	Wing area mm. ²	Wing weight mg.	Moment of inertia of wings mg. (mm.) ²
LEPIDOPTERA:						
<i>Pieris brassicae</i>	10.5	144	34.0	1,720	17.975	4,230
" <i>napi</i>	6	37	23.6	853	5,975	698
<i>Macroglossum stellatarum</i> ..	73	282	21.3	379	9.180	593
<i>Poecilocampa populi</i>	55	112	16.7	317	5.225	265
HYMENOPTERA:						
<i>Aculeata</i>						
<i>Apis mellifica</i>	234	111	10.2	62.0	0.425	9.55
" "	247	84	9.7	57.6	0.425	7.32
" "	(240)	69	9.3	57.6	0.360	6.14
" "	(240)	77	9.6	57.9	0.365	6.92
<i>Bombus lapidarius</i>	143	477	16.6	172	2.465	131
" "	(161)	658	17.3	189	2.745	169
" <i>terrestris</i>	156	880	17.3	197	2.860	158
<i>Vespa germanica</i>	139	240	16.2	133	1.390	69.6
" <i>vulgaris</i>	139	81	13.2	81.7	0.665	26.0
" "	147	98	13.3	85.2	0.760	27.8
" <i>crabro</i>	104	597	24.3	304	5.675	608
<i>Terebrantia</i>						
<i>Ophion luteus</i>	62	33	15.0	155	0.675	32.2
<i>Nemeritis canescens</i>	147	3.625	4.0	...	0.025	(0.061)
COLEOPTERA:						
<i>Melolontha vulgaris</i>	62	597	28.1	445	8.955	1,180
<i>Cerambycidae</i> sp.	80	142	15.5	133	1.845	68.8
<i>Amphimallon solstitialis</i>	78	291	19.9	229	2.840	187
DIPTERA:						
<i>Brachycera</i>						
<i>Calliphora erythrocephala</i>	143	...	11.4	85.9	0.605	14.9
" "	180	15	7.4	30.6	0.170	1.39
" "	156	94	11.3	79.6	1.030	18.2
" "	165	62	10.7	67.7	0.670	10.5
" "	156	106	11.4	73.1	1.000	17.4
" "	165	...	11.0	69.8	0.520	...
" "	161	61	9.8	61.1	0.460	7.33
" "	152	64	10.7	61.1	0.445	7.89
" " .....	...	...	9.3	50.5	0.275	4.37
" "	(161)	47	8.9	48.8	0.290	3.70
" "	127	...	10.3	67.6	0.375	...
" "	156	35	9.0	50.6	0.275	...
" "	165	33	9.0	52.5	0.360	...
" "	(161)	39	9.6	53.4	0.345	6.30
" "	161	30	10.0	57.0	0.430	...
" "	165	44	9.8	58.0	0.460	8.06
<i>Eristalis tenax</i>	175	50	11.5	67.3	0.655	15.9
" "	185	206	13.3	98.8	0.985	31.0
" "	175	106	12.2	76.5	1.050	23.8
" "	180	93	13.1	83.9	1.030	24.7
" "	156	...	12.5	81.1	0.645	...
" "	170	...	13.3	91.4	0.835	...
" "	185	176	13.0	87.9	1.355	27.6
" "	185	143	12.4	81.9	1.090	25.9
" "	191	...	11.8	76.9	1.045	24.2
<i>Musca domestica</i>	165	...	5.9	19.9	0.055	...

TABLE 2.—concluded

	Wing- beat rate sec-1	Body weight mg.	Wing length mm.	Wing area mm. ²	Wing weight mg.	Moment of inertia of wings mg. (mm.) ²
DIPTERA, Continued						
<i>Brachycera</i> , Continued						
<i>Drosophila melanogaster</i>	185	0.740	2.0	...	(0.0027)	(0.0017)
<i>Nematocera</i>						
<i>Tipula</i> sp.	63	21	15.5	75.5	0.460	29.0
" "	42	35	20.3	138	0.865	100
" "	63	30	15.5	87.9	0.655	44.1
" "	49	34	18.5	125	0.890	86.2
" "	49	30	18.5	130	0.930	83.2
" "	49	21	16.1	90.7	0.720	55.7
" "			16.9			
" "	63	20	12.7	61.4	0.465	13.9
" "	49	75	20.0	152	1.385	132
" "	48	23	18.5	131	0.930	71.4
" "	48	22	17.9	120	0.875	74.6
" "	48	22	17.0	106	0.785	51.5
" " .....	...	...	19.7	123	0.940	104
" "	49	25	16.5	101	0.785	54.3
<i>Trichocera</i> sp.	67	1.565	7.2	21.3	0.050	0.674
" "	80	0.830	6.5	18.0	0.025	(0.30)
<i>Theobaldia annulata</i>	262	9.900	6.2	16.9	0.065	60
" " .....	...	...	6.8	20.3	0.060	0.62
<i>Aedes aegypti</i>	600	1.025	2.5	2.4	(0.0022)	(0.003)
" "	360	1.890	3.5	5.0	(0.0080)	(0.020)
<i>Culicidae</i> sp. ♀	277	5.800	5.9	15.0	0.040	(0.30)

TABLE 3.—DATA FROM O. SOTAVALTA, ANN. ENTOMOLOGICA FENNICA,
VOL. 20, NO. 3 (1954)

	Wing- beat rate sec-1	Body weight mg.	Wing length mm.	Wing weight mg.	Moment of inertia of wings mg. (mm.) ²
LEPIDOPTERA:					
<i>Agrotis ypsilon</i>	58	169	18.2	5.235	325
" "	44	...	22.1	7.315	671
<i>Amphitrota clandestina</i>	44	150	22.0	6.730	654
" "	48	...	22.7	7.830	701
" "	46	...	21.3	5.845	428
<i>Sideridis unipuncta</i>	41	...	20.3	6.875	548
" "	46	111	18.6	3.025	233
<i>Amathes bicolorago</i>	54	69	15.5	2.645	138
" "	51	114	15.2	2.030	105
" "	53	64	15.6	2.225	99
" "	41	112	16.1	3.455	201
<i>Peocilocampa populi</i>	55	112	16.7	5.225	265
BLATTARIA:					
<i>Periplaneta americana</i> ♂	36	820	28.8	25.8	2,590
" " ♂	35	830	34.0	36.4	6,360
" " ♂	32	...	...	...	...
ODONATA:					
			Fore	Hind	
<i>Sympetrum danae</i> ♂	41	92	24.0	23.0	5.0
" " ♂	44	101	27.5	26.5	9.4
" " ♂	41	137	28.7	27.0	6.6
" " ♀	41	102	23.0	22.0	4.4
" " ♂	41	77	22.9	21.6	3.7
" " ♂	46	90	25.8	25.0	2.6
" " ♂	41	91	26.0	24.8	5.0

TABLE 4.—DATA FROM B. HOCKING, TRANS. ROY. ENTOMOLOGICAL SOC.,
VOL. 104, PT. 8 (1953)

	Wing- beat rate <i>sec-1</i>	Wing area <i>mm.²</i>	Wing length <i>mm.</i>
HYMENOPTERA:			
<i>Aculeata</i>			
<i>Apis</i>	198	28.3	9.2
DIPTERA:			
<i>Brachycera</i>			
<i>Tabanus affinis</i>	119	57.4	14.3
" <i>septentrionalis</i>	98	29.3	10.2
<i>Chrysops furcata</i>	110	21.9	8.6
" <i>nigripes</i>	109	18.9	8.1
<i>Drosophila</i>	208	1.5	2.14
<i>Nematocera</i>			
<i>Aedes campestris</i>	322	6.4	5.3
" <i>communis</i>	216	3.9	4.4
" <i>nearcticus</i>	318	3.6	3.8
" <i>punctor</i>	290	6.4	5.3
<i>Simulium venustum</i>	258	3.8	3.2
" <i>vittatum</i>	209	4.6	3.3

Hocking's paper is not clear as to whether the wing areas in the table above are for both wings or only one. In a recent letter he states that the measurements are for one wing and in the case of *Apis* for a pair of wings on one side.

TABLE 5.—DATA FROM REED, WILLIAMS, AND CHADWICK, GENETICS,
VOL. 27, NO. 3 (1942)

	Wing- beat rate sec-1	Wing area* mm. ²	Wing length mm.
<i>Drosophila immigrans</i>	166	3.19	3.40
" <i>virilis</i>	156	3.39	3.23
" <i>pseudoobscura</i>	191	2.31	2.83
" "	191	2.23	2.73
" "	175	2.48	2.84
" "	180	2.53	2.88
" "	173	2.63	2.88
" "	169	2.74	3.00
" "	166	2.82	3.00
" "	174	2.75	2.96
" "	179	2.60	2.98
" "	178	2.55	2.96
" "	182	2.56	2.96
" <i>miranda</i>	173	2.93	3.09
" "	154	3.39	3.37
" "	159	3.29	3.21
" "	166	3.23	3.29
" <i>athabasca</i>	154	2.72	2.96
" <i>azteca</i>	188	2.43	2.86
" "	185	2.18	2.77
" <i>repleta</i>	177	3.42	3.34
" <i>junebris</i>	160	3.63	3.46
" <i>melanogaster</i>	178	2.13	2.61
" <i>duncani</i>	169	2.33	2.82

* Both wings.

TABLE 6.—DATA FROM A. MAGNAN, LE VOL DES INSECTES, PARIS, 1934

	Weight mg.	Wing spread mm.	Wing length mm.	Wing surface mm. ²	Wing weight mg.	Wing- beat rate sec-1
DIPTERA:						
<i>Culex pipiens</i>	2.25	10	4.8	21	—	—
<i>Tipula gigantea</i>	69	51	23.6	226	2.0	48
<i>Trichocere fuscata</i>	2.25	15.5	7.0	—	—	100
<i>Tabanus bovinus</i>	276	41	15.5	184	3.0	96
<i>Dasyrampus atra</i>	233	37	15.7	150	2.4	100
<i>Bombylius major</i>	45	22	9.0	44	0.4	—
<i>Chrysotoxum bicinctum</i>	75	28.5	12.8	68	1.0	120
“ <i>vernale</i>	64	23.5	10.5	60	0.5	150
“ <i>arcuatum</i>	73	28	12	74	0.6	144
<i>Volucella pellucens</i>	73	27.5	12	78	0.5	120
“ <i>bombylans</i>	96	33	14	96	1.0	—
“ <i>plumata</i>	124	32.5	13.0	92	1.2	120
“ <i>sonaria</i>	215	40	17	124	3.0	—
“ <i>inanis</i>	115	32	13	108	2.0	—
<i>Eristalis tenax</i>	73	28	11.5	74	0.6	210
<i>Echinomya grossa</i>	197	34.5	14	124	2.0	—
<i>Catabomba pirastris</i>	34	27.5	12	40	0.4	190
<i>Sarcophaga carnaria</i>	45	19	7.5	36	0.45	160
<i>Calliphora vomitoria</i>	90	22	10	50	0.9	—
“ <i>erythrocephala</i>	23	18	7.5	24	0.2	160
<i>Musca domestica</i>	12	13.5	5.5	20	0.2	190
<i>Fannia scalaris</i>	10	14	6	19.6	—	210
HYMENOPTERA:						
<i>Xylocopa violacea</i>	614	44	18	172	3.0	130
<i>Bombus lapidarius</i>	495	40	16.5	165	3.1	90
“ <i>terrestris</i>	388	39	16	142	2.5	130
“ <i>hortorum</i>	159	31	13	90	1.2	135
“ <i>muscorum</i>	226	30.5	12.5	90	1.0	128
<i>Vespa crabo</i> ♀	567	52.5	22.5	260	6.0	100
“ ♂	373	40	18	180	2.4	—
“ <i>germanica</i>	187	31	14	98	0.9	110
<i>Polistes gallicus</i>	115	26.5	11.5	46	0.6	220
<i>Apis mellifica</i>	78	20	8.5	42	0.5	250
<i>Ammophila sabulosa</i>	45	20	9	42	0.5	120
<i>Allantus temulus</i>	52	—	11.4	—	—	70
LEPIDOPTERA:						
I. Rhopalocera						
<i>Papilio podalirius</i>	300	80	37	3,600	80	10
“ <i>machaon</i>	370	82	38	2,200	45	—
<i>Pieris brassicae</i>	127	67	31	1,840	21	12
“ <i>rapae</i>	87	52	25	1,000	8	—
“ <i>napi</i>	55	49	22	760	5	—
<i>Anthocaris cardamines</i>	45	48	22	780	4.2	—
<i>Rhodocera rhamni</i>	107	61	27	1,200	12	21
<i>Vanessa urticae</i>	112	52	24	1,000	8	—
“ <i>io</i>	195	62	28.5	1,400	17	18
“ <i>levana</i>	131	45	20	820	8	—
“ <i>atalanta</i>	134	57	27	1,080	15	10
“ <i>cardui</i>	173	58	26.5	1,040	12	20
<i>Argynnis paphia</i>	160	66	30	1,760	18	—
“ <i>pandora</i>	278	70	32	1,800	28	10
<i>Pararga moera</i>	67	53	24.5	1,160	7.2	—
“ <i>megeera</i>	45	44	20	720	3	—
<i>Coenonympha pamphilus</i>	46	37.5	16	480	3.5	22

TABLE 6.—continued

	Weight mg.	Wing spread mm.	Wing length mm.	Wing surface mm. ²	Wing weight mg.	Wing- beat rate sec-1
II. Heterocera						
a. Sphingids:						
<i>Acherontia atropos</i>	1,600	110	51	2,050	67.0	22
<i>Sphinx convolvuli</i>	2,200	110	49	2,160	—	—
" <i>ligustri</i>	2,400	104	44	2,000	—	—
<i>Macroglossa stellatarum</i>	345	47.0	20	400	10	85
" <i>bombylifomis</i>	189	43.5	19.5	262	7.4	80
<i>Zygoena filipendulae</i>	127	38	18	300	5	48
b. Bombyces:						
<i>Callimorpha hera</i>	196	63	28	1,080	16.4	—
<i>Chelonia villica</i>	165	49	21	800	13.0	20
<i>Spilosoma fuliginosa</i>	106	36	14	300	3	—
" <i>menthastris</i>	100	39.5	17	460	6	—
<i>Zeuzera aesculi</i>	340	51	20	480	15.6	—
<i>Dasichyra pudibunda</i>	237	62	27.5	800	13	28
<i>Bombyx rubi</i>	595	69.5	31	1,300	34	18
" <i>quercus</i>	189	60	27	1,080	26.4	—
<i>Philosamia cynthia</i>	605	132	61	5,000	93	8
<i>Saturnia pyri</i>	1,890	150	70	12,000	300	8
<i>Notodonta dictaea</i>	201	52	23	500	8.4	22
<i>Pygoera bucephala</i>	257	58	26	800	18	—
c. Noctuids:						
<i>Agrostis exclamationis</i>	133	35	14.5	320	5	41
<i>Triphoea promuba</i>	485	61	30	780	30	24
<i>Plusia gamma</i>	144	42	18	440	5	48
d. Phalenides:						
<i>Venilia macularia</i>	21	33.5	16	340	2.2	25
<i>Ephemera vulgata</i>	93	43	20	—	7	29
COLEOPTERA*:						
<i>Oryctes nasicornis</i>	2,700	87	37	744	34.6	—
<i>Lucanus cervus</i>	2,600	83	36	800	38.5	33
<i>Prionus cariaris</i>	1,700	56	24	450	15	—
<i>Melolontha vulgaris</i>	961	62	28	402	12.8	46
<i>Cetonia aurata</i>	537	50	20	130	4	86
<i>Dorcus parallelepipedus</i>	418	45	20	200	5	—
<i>Amphimallus fuscus</i>	201	39	16	160	4	—
<i>Cerambyx scopolii</i>	183	37.5	16	166	1.8?	—
<i>Telephorus fuscus</i>	109	28.5	12.5	116	1.6?	72
<i>Clerus alvearius</i>	71	24	11	82	1	—
<i>Aromia moschata</i>	133	31.6	14.3	—	—	—
ORTHOPTERA*:						
<i>Paracnema tricolor</i>	1,400	64	30	800	12.5	—
<i>Oedipoda coerulea</i>	614	46	22	460	6.1	—
NEUROPTERA:						
<i>Libellules</i>						
<i>Sympetrum striolata</i>	232	61	31	780	8.8	—
" <i>meridionale</i>	281	67	32	1,000	12.5	21
" <i>fonsconlombi</i>	157	61	29.5	760	8.2	—
" <i>sanguineum</i>	101	58.5	28	860	6	—
<i>Leucorhinia caudalis</i>	237	68.5	33	1,020	9.8	—
<i>Libellula depressa</i>	245	80	38.5	1,320	14.4	20
<i>Orthetrum coeruleum</i>	248	65	32.5	1,080	14.6	20
" <i>cancellatum</i>	303	80	39.5	1,200	18.9	—

* For membranous wings only.

TABLE 6.—concluded

	Weight mg.	Wing spread mm.	Wing length mm.	Wing surface mm. ²	Wing weight mg.	Wing- beat rate sec-1
NEUROPTERA, Continued						
Libellules, Continued						
<i>Leptetrum 4 maculatum</i>	307	72	34.5	1,060	12.0	21
<i>Cordulia aenea</i>	201	71	33.5	—	9.6	33
<i>Gomphus vulgatissimus</i>	638	70	33.5	940	11.1	—
<i>Brachytron pratense</i>	557	77	36.5	1,200	14.4	33
<i>Ophiogomphus serpentinus</i>	312	71	34	940	12.8	42
<i>Anax jormosus</i>	1,200	109	50	2,280	45.4	22
" <i>parthenope</i>	703	94	45	1,950	27	—
<i>Aeschna rufescens</i>	611	90	43	1,780	31.2	20
" <i>mixta</i>	530	80	39.5	1,380	21.5	38
<i>Calopteryx splendens</i>	120	64	30	—	11.8	16
" <i>virgo</i>	91	70	34	880	5.2	—
<i>Pyrhosoma minimum</i>	38	49	25	—	2.0	27
<i>Ischnura elegans</i>	20	30.5	15.5	130	1.0	—
<i>Panorpa communis</i>	30	32	14.5	175	1.0	28
<i>Myrmeleon formicarius</i>	90	68.5	33	700	5	—

TABLE 7.—DATA FROM MAGNAN AND PERRILLIAT-BOTONET, C.R. ACAD. SCI., VOL. 195, PP. 559-561 (1932)

Weight of pectoral muscles and weight of body for insects

	Body weight mg.	Weight of muscle mg.	% Muscle weight
DIPTERA :			
<i>Musca domestica</i>	14	1.50	10.7
"	14.5	1.20	8.27
<i>Volucella zonaria</i>	140	21.0	15.0
<i>Tabanus bovinus</i>	276.8	47.1	17.0
"	393.4	70.9	18.0
<i>Echinomya grossa</i>	197	23.3	11.8
<i>Gastrophilus equi</i>	115	17.3	15.0
<i>Eristalis tenax</i>	126.5	18.2	14.4
<i>Tabanus bovinus</i>	186	33.5	18.0
"	183	33.5	18.3
HYMENOPTERA :			
<i>Bombus lapidarius</i>	149.5	22.4	15.0
"	95	11.9	12.5
" <i>hortorum</i>	159.5	17.9	11.2
<i>Vespa crabo</i>	373.4	40.0	10.7
"	381	40.4	10.6
"	389	31.5	8.1
<i>Bombus terrestris</i>	215.5	32.7	15.2
"	205.5	30.0	14.6
" <i>muscorum</i>	115	18.6	16.2
<i>Vespa crabo</i>	339	44.7	13.2
<i>Apis mellifica</i>	115	14.9	13.0
<i>Ammophila sabulosa</i>	45.2	3.17	7.0

TABLE 7.—concluded

LEPIDOPTERA :			
<i>Pieris brassicae</i>	127.3	8.82	7.0
" <i>rapae</i>	87.7	3.51	4.0
" <i>napi</i>	55.2	2.76	5.0
" "	59.5	2.38	4.0
" "	54.2	3.79	7.0
<i>Vanessa atalanta</i>	134	28.0	20.9
" "	249	54.8	22.0
<i>Macroglossa stellatarum</i>	345.5	48.4	14.0
<i>Callimorpha hera</i>	196.4	17.6	9.0
" "	157.5	16.5	10.5
" "	214.5	19.3	9.0
<i>Vanessa io</i>	195	33.6	17.2
<i>Rhodocera rhamni</i>	150.5	7.5	5.0
<i>Argynnis pandora</i>	250.5	31.6	12.6
" "	148.6	13.4	9.0
" "	206	25.4	12.3
" "	160	17.6	11.0
" "	278.5	24.2	8.7
<i>Plusia gamma</i>	72.5	5.80	8.0
<i>Spilosoma fuliginosa</i>	106.5	13.85	13.0
<i>Zeuzera aesculi</i>	340.7	76.0	22.3
<i>Bombyx quercus</i>	189.5	21.2	11.2
ORTHOPTERA :			
<i>Oedipoda caerulycens</i>	614	49.1	8.0
<i>Cetonia aurata</i>	297.5	33.4	11.2
<i>Paracrinema tricolor</i>	1,403.5	70.0	5.0
NEUROPTERA :			
<i>Diplax sanguinea</i>	101	18.2	18.0
" "	156.5	33.0	20.0
" "	117.5	25.5	21.7
" "	161.5	35.5	22.0
" <i>fonscolombei</i>	157	36.1	23.0
<i>Myrmeleon formicaris</i>	90.5	4.52	5.0
<i>Diplax meridionalis</i>	281.6	61.9	22.0
<i>Ischnura elegans</i>	20	3.20	16.0
<i>Orthetrum caeruleescens</i>	248.2	42.7	17.2
<i>Aeschna cyanea</i>	445	106.7	24.0
" <i>mixta</i>	530.5	136	25.6

TABLE 8.—DATA FROM KARL MÜLLENHOFF, PFLUEGER'S ARCH. GESAMTE PHYSIOLOGIE, VOL. 35, PP. 407-453 (1885)

Data for birds, bats, and insects

P—Total weight in grams.

Weighings made to three significant figures on freshly killed animals.

p—Weight of flight muscles in grams.

F—Total sustaining surface in square centimeters (values not given in the tables which follow). Birds were placed on their back with wings and tail feathers extended as in flight and the entire contour traced on white paper. Parallel lines 1 centimeter apart were drawn on the figure and the area measured, taking the mean length between lines and summing the areas.

Insects were mounted on needles, the wings arranged as in flight. After drying the specimens, the contours were traced on millimeter cross-section paper and the individual square millimeters counted.

f—Area of both wings in square centimeters.

Determination as for sustaining surface.

The area for a given contour could be measured with an accuracy 1 to 1,000, but repeated measurements on a given bird, because of variable stretching of the wings, would deviate by as much as 1 in 100.

K—Wing spread in centimeters.

l—Length of both wings in centimeters.

These were taken directly from the contour drawings made for the determination of F and f. They are accurate to 1 part in 100.

The values given by other observers were selected by Müllenhoff on the basis of their accuracy and self-consistency. The different observers are identified in the second column as follows:

1, Müllenhoff	4, V. Ledenfeld	7, De Lucy
2, Harting	5, Marey	8, Pettigrew
3, Mouillard	6, Legal and Reichel	9, Krarup Hansen

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l	
BATS:							
1	<i>Pteropus edulis</i>	2	1,380	117.6	1,630	120	104.4
2	" <i>geoffroyi</i>	3	53	—	—	48.4	—
3	<i>Macroglossus minimus</i>	2	21.4	—	94	24.5	22.4
4	<i>Phyllostoma perspicillatum</i>	2	47.7	—	190	36.8	33.2
5	" <i>spectrum</i>	2	164	—	626	59.9	52.8
6	<i>Megaderma trifolium</i>	2	52.1	—	164	44.8	39.0
7	<i>Glossophaga soricinus</i>	2	14.6	—	94	24.0	22.8
8	<i>Vespertilio pipistrellus</i>	2	5.6	0.35	50	23.5	21.0
9	" <i>murinus</i> ♂	4	20.9	—	180	—	—
10	" "	2	34.9	—	140	42.0	36.0
11	" <i>pipistrellus</i>	1	3,703	—	49.59	19.75	17.45
12	<i>Plecotus auritus</i>	2	10.4	0.76	70	26.0	25.0
13	<i>Taphozous saccolaemus</i>	2	18.7	—	158	29.5	26.4
14	<i>Mormops</i> sp.	2	20.8	—	94	28.7	23.4

TABLE 8.—continued

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l
BATS, Continued						
15	<i>Nyctinomus aegyptiacus</i> ..	3	6	—	24.3	—
16	<i>Molossus longicaudatus</i>	2	33.5	—	104	31.0
17	<i>Noctilio unicolor</i>	2	44.5	—	254	44.0
FLYING FISH:						
308	<i>Dactylopterus volitans</i>	2	572	—	440	43
309	<i>Exocoetus volans</i>	2	107	—	124	21
BIRDS:						
18	<i>Lanius excubitor</i> ♀	4	31	—	144	—
19	<i>Turdus merula</i>	5	94.0	—	230	—
20	" " ♂	2	88.8	19.05	212	—
21	" "	6	74	19.6	168	—
22	" <i>pilaris</i>	1	100	—	186	39
23	" " ♂	2	103.4	23.3	202	—
24	<i>Saxicola oenanthe</i>	5	56.1	—	125	—
25	<i>Parus coerules</i>	2	9.1	—	28	—
26	" <i>major</i>	2	14.5	2.10	62	—
27	<i>Alauda cristata</i>	5	36.8	—	202	—
28	" "	3	34	—	—	30.5
29	" " ♂	3	37	—	—	33.1
30	" <i>arvensis</i>	2	32.2	5.10	150	—
31	<i>Emberiza gubernatrix</i>	2	25.5	2.03	100	—
32	<i>Fringilla spinus</i>	2	10.1	—	50	—
33	" <i>cannabina</i>	6	19	5.18	55	—
34	<i>Petrocincla cyanea</i>	3	53	—	—	—
35	<i>Budytes flava</i>	3	20	—	—	27
36	<i>Passer domesticus</i> ♀	4	28.33	—	76	—
37	" " ♂	3	27	—	—	23
38	" " ♀	3	25	—	—	22.6
39	" "	6	34	8.74	82	—
40	<i>Bombycilla garrula</i>	2	60.0	11.0	88	—
41	<i>Sturnus vulgaris</i>	5	78	—	202	—
42	" "	6	82.5	20.48	192	36.5
43	" " ♂	2	86.4	16.45	170	—
44	" "	3	71	—	—	38.4
45	<i>Gracula religiosa</i>	2	161	17.2	376	—
46	<i>Corvus aegyptiacus</i>	3	395	—	—	84
47	" <i>corax</i>	3	615	—	—	107.5
48	" <i>cornix</i>	6	615	141	1,343	—
49	" "	6	615	151	1,280	—
50	" "	6	598	140	1,144	—
51	" "	6	595	131	1,286	—
52	" "	6	565	140	1,310	—
53	" "	6	557	115	1,260	78
54	" "	6	557	120	1,324	—
55	" "	6	547	129.7	1,324	—
56	" "	6	519	121	1,280	—
57	" "	6	498	103.9	1,003	—
58	" "	5	375	—	1,156	—
59	" "	6	493	108.4	—	—
60	" <i>frugilegus</i>	6	575	1,219	1,285	92
61	" "	6	419	89	1,144	—
62	" <i>corone</i>	6	507	109.6	1,144	—
63	" "	6	484	100.6	988	—

TABLE 8.—continued

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l
BIRDS, Continued						
64	<i>Corvus corone</i>	6	498	115.1	1,284	—
65	" "	6	477	93.6	1,190	—
66	" <i>monedula</i>	6	230	54.06	700	—
67	" "	6	225	55.0	601.4	60.0
68	" "	6	204	53.3	610	64
69	" <i>pica</i>	6	202	48.96	560	55.5
70	" "	6	190	35.3	522	—
71	" "	5	179	42.02	482	51
72	" "	5	275	—	690	—
73	" "	6	212	—	540	—
74	<i>Nucifraga caryocatactes</i>	6	176	43.3	460	—
75	" "	6	174	39.6	466	—
76	<i>Garrulus glandarius</i>	6	125	36.4	443	—
77	" "	6	132	37.5	508	—
78	" "	1	180	—	565	56
79	" "	6	156	40.1	546	—
80	" "	6	165	39.9	490	—
81	" "	6	188	45.0	551	—
82	<i>Upupa epops</i>	5	49.1	—	329	—
83	" "	3	62	—	—	43.0
84	<i>Cypselus apus</i> ♀	4	33.5	—	144	—
85	" "	3	33	—	—	37.6
86	<i>Hirundo rustica</i>	4	15.7	—	135	—
87	" "	4	19.4	—	114	—
88	" "	4	18	—	110	—
89	" "	4	19.9	—	134	—
90	" " ♀ adult	4	19.9	—	134	—
91	" " ♀ juv.	4	19.4	—	114	—
92	" <i>urbica</i>	5	18.0	—	120	—
93	<i>Cotyle rupestris</i>	3	16	—	—	31
94	<i>Caprimulgus</i>	3	62	—	—	50.9
95	<i>Ceryle maxima</i>	5	86.0	—	2.88	—
96	" "	5	82.9	—	270	—
97	<i>Psittacus erithacus</i>	2	300	37.9	584	—
98	" "	1	200	—	710	71
99	<i>Chrysotis amazonica</i>	1	300	—	895	73
100	<i>Plectolophus sulfureus</i>	2	250	23.9	544	—
100a	<i>Picus viridis</i>	6	101	28.08	408	—
101	<i>Alcedo ispida</i> ♀	3	27	—	—	23.2
102	" " ♂	3	31	—	—	25
103	" " ♂	3	34	—	—	26.2
104	<i>Coracias garrula</i>	3	133	—	—	62.5
105	<i>Merops apiaster</i>	5	18.30	—	117	—
106	<i>Vultur cinereus</i>	5	1,535	—	3,233	—
107	" sp.	5	1,664	—	3,131	—
108	<i>Otogyps auricularis</i>	3	8,152	—	—	266
109	<i>Gyps fulvus</i>	3	7,501	—	—	251
110	<i>Neophron percnopterus</i>	3	1,705	—	—	161.5
111	<i>Haliaetus albicilla</i>	1	5,000	—	7,973	226
112	" "	1	4,500	—	7,000	217
113	" "	1	4,900	—	6,200	209
114	<i>Pandion haliaetos</i>	6	3,055	744	5,852	—
115	" "	3	1,270	—	—	155
116	" "	6	1,950	518	3,142	—
117	<i>Falco migrans</i>	5	620	—	1,904	—

TABLE 8.—continued

	Observer	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l
BIRDS, Continued						
118	<i>Falco tinnunculus</i>	5	129	—	642	—
119	" "	3	181	—	74.0	—
120	" "	6	260	51.7	680	65
121	" " <i>minor</i>	5	147	—	546	—
122	" <i>kobeck</i> (?)	5	282	—	970	—
123	" <i>subbuteo</i>	5	510	—	1,684	—
124	" <i>peregrinus</i>	3	580	—	—	104
125	<i>Milvus aegyptius</i>	3	640	—	—	133
126	<i>Astur palumbarius</i>	1	800	—	1,520	103
127	" "	3	290	—	—	71.8
128	<i>Accipiter nisus</i> ♀	1	260	—	800	75
129	" " <i>juv.</i>	6	275	85.1	690	68
130	" "	6	766	250	—	88.5
131	" "	3	152	—	—	61.8
132	" "	1	150	—	496	55.5
133	" " ♀	1	250	—	710	69
134	" " ♂	4	266	—	866	—
135	<i>Circus aeruginosus</i>	5	209	—	1,188	—
136	<i>Buteo vulgaris</i>	1	900	—	2,610	130
137	" "	1	900	—	2,590	126
138	" "	1	800	—	2,210	125
139	" "	1	600	—	2,170	117
140	" "	5	785	—	1,651	—
141	" "	6	785	154.6	—	—
142	" "	6	1,217	242	2,350	123
143	<i>Archibuteo lagopus</i>	6	862	176.9	2,280	120
144	" "	1	1,000	—	2,359	140
145	" "	1	890	—	2,020	129
146	" "	1	1,000	—	2,445	135
147	" "	1	1,000	—	2,510	144
148	" "	1	900	—	2,220	132
149	" "	1	1,125	—	2,880	143
150	" "	1	750	—	2,420	137
151	<i>Strix flammea</i>	1	400	—	1,190	97
152	" "	1	250	—	1,440	97
153	" "	3	305	—	—	94
154	<i>Asio otus</i>	1	275	—	1,010	92
155	" "	6	232	47.9	1,102	92
156	" "	6	237	50.84	1,154	—
157	<i>Asyo brachyotus</i>	1	370	—	1,230	103
158	<i>Syrnium aluco</i>	6	1,777	376	3,020	94.5
159	<i>Athene passerina</i>	5	129	—	442	—
160	" "	5	123	—	394	—
161	<i>Ephialtes scops</i>	3	150	—	—	52.6
162	<i>Columba livia</i>	7	290	—	750	—
163	" " ♂	4	298	—	608	—
164	" " ♂	1	205	—	598	70
165	" " ♀	1	202	—	541	64
166	" <i>domestica</i>	6	206	93.8	—	—
167	" "	6	335	113	650	64
168	" <i>aegyptiaca</i> ♂	3	257	—	—	56
169	" <i>vinacea</i>	5	112	—	292	—
170	" <i>aegyptiaca</i>	3	223	—	—	59.4
171	" "	3	110	—	—	21.5
172	<i>Tetrao urogallus</i> ♂	1	2,700	—	1,785	116

TABLE 8.—continued

	Ob- server	Weight gms. P	Flight muscles Wt., gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l	
BIRDS, Continued							
173	<i>Tetrao urogallus</i> ♂	1	2,600	—	1,800	113	96
174	" " ♀	1	1,450	—	1,380	102	85
175	" <i>tetrix</i> ♂	1	1,350	—	995	82	79.5
176	" " ♂	1	1,030	—	850	80	68
177	" " ♂	1	1,200	—	880	87	71
178	" " ♀	1	730	—	530	62.5	51
179	" " ♀	1	1,000	—	775	75	61.5
180	" <i>bonasia</i>	1	370	—	340	52	40
181	" "	1	375	—	375	51	40
182	<i>Lagopus alpinus</i>	1	530	—	640	66	56
183	" "	1	650	—	452	60	50
184	<i>Perdix rufa</i>	1	380	—	400	51	41
185	" "	1	340	—	340	49	38
186	" <i>cinerea</i> ♂	1	450	—	365	53	41
187	" "	6	320	105	336	—	—
188	" "	6	372	123	382	—	—
189	" "	6	375	126	366	—	—
190	" "	5	280	—	320	—	—
191	<i>Coturnix communis</i>	3	100	—	—	—	—
192	" " ♂	4	92.1	—	142	—	—
193	<i>Pavo crist</i> ♂	1	3,300	—	3,480	128	104
194	<i>Phasianus colchicus</i> ♀	1	950	—	755	64	52
195	" " ♂	1	1,100	—	855	72	57
196	" " ♂	1	1,000	—	880	76	61
197	" " ♂	1	1,570	—	895	72	55
198	" " ♂	1	1,250	—	896	72	56
199	" " ♂	1	1,125	—	900	73	59
200	<i>Meleagris gallopavo</i>	3	3,000	—	—	110	—
201	<i>Otis tarda</i> ♀	1	8,900	—	5,729	207	184
202	" " ♂	1	9,600	2,300	5,937	208	181
203	<i>Grus</i>	7	9,500	—	8,543	—	—
204	<i>Rallus pectoralis</i>	2	142	15.4	328	—	42.0
205	" <i>aquaticus</i> ♂	2	170.5	19.05	202	—	33.0
206	" "	3	192	—	—	—	—
207	<i>Fulica atra</i>	2	495	51.8	524	—	53
208	<i>Gallinula chloropus</i>	3	595	—	—	69.6	—
209	<i>Oedinenemus crepitans</i> ♀	3	455	—	—	80	—
210	" " ♂	3	470	—	—	77.3	—
211	<i>Hoplopterus spinosus</i>	5	160	—	636	—	—
212	" "	3	170	—	—	60.0	—
213	<i>Charadrius pluvialis</i>	3	160	—	—	58.2	—
214	" "	6	190	55.8	366	—	—
215	" "	6	170	49.3	334	—	—
216	" <i>minor</i>	6	59.5	17.6	183	—	—
217	<i>Haematopus ostralegus</i>	6	555	137	722	81	—
218	" "	6	488	79.5	—	75	—
219	" "	6	521	128.1	740	—	—
220	" "	6	445	106	642	—	—
221	" "	6	437	99.4	697	—	—
222	" "	6	389	93.9	670	—	—
223	" "	6	358	42.1	562	—	—
224	" "	6	341	84.8	708	—	—
225	<i>Glareola torquata</i>	3	67	—	—	52.5	—
226	" "	5	95.2	—	343	—	—
227	<i>Vanellus cristatus</i>	6	190	53.5	614	—	—

TABLE 8.—continued

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l
BIRDS, Continued						
228	<i>Vanellus cristatus</i>	6	204	55.0	624	—
229	" "	6	232	63.0	720	—
230	" "	6	232	64.4	730	66
231	" "	3	210	—	—	75.5
232	<i>Streptilas interpres</i>	6	136	32.7	235	—
233	<i>Scolopax rusticola</i>	1	300	—	500	63
234	" "	1	320	—	500	64
235	" "	1	300	—	505	63
236	" <i>gallinago</i>	3	100	—	—	44.3
237	" "	1	300	—	440	59
238	" "	1	270	—	490	62
239	" "	1	300	—	505	60
240	" "	6	55	13.3	137	—
241	<i>Rhynchaea capensis</i>	3	103	—	—	40.6
242	<i>Numenius phaeopus</i>	2	440	59.3	964	—
243	" <i>arquatus</i> ♂	3	764	—	—	103
244	" " ♀	3	520	—	—	95.5
245	"	6	585	167	920	—
246	"	6	615	175	—	—
247	"	6	676	169	1,020	—
248	"	6	695	199	936	93.5
249	"	6	762	203	924	98
250	"	6	898	217	1,160	—
251	<i>Machetes pugnax</i> ♂	2	190	48.4	328	—
252	<i>Tringa cinclus</i>	6	120	31.5	262	—
253	" <i>subarquata</i>	3	76	—	—	43.8
254	" <i>canutus</i>	3	24	—	—	29.6
255	" sp.	6	49.5	13.5	136	37
256	<i>Limosa rufa</i>	6	208	53.2	425	—
257	" "	6	220	56.2	428	—
258	" "	6	227	57.6	444	—
258a	" "	6	235	67.4	492	—
259	<i>Totanus</i> sp.	6	47	12.4	144	—
260	" sp.	6	49	12.54	149.4	—
261	" <i>fuscus</i>	6	229	58.6	494	—
262	<i>Recurvirostra avocetta</i>	3	325	—	—	70
263	<i>Ibis falcinellus</i>	3	365	—	—	90.0
264	<i>Ciconia</i>	6	3,300	857	4,880	170
265	" <i>alba</i>	3	2,140	—	—	208
266	" "	7	2,265	—	4,506	—
267	<i>Ardea nycticorax</i>	3	615	—	—	104
268	" <i>cinerea</i> ♀	4	1,409.5	—	3,584	—
269	<i>Botaurus stellaris</i> ♂	1	1,500	—	1,915	120
270	<i>Ardetta minutus</i>	3	318	—	—	89.3
271	<i>Anser cinereus</i>	3	2,020	—	—	137
272	<i>Anas</i>	6	606	165	642	78
273	" <i>boschas</i> ♀	1	880	—	685	83
274	" " ♂	1	1,100	—	900	94
275	" " ♂	1	900	—	710	83.5
276	" " ♀	1	900	—	735	89
277	" " ♂	1	950	—	838	87.5
278	" " ♀	1	900	—	813	88
279	" " ♂	1	1,000	—	687	85
280	" <i>querquedula</i>	3	297	—	—	—
281	" <i>crecca</i> ♂	2	275.5	63.85	—	—

TABLE 8.—continued

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l
BIRDS, Continued						
282	<i>Anas clypeata</i> ♂	3	925	—	72	—
283	" " ♀	3	727	—	70	—
284	<i>Fuligula cristata</i>	6	1,116	343	1,440	104
285	" <i>clangula</i>	1	827	—	480	69
286	" <i>glacialis</i>	1	922	—	550	74
287	" <i>nyroca</i>	2	508	76.6	642	—
288	<i>Pelecanus onocrotalus</i>	3	6,625	—	—	280
289	<i>Procellaria gigantea</i>	3	2,880	—	—	175
290	<i>Puffinus kuhlii</i>	3	700	—	—	125
291	" "	3	500	—	—	117
292	<i>Diomedea exulans</i>	8	12,700	—	—	400
293	<i>Larus melanoccephalus</i>	3	232	—	—	94.6
294	" "	3	280	—	—	96.5
295	" <i>argentatus</i>	2	565	93.0	1,082	—
296	" "	6	842	143	1,550	—
297	" "	6	1,035	161.2	2,380	—
298	" "	6	1,225	198	1,880	—
299	" "	6	1,080	185	1,936	—
300	" <i>ridibundus</i>	2	197	26.13	662	—
301	" <i>canus</i>	6	355	68.3	1,118	108
302	" "	6	642	—	1,748	—
303	" "	6	720	130	1,742	—
304	" "	6	785	130	1,920	—
305	<i>Sterna cantiaca</i>	6	174	34.9	660	93.6
306	" <i>hirundo</i>	6	116	25.3	427	79
307	" <i>minuta</i>	6	53.0	11.9	185.4	50
INSECTS:						
311	<i>Ephemera vulgata</i>	1	30.8	—	126	34.5
312	<i>Calopteryx virgo</i> ♀	4	200	—	1,394	75
313	" " ♂	4	100	—	1,112	68
314	<i>Agrion puella</i> ♂	4	26	—	220	45
315	<i>Libellula cyanea</i> ♂	4	920	—	2,290	108
316	" <i>depressa</i>	9	200	—	—	80
317	" " ♂	4	600	—	1,332	82
318	" <i>vulgata</i> ♂	4	150	—	728	57
319	" <i>cancellata</i> ♀	1	620	—	1,456	85
320	<i>Cordulia aenea</i> ♂	4	240	—	1,048	71
321	<i>Libellula cancellata</i> ♂	4	440	—	1,408	86
322	" <i>quadrimaculata</i> ♂	4	290	—	1,108	76
323	<i>Setodes pilosus</i>	1	13	—	141	30
325	<i>Calosoma sycophanta</i>	1	641.4	—	390	54
326	" "	1	802.6	—	336	57
327	<i>Hydrophilus piceus</i> ♂	1	5,212.4	—	779	88
328	" " ♀	1	4,950	—	770	85
329	" " ♂	1	3,327.6	—	674	79
330	" " ♀	1	3,175	—	600	72
331	<i>Dyticus marginalis</i> furrowed	1	1,777.2	—	479	60
332	<i>Dyticus marginalis</i> smooth	1	2,323	—	658	73
333	<i>Dyticus marginalis</i> furrowed	1	1,962	—	510	66
334	<i>Dyticus marginalis</i> ♂	1	1,277	—	600	70
335	<i>Acilius sulcatus</i> ♂	1	314.7	—	201	40

TABLE 8.—continued

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. D	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l
INSECTS, Continued						
336	<i>Colymbetes fuscus</i>	1	275.5	—	240	35
337	" <i>grapii</i>	1	77	—	89	21
338	<i>Geotrupes stercorarius</i>	1	997.5	—	177	36
339	<i>Melolontha vulgaris</i> ♀	1	950.8	—	366	50
340	" " ♂	1	975	—	357	53
341	" " ♂	1	667	—	285	49
342	<i>Ludius aeneus</i>	1	68.6	—	67	14
343	<i>Culex pipiens</i>	7	3	—	30	—
344	<i>Chironomus stercorarius</i> ..	1	1.2	—	3.5	6.5
345	<i>Pachyrhina pratensis</i> ♂	1	41	—	69	32
346	" " ♀	1	73	—	62	33
347	<i>Tabanus infuscatus</i> ♂	4	160	—	176	—
348	<i>Leptis scolopacea</i> ♂	1	29.5	—	62	25
349	" " ♂	1	34	—	58	23
350	" " ♀	1	78.2	—	58	23
351	" " ♂	1	26	—	46	20
352	<i>Musca vomitoria</i>	1	65	—	72	18
353	" <i>domestica</i> ♀	1	16.9	—	25	12
354	" "	1	10	—	18	12
355	" "	1	11.5	—	16	12
356	<i>Pollenia rudis</i>	1	53.4	—	37	16
357	<i>Eristalis rupium</i>	1	88.2	—	34	16
358	" <i>aeneus</i>	1	38.4	—	32	17
359	" "	1	38.7	—	31	18
360	" "	1	62.9	—	37	19
361	" "	1	35.5	—	27	15
362	" "	1	38.0	—	32	17
363	<i>Syrphus scriptus</i>	1	7	—	17	13
364	<i>Sarcophaga carnaria</i>	1	69	—	50	19
365	" <i>stercoraria</i>	1	23	—	38	19
366	<i>Papilio podalirius</i>	1	340	—	1,120	68
367	<i>Pieris brassicae</i>	1	81.8	—	928	47
368	" "	7	200	—	1,660	—
369	<i>Rhodocera rhamnii</i> ♂	4	183	—	1,254	—
370	" "	1	128.4	—	1,138	53
371	<i>Argynnis aphirophoe</i> ♂	4	25	—	404	—
372	<i>Vanessa urticae</i>	1	114	—	840	51
373	" <i>C-album</i>	1	38.8	—	330	31
374	<i>Lycaena argus</i> ♂	4	12	—	294	—
375	<i>Sphinx pinastri</i> ♂	4	430	—	1,010	—
376	" " ♀	4	540	—	1,030	—
	(with eggs)	4	540	—	1,030	—
377	<i>Sphinx ligustri</i> ♀	4	1,920	—	1,864	—
378	" " ♂	4	1,370	—	1,600	—
379	<i>Smerinthus ocellatus</i> ♂	4	550	—	984	—
380	<i>Euplexia lucipara</i> ♀	4	75	—	334	—
381	<i>Apis mellifica</i> ♀	1	81.2	10	—	—
382	" " ♀	1	80.2	12.4	—	—
383	" " ♀	1	93.5	12.1	—	—
383a	" " ♀	1	108.4	14.8	—	—
384	" " ♀	1	103	—	57	16
	(with pollen)	1	103	—	57	16
385	<i>Apis mellifica</i> ♀	1	74.2	—	39	15
386	<i>Bombus muscorum</i>	1	345.6	—	81	20
387	" <i>pratorum</i>	1	443	—	103	28

TABLE 8.—concluded

	Ob- server	Weight gms. P	Flight muscles Wt.-gms. p	Wing area for both wings cm. ² f	Wing spread cm. K	Length of both wings cm. l	
INSECTS, Continued							
388	<i>Bombus pratorum</i>	1	271.2	—	52	26	19
389	" "	1	257	—	90	26	22
390	<i>Systropha spiralis</i>	1	24.4	—	34	17	14
391	" "	1	14.5	—	45	17	14
392	" "	1	15.2	—	32	16	14
393	" "	1	21.0	—	27	21	18
394	<i>Osmia bicornis</i>	1	52.9	—	47	21	16
395	" <i>adunca</i>	1	34.5	—	38	20	18
396	<i>Dichroa gibba</i>	1	19.2	—	28	16	14

TABLE 9.—DATA FROM AUGUSTO RUSCHI AND
CRAWFORD H. GREENEWALT, UNPUBLISHED

Wing-beat rate, body weight, and wing length for certain hummingbirds.

The nomenclature is from Ruschi, derived, I believe, from Simon.

The wing-beat rates were measured, some by Ruschi, some by Greenewalt, using a portable stroboscope. In principle a slotted disk was fitted to a monocular so that the slotted portion of the disk passed through the optical axis. The disk was driven by a battery-operated variable-speed motor. A small generator, mounted on the shaft which carried the disk and driving motor, was connected to an ammeter calibrated in revolutions per second. The technique comprised sighting on a hovering bird and adjusting the motor speed until the wings appeared stationary. The wing-beat rate was read off from the ammeter connected to the generator.

The individual readings differ widely in probable error. In two cases—*Calliphlox amethystina* ♂ and *Melanotrochilus fuscus*—many readings were made and the observed rates are believed reliable to a few percent. For most of the others only one or two readings were possible, and the birds moved so rapidly that only a few seconds were available to bring the instrument to equilibrium. Individual readings could easily be in error by as much as plus or minus 10 percent.

Weights and wing lengths were obtained by Ruschi on the same individuals. These are not necessarily the same individuals for which wing-beat rates were determined.

For comparison, wing lengths, supplied by Lanyon, American Museum of Natural History, from the literature (principally Hartert), are also given.

The wing areas are calculated values. Length and area measurements are available for three species (*Archilochus colubris* and *A. alexandri* (Poole, 1938) and *Eupherusa eximia* (Magnan, 1922)). The averages for these three species result in the equation $A = 0.71 P$ where l is the length in centimeters and A the area of both wings in square centimeters. The areas given in the table are calculated from Ruschi's wing-length measurements using this equation.

TABLE 9.—concluded

	Wing-beat rate sec-1	Weight of bird gm.	Wing area both wings cm. ² calculated	Wing length mm.	
				Ruschi	Lanyon
<i>Melanotrochilus fuscus</i>	25	6.8	45.6	80	84.4
<i>Aphantochroa cirrochloris</i>	27	6.9	31.9	67	69.7
<i>Clytolaema rubricauda</i> ♂	28	6.8	38.9	74	74.7
♀	22	6.5	30.0	65	66.7
<i>Lophornis magnificus</i> ♂	58	2.3	11.35	40	41
♀	52	2.1	11.35	40	41
<i>Anthracothonax nigricollis</i> ♂	28	6.8	34.8	70	69
<i>Eupetomena macroura macroura</i>	19	7.5	39.9	75	74.7
<i>Amazilia brevirostris</i> ♂	38	4.0	17.8	50	50.7
<i>Colibri serrirostris</i>	28	6.0	34.8	70	74.7
<i>delphinae</i>	24	7.1	35.8	71	74.3
<i>coruscans</i>	24	8.9	49.0	83	80.3
<i>Boissonneaua jardini</i>	20	8.1	42.1	77	78
<i>Phaiolaema rubinoides aequatorialis</i>	20	6.7	30.0	65	72.7
<i>Hylocharis chrysura</i>	28	4.6	22.2	56	51.3
<i>Helianthus wilsoni</i> ♂	18	7.1	32.8	68	72.7
<i>Hylocharis cyanus</i> ♀	30	3.4	18.5	51	49.3
♂	32	3.7	19.2	52	—
<i>sapphirina</i> ♂	31	4.2	19.2	52	51.7
<i>Lophornis verreauxi</i> ♀	41	3.0	11.35	40	44.7
<i>Calliphlox amethystina</i> ♂	78	2.8	7.74	33	36
♀	62	2.8	7.74	33	37
<i>Popelairia langsdorffi melanosternum</i> ♀	51	3.0	7.74	33	37.3
<i>Ensifera ensifera</i> ♂	22	12.5	42.1	77	80
<i>Florisuga mellivora</i> ♂	27	6.2	31.9	67	69.7
<i>Popelairia langsdorffi melanosternum</i> ♂	58	3.0	7.74	33	—
<i>Florisuga mellivora</i> ♀	22	6.7	31.9	67	—
<i>Chrysolampis mosquitos</i> ♂	30	4.1	23.1	57	56.3
<i>Chlorostilbon aureoventris</i> ♂	30	3.5	17.0	49	50
<i>Stephanoxis lalandi</i> ♂	25	4.2	20.7	54	52
♀	20	4.1	19.2	52	—
<i>Thalurania nigrofasciata</i> ♂	33	4.3	23.1	57	57
<i>Eriocnemis luciani</i> ♂	27	7.0	36.8	72	73
<i>Phaethornis h. hispidus</i> ♂	26	7.0	25.6	60	60.7
<i>Leucochloris albicollis</i> ♂	32	6.0	25.6	60	60
<i>Aglaeactis cupripennis</i> ♀	15	7.3	52.6	86	87.7
<i>Amazilia tephrocephala</i> ♂	30	5.2	33.9	58	59
<i>Glaucis hirsuta</i> ♀	21	7.0	23.1	57	57.7
<i>Prasites daphne</i> ♂	31	3.1	13.7	44	48
<i>Coeligena torquata</i> ♂	22	7.8	39.9	75	78.7
<i>Heliomaster furcifer</i> ♂	29	5.3	22.3	56	56
<i>Patagona gigas</i> ♂	—	20.0	120	130	132.7
<i>Heliothrix aurita auriculata</i> ♂	19	5.9	30.0	65	65.3
<i>Stephanoxis loddigesi</i> ♂	25	4.0	19.2	52	51.3
<i>Discosura longicauda</i> ♂	40	3.7	14.4	45	—
<i>Augastes superbus</i> ♂	28	3.8	20.7	54	—
<i>Schistes albogularis</i> ♂	30	3.5	18.5	51	—
<i>Campylopterus obscurus aequatorialis</i> ♀	—	7.6	36.8	72	—
<i>Chlorestes n. notatus</i> ♂	28	3.8	17.0	49	—
<i>Thalurania f. baeri</i> ♂	30	4.4	20.7	54	—
<i>Amazilia fimbriata nigricauda</i>	25	3.8	20.7	54	—
<i>Thalurania watertoni</i> ♂	32	4.8	20.7	54	—
<i>Anisoterus pretrei</i> ♂	22	5.6	27.3	62	—
<i>Pigmornis nattereri</i>	30	3.1	13.1	43	—
<i>ruber ruber</i> ♀	48	2.3	7.74	33	—
<i>idaliae</i> ♀	38	2.4	8.70	35	—
<i>Popelairia langsdorffi langsdorffi</i> ♂	60	3.2	9.22	36	—
<i>Thalurania f. furcata</i> ♂	30	4.2	21.5	55	—
<i>Eupetomena m. simoni</i>	20	7.0	36.8	72	—
<i>Amazilia milleri</i> ♂	32	4.1	17.8	50	—

TABLE 10.—DATA ON HUMMINGBIRDS AND OTHER BIRDS
FROM VARIOUS AUTHORS

The wing-beat rates given here for hummingbirds are believed to have higher precision than those determined by Ruschi and Greenewalt using the portable monocular stroboscope. They were determined either from high-speed moving pictures or with stroboscopic methods of higher precision.

	Wing-beat rate <i>sec-1</i>	Weight of bird <i>gm.</i>	Wing length <i>mm.</i>	Method
M = High-speed moving pictures S = Stroboscopic				
HUMMINGBIRDS: (from Crawford H. Greenewalt, unpublished)				
<i>Calliphlox amethystina</i> ♂	78	—	33 ¹	S
<i>Archilochus colubris</i> ♂	70	—	38.5	M
" " ♀	52	—	44.5	M
<i>Melanotrochilus fuscus</i>	25	—	80	S
<i>Amazilia cyanura</i>	41.5	—	53	M
<i>Campylopterus hemileucurus</i>	27	—	74	M
<i>Microchera albocoronata</i> ♂	52	—	40.5	M
" " ♀	48	—	40.5	M
HUMMINGBIRDS: (from E. Stresemann and K. Zimmer, Ornithologische Monatsberichte, vol. 5 (1932))				
<i>Eupetomena macroura</i>	22	6.0	78 ^a	S
<i>Chlorestes caeruleus</i>	31.5	3.2	50	S
<i>Chrysolampis elatus</i>	32.5	3.5	57	S
<i>Phaëtornis rufus</i>	50.5	2.0	36	S
HUMMINGBIRDS: (from M. Stolpe and K. Zimmer, Journ. Ornithologie, vol. 87, pp. 136-155 (1939))				
<i>Chlorostilbon aureoventris</i>	37.5	—	50 ^a	M
<i>Melanotrochilus fuscus</i>	28.5	—	80	M
OTHER BIRDS: (from Crawford H. Greenewalt, unpublished)				
<i>Parus carolinensis</i>	27	—	65 ⁴	M
<i>Sitta carolinensis</i>	21	—	92	M
<i>Parus bicolor</i>	24	—	82	M
<i>Dendrocopus pubescens</i>	18	—	97	M
<i>Mimus polyglottos</i>	14	—	112	M
<i>Carpodacus p. purpureus</i>	20	—	83	M
Common crow	3	—	320	Visual
OTHER BIRDS: (from H. Oehme, Journ. Ornithologie, vol. 100, pp. 363-396 (1959))				
<i>Hirundo rustica</i>	6	—	150 ^a	M
<i>Passer domesticus</i>	13	—	110	M
<i>Phoenicurus phoenicurus</i>	15	—	120	M
<i>Apus apus</i>	10	—	170	M
"Haustaube"	6	—	310	?
"Nebel krähe"	4	—	410	?
Wing length from wing tip to first articulated joint: ¹ Ridgway. ² Authors. ³ Ruschi. ⁴ The American Museum of Natural History (Lanyon). ⁵ Author.				
	Wing span <i>cm.</i>	Wing area <i>cm.²</i>		
<i>Apus apus</i>	38.8	111.2		
<i>Hirundo rustica</i>	32.9	123.6		
<i>Phoenicurus ochruros</i>	25.3	106.4		
<i>Parus major</i>	24.0	99.4		
<i>Passer domesticus</i>	24.8	103.0		
" <i>montanus</i>	22.1	81.6		

TABLE 11.—DATA FROM FRANK A. HARTMAN, AUK,
VOL. 71, NO. 4, PP. 467-469 (1954)
Cardiac and pectoral muscles of trochilids

	Body weight gm.	Weight of heart	Weight of pectoral musculature	Wing length* mm.
		% of body weight		
<i>Glaucis hirsuta affinis</i> ♀	6.13	2.27	27.6	56.5
♂	6.95	—	—	58.6
<i>Phaethornis guy coruscus</i> ♂	5.78	2.40	28.6	61.5
♀	6.15	2.19	—	—
♀	2.64	2.42	—	37.9
<i>Phaeochroa curvierii</i> ♀	7.95	—	—	68.6
♂	9.30	1.74	—	72.2
<i>Campylopterus hemileucurus</i> ♂	11.92	1.95	33.7	73.9
<i>Florisuga mellivora</i> ♀	6.96	1.83	—	65.2
<i>Colibri thalassinus cabanidis</i> ♀	4.8	—	—	61.0
♂	5.28	1.95	—	66.9
<i>Anthracothorax nigricollis nigricollis</i> ♀	7.33	2.27	—	65.2
♂	6.86	—	—	66.9
<i>Chlorostilbon canivetii assimilis</i> ♀	3.13	1.88	26.5	44.1
♂	3.03	—	—	45.6
<i>Damophila julie panamensis</i> ♀	3.03	2.02	—	42.6
♂	3.35	—	—	43.4
<i>Amazilia amabilis costaricensis</i> ♀	3.85	2.23	—	—
♂	4.78	—	—	—
♀	4.74	2.30	—	54.0
♂	4.43	2.28	28.5	51.0
♀	4.97	—	—	53.8
♂	4.15	—	—	52.2
<i>tsacatl tsacatl</i> ♀	4.72	2.12	26.6	54.9
♂	5.40	—	—	58.3
<i>Eupherusa exima egregia</i> ♂	4.35	2.34	—	60.1
<i>Elvira chionura</i> ♀	2.83	2.25	—	46.8
♂	2.93	—	—	50.3
<i>Chalybura buffonii micans</i> ♀	5.6	—	—	62.0
<i>Lampornis castaneiventris</i> ♀	5.26	2.16	22.5	64.3
<i>Heliodoxa jacula henryi</i> ♀	7.39	1.98	27.9	66.2
<i>Eugenes fulgens spectabilis</i> ♂	5.7	2.16	—	73.5
<i>Heliothrix barroti</i> ♀	5.7	—	—	66.6
<i>Archilochus colubris</i> ♀	3.36	2.31	—	44.5
♂	3.2	—	—	38.5
<i>Selasphorus scintilla</i> ♀	2.23	2.40	24.7	35.7
♂	2.33	—	—	32.7

* The wing-length measurements are averages taken from Ridgway, "Birds of North and Middle America."

Unpublished data from Frank A. Hartman (Letter to C. H. Greenewalt,
March 17, 1960)

	Pectoral muscle as % of body weight		Ratio Large/Small
	Large	Small	
<i>Anthracothorax nigricollis</i>	21.5	8.6	2.50
<i>Damophila julie</i>	16.0	10.5	1.52
<i>Selasphorus scintilla</i>	18.2	9.9	1.84
<i>Florisuga mellivora</i>	20	10	2.00

TABLE 12.—DATA FROM D. B. O. SAVILLE, AUK, VOL. 67, P. 502 (1950)

	Pectoral muscle as % of body weight		Ratio Large/Small
	Large	Small	
<i>Archilochus colubris</i>	20.5	9.2	2.22

TABLE 13.—DATA FROM R. MEINERTZHAGEN, IBIS,
VOL. 97, NO. 1, PP. 111-114 (1955)

Wing-beat rates—large birds

Wing lengths supplied by Charles Vaurie,
The American Museum of Natural History

	Wing-beat rate sec-1	Wing length mm.
Raven	3.5	455
Carrion crow	3.6	325
Fantailed raven	3.5	371
Rook	2.3	315
Jackdaw	3.9	237
Jungle crow	3.3	377
Magpie	3.0	204
Starling	5.1	128
Blackbird	5.6	125
Cuckoo	4.8	222
Short-eared owl	2.6	312
Peregrine falcon	4.3	309
Barbary falcon	4.9	283
Merlin	4.9	199
Kestrel	3.5	245
Hen harrier	3.2	342
Montagu's harrier	3.1	360
Black kite	2.8	490
Osprey	2.4	472
Egyptian vulture	2.7	495
Heron	2.5	450
Great white egret	2.1	437
Flamingo	2.4	400
Mute swan	2.7	591
Shell duck	3.0	375
Mallard	5.0	274
Gadwall	5.0	271
Wigeon	5.1	262
Shoveler	5.0	242
Common scoter	5.0	235
Velvet scoter	4.3	281
Eider duck	4.8	289
Merganser	4.6	289
Gannet	3.0	493
Cormorant	3.9	350
Shag	4.8	270

TABLE 13.—concluded

	Wing-beat rate sec-1	Wing length mm.
Great crested grebe	6.3	187
Great northern diver	4.2	360
Fulmar	3.6	321
Manx shearwater	5.1	234
Wood pigeon	4.0	245
Rock pigeon	4.3	222
Ringed plover	5.3	134
Golden plover	4.0	190
Lapwing	2.3	226
Turnstone	4.0	152
Red shank	4.2	155
Ruff	4.1	192
Oystercatcher	4.1	257
Curlew	4.0	292
Snipe	5.8	133
Greater black-backed gull	2.7	497
Lesser black-backed gull	2.8	422
Herring gull	2.8	438
Common gull	3.0	355
Black-headed gull	2.8	307
Kittiwake	3.3	312
Sandwich tern	2.4	308
Puffin	5.7	160
Guillemot	4.5	200
Black guillemot	8.0	163
Coot	5.8	212
Pheasant	9.0	247
Capercailzie	4.6	393

TABLE 14.—DATA FROM EARL L. POOLE, AUK,
VOL. 55, PP. 511-517 (1938)

Weights and wing area of 143 species of North American birds

Poole's table is arranged in order of ascending weights and I have retained this format, although it might have been better to group the birds in accordance with families and genera.

The wing areas are for both wings.

Poole did not give wing-length measurements. These have been taken principally from Ridgway's "Birds of North and Middle America" and Forbush's "Birds of Massachusetts and other New England States." The measurements for *Sthenelides olor* and *Columba l. livia* were taken from Witherby's "Handbook of British Birds."

Ridgway's measurements were made with dividers, one point resting against the anterior side of the bend of the wing, the other point touching the extremity of the longest primary. The value given in the table is the average either as reported by Ridgway or obtained by averaging the values given for the extremes.

TABLE 14.—*continued*

Forbush's measurements were made of the folded wing. Here again the value given in the table is the average of the two extremes. It is evident from the good correlation in the charts that Ridgway and Forbush were both measuring the same dimension within a very small error.

In the table that follows, wing-length measurements from Forbush are marked *; the two from Witherby, **; all others are from Ridgway.

	Weight gm.	Wing area cm. ²	Wing length cm.
<i>Regulus s. satrapa</i>	5.75	51	5.84
<i>Corthylio c. calendula</i> ♂	6.73	58.25	5.89
<i>Setophaga ruticilla</i> ♂	8	62.5	6.35
<i>Certhia familiaris americana</i> ♂	8	66.5	6.55
<i>Dendroica magnolia</i> ♂	9.20	69	6.01
" <i>v. vierns</i> ♂	9.20	58.5	6.38
" <i>c. caerulescens</i> ♂	9.25	67	6.52
<i>Nannus h. hiemalis</i> ♂	9.4	41	4.76
<i>Geothlypis trichas brachidactyla</i> ♂	9.5	58.53	5.51
<i>Mniotilta varia</i> ♂	10.5	71	6.86
<i>Troglodytes a. aëdon</i> ♂	11	48.40	5.07
<i>Dendroica pensylvanica</i> ♂	11.1	60.5	6.33
<i>Compothlypis americana pusilla</i> ♂	11.85	56	6.06
<i>Spizella p. pusilla</i> ♂	12.1	62	6.45
<i>Penthestes a. atricapillus</i> ♂	12.5	76	6.6
<i>Passerina cyanea</i> ♂	13	82	6.78
<i>Spizella p. passerina</i> ♂	13.5	91	6.91
<i>Spinus t. tristis</i> ♂	14	83	7.26
<i>Seiurus n. noveboracensis</i> ♂	14.5	86	7.67
<i>Dendroica coronata</i> ♂	15.5	91	7.41
<i>Stelgidopteryx ruficollis serripennis</i> ♂	15.75	107	11.1
<i>Vireo a. solitarius</i> ♂	16.75	88	7.46
<i>Hirundo erythrogaster</i> ♂	17	118.5	11.8
<i>Melospiza georgiana</i> ♂	17	73	6.25
<i>Chaetura pelagica</i> ♂	17.3	104	12.9
<i>Melospiza l. lincolni</i> ♂	17.8	72.5	6.30
<i>Spizella a. arborea</i> ♂	18	90	7.60
<i>Ammodramus savannarum australia</i> ♂	18.5	89	6.10
<i>Anthus spinoletta rubescens</i> ♀	19	109	8.19
<i>Sayornis phoebe</i> ♀	20	134.5	8.33
<i>Iridoprocne bicolor</i> ♂	20.1	125	11.74
<i>Junco h. hyemalis</i> ♂	21.5	99	7.93
<i>Melospiza m. melodia</i> ♂	22	86.5	6.73
<i>Baeolophus bicolor</i> ♂	22.5	117.8	7.98
<i>Icterus spurius</i> ♂	23	100.5	7.82
<i>Passer d. domesticus</i> ♂	24.5	92.5	7.60
<i>Carpodacus p. purpureus</i> ♂	24.5	104	8.33
<i>Dryobates pubescens medianus</i> ♂	24.8	136	9.41
<i>Bombycilla cedrorum</i> ♂	25	130	9.38
<i>Oceanodroma l. leucorhoa</i>	26.5	251	15.9*
<i>Zonotrichia albicollis</i> ♂	26.5	108	7.47
<i>Poocetes g. gramineus</i> ♂	27	108	8.10
<i>Hyllocichla guttata jaxoni</i> ♂	29.5	116	9.44
" <i>f. fuscescens</i> ♂	32.3	147	10.23
<i>Sialia s. sialis</i> ♂	32.7	148	10.01
<i>Hyllocichla minima aliciae</i> ♂	34	150	10.40

TABLE 14.—*continued*

	Weight gm.	Wing area cm. ²	Wing length cm.
<i>Piranga flava hepatica</i> ♂	35.8	153	10.26
<i>Dumetella carolinensis</i> ♂	39	150	9.12
<i>Hedymeles ludovicianus</i> ♂	40	166.5	10.14
<i>Passerella i. iliaca</i> ♂	40.5	116	8.92
<i>Pipilo e. erythrophthalmus</i> ♂	41.7	145	8.92
<i>Progne s. subis</i> ♂	43	185.5	14.63
<i>Hedymeles m. melanocephalus</i> ♂	44.7	200	9.98
<i>Tringa s. solitaria</i> ♂	47	192	12.65
<i>Actitis macularia</i> ♂	47.5	146	10.05
<i>Pinicola enucleator leucura</i> ♂	50	189	11.41
<i>Molothrus a. ater</i> ♂	50.5	179	11.05
<i>Coccyzus a. americanus</i> ♂	61	266	14.36
<i>Rallus l. limicola</i> ♂	65	221	10.59
<i>Agelaius p. phoeniceus</i> ♂	70	245	12.09
<i>Balanosphyra f. formicivora</i> ♂	74.5	306	14.11
<i>Porzana carolina</i> ♂	75	176	10.70
<i>Chordeiles m. minor</i> ♂	75.25	349.5	19.80
<i>Turdus m. migratorius</i> ♂	82	244	13.43
<i>Sturnus v. vulgaris</i> ♂	84	190.3	12.90
<i>Oxyechus v. vociferus</i> ♂	85	275	16.02
<i>Centurus carolinus</i> ♂	87	262	13.10
<i>Cyanocitta c. cristata</i> ♂	89	236	13.15
<i>Alle alle</i> ♂	96	146	11.58
<i>Accipiter v. velox</i> ♂	97.5	439	17.11
<i>Colaptes auratus luteus</i> ♂	100	324	15.63
<i>Pisobia melanotos</i> ♂	101	199	13.98
<i>Cyanocephalus cyanocephalus</i> ♂	108	390	15.40
<i>Cryptoglaux a. acadica</i> ♂	108	420	13.63
<i>Capella delicata</i> ♂	112	250	12.71
<i>Quiscalus q. quiscula</i> ♂	122.3	324	14.38
<i>Zenaidura macroura carolinensis</i> ♂	130	357.5	14.72
<i>Valco s. sparverius</i> ♀	137	372	19.5
<i>Sturnella m. magna</i> ♂	145	265	12.24
<i>Megaceryle a. alcyon</i> ♂	155	376	15.63
<i>Totanus melanoleucus</i> ♂	170	412	18.78
<i>Accipiter v. velox</i> ♀	171	607	20.03
<i>Falco c. columbarius</i> ♂	173	410	18.89
<i>Otus asio naevius</i> ♂	178	523	16.02
<i>Philohela minor</i> ♂	198.5	354.66	12.35
<i>Colinus v. virginianus</i> ♂	198.64	216.8	11.15
<i>Rallus e. elegans</i> ♂	227	536	16.34
<i>Butorides v. virescens</i>	230	660	18.1*
<i>Asio wilsonianus</i> ♂	230	1,182	29.20
<i>Otus asio naevius</i> ♀	254	476	16.60
<i>Corvus ossifragus</i> ♀	273.5	912.5	27.15
<i>Asio wilsonianus</i> ♀	288	1,198	29.39
<i>Corvus ossifragus</i> ♂	309	1,072	27.80
<i>Columba l. livia</i>	314	567	21.93**
<i>Nettion carolinense</i>	321	374	17.5*
<i>Querquedula discors</i>	332	370	18.4*
<i>Gallinula chloropus cachinnans</i> ♂	332	479.5	17.45
<i>Podilymbus p. podiceps</i>	343.5	291	12.4*
<i>Colymbus auritus</i>	369.5	350	14.5*
<i>Buteo p. platypterus</i> ♂	376	1,012	26.28
<i>Charitonetta albeola</i>	377	412	16.4*
<i>Circus hudsonius</i> ♂	414	1,382	33.96
<i>Accipiter cooperi</i> ♂	428.5	898	23.10

TABLE 14.—concluded

	Weight gm.	Wing area cm. ²	Wing length cm.
<i>Fulica a. americana</i> ♂	435	596	19.03
<i>Florida c. caerulea</i>	449	1,246.5	26.0*
<i>Tyto alba partincola</i> ♂	505	1,683	32.86
<i>Strix v. varia</i> ♂	510	1,830	33.28
<i>Bonasa u. umbellus</i> ♂	516.5	527	18.36
<i>Corvus b. brachyrhynchos</i> ♂	552.5	1,344	32.10
<i>Spatula clypeata</i>	570	570	24.1*
<i>Aix sponsa</i> ♂ & ♀	589	660	22.7*
<i>Circus hudsonius</i> ♀	615	1,696	36.75
<i>Botaurus lentiginosus</i>	625	1,258	29.2*
<i>Erismatura jamaicensis rubida</i>	635	394	14.7*
<i>Falco peregrinus anatum</i> ♂	712	1,146	31.42
<i>Chaulelasmus streperus</i>	723	718	26.2*
<i>Nyroca collaris</i>	757.31	460	19.7*
" <i>affinis</i> ♀	763	472	20.0*
<i>Nycticorax nycticorax hoactli</i>	804	1,773	30.4*
<i>Buteo l. lineatus</i> ♂	804	1,656	32.08
<i>Astur a. atricapillus</i> ♂	848.6	1,480	32.52
<i>Larus argentatus smithsonianus</i> ♂	850	2,006	41.0
<i>Buteo b. borealis</i> ♂	875	1,878	36.96
<i>Casmerodius albus egretta</i>	899	2,528	38.1*
<i>Dafila acuta tsitsihos</i>	970	761	26.2*
<i>Branta bernicla hrota</i>	1,024	1,264	33.6*
<i>Clangula hyemalis</i> ♂	1,038	550.48	22.1*
<i>Buteo lagopus s. johannis</i> ♂	1,110	2,592	40.74
<i>Anas rubripes tristis</i> ♀	1,142	1,007	26.2*
<i>Falco peregrinus anatum</i> ♀	1,222.5	1,342	35.63
<i>Anas p. platyrhynchos</i> ♀	1,233.5	952	27.9*
<i>Phasianus colchicus torquatus</i> ♂	1,304	917	23.41
<i>Buteo b. borealis</i> ♀	1,307	2,294	38.88
<i>Astur a. atricapillus</i> ♀	1,370	2,004	33.36
<i>Nyctea nyctea</i> ♂	1,404	2,576	40.81
<i>Anas p. platyrhynchos</i> ♂	1,408	1,029	27.9*
<i>Bubo v. virginianus</i> ♀	1,446.5	2,534	36.63
" <i>virginianus pacificus</i> ♂	1,480	2,426	33.65
<i>Pandion haliaetus carolinensis</i> ♂	1,797.5	3,211	47.74
<i>Ardea h. herodias</i>	1,905	4,436	48.1*
<i>Cathartes aura septentrionalis</i> ♂	2,409	4,356	53.59
<i>Gavia i. immer</i> ♀ & ♂	2,425	1,358	36.0*
<i>Meleagris gallopavo silvestris</i> ♀	3,897	3,752	41.43
<i>Aquila chrsaetos canadensis</i> ♀	4,664	6,520	63.32
<i>Branta c. canadensis</i>	5,662	2,820	46.4*
<i>Cygnus columbianus</i>	5,943	4,156	55.0*
<i>Sthenelides olor</i> ♀	11,602	6,808	55.25**
HUMMINGBIRDS:			
<i>Archilochus alexandri</i> ♂	2.55	12.75	4.27
" <i>colubris</i> ♂	2.98	12.40	3.85

TABLE 15.—DATA FROM A. MAGNAN, ANN. SCI. NATURELLE, SER. 10, VOL. 5, PP. 125-334 (1922)

Les caractéristiques des oiseaux

Magnan has divided his birds into groups in accordance with their mode of flight. His short titles are difficult to translate, and I have left them in the original French. The basis for his classification is given on pages 165-171 of the original paper, together with the French common names of the species.

In addition to the data presented in the following tables, Magnan has measured many other characteristics, such as, for example, the length of body, length of tail, weight of wing skeleton, weight of heart, etc. I have given here those measurements which seemed particularly pertinent to flight.

The one measurement which presents difficulties is that of wing spread. Magnan says "The measurement is a matter of individual judgment; it is essential that all species be measured by the same hand, the wings must be stretched in precisely the same manner. The point is important, not if the wing spreads differ by a factor of 2, but if the differences are small."

All measurements appear to have been made with the greatest care. Captive birds were used, and those which appeared to be in bad health were discarded. Nowhere else in the literature is there such an abundance of data. For anyone interested in dimensional relationships the entire paper is well worth careful study.

	Total weight gm.	Wing area cm. ²	Wing weight gm.	Wing spread cm.	Wing length cm.	Pectoral muscles weight, gm.	
						Large	Small
Rapaces diurnes voliers							
<i>Gyps fulvus</i>	7,269	10,540	1,599	255.7	69.8	958	61.8
<i>Gypaëtus barbatus grandis</i>	5,385	7,431	1,279	252.4	71.7	715	46.8
<i>Catharista atrata</i>	1,702	3,012	327	140.8	50.2	299	15.3
<i>Aquila chrysaetos</i>	3,712	5,382	813	212.1	68.2	476	25.6
<i>Hieraëus fasciatus</i>	2,060	3,172	408	155.2	56.0	223	14.6
<i>Helotarsus caudatus</i>	2,095	3,582	406	153.6	51.2	270	12.4
<i>Geranoetus melanoleucus</i>	2,123	3,550	402	145.3	51.5	194	10.8
<i>Circatus gallicus</i>	1,655	4,121	400	181.0	53.3	226	10.9
<i>Buteo buteo</i>	1,027	2,691	181	132.2	40.4	113.5	8.94
<i>Pernis apivorus</i>	615	1,894	109	119.9	45.1	79.8	3.88
<i>Pandion haliaetus</i>	1,105	2,921	310	157.2	49.6	149	8.84
<i>Circus aeruginosus</i>	680	2,264	141	134.5	41.3	84.2	3.74
" <i>cyaneus</i> ♀	471.5	1,759	101	116.7	37.4	73.8	3.25
" " ♂	331	1,406	70.1	104.4	33.9	53.8	2.28
" <i>pygargus</i>	236.5	1,296	61.5	110.1	35.9	36.0	1.63
" <i>macrurus</i>	386	1,413	75.1	110.7	35.7	48.0	1.93
<i>Milvus milvus</i>	927	2,902	218	162.8	50.7	151	7.88
Palmipèdes voliers							
<i>Diomedea exulans</i>	8,502	6,206	1,377	340.8	67.4	1,036	59.5
<i>Fregata aquila</i>	1,620	3,240	326	201.9	61.0	186	9.7
<i>Sula bassana</i>	2,690	2,450	390	183.6	48.7	323	20.7
<i>Puffinus kuhli</i>	572	1,280	98.0	121.1	34.9	67.3	4.2
<i>Hydrobates pelagicus</i>	17.40	100	2.61	33.2	12.4	2.44	0.16
<i>Larus marinus</i>	1,915	2,719	394	172.6	50.9	228	23.0

TABLE 15.—continued

	Total weight gm.	Wing area cm. ²	Wing weight gm.	Wing spread cm.	Wing length cm.	Pectoral muscles weight, gm.	
						Large	Small
Échassiers ramo-planeurs							
<i>Ardea cinerea</i>	1,408	3,590	329	172.6	43.7	217	16.2
<i>Egretta alba</i>	1,178	2,827	225	144.7	43.3	161	14.1
<i>Botaurus stellaris</i>	1,198	2,696	171	132.9	35.1	167	17.2
<i>Nycticorax nycticorax</i>	512	1,577	78.0	104.8	27.2	69.1	7.5
<i>Platalea leucorodia</i>	1,565	2,488	282	137.0	37.2	266	24.4
<i>Ciconia ciconia</i>	3,438	4,951	670	197.8	55.9	537	48.2
<i>Megalornis grus</i>	4,175	5,553	810	211.0	56.4	550	65.6
<i>Leptopilus crumeniferus</i>	7,030	8,225	1,516	281.7	78.6	1,202	103.6
<i>Vanellus vanellus</i>	211	668	38.6	75.0	22.6	44.0	4.1
Rapaces nocturnes ramo-planeurs							
<i>Bubo bubo</i>	1,720	3,715	366	164.1	43.1	246	13.1
<i>Asio otus</i>	247	1,082	49.9	94.1	31.5	27.3	1.73
" <i>flammeus</i>	390	1,396	75.0	107.5	32.9	46.4	2.57
<i>Otus scops</i>	49.75	405	11.3	52.3	15.1	4.70	0.27
<i>Tyto alba</i>	279	1,163	54.5	97.3	28.1	33.2	2.15
<i>Sirix aluco</i>	418	1,304	76.1	95.0	22.4	39.5	2.30
<i>Athene noctua</i>	161.5	459	25.3	58.9	19.6	18.0	1.19
Rapaces diurnes ramo-planeurs							
<i>Accipiter gentilis</i>	708	1,317	113	100.7	30.3	105.5	3.75
" <i>nisus</i> ♀	221	822	46.9	75.0	23.6	45.1	2.34
" " ♂	136	530	28.2	62.2	19.0	22.8	1.24
<i>Polyborus tharus</i>	1,209	2,321	224	135.4	41.6	148.5	9.55
<i>Falco tinnunculus</i> ♀	245	708	42.4	73.8	23.2	28.3	1.64
" " ♂	172	703	30.5	75.1	25.6	21.2	1.55
" <i>peregrinus</i>	813	1,285	153	106.4	34.5	148.6	6.58
" <i>subbuteo</i>	165	558	32.1	75.7	25.2	30.0	1.44
" <i>columbarius regulus</i>	145	438	23.8	60.4	24.7	27.9	1.35
Corvidés ramo-planeurs							
<i>Corvus corone</i>	470	1,058	74.7	89.4	29.5	60.9	4.89
" <i>cornix</i>	633	1,317	96.0	97.9	31.8	86.0	6.14
<i>Trypanocorax frugilegus</i>	470	1,387	80.0	97.2	31.9	69.2	5.08
<i>Coloeus monedula spermologus</i>	253	665	37.0	70.8	23.4	33.5	2.73
<i>Pyrrhocorax pyrrhocorax</i>	390	948	58.5	67.2	26.3	52.7	3.90
<i>Graculus graculus</i>	223	997	36.5	78.2	27.9	27.8	2.14
<i>Nucifraga caryocatactes</i>	161	515	21.8	59.8	18.5	22.5	2.05
<i>Coracias garrulus</i>	128	483	18.9	61.5	19.7	16.0	1.60
<i>Pica pica</i>	214	640	31.4	59.2	19.1	26.8	2.18
<i>Garrulus glandarius</i>	160	554	20.9	54.3	19.0	18.9	1.93
<i>Upupa epops</i>	91	366	12.3	47.7	15.7	14.3	1.09
<i>Xanthoura yncas</i>	71.3	316	9.27	37.3	14.1	7.80	0.87
Passereaux ramo-planeurs							
<i>Cuculus canorus</i>	104	419	20.3	58.3	19.8	19.5	1.64
<i>Caprimulgus europaeus</i>	92	398	16.1	56.9	19.4	16.6	1.85
<i>Apus apus</i>	36.2	165	4.99	42.0	17.5	6.75	0.90
<i>Chelidon rustica</i>	18.35	135	2.71	33.0	11.9	3.40	0.33
<i>Hirundo urbica</i>	14.35	92.0	1.80	29.2	10.0	1.90	0.17
<i>Riparia rupestris</i>	15.50	119	2.25	31.4	11.2	2.52	0.165
Palmipèdes ramo-planeurs							
<i>Phalacro corax carbo</i>	2,115	1,967	265	171	42.4	262	26.5
<i>Puffinus puffinus</i>	342	575	45.5	81.1	23.8	42.6	4.10
<i>Larus argentatus</i>	1,189	2,105	226	143	46.6	141	12.1
" <i>canus</i>	367	1,149	71.0	108	34.4	47.0	3.60

TABLE 15.—*continued*

	Total weight gm.	Wing area cm. ²	Wing weight gm.	Wing spread cm.	Wing length cm.	Pectoral muscles weight, gm.	
						Large	Small
<i>Palmipèdes ramo-planeurs, continued</i>							
<i>Rissa tridactyla</i>	488	967	71.7	105	32.3	65.0	6.30
<i>Larus ridibundus</i>	261	853	42.5	97.1	30.7	33.3	3.00
<i>Sterna hirundo</i>	118	563	22.0	82.9	28.4	19.0	1.90
<i>Passereaux rameurs a vol soutenu</i>							
<i>Muscicapa striata</i>	14.35	119	1.80	26.7	8.99	2.10	0.20
<i>Ficedula hypoleuca</i>	12.50	91.0	1.38	24.4	7.89	1.95	0.20
<i>Alauda arvensis</i>	28.30	163	3.65	31.7	9.45	6.05	0.55
<i>Anthus pratensis</i>	18	96.8	2.11	25.9	7.86	3.91	0.35
" <i>trivialis</i>	20.70	125	2.54	28.6	9.06	3.97	0.38
<i>Motacilla alba</i>	22	132	3.05	28.3	8.97	4.55	0.38
" <i>flava</i>	16.50	101	2.00	25.0	7.64	3.40	0.26
" <i>cinerea</i>	16	92.0	1.94	25.2	8.06	3.70	0.29
<i>Lanius excubitor</i>	50.50	210	5.80	35.5	11.1	7.22	0.77
" <i>senator</i>	26.10	144	3.05	31.4	11.0	3.80	0.39
" <i>collurio</i>	30.95	182	2.82	28.6	8.79	3.20	0.30
<i>Luscinia megaryncha</i>	17.1	100	1.70	25.5	8.24	2.35	0.29
<i>Erythacus rubecula</i>	17.75	88.0	1.65	22.7	6.78	2.14	0.25
<i>Phoenicurus phoenicurus</i>	13	91.0	1.45	25.6	7.99	2.26	0.22
" <i>ochrurus</i>							
" <i>gibraltariensis</i>	16.95	122.4	2.10	27.0	8.73	2.50	0.25
<i>Pratincola rubetra</i>	13.05	98.8	1.55	23.5	7.77	2.04	0.20
" <i>cubicola</i>	11.45	76.8	1.20	21.6	6.54	1.68	0.17
<i>Phylloscopus bonellii</i>	7.65	63.0	0.80	19.1	5.71	1.20	0.14
" <i>rufus</i>	5.25	48.2	0.60	17.4	5.39	0.65	0.10
<i>Oriolus oriolus</i>	72	274	9.91	47.0	15.39	14.7	1.22
<i>Monticola solitarius</i>	62.8	236	6.59	38.6	12.32	8.40	0.82
" <i>saxatilis</i>	47.5	160	4.38	35.5	11.23	7.25	0.70
<i>Turdus merula</i>	91.5	260	8.99	40.6	12.62	14.6	1.70
" <i>naumanni</i>	76.2	225	7.15	37.7	11.87	11.3	1.35
" <i>viscivorus</i>	106	307	11.25	44.0	14.20	22.5	1.80
" <i>pilaris</i>	98	225	9.90	42.9	13.83	22.8	1.84
" <i>musicus</i>	70.3	191	6.64	36.7	11.14	14.0	1.40
" <i>iliacus</i>	56	180	5.70	37.1	11.48	10.9	1.00
" <i>torquatus</i>	96.5	222	8.85	42.7	13.30	15.7	1.59
<i>Sturnus vulgaris</i>	79.5	192	7.96	39.1	12.47	15.0	1.54
<i>Loxia curvirostra</i>	47.6	167	5.82	31.9	10.16	10.3	1.02
<i>Coccothraustes coccothraustes</i>	42	148	4.65	32.0	9.73	8.18	0.87
<i>Pyrrhula p. europaea</i>	21.4	94.8	2.35	25.5	8.05	3.20	0.40
<i>Serinus canarius serinus</i>	8.35	73.1	1.17	22.1	7.10	1.83	0.17
<i>Choris chloris</i>	23.70	100	2.75	27.0	8.62	5.75	0.47
<i>Fringilla caelebs</i>	21.15	102	2.75	28.5	8.85	4.95	0.40
" <i>montifrigilla</i>	25.1	123	2.90	28.1	9.08	4.10	0.40
<i>Passer domestica</i>	30	101	2.90	25.2	7.46	4.85	0.49
" <i>montana</i>	15.2	76.0	1.58	21.8	7.18	2.55	0.33
<i>Petronia petronia</i>	25	100	2.30	28.4	9.06	4.90	0.49
<i>Carduelis carduelis</i>	16.65	92.1	2.10	24.8	7.91	3.42	0.35
<i>Spinus spinus</i>	11.80	68.0	1.24	21.4	6.83	2.42	0.17
<i>Acanthus cannabina</i>	15.80	96.1	1.85	24.8	8.03	3.60	0.36
<i>Spinus citrinella</i>	11.95	73.9	1.45	24.5	7.31	2.40	0.25
<i>Emberiza citrinella</i>	25	130	3.36	28.1	9.06	5.00	0.55
" <i>cirlus</i>	23.1	104	2.60	24.8	7.40	4.70	0.40
" <i>hortulana</i>	33	122	2.45	27.3	8.66	4.20	0.48
" <i>cia</i>	21.40	108	1.78	25.8	7.77	3.95	0.32
" <i>schoeniclus</i>	20	114	1.65	25.5	7.60	4.00	0.30
<i>Regulus regulus</i>	3.80	32.2	0.40	14.3	5.00	0.45	0.05

TABLE 15.—continued

	Total weight gm.	Wing area cm. ²	Wing weight gm.	Wing spread cm.	Wing length cm.	Pectoral muscles weight, gm.	
						Large	Small
Passereaux rameurs a vol peu soutenu							
<i>Cyanecula suesica cyanecula</i>	14.30	78.9	1.64	21.4	6.31	1.75	0.26
<i>Sylvia atricapilla</i>	16.25	88.9	1.75	23.8	7.60	1.75	0.23
“ <i>jimplex</i>	15.8	74.9	1.52	23.6	7.53	1.58	0.22
“ <i>communis</i>	18.65	87.1	1.69	22.5	7.16	2.20	0.25
<i>Prunella modularis</i>	18	80.1	1.55	22.0	6.55	2.40	0.24
<i>Hypolais icterina</i>	10.65	80.0	0.88	20.5	6.60	1.18	0.14
<i>Acrocephalus cirpaeus</i>	12.80	67.2	1.00	20.3	6.78	1.52	0.18
“ <i>schoenobaenus</i>	10.40	52.9	0.98	19.2	6.11	1.22	0.14
<i>Parus major</i>	21.45	102	1.60	23.3	7.50	2.75	0.25
“ <i>caeruleus</i>	11	66.0	0.98	21.4	6.67	1.77	0.18
“ <i>cristatus mitratus</i>	10.20	72.9	1.26	20.2	6.29	1.42	0.15
“ <i>palustris longirostris</i>	10.90	64.1	1.14	20.0	6.21	1.75	0.17
“ “ <i>communis</i>	11.75	71.9	1.20	20.9	6.82	1.70	0.17
<i>Aegithalus caudatus</i>	8	58.0	0.73	18.6	6.00	1.25	0.12
<i>Gecinus viridis</i>	156	457	20.5	51.7	16.15	25.4	1.95
<i>Dryobates major pinetorum</i>	73	238	9.75	42.2	12.95	13.0	1.14
“ <i>minor hortorum</i>	15.50	103	1.90	26.9	8.48	2.50	0.25
<i>Jynx torquilla</i>	37.30	116	3.58	29.4	8.69	6.95	0.48
<i>Certhia brachydactyla</i>	8.50	66.0	0.92	20.0	6.12	1.25	0.13
<i>Sitta europaea coesia</i>	21.10	132.7	2.55	27.4	8.57	3.20	0.30
<i>Trichodroma muraria</i>	15	174	2.25	30.1	9.86	2.30	0.17
<i>Troglodytes troglodytes</i>	10.1	41.4	0.75	16.9	4.76	1.15	0.15
Passereaux vibrateurs							
<i>Eupherusa eximia</i>	2.85	15.4	0.18	13.0	5.10	0.86	0.12
Échassiers rameurs terrestres							
<i>Otis tarda</i>	8,950	5,728	1,298	208	51.9	1,790	224
“ <i>tetrax</i>	830	1,038	120	86.5	22.6	182	22.5
<i>Burhinus oedicephalus</i>	522	757	71.0	83.7	23.4	81.3	9.20
<i>Charadrius apricarius</i>	178	356	20.3	58.5	17.4	41.2	6.04
“ <i>morinellus</i>	90	247	9.9	46.6	14.8	20.1	2.75
<i>Crex crex</i>	155	318	16.1	47.8	14.0	24.3	3.35
<i>Scolopax rusticola</i>	322	596	37.5	66.5	20.6	82.0	17.8
Échassiers rameurs riverains							
<i>Numenius arquatus</i>	768	1,175	108	104.4	30.2	145	18.0
<i>Haematopus ostralegus</i>	438	622	64.0	80.5	25.8	65.6	8.68
<i>Charadrius hiaticula</i>	62.2	188	5.90	40.8	13.1	10.7	1.30
<i>Squatarola squatarola</i>	216	413	23.8	65.4	20.4	40.7	5.20
<i>Gallinago gallinago</i>	95.5	244	9.29	44.8	12.8	25.3	5.20
<i>Lymnocyptes gallinula</i>	57	178	6.40	39.3	10.8	11.3	2.24
<i>Canutus canutus</i>	88	269	11.2	50.3	15.6	18.7	2.46
<i>Eriolia alpina</i>	44	126	3.65	36.0	10.9	8.45	1.10
<i>Arenaria interpres</i>	107.8	213	9.80	47.6	14.8	22.4	3.04
<i>Calidris leucophaea</i>	41.9	160	4.20	35.4	11.5	8.60	1.52
<i>Machetes pugnax</i>	180	457	22.5	63.2	19.2	41.3	5.18
<i>Tringa nebularius</i>	156	406	18.5	60.8	18.8	33.8	4.64
“ <i>erythropus</i>	133	326	15.5	54.1	16.3	28.6	4.39
“ <i>totanus</i>	133	366	14.2	51.6	14.8	26.2	3.79
“ <i>ocrophus</i>	72.7	248	8.35	47.2	14.6	18.2	3.00
“ <i>hypoleucus</i>	48.5	148	4.25	35.7	11.3	8.10	1.52
<i>Limosa lapponica</i>	197	520	27.6	73.3	22.1	40.4	7.80
“ <i>limosa</i>	228	527	30.3	69.0	20.8	51.7	7.00
<i>Recurvirostra avocetta</i>	295	684	41.6	77.2	22.0	49.4	3.98

TABLE 15.—continued

	Total weight	Wing area	Wing weight	Wing spread	Wing length	Pectoral muscles weight, gm.	
	gm.	cm. ²	gm.	cm.	cm.	Large	Small
Colombins rameurs							
<i>Columba palumbus</i>	495	797	70.0	75.1	24.5	118	18.5
" <i>aenas</i>	306	532	44.3	75.3	20.9	73.9	12.3
<i>Turtur turtur</i>	178	376	24.5	52.9	17.5	39.4	7.30
Gallinacés rameurs							
<i>Tetrao urogallus</i> ♂	3,361	1,412	339	131.8	36.0	607	208
" " ♀	1,890	1,219	206	91.5	33.6	413	116
<i>Lyrurus tetrix</i> ♂	1,030	968	105	83.8	23.2	238	74.0
" " ♀	940	846	96.9	76.4	21.6	144	57.0
<i>Tetrao medius</i>	1,193	978	130	87.0	25.5	270	75.4
<i>Lagopus mutus</i>	462.5	486	42.0	60.3	18.6	78.7	21.1
" <i>lagopus</i>	620	626	57.3	68.2	21.3	124	37.2
" <i>scoticus</i>	624	593	56.0	70.9	21.4	122	36.5
<i>Tetrastes bonasia</i>	278	386	21.5	52.9	16.3	73.0	24.7
<i>Caccabis rufa</i>	490	519	42.7	54.4	16.6	91.2	32.2
<i>Caccabis saxatilis</i>	606.5	473	48.2	55.0	16.1	92.6	31.2
<i>Perdix perdix</i>	387	433	30.4	52.5	15.3	83.6	28.6
<i>Coturnix coturnix</i>	83.2	171	7.60	35.8	10.5	14.75	4.13
<i>Colinus pectoralis</i>	131.5	196	9.89	33.1	9.66	26.1	9.86
<i>Rhynchotus rufescens</i>	821.7	657	61.6	67.4	21.5	159	37.0
Palmipèdes nageurs rameurs							
<i>Cygnus cygnus</i>	5,925	3,377	978	230	56.1	884	70.1
<i>Anser fabalis</i>	3,110	2,675	425	162	46.7	555	59.7
" <i>anser</i>	3,065	2,697	491	163	46.5	570	59.8
" <i>albifrons</i>	1,715	1,835	294	141	40.7	309	39.3
<i>Branta bernicla</i>	1,273	1,388	165	119	33.6	209	22.9
" <i>leucopsis</i>	1,150	1,150	150	108	35.6	192	20.8
<i>Anas platyrhynchos</i>	1,105	928	117	90.0	25.9	215	32.7
<i>Spatula clypeata</i>	633	614	66.0	79.8	23.2	116	15.2
<i>Dafila acuta</i>	955	840	98.0	91.6	25.6	186	20.0
<i>Mareca penelope</i>	830	664	83.6	85.5	25.4	146	17.7
<i>Querquedula crecca</i>	293	349	31.0	57.8	17.9	57.7	7.33
" <i>querquedula</i>	327	399	36.2	65.4	19.3	63.4	8.90
<i>Clangula clangula</i>	622	516	57.0	70.0	19.6	106	14.5
<i>Nyroca nyroca</i>	512	512	50.0	68.0	18.4	86.8	10.25
" <i>fuligula</i>	741	474	55.9	70.6	20.8	123	13.55
" <i>ferina</i>	842	615	80.0	77.4	21.7	166	16.4
" <i>marila</i>	675	621	98.6	81.6	21.9	176	16.3
<i>Oidemia nigra</i>	870	679	88.0	85.0	22.9	102	12.2
" <i>fusca</i>	1,578	1,010	160	96.7	25.6	218	26.8
Palmipèdes plongeurs rameurs							
<i>Mergus serrator</i>	818	589	77.7	88.6	24.4	142	14.7
" <i>merganser</i>	1,470	853	167	95.5	26.2	213	22.0
" <i>albellus</i>	495	431	41.0	62.5	17.4	86.5	9.37
<i>Colymbus cristatus</i>	790	561	72.0	78.6	17.6	92.0	8.90
" <i>griseigena</i>	480	542	43.2	72.0	16.4	57.2	5.28
" <i>ruficollis</i>	180	236	10.9	44.0	10.2	14.65	1.95
<i>Gavia septentrionalis</i>	957	890	102	104	26.6	58.0	5.55
" <i>arctica</i>	1,495	1,196	168	120	30.9	147	10.45
<i>Alca torda</i>	780	382	48.0	68.1	19.3	97.0	28.9
<i>Uria troille</i>	1,010	424	61.9	70.2	20.1	148	48.0
<i>Fratercula arctica</i>	272	345	23.7	56.4	16.2	30.4	9.50
<i>Alle alle</i>	91.2	167	7.75	38.7	12.6	12.8	3.65

TABLE 15.—concluded

	Total weight gm.	Wing area cm. ²	Wing weight gm.	Wing spread cm.	Wing length cm.	Pectoral muscles weight, gm.	
						Large	Small
Échassiers plongeurs rameurs							
<i>Fulica atra</i>	578	618	40.5	72.5	20.0	57.3	7.30
<i>Gallinula chloropus</i>	265	368	21.0	55.9	12.8	33.0	4.70
<i>Porzana porzana</i>	69	228	6.44	39.4	11.5	9.15	1.45
<i>Rallus aquaticus</i>	128	261	9.50	41.3	11.6	11.4	2.14
Passereaux plongeurs rameurs							
<i>Alcedo ispida</i>	36.4	108	3.75	28.8	8.29	6.02	0.76

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NOTE: After completion of the present manuscript I have noted Frank A. Hartman's "Locomotor Mechanisms of Birds" (*Smithsonian Misc. Coll.*, vol. 143, No. 1). This paper contains many data on dimensional relationships for birds. A cursory inspection of the tables indicates general agreement with the relationships presented here. It is unfortunate that I was unable to include Hartman's excellent and abundant data in the present compilation.—C. H. G.



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