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A New Method for Calculating the Wing Area of Bats

by B.R. BLOOD [1] and D.A. MCFARLANE [2]

[1] *Mt. St. Mary's College, Department of Physical Therapy,*
Chalon Campus, 12001 Chalon Rd. Los Angeles, CA 90049, U.S.A.
[2] *Section of Birds and Mammals, Natural History Museum of Los Angeles Co.,*
900, Exposition Blvd., Los Angeles CA 90007

Wing area is a parameter important to any study of chiropteran flight behaviour (Struthsaker 1961 ; Findley *et al.* 1972 ; Lawlor 1973), because it is a necessary component for the calculation of aspect ratio and wing loading. Bats possessing high aspect ratio wings usually display swift and steady flight, often at high altitudes. Bats that possess low aspect ratio wings usually display slower, more manouverable flight and often fly at lower altitudes (Findley 1972 ; Findley *et al.* 1972 ; Mortensen 1977 ; Vaughan 1970). However, despite the importance of wing area, no-one has published a simple, yet accurate, method which can be used to calculate it.

Currently, there are three methods available in the literature for quantifying wing area. One method is the calculation of a wing area index (Findley *et al.* 1972) which compares the length of the forearm and third digit with the width of the wing across the fifth digit. The second method involves tracing the bat's wing onto paper and measuring the enclosed area with a polar planimeter (eg. Farney and Fleharty 1969 ; Strickler 1961). The third method estimates wing area from the lengths of the forearm and digits, and the arctangent of the angle between the third and fourth digits (Smith and Starrett 1979). Each method has advantages and disadvantages.

Findley's method is simple, but provides an 'index' of the wing length/width relationship, and not an estimate of true wing area. Farney and Fleharty's method is potentially accurate, but is time consuming, damaging to the specimens, and limited to use on fluid-preserved specimens or dry skins prepared with their wings spread. Smith and Starrett's method seems to overcome these problems, but yields inaccurate results (Blood, unpubl. data and this paper).

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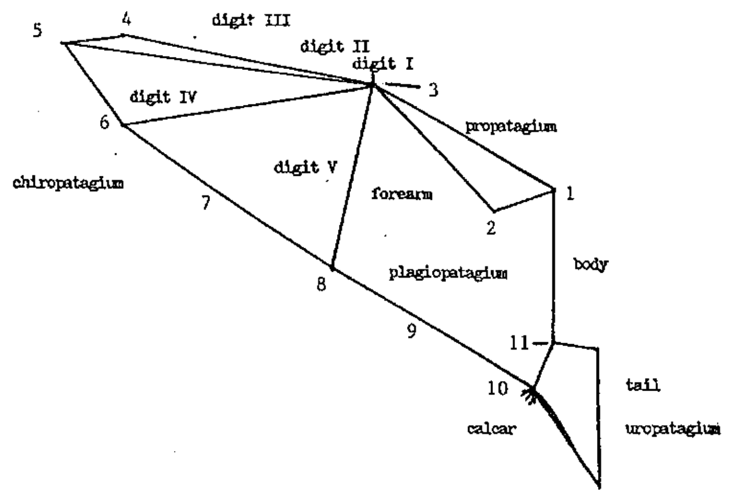

Fig. 1. — Diagrammatic representation of a typical bat wing. Numbers indicate the points and order used in calculation of wing area (see text) The stylus was moved about the wing starting at position one and ending at position eleven. The digitizer automatically enclosed the area of the polygon and calculated the area in square millimeters.

One of us (BRB) has devised a method for the calculation of wing area which is simple, useful on any bat specimen in which the digits are accessable, and non-destructive. Most importantly, the technique yields estimates which accurately reflect true wing area.

We consider the chiropteran wing as being composed of two elements. One, the plagiopatagium, we represent as a simple rectangle bounded by the forearm and fifth digit. The second, the chiropatagium, we represent as a simple right triangle which has as its base the fifth digit and as its height the length of the third digit. The total wing area is the sum of these two elements. Our method can therefore be represented by the equation :

$$\text{Area of one wing} = (\text{FA} \times \text{D5}) + 0.5\ (\text{D5} \times \text{D3})$$

Where FA is the length of the forearm, and D3 and D5 are the lengths of the third and fifth digit respectively. We have not concerned ourselves with the area of the uropatagium or the undersurface of the body, which have been included in the calculation of flight surface area by some authors, but whose significance is unclear.

We have tested the accuracy of our method and that of Smith and Starrett by comparing the results of both with known wing areas of 20 *Myotis velifer* (Vespertilionidae) and 20 *Tadarida brasiliensis* (Molossidae) housed in the mammal collections of the Natural History Museum of Los Angeles County (LACM). We selected these specimens because they were all collected from a single cave roost, eliminating geographic variation. All the specimens were prepared by the same individual as dry skins with their wings fully spread, minimizing preparator variation. Calculations were performed on each specimen independently to avoid problems with sexual dimorphism. We used an electronic digitizer board with a spatial resolution of 0.1 mm to determine the lengths of head-and-body, forearm, and digits 3, 4 and 5. We also determined the area of the right wing directly by defining eleven points on the wing margin (Figure 1) and allowing the digitizer to compute the area of the enclosed polygon.

Table 1 lists the mean measured wing areas and estimated wing areas by our method and that of Smith and Starrett. Absolute errors are calculated as a percentage of the measured area. The mean error for our method as applied to *M. velifer* was + 10.65 %, and for *T. brasiliensis* it was + 8.0 %. Smith and Starrett's method averaged + 54.6 % error for *M. velifer* and + 99.98 % for *T. Brasiliensis.*

TABLE 1. — Wing measurements, Wing areas, and absolute errors (ab-error) for *Myotis velifer* and *Tadarida brasiliensis.* Abbreviations are as follows : Head and body length (HB), Forearm length (FA), Length of digits III, IV and V (D3, D4, D5). Blood-McFarlane Area (BM-Area), Smith and Starrett Area (SS Area). All specimens were obtained from the Natural History Museum of Los Angeles County. Absolute error was calculated by the following : Digitized area minus method area divided by digitized area multiplied by 100.

Species and Museum Number	HB	FA	D3	D4	D5	Digitized wing area	BM-Area	Ab-Error as a percent	SS Area	Ab-Error
M. velifer										
69244	74.72	50.42	67.86	66.02	62.48	6132.00	5270.19	14.05	9240.06	50.69
69246	72.62	48.04	68.05	64.23	60.82	5619.00	4991.19	11.17	8783.95	56.33
69245	65.65	47.84	63.74	61.42	57.24	4808.00	4562.60	5.10	8000.15	66.39
69240	73.61	49.92	65.26	62.26	57.60	5127.00	4754.88	7.26	8294.71	61.78
69239	70.88	49.99	66.69	62.91	59.58	5210.00	4965.10	4.70	8604.31	65.15
69238	73.07	47.16	62.63	60.73	55.05	5377.00	4320.05	19.66	7660.12	42.46
69243	65.00	50.80	63.49	58.77	58.85	5312.00	4857.77	8.55	8077.27	52.06
69242	72.00	48.14	65.22	59.65	56.30	4768.00	4546.23	4.65	7849.64	64.63
69241	73.11	48.38	62.28	59.83	57.40	5048.00	4564.45	9.58	7844.37	55.40
69268	68.24	49.28	64.72	59.32	57.06	5095.00	4658.38	8.57	7930.13	55.65
69269	66.69	47.42	64.11	62.35	56.44	5517.00	4485.57	18.70	8001.94	45.04
69270	73.07	50.07	66.14	60.01	58.91	5279.00	4897.78	7.22	8264.77	56.56
69272	75.39	51.28	69.80	64.05	58.53	5513.00	5044.12	8.50	8835.86	60.27
69271	65.62	45.99	62.42	56.56	56.65	5032.00	4373.38	13.09	7372.97	46.52
69273	72.12	51.82	71.50	65.89	59.96	5734.00	5250.70	8.43	9255.55	61.42
69262	71.89	49.23	61.78	59.95	56.75	5484.00	4546.81	17.09	7822.91	42.65
69264	68.04	48.58	63.31	61.13	57.56	5203.00	4618.33	11.24	8026.82	54.27
69263	69.22	49.65	60.26	60.07	57.24	5267.00	4566.61	13.30	7834.53	48.75
69266	69.12	47.92	63.77	59.16	58.35	5320.00	4656.62	12.47	7909.73	48.68
69267	70.44	48.20	63.82	56.88	56.08	4978.00	4492.57	9.75	7535.51	51.38
Mean	70.53	49.01	64.84	..	57.94	5291.15	4721.17	10.65	8157.27	54.30
Std dev.	3.08	1.45	2.73	..	1.73	313.74	265.75	4.25	515.01	7.20
T. brasiliensis										
69131	75.40	36.90	73.20	61.19	44.63	3960.00	3280.31	17.16	6892.81	74.06
69133	71.69	40.71	75.25	61.21	46.81	4521.00	3666.86	18.89	7330.12	62.13
69132	73.00	47.53	77.55	63.28	46.67	4179.00	4027.85	3.62	7945.71	90.13
69130	72.96	44.91	77.92	55.24	48.02	4313.00	4027.44	6.62	7212.59	67.23
69118	75.02	47.82	72.09	64.02	46.52	4612.00	3920.01	15.00	7760.39	68.27
69117	74.62	41.67	78.80	66.10	46.30	4530.00	3753.54	17.14	7970.56	75.95
69115	76.72	48.53	74.32	66.14	45.53	4128.00	3901.47	5.49	7974.18	93.17
69090	68.31	50.27	78.89	63.89	46.50	3836.00	4171.75	8.75	8188.23	113.46
69091	72.71	46.40	75.99	63.93	43.00	3644.00	3628.99	0.41	7577.02	107.93
69088	68.10	49.57	77.61	65.71	42.21	4013.00	3730.31	7.04	7897.54	96.80
69087	74.44	47.81	73.86	64.17	43.78	3464.00	3709.92	7.10	7602.70	119.48
69089	74.35	47.19	74.81	64.51	41.79	3593.00	3535.23	1.61	7499.99	108.74
69086	73.58	43.41	74.55	63.11	44.89	3801.00	3621.95	4.71	7440.61	95.75
69084	70.51	47.54	78.23	67.47	43.92	4096.00	3805.89	7.08	8141.07	98.76
69069	66.92	50.14	75.64	66.63	46.74	3954.00	4111.25	3.98	8267.97	109.10
69068	71.60	46.44	71.04	63.53	42.10	3586.00	3450.52	3.78	7201.23	100.82
69070	67.92	49.27	75.41	66.42	43.08	3204.00	3746.88	16.94	7890.98	146.29
69066	70.17	45.82	72.71	63.51	42.68	3432.00	3496.56	1.88	7282.78	112.20
69056	64.25	48.37	74.19	65.12	46.67	3677.00	3988.65	8.48	7965.08	116.62
69055	64.62	47.65	70.92	63.19	45.84	3469.00	3809.76	9.82	7520.31	116.79
Mean	71.34	46.40	75.16	63.92	44.88	3900.60	3769.26	8	7678.09	99.98
Std Dev.	3.53	3.32	2.38	2.58	1.88	390.44	227.07	5	368.58	20.39

The large error incurred by Smith and Starrett's method appears to result from a simple geometric error. The areas of the triangles used to represent the chiropatagium are computed as base × height, not 1/2 (base × height) (Smith and Starrett 1979). However, even after applying this correction, the method still yields mean errors of 5.2 % and 26.2 % for *M. velifer* and *T. brasiliensis* respectively.

We conclude that Smith and Starrett's method, as published, is inappropriate for the estimation of wing area. Both Smith and Starrett's corrected method and Blood's method provide reasonable estimates of wing area in some cases, but the highly variable error of the former method leads us to recommend caution in its use.

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Observation d'un Grand dauphin *(Tursiops truncatus)* dans la Garonne

par R. DUGUY et A. COLLET

Centre National d'Etude des Mammifères marins,
Musée Océanographique, Port des Minimes, 17000 La Rochelle

Le 4 avril 1988, des pêcheurs de l'Isle-Saint-Georges (Gironde) observèrent le matin un dauphin qui remontait la Garonne en accompagnant un bateau de plaisance et, le soir même, qui descendait la rivière en suivant un petit navire

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