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BIRD SPECIES DATABASE OF EGG VOLUMES AND SURFACE AREAS

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The computer-based analysis of 13458 photographs of avian eggs belonging to 257 species of 19 orders provided empirical data for the coefficients of egg volume and surface area calculation using the dimensions of length and breadth. The calculated species-specific and order-specific coefficients are given. The method of estimation of egg volume and surface by means of taking digital photographs with further computer calculation may be used to study the intrapopulation variability and to estimate incubation efficiency.
Key words: eggs volume, surface area of eggs, indices of eggs volume, indices of surface area of eggs

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INTRODUCTION

The research of birds eggs is one of the most important and affordable chapter of ornithological researches. Probably it is hard to find the ornithologist, which will go through the nest of bird and will not measure the laying. But two of received measurements (length and diameter) give less information, than for example volume-surface measurements. As known, volume limits the quantity of eggwhite and yolk, which surface the capacity of shell, and that it is material-energetical embryo stock. To surface area addicted such functions as: gas exchange, transpiration and temperature schedule, that provide development of embryo. In the complex, two of these indices are the most valuable criteria of incubative quality of eggs, with the help of which it is possible to research different types of variability and to predict potential success of reproduction.

All sum of publications, dedicated to determination methods of volume can be divided to three groups. First of them is based on calculations, that are made on the basis of linear measurements of eggs and coefficients (Barth, 1953; Romanov & Romanova, 1959; Stonehous, 1966; Carter, 1974; Preston, 1974; Hoyt, 1976; Loftin & Bowman, 1978; Narushin, 2005). Method is really convenient, but in a lot of cases coefficients, which are proposed by different authors, are plenty general and gives some infelicity for some species. According to the another method, volume is determined according to quantity of ousted water (Bonnet & Mongin, 1965; Paganelli et al., 1974; Tarasov, 1977; Hoyt, 1979; Komarov, 1993; Chernichko & Chirkin, 1999). It gives the opportunity to concretize research and rise their preciseness, but the process of getting data plenty cumbersome and inconvenient for realization in the field.

The third method is based on using the modern technologies, namely computer analysis of digital eggs photos. This direction of oological researches has started in the beginning of the last century and nowadays it became more popular (Monus & Barta, 2005; Bridge et al., 2007; Mytiai, 2003; 2008; 2009; Zhou et al., 2009). Computer analysis gave the opportunity to work out the considerable factual material, and calculate intraspecific coefficients. These coefficients gives the opportunity to calculate volume and area of the surface eggs shells in absolute terms, and also calculate dimensional indices (more details are below). The last opens the perspectives

for comparing the eggs of different species of birds and gives opportunity to colligate the effectiveness of embryogeness and potential successfulness of reproduction with some quantitative morphological indices.

MATERIAL AND METHODS

All the data were collected during the field suveys and in the museums of Ukraine: National Scientifically-Naturalistic Museum National Academy of Sciences of Ukraine, Zoological Museum of Taras Shevchenko National University of Kyiv, Zoological Museum of Ivan Franko National University of Lviv, Lviv State Natural-Scientific Museum National Academy of Sciences of Ukraine, State Museum of Nature of V.N. Karazin National University of Charkiv, Cherkassy Local History Museum. Photo were made with help of Pentax K10D, fixed on special equipped tripod. The main condition during the photographing were placing the egg in the manner, that its longitudinal axis was perpendicular to the objective of photocamera. Beside this, the important was the equable light, that was provided by round lamp of the day light and background of black velvet. For analysis of photo shoots were used computer programs, which were written on the basis of equation smooth piecewise continuous curve and integrals for calculating the volume:

$$V = \int_{x_1}^{x_2} \pi y^2(x)dx \qquad \text{and area of surface:} \qquad S = 2\pi \int_{x_1}^{x_2} y(x)\sqrt{1+y'^2(x)}dx.$$

The volume of researched material is 12579 pcs of eggs of 241 species, that contributes to bird orders.

RESULTS AND DISCUSSIONS

On the basis of calculating were used the formulas, that in different modifications were used by authors mentioned earlier. Their general view: $k_V = V/LD^2$ and $k_S = S/LD$, where V- volume, S- area of surface, L- length, D- diameter; k_V, k_S – volume and surface coefficients. Defining by computer method the volume and area of surface on the basis of mass material we calculated mentioned coefficients (Table 1).

These calculations, as were marked earlier, give the opportunity to transfer from absolute value to dimensional indices: cubical dilatation - $I_{rV} = V_{ov}/V_{sph}$ and comparative surface: $I_{rS} = S_{ov}/S_{sph}$, where I_{rV} i. I_{rS} – indices, V_{ov} *i* S_{ov} –volume and surface area of real eggs, V_{sph} S_{sph} – volume and surface area of sphere with the diameter which equal to the length of the egg. Such approach can be easily visible demonstrated (Fig. 1).

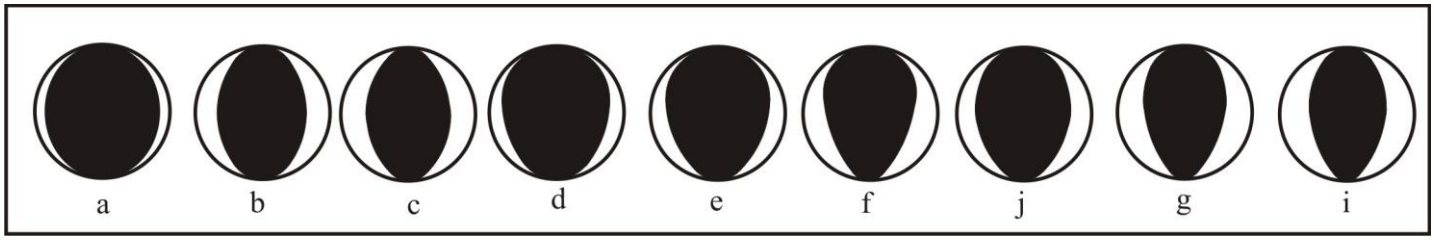

Fig. 1. Comparing of egg shapes and sphere (sphere diameter is equal to egg length).

Thesed indices give the opportunity to make needed comparisons, and also to analyze eggs from the point of more or less incubation usefulness. As etalon for comparison the sphere was used. The last has the range of distinctive only for itself qualities. For example, only this physical body has the correlation of volume to area surface maximally. This index is very important for bird eggs, because it is linked to material-energetically side of the process of incubation. The eggs with max volume with min area of surface have whole chain of preferences. Their shell has max strength with min thickness. The processes of gas exchange and transpiration in this case pass more optimal, than with thick shell. The small area of surface has less heat emission, that is better index for embryo surviving at the moment of absence of sitting bird in the nest. The max volume gives opportunity to place more quantity of needed substances.

Foregoing material show, that using the digital photos and their computer analyzing open wide perspectives in the research of the bird eggs. Absolute and comparative dimensional indices allow not only delimit eggs between themselves but also make analyzes of their incubational usefulness. The last circumstance is very important, because with the presence only oological material it is possible to make the prognosis of potential condition of the population before the beginning of the nests period.

Essential advantage of this method are its economy, speediness of accomplishment, and occurring during one's lifetime the max of information.

Table 1. Indices for calculating the volume and surface area of eggs

Order / Species	*n*	*L*	*D*	*Kv*	*Vcal*	*Vexp*	*Ks*	*Scal*	*Sexp*
Gaviiformes	113	78.7	48.8	0.512	97.16	96.47	2.746	105.84	105.06
Gavia stellata	39	73.1	45.1	0.515	76.55	75.99	2.757	90.86	90.08
Gavia arctica	58	80.2	50.1	0.510	102.63	102.34	2.743	110.22	109.59
Gavia immer	6	94.6	59.1	0.508	168.18	167.48	2.731	152.79	152.17
Gavia adamsii	10	91.6	55.4	0.509	143.21	142.31	2.723	138.27	137.21
Podicipediformes	337	50.5	34.0	0.506	30.51	30.42	2.766	47.99	47.86
Podiceps ruficollis	22	36.3	25.8	0.506	12.17	12.12	2.795	26.11	25.98
Podiceps nigricollis	73	44.5	30.1	0.507	20.46	20.56	2.772	37.13	37.14
Podiceps auritus	9	44.9	30.7	0.500	21.23	21.33	2.745	37.89	38.08
Podiceps grisegena	66	51.1	34.9	0.507	31.59	31.66	2.777	49.56	49.49
Podiceps cristatus	167	54.8	36.4	0.506	36.68	36.64	2.755	54.91	54.79
Procellariiformes	22	57.8	41.9	0.513	64.07	64.44	2.84	74.40	74.78
Fulmarus glacialis	8	72.4	51.2	0.512	97.84	98.74	2.808	104.31	105.24
Puffinus puffinus	7	58.6	43.2	0.514	56.41	56.19	2.853	72.27	71.97
Hydrobates pelagicus	7	27.8	21.7	0.516	6.74	6.83	2.885	17.39	17.61
Pelecaniformes	163	64.7	40.9	0.512	59.96	59.74	2.752	74.63	74.41
Pelecanus onocrotalus	12	93.8	60.0	0.509	171.74	171.56	2.751	154.72	153.88
Pelecanus crispus	8	94.2	59.5	0.506	169.36	167.69	2.734	153.25	151.69
Phalacrocorax carbo	113	62.9	39.6	0.512	50.52	50.48	2.751	68.52	68.38
Phalacrocorax aristotelis	22	61.0	37.8	0.509	44.51	44.18	2.732	63.01	62.48
Phalacrocorax pygmaeus	8	47.9	30.2	0.517	22.61	22.86	2.763	40.00	40.42
Ciconiiformes	461	56.7	40.4	0.508	49.33	49.19	2.808	65.29	65.11
Botaurus stellaris	17	51.5	38.4	0.507	38.49	38.23	2.834	56.03	56.00
Ixobrychus minutus	53	35.3	25.8	0.512	12.12	12.04	2.845	25.94	25.75
Nycticorax nycticorax	35	48.3	34.9	0.511	30.10	30.12	2.829	47.73	47.60
Ardeola ralloides	13	38.5	28.6	0.513	16.15	15.92	2.857	31.43	31.01
Egretta alba	55	61.2	42.5	0.508	56.08	56.23	2.792	72.56	72.43
Egretta garzetta	53	47.1	33.5	0.508	26.78	26.72	2.802	44.16	44.04
Ardea cinerea	110	60.3	42.3	0.507	54.72	54.61	2.792	71.21	71.03
Ardea purpurea	84	55.3	40.6	0.509	46.44	46.47	2.827	63.48	63.48
Platalea leucorodia	22	68.0	46.3	0.508	74.04	73.91	2.782	87.55	87.18
Ciconia ciconia	19	74.8	53.5	0.513	109.89	109.95	2.828	113.24	113.01
Anseriformes	523	68.17	46.9	0.515	101.36	100.98	2.817	98.39	98.06
Anser anser	52	87.8	58.4	0.511	153.15	152.43	2.778	141.82	142.48
Cygnus olor	57	114.3	74.4	0.509	322.24	321.48	2.761	234.63	234.00
Cygnus cygnus	16	110.7	74.7	0.511	315.57	313.85	2.788	230.56	229.08
Tadorna tadorna	47	65.8	47.0	0.510	74.02	73.76	2.816	87.07	86.61
Anas platyrhynchos	88	56.3	40.7	0.515	48.07	47.94	2.842	65.08	64.93
Anas strepera	69	53.9	38.0	0.515	40.11	40.04	2.828	57.86	57.81
Anas querquedula	76	46.6	32.8	0.519	25.97	25.86	2.839	43.36	43.19
Anas clypeata	13	51.9	37.3	0.519	37.38	37.11	2.857	55.22	54.82
Aythya ferina	35	60.6	43.3	0.518	58.78	58.57	2.847	74.64	74.36
Aythya nyroca	22	51.3	37.8	0.519	37.96	37.91	2.866	55.52	55.48
Somateria mollissima	9	79.2	51.9	0.515	109.98	109.06	2.789	114.71	113.65
Mergus serrator	39	65.1	44.7	0.514	66.65	66.72	2.803	81.49	81.50
Falconiformes	1264	51.2	44.0	0.515	48.22	48.06	2.904	62.11	61.63
Pandion haliaetus	30	61.7	46.6	0.517	69.41	73.27	2.874	82.73	84.25
Pernis apivorus	23	51.9	41.9	0.513	46.72	46.76	2.914	63.38	63.17
Milvus milvus	48	56.6	44.3	0.514	57.10	56.82	2.893	72.55	72.16
Milvus migrans	102	54.6	42.4	0.515	50.51	50.35	2.893	66.94	66.57
Circus cyaneus	13	45.8	35.9	0.517	30.92	30.78	2.907	48.02	47.81
Circus pygargus	26	42.5	34.2	0.517	25.68	25.83	2.925	42.48	42.48
Circus aeruginosus	65	48.9	38.1	0.516	36.52	36.62	2.893	53.82	53.87

Order / Species	*n*	*L*	*D*	*Kv*	*Vcal*	*Vexp*	*Ks*	*Scal*	*Sexp*
Accipiter gentilis	88	57.2	44.0	0.515	57.02	56.95	2.886	72.12	72.39
Accipiter nisus	70	39.4	31.8	0.516	20.49	20.54	2.922	36.54	36.49
Buteo rufinus	28	55.9	44.0	0.516	57.07	56.57	2.909	71.61	71.36
Buteo buteo	237	54.8	43.2	0.513	52.52	52.42	2.898	68.67	68.32
Circaetus gallicus	9	75.5	59.5	0.515	138.15	136.70	2.907	130.72	129.36
Hieraaetus pennatus	35	55.6	45.5	0.516	60.05	59.36	2.936	74.56	74.01
Aquila clanga	10	64.7	52.0	0.515	90.76	90.11	2.917	98.25	97.77
Aquila pomarina	47	63.9	50.7	0.514	84.44	84.39	2.907	94.32	94.22
Aquila heliaca	11	74.2	57.1	0.516	124.71	123.62	2.892	122.55	121.27
Aquila chrysaetos	8	75.1	59.2	0.515	135.69	132.85	2.917	129.69	126.96
Haliaeetus albicilla	16	73.6	56.8	0.513	121.65	121.63	2.881	120.34	119.87
Aegypius monachus	12	96.5	73.7	0.510	267.31	267.96	2.861	203.45	202.91
Falco rusticolus	10	61.9	47.9	0.513	72.71	72.65	2.878	85.21	85.14
Falco cherrug	72	54.7	41.9	0.514	49.38	49.41	2.879	66.01	65.89
Falco peregrinus	12	51.7	41.1	0.522	45.51	45.69	2.929	61.86	62.44
Falco subbuteo	36	41.4	32.8	0.516	22.94	22.98	2.909	39.46	39.37
Falco columbarius	14	40.3	32.9	0.519	22.64	23.78	2.908	38.52	40.43
Falco vespertinus	81	36.8	29.3	0.516	16.35	16.41	2.912	31.47	31.47
Falco naumanni	23	36.9	30.4	0.517	17.69	17.91	2.936	32.99	33.25
Falco tinnunculus	138	39.2	31.7	0.514	20.19	20.24	2.917	36.17	36.17
Galliformes	383	36.8	28.1	0.506	16.37	16.37	2.848	30.82	30.46
Lagopus lagopus	34	42.3	31.1	0.509	20.82	20.79	2.841	37.35	37.08
Lyrurus tetrix	13	49.7	35.9	0.510	32.56	32.52	2.823	50.26	50.12
Tetrao urogallus	15	56.1	41.4	0.508	50.37	50.77	2.821	66.24	66.72
Tetrastes bonasia	20	40.4	29.4	0.512	17.87	17.78	2.834	33.65	33.48
Alectoris chukar	27	41.5	31.2	0.502	20.26	20.11	2.829	36.61	36.34
Perdix perdix	81	34.1	26.7	0.503	12.22	12.47	2.853	25.96	26.27
Perdix dauricae	26	32.6	25.3	0.503	10.51	10.41	2.856	23.56	23.33
Coturnix coturnix	127	30.1	23.0	0.503	8.02	8.00	2.846	19.71	19.61
Phasianus colchicus	40	44.7	35.1	0.512	28.28	28.42	2.889	45.41	45.36
Gruiformes	465	49.4	34.4	0.510	41.39	41.28	2.806	52.96	52.86
Grus grus	24	97.7	62.3	0.509	192.93	191.78	2.752	167.44	165.98
Anthropoides virgo	24	82.3	52.0	0.509	113.11	113.09	2.740	117.19	116.97
Rallus aquaticus	20	36.6	26.6	0.511	13.28	13.47	2.822	27.53	27.89
Porzana porzana	42	35.1	24.2	0.512	10.56	10.57	2.801	23.84	23.83
Porzana parva	26	30.5	22.1	0.511	7.64	7.63	2.829	19.11	19.07
Crex crex	80	36.7	26.7	0.510	13.36	13.40	2.828	27.72	27.74
Gallinula chloropus	96	42.8	30.7	0.513	20.68	20.95	2.825	37.09	37.39
Fulica atra	111	51.8	36.1	0.508	34.28	34.22	2.789	52.09	52.04
Otis tarda	26	79.3	57.1	0.510	131.79	131.66	2.822	127.81	127.11
Tetrax tetrax	16	51.3	39.6	0.508	41.37	40.98	2.863	58.45	57.94
Charadriiformes	1649	49.3	35.1	0.501	35.21	35.24	2.790	50.76	50.57
Burhinus oedicnemus	17	54.5	40.2	0.512	45.01	45.08	2.843	62.22	62.16
Pluvialis squatarola	13	54.1	37.1	0.493	36.78	35.77	2.759	55.38	53.78
Pluvialis apricaria	11	52.4	36.5	0.490	34.28	33.65	2.748	52.62	52.00
Charadrius dubius	25	29.9	22.5	0.496	7.53	7.59	2.804	18.89	18.94
Charadrius alexandrinus	12	32.0	23.7	0.500	9.02	9.00	2.812	21.38	21.28
Eudromias morinellus	13	43.0	30.1	0.502	19.53	19.48	2.778	35.88	35.78
Vanellus vanellus	94	46.3	33.1	0.488	24.71	24.62	2.742	41.97	41.82
Arenaria interpres	12	39.5	29.3	0.491	16.70	16.79	2.775	32.18	32.27
Himantopus himantopus	32	44.7	32.0	0.494	22.64	22.88	2.760	39.51	39.82
Recurvirostra avosetta	50	50.7	35.3	0.495	31.18	31.14	2.752	49.18	49.05
Haematopus ostralegus	31	55.5	40.2	0.505	45.34	45.49	2.804	62.59	62.73
Tringa ochropus	12	40.1	28.6	0.492	16.14	16.09	2.758	31.64	31.50
Tringa glareola	13	39.6	28.1	0.488	15.26	15.34	2.738	30.44	30.59

Order / Species	*n*	*L*	*D*	*Kv*	*Vcal*	*Vexp*	*Ks*	*Scal*	*Sexp*
Tringa nebularia	12	51.5	35.4	0.489	31.51	31.68	2.729	49.73	49.52
Tringa totanus	67	44.0	30.8	0.487	20.29	20.30	2.728	36.94	36.89
Tringa erythropus	10	48.9	34.3	0.492	28.30	28.32	2.747	46.08	46.12
Tringa stagnatilis	12	38.4	26.6	0.492	13.34	13.35	2.740	27.96	27.98
Actitis hypoleucos	36	35.2	25.9	0.492	11.61	11.58	2.776	25.31	25.19
Xenus cinereus	12	37.8	27.7	0.490	14.23	14.13	2.768	28.97	28.78
Phalaropus lobatus	20	29.8	20.6	0.487	6.19	6.13	2.726	16.75	16.60
Philomachus pugnax	11	45.0	31.2	0.487	21.38	21.39	2.727	38.34	38.17
Calidris temminckii	15	28.3	21.4	0.494	6.39	6.37	2.802	16.94	16.89
Calidris maritima	10	39.5	27.6	0.494	14.89	14.80	2.758	30.08	29.90
Gallinago gallinago	47	39.3	28.0	0.492	15.14	15.28	2.752	30.26	30.47
Gallinago media	13	45.1	32.7	0.492	23.66	23.45	2.770	40.78	40.41
Scolopax rusticola	34	44.9	34.1	0.502	26.13	26.13	2.830	43.26	43.12
Numenius arquata	12	70.4	48.1	0.493	80.19	78.18	2.752	93.11	90.61
Numenius phaeopus	11	61.3	41.8	0.488	52.42	51.92	2.724	69.85	69.19
Limosa limosa	23	55.5	38.5	0.487	40.07	39.96	2.756	58.27	57.96
Glareola pratincola	13	31.0	24.2	0.512	9.30	9.25	2.889	21.66	21.58
Stercorarius parasiticus	11	58.1	41.4	0.499	49.76	49.38	2.786	66.95	66.45
Larus ichthyaetus	14	77.8	53.3	0.506	112.18	111.94	2.780	115.37	115.08
Larus melanocephalus	45	54.6	38.8	0.506	41.61	41.68	2.804	59.43	59.34
Larus ridibundus	283	52.0	36.7	0.506	35.36	35.34	2.797	53.28	53.16
Larus genei	31	54.7	39.0	0.508	42.22	42.21	2.804	59.77	59.74
Larus argentatus	25	74.5	51.6	0.511	101.24	100.91	2.805	107.73	107.02
Larus cachinnans	138	71.2	49.8	0.507	89.68	89.30	2.798	99.32	98.56
Larus canus	43	56.0	41.0	0.509	48.05	49.00	2.821	64.88	65.79
Rissa tridactyla	17	58.3	41.7	0.508	51.55	51.30	2.814	68.47	68.09
Chlidonias niger	82	34.5	25.2	0.499	10.92	10.88	2.796	24.30	24.17
Chlidonias leucopterus	22	36.8	26.4	0.499	12.77	12.88	2.779	26.97	27.03
Chlidonias hybrida	33	39.1	28.2	0.500	15.59	15.37	2.799	30.92	30.43
Gelochelidon nilotica	22	50.6	36.2	0.509	33.80	33.88	2.811	51.54	51.53
Hydroprogne caspia	12	66.3	46.1	0.512	72.21	72.50	2.803	85.89	85.84
Sterna hirundo	94	41.7	30.8	0.505	20.00	19.95	2.822	36.28	36.13
Sterna paradisaea	45	40.6	29.2	0.508	17.64	17.45	2.820	33.40	33.08
Sterna albifrons	39	32.0	23.9	0.506	9.24	9.23	2.834	21.66	21.58
Columbiformes	123	35.6	26.4	0.517	13.30	13.44	2.867	27.25	27.12
Columba palumbus	31	41.0	29.7	0.516	18.68	18.64	2.848	34.72	34.59
Columba oenas	24	36.9	28.1	0.516	15.07	15.09	2.881	29.91	29.87
Columba livia	17	37.6	28.3	0.518	15.56	15.47	2.881	30.62	30.44
Streptopelia turtur	51	30.9	22.9	0.517	8.38	8.34	2.868	20.30	20.17
Cuculiformes	39	22.8	16.9	0.518	3.36	3.37	2.866	11.02	11.05
Cuculus canorus	39	22.8	16.9	0.518	3.36	3.37	2.866	11.02	11.05
Strigiformes	232	43.6	35.6	0.517	31.66	31.76	2.931	47.01	47.15
Nyctea scandiaca	24	55.9	45.2	0.514	58.77	58.96	2.914	73.70	73.81
Bubo bubo	19	61.2	49.5	0.514	77.22	77.33	2.914	88.37	88.43
Asio otus	62	40.4	32.6	0.517	22.23	22.19	2.926	38.56	38.48
Asio flammeus	40	39.9	32.3	0.516	21.41	22.16	2.905	37.35	38.39
Otus scops	20	31.5	27.0	0.519	11.88	11.89	2.978	25.27	25.30
Athene noctua	20	33.4	28.6	0.518	14.18	14.12	2.978	28.47	28.36
Strix aluco	35	46.9	38.5	0.518	36.12	36.18	2.943	53.24	53.21
Strix nebulosa	12	51.8	41.9	0.517	47.06	46.87	2.929	63.63	63.34
Caprimulgiformes	31	30.9	21.7	0.521	7.63	7.60	2.850	19.16	19.07
Caprimulgus europaeus	31	30.9	21.7	0.521	7.63	7.60	2.850	19.16	19.07
Apodiformes	20	24.7	16.5	0.523	3.53	3.55	2.825	11.54	11.58
Apus apus	20	24.7	16.5	0.523	3.53	3.55	2.825	11.54	11.58
Coraciiformes	238	27.2	22.1	0.518	7.66	7.66	2.941	18.29	18.31

Order / Species	*n*	*L*	*D*	*Kv*	*Vcal*	*Vexp*	*Ks*	*Scal*	*Sexp*
Coracias garrulus	66	35.7	28.1	0.516	14.53	14.55	2.904	29.10	29.10
Alcedo atthis	101	22.2	18.6	0.519	3.97	3.98	2.959	12.18	12.20
Merops apiaster	71	26.5	21.7	0.521	6.47	6.51	2.949	16.90	16.98
Upupiformes	133	25.8	17.8	0.517	4.25	4.24	2.820	12.98	12.97
Upupa epops	133	25.8	17.8	0.517	4.25	4.24	2.820	12.98	12.97
Piciformes	536	23.7	17.9	0.516	4.21	4.19	2.878	12.55	12.49
Jynx torquilla	248	20.5	15.6	0.517	2.58	2.57	2.888	9.22	9.19
Picus viridis	13	30.5	23.4	0.515	8.57	8.60	2.881	20.52	20.56
Picus canus	41	28.4	21.4	0.512	6.64	6.64	2.862	17.37	17.35
Dryocopus martius	15	34.7	25.2	0.506	11.36	11.19	2.808	24.56	24.69
Dendrocopos major	125	26.7	19.9	0.516	5.43	5.41	2.868	15.18	15.11
Dendrocopos medius	71	25.0	19.0	0.515	4.64	4.64	2.875	13.64	13.62
Dendrocopos minor	23	18.7	14.8	0.518	2.12	2.12	2.912	8.03	8.04
Passeriformes	5847	21.6	15.9	0.511	3.60	3.58	2.849	10.56	10.52
Riparia riparia	79	17.2	12.6	0.511	1.40	1.40	2.837	6.15	6.15
Hirundo rustica	48	19.6	13.6	0.512	1.87	1.87	2.81	7.52	7.52
Delichon urbica	60	19.5	13.5	0.51	1.82	1.82	2.801	7.39	7.38
Galerida cristata	28	22.6	16.9	0.51	3.29	3.28	2.85	10.86	10.82
Melanocorypha calandra	22	24.2	17.7	0.506	3.87	3.87	2.815	12.11	12.10
Lullula arborea	16	21.6	16.7	0.515	3.10	3.11	2.886	10.39	10.43
Alauda arvensis	36	23.5	16.8	0.508	3.37	3.35	2.816	11.11	11.05
Anthus campestris	12	20.2	15.2	0.51	2.39	2.38	2.853	8.78	8.74
Anthus trivialis	91	20.3	15.4	0.509	2.44	2.43	2.85	8.90	8.84
Anthus pratensis	17	20.0	14.8	0.514	2.26	2.25	2.852	8.44	8.43
Motacilla flava	49	18.5	14.1	0.506	1.86	1.85	2.85	7.42	7.39
Motacilla alba	52	19.9	14.8	0.511	2.22	2.22	2.848	8.37	8.34
Lanius collurio	181	21.8	16.4	0.514	3.02	3.00	2.869	10.27	10.21
Lanius minor	29	24.9	17.8	0.512	4.05	3.99	2.835	12.57	12.39
Oriolus oriolus	49	30.6	21.4	0.515	7.24	7.23	2.827	18.51	18.48
Sturnus vulgaris	124	28.8	21.2	0.512	6.61	6.61	2.839	17.30	17.31
Garrulus glandarius	112	31.0	22.8	0.509	8.24	8.20	2.835	20.08	19.97
Pica pica	327	33.3	23.7	0.507	9.52	9.47	2.807	22.15	22.01
Corvus monedula	109	34.7	24.9	0.508	11.00	10.92	2.817	24.39	24.21
Corvus frugilegus	121	40.1	28.0	0.503	15.88	15.83	2.783	31.27	31.17
Corvus corone	27	43.5	30.0	0.506	19.83	19.78	2.781	36.30	36.20
Corvus cornix	190	41.4	29.4	0.506	18.15	18.10	2.799	34.08	33.97
Corvus corax	97	49.3	33.4	0.509	27.95	27.79	2.783	45.75	45.49
Troglodytes troglodytes	19	16.7	12.3	0.508	1.28	1.28	2.835	5.81	5.80
Locustella luscinioides	16	19.4	14.6	0.515	2.13	2.12	2.867	8.11	8.09
Locustella naevia	15	17.1	13.6	0.511	1.62	1.61	2.898	6.72	6.69
Acrocephalus paludicola	16	16.9	13.3	0.51	1.53	1.55	2.874	6.45	6.55
A. schoenobaenus	15	18.0	13.8	0.511	1.74	1.74	2.865	7.09	7.09
Acrocephalus agricola	13	16.5	12.4	0.514	1.30	1.30	2.865	5.84	5.83
Acrocephalus palustris	54	18.1	13.3	0.509	1.64	1.63	2.835	6.84	6.79
Acrocephalus scirpaceus	43	18.4	13.8	0.513	1.80	1.79	2.864	7.28	7.22
Acrocephalus arundinaceus	49	22.6	16.2	0.511	3.03	3.04	2.82	10.32	10.33
Hippolais icterina	52	18.7	13.7	0.511	1.80	1.80	2.842	7.28	7.26
Sylvia nisoria	80	21.3	15.6	0.512	2.65	2.64	2.841	9.41	9.37
Sylvia hortensis	15	20.1	15.2	0.517	2.39	2.38	2.88	8.78	8.75
Sylvia atricapilla	232	19.8	14.7	0.512	2.20	2.20	2.853	8.31	8.29
Sylvia borin	70	20.1	15.2	0.512	2.38	2.37	2.86	8.75	8.72
Sylvia communis	149	18.6	14.1	0.51	1.90	1.89	2.864	7.52	7.48
Sylvia curruca	45	16.9	12.9	0.51	1.44	1.44	2.867	6.26	6.23
Phylloscopus trochilus	29	20.1	12.0	0.512	1.49	1.17	2.871	6.92	5.43
Phylloscopus collybita	44	15.3	12.1	0.512	1.16	1.15	2.9	5.38	5.36

Order / Species	*n*	*L*	*D*	*Kv*	*Vcal*	*Vexp*	*Ks*	*Scal*	*Sexp*
Phylloscopus sibilatrix	169	16.2	12.8	0.512	1.36	1.37	2.888	5.98	5.99
Ficedula hypoleuca	24	17.5	13.5	0.511	1.64	1.63	2.876	6.80	6.77
Ficedula albicollis	100	18.1	13.4	0.513	1.66	1.65	2.852	6.91	6.87
Ficedula parva	134	17.2	12.9	0.516	1.48	1.44	2.888	6.41	6.23
Muscicapa striata	115	18.8	14.1	0.514	1.93	1.92	2.864	7.61	7.59
Saxicola rubetra	78	18.7	14.5	0.509	1.99	1.99	2.867	7.75	7.73
Saxicola torquata	31	17.9	14.3	0.51	1.86	1.86	2.893	7.38	7.38
Oenanthe oenanthe	49	20.4	15.6	0.512	2.54	2.53	2.869	9.11	9.10
Phoenicurus phoenicurus	50	19.1	14.0	0.51	1.91	1.90	2.83	7.57	7.56
Erithacus rubecula	64	19.5	15.1	0.519	2.30	2.30	2.904	8.53	8.53
Luscinia megarhynchos	16	20.4	15.2	0.514	2.43	2.42	2.862	8.88	8.84
Luscinia luscinia	114	21.8	16.0	0.513	2.87	2.86	2.846	9.93	9.91
Luscinia svecica	61	18.6	14.5	0.509	1.99	1.98	2.87	7.73	7.71
Turdus pilaris	20	28.3	21.1	0.514	6.51	6.47	2.869	17.15	17.05
Turdus merula	122	29.1	21.5	0.515	6.96	6.99	2.858	17.89	17.92
Turdus philomelos	122	27.0	20.4	0.509	5.71	5.69	2.851	15.66	15.62
Turdus viscivorus	13	33.3	23.2	0.51	9.17	9.13	2.8	21.64	21.56
Panurus biarmicus	25	17.9	14.2	0.517	1.87	1.87	2.921	7.43	7.41
Aegithalos caudatus	93	14.2	11.2	0.513	0.91	0.91	2.893	4.59	4.58
Remiz pendulinus	45	16.2	10.6	0.517	0.94	0.94	2.789	4.78	4.77
Parus palustris	43	16.2	12.6	0.508	1.31	1.31	2.87	5.87	5.85
Parus caeruleus	128	15.8	12.1	0.509	1.18	1.20	2.856	5.45	5.49
Parus cyanus	13	16.6	11.9	0.512	1.20	1.20	2.823	5.55	5.55
Parus major	115	17.8	13.6	0.508	1.68	1.68	2.856	6.93	6.93
Sitta europaea	54	20.0	14.8	0.512	2.24	2.24	2.85	8.43	8.41
Certhia familiaris	40	15.8	12.0	0.512	1.17	1.16	2.863	5.43	5.43
Passer domesticus	74	22.3	15.6	0.515	2.80	2.78	2.829	9.84	9.75
Passer hispaniolensis	14	21.2	15.9	0.528	2.83	2.85	2.909	9.80	9.87
Passer montanus	122	19.2	14.2	0.517	1.99	1.98	2.867	7.78	7.75
Fringilla coelebs	225	19.8	14.6	0.51	2.16	2.16	2.839	8.21	8.19
Serinus serinus	11	17.3	12.7	0.5	1.40	1.39	2.807	6.16	6.12
Chloris chloris	143	19.8	14.6	0.514	2.17	2.16	2.854	8.23	8.21
Carduelis carduelis	71	17.7	13.2	0.51	1.56	1.56	2.844	6.61	6.61
Acanthis cannabina	76	18.1	13.5	0.512	1.70	1.70	2.853	7.00	6.98
Acanthis flammea	16	17.7	12.3	0.511	1.37	1.37	2.809	6.12	6.12
Carpodacus erythrinus	30	20.1	14.4	0.505	2.09	2.09	2.799	8.07	8.07
C. coccothraustes	149	23.9	17.7	0.51	3.84	3.83	2.842	12.05	12.02
Emberiza calandra	9	22.1	16.3	0.508	3.05	3.06	2.828	10.24	10.28
Emberiza citrinella	99	21.4	16.3	0.513	2.94	2.94	2.871	10.04	10.03
Emberiza schoeniclus	30	19.8	14.9	0.509	2.24	2.25	2.845	8.40	8.43
Emberiza aureola	71	20.2	15.0	0.512	2.33	2.33	2.851	8.65	8.62
Emberiza hortulana	37	20.3	15.6	0.512	2.53	2.52	2.87	9.09	9.06

Note: *n* – quantity of eggs, *L* – length of egg, *D* – egg diameter, k_v – volume index, V_{cal} – directly calculated volume, *Vexp* – volume, calculated by computer method, *ks* – surface index, S_{cal} – directly calculated surface area, S_{exp} – surface area, calculated by computer method.

DISCUSSION

As follows, given in this work indices for measurement of volume and surface area of birds eggs according to their length and diameter, which were gotten on the basis of huge factual material,are more definitive and informative in the comparison with existing in the literature methods.

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