THE GLOSS OF EGGS

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IT HAS been a matter of occasional comment from the earliest times that some species of birds lay very glossy eggs while others lay very dull or matt ones. It has no doubt been observed that within the same species, one female will sometimes lay much glossier eggs than another. Presumably it may have been noted that sometimes within a single clutch some eggs will be glossier than others, for at times it is very obvious, but we have seen no comments on the point. Much more often the difference may escape casual notice, but can be seen if it is deliberately looked for. In other cases it seems impossible to say that any difference exists with the unaided eye, and objective instrumental tests become necessary. It seemed to us that the phenomenon was very widespread among many species, and, by considering the egg shapes and pigmentation, it appeared probable that it was the last egg that was normally the least glossy. The present investigation tests these points by means of a gloss-meter devised for this purpose.

METHODS

The following sets of eggs became available:

Great Skua or Bonxie (*Catharacta skua*). Through the kindness and collaboration of Dr. Finnur Gudmundsson, nine clutches each of two eggs, of the nominate race from southeast Iceland, collected at one time in 1954, were obtained.

Black Guillemot (*Cepphus grylle*). Through the kindness of Professor Charles E. Huntington, ten clutches were obtained from Kent Island, Maine in 1955 and 1956. Since they were not obtained simultaneously, there is a possibility of duplication of parentage, but the eggs of 1955 and those of 1956 show much the same significant differences when tested separately.

House Wren (*Troglodytes aedon*). Fifteen clutches obtained on the Preston Laboratory grounds (Butler, Pennsylvania) in 1956 were tested. It is practically certain that some parentages were duplicated, but in 1957 a much longer series, more than forty clutches, was obtained, and it was clear that the phenomena were persistent ones and that duplication of parentage was not too serious a disturbing factor.

American Robin (*Turdus migratorius*). Thirteen clutches were available, collected on the Preston Laboratory grounds, mostly in 1957. There was probably little or no duplication of parentage here, and the decline of gloss on the last egg was quite pronounced in most clutches.

Laughing Gull (*Larus atricilla*) and Common Tern (*Sterna hirundo*). These collections of eggs from New Jersey served for previous reports on egg shape and egg pigmentation (Preston and Preston, 1953; Gemperle and Preston, 1955; Preston, 1957). In the present investigation we used 16 clutches of the Laughing Gull and 22 of the Common Tern.

Common Starling (*Sturnus vulgaris*). Thirteen clutches of these eggs were collected on the Preston Laboratory grounds in 1957. Here it is certain that there was much duplication of parentage due to renesting, and the series was not very satisfactory on that account. The measurements show a substantial difference in gloss due to parentage, that is, from clutch to clutch, but no certain difference due to sequence. This finding should not be assumed to apply to the species in its entirety on the basis of this sample, but the results are included since they may indicate that there are species that do not follow the general rule of decreasing gloss.

Assorted Eggs

With the point proved for several species, it becomes possible to take a short cut as to how "birds in general" behave. By taking a random sample of clutches of many species, it is possible to establish that most species act in a particular way, though it is *not* possible to say that any specified species does so, since the number of clutches of any *single* species was statistically inadequate. We had available eighteen clutches of fourteen species, all but three collected at Preston Frith (the Preston Laboratory Grounds), mostly in 1956 and 1957. These may fairly be regarded as a random sample of the commoner birds of western Pennsylvania, or indeed of a much more extensive area of the northeastern United States.

The series (one clutch of each species, unless otherwise stated) is as follows: Least Tern (*Sterna albifrons*), Mourning Dove (*Zenaidura macroura*), Yellow-shafted Flicker (*Colaptes auratus*), Great Crested Flycatcher (*Myiarchus crinitus*), Eastern Phoebe (*Sayornis phoebe*) (two clutches), Tree Swallow (*Iridoprocne bicolor*), Tufted Titmouse (*Parus bicolor*), Catbird (*Dumetella carolinensis*) (two clutches), Brown Thrasher (*Toxostoma rufum*) (two clutches), Eastern Bluebird (*Sialia sialis*), American Redstart (*Setophaga ruticilla*), House Sparrow (*Passer domesticus*), Rufous-sided Towhee (*Pipilo erythrophthalmus*) (two clutches), and Song Sparrow (*Melospiza melodia*).

The selection, from the material available with known sequence of laying, is random, except that species covered more completely in the other series are omitted. Note that most are passerines, though three

are not, and that all were obtained in western Pennsylvania except the Least Tern and Tree Swallow (southern New Jersey).

With the smaller eggs we measured the gloss at four points around the egg; with the larger eggs this was increased to six. The variations in readings thus obtained, usually small, are ascribed to the "Test." They might represent real variations in gloss from place to place on the egg, or might be due to our placing the egg slightly differently over the testing aperture.

In the case of the Laughing Gull and Common Tern we used only clutches that consisted of three eggs, and we measured all the eggs. Then by an Analysis of Variance we first proved a significant difference between first and terminal ('F' and 'T') eggs, and then proved further that a smaller, but still significant, difference existed between first and second ('F' and 'S') eggs. With all other species we measured only first and terminal eggs, though with the Skua and some others the second egg was also the terminal one.

TABLE 1

"G" VALUES FOR FIRST AND TERMINAL EGGS OF VARIOUS SERIES

	Mean "F"	*Mean "T"*	*Difference*	*% Diff. Mean F*	*No. of Clutches Tested*
Great Skua	2.07	1.89	0.18	8.7	9
Laughing Gull	3.06	2.85	0.21	6.9	14
Common Tern	2.50	2.32	0.18	7.2	22
Black Guillemot	2.46	2.33	0.13	5.3	10
House Wren	1.88	1.78	0.10	5.3	15
Robin	3.20	2.94	0.26	8.1	13
Starling	3.29	3.27	0.02	0.6	13
"Assorted Eggs"	2.76	2.61	0.15	5.4	18

"G" VALUES FOR FIRST AND SECOND EGGS OF VARIOUS SERIES

	Mean "F"	*Mean "S"*	*Difference*	*% Diff. Mean F*	*No. of Clutches Tested*
Laughing Gull	3.06	2.98	0.08	2.6	14
Common Tern	2.50	2.42	0.08	3.2	22

In all cases except that of the Starling the difference reported is significant to the 1% level.

Procedure and Apparatus

When light is incident on a perfectly glossy surface, its reflection can only be observed at the specular angle, equal to the angle of incidence. A perfectly matt surface, on the other hand, is one with uni-

form microscopic irregularities and it reflects, or diffuses, the light equally in all directions. Most surfaces combine the properties of the matt and glossy surfaces. The incident light, besides being reflected at the surface, may also penetrate beneath the surface to be absorbed, transmitted, or internally reflected. In the case of egg shells, moreover, instead of uniform plane surfaces we must deal with curved, pigmented surfaces, further complicating the picture.

Since light which is reflected from a surface, then, is composed of a diffuse component reflected in all directions and a glossy component, reflected in the specular direction, we decided to measure the gloss by means of a gloss number, G, defined as

$$G = I_1/I_2$$

where I_1 is the measured intensity in the direction of specular reflection and I_2 is the intensity in the direction of the normal measured at the same distance from the point of incidence on the shell. The angle of incidence used was 45°.

While it is not certain that these measurements will correlate perfectly with visual gloss estimates, they seem to come close to doing so and the method adopted measures a property of the egg which is closely allied with its "gloss," and a systematic tendency of this property to vary with the clutch sequence is indicated.

The measurement of the specular and normal light intensities was done with a light balancing circuit using two photo-electric cells. The size of the aperture through which light reached one of the cells was varied until both cells received the same amount of light. The ratio of intensities was then found from the inverse of the ratio of sizes of the apertures. More details on the optical arrangement and the electrical circuit may be found in the complete report of these tests being filed at Carnegie Museum, Pittsburgh.

The procedure followed was to position the egg carefully against a small aperture where a small beam of light was incident on the shell at an angle of 45° to the plane of the aperture. The specularly reflected beam, somewhat defocussed by the texture and curvature of the shell, was then centered on the aperture to one of the photo cells. The other cell was placed so as to receive the light diffusely reflected in a direction perpendicular to the plane of the aperture. The aperture to the first cell was then adjusted for balance.

An effort was made to select a portion of the egg as free as possible from dark spots, that is, a region of uniform background color. But it is not the nature of eggs to be perfectly uniform in this respect and no doubt some tiny spots of pigment were often included. Further-

more, the so-called background colors of the eggs to be compared, that is, of the two or three eggs of the same clutch, were not necessarily identical. It must be emphasized, then, that a single measurement is a function only of the spot on which it was made and is not necessarily characteristic of the whole egg. However, by measuring several places around the egg, we put ourselves in a position, by means of a partition of variance, to see if this matter is important.

The tabulations of the actual measurements are voluminous and tedious; they also are being filed at Carnegie Museum. The data were submitted to a three-way analysis of variance to determine (a) whether gloss varied significantly from spot to spot around the egg, (b) whether it varied significantly between the various eggs of a clutch and especially between the first and last eggs of a clutch, and (c) whether it varied with the parent. The interactions between these factors must also be considered. This is standard practice, but is once more a lengthy and tedious business. The details are being filed at Carnegie Museum, where they may be consulted by those interested.

When the variance ratio is less than that for the 5 per cent level we have considered that we have failed to prove significance: if it exceeds the 1 per cent level we have considered it definitely significant: in between is a zone where we might suspect significance but conviction could come only from much more testing.

DISCUSSION

It appears that, in general, eggs are about equally glossy all the way round, which in a sense is evidence that the apparatus is satisfactory as well as the egg. Except in the case of the Starling, there is substantial (significant) difference between the gloss of eggs from one parent and those from another, and there is also substantial difference between the gloss of the first and last eggs of a clutch, the first tending to be definitely more glossy, though there are occasional exceptions. Further, the interaction component shows that some parents lay eggs that, independently of the actual level of gloss in the clutch as a whole, decline more spectacularly in gloss from first to last egg than do the eggs from other parents.

In some cases the decline in gloss appears to be concentrated on the last egg. For instance in the Flicker clutch, all the eggs but the last were very glossy, while the last egg was very matt, as if the bird had suddenly run out of mucin (Romanoff, 1949:170), or whatever it is that makes eggs glossy. But in many other cases the decline is clearly spread over the whole sequence, though generally accelerated at the last egg. This can often be detected without instruments. As men-

tioned above we have investigated the matter instrumentally for two species only, the Laughing Gull and the Common Tern and shown that there is a statistically significant difference between first and second eggs (a matter we were not sure about in these species by mere visual inspection), but the major decline is between the second and third (or terminal) eggs. In this respect gloss follows the general pattern of pigmentation and shape—the major change comes with the last egg.

In the collection of "Assorted Eggs," in most cases the last egg was distinctly less glossy than the first. In any species, the extent to which the first egg is glossier than the last varies considerably: it may be a big difference, or it may be a slight one, but it is almost always in the same direction. The reverse arrangement, with the last egg *more* glossy, has been encountered several times, but then the difference is usually slight, so that there is virtual equality of gloss between first and last eggs. These exceptions are: (1) Mourning Dove (one clutch); the difference is slight. However there is some possibility that doves and pigeons rather generally lay eggs that do not differ appreciably in gloss. (2) Song Sparrow (one clutch); this may have been a freak instance. (3) Eastern Phoebe (two clutches); in one clutch there was no difference; in the other, the last egg was somewhat more glossy. This species is peculiar in that the last egg of a clutch seems to carry more pigment, the wreath of cinnamon spots at the large end being more pronounced on the last egg. (4) American Redstart (one clutch); the first and last eggs are almost identical in gloss. (5) Brown Thrasher (two clutches); in one clutch the gloss declined a great deal from first to last egg; in the other clutch there is a very trifling *increase* in gloss, the two eggs being almost identical. None of these observations has any statistical significance, but a larger series of clutches might uncover species besides the Starling where gloss does not decline regularly with sequence.

While the readings of the gloss meter probably give an accurate comparison between eggs of approximately the same size, so that, for instance, the relative gloss of American Robin and Starling eggs may be compared directly, it is possible that with eggs of radically different size and curvature we cannot make a very direct comparison. The gloss values as reported by the instrument may not be completely independent of the size of eggs. For all we know the human eye may experience the same difficulty, but perhaps we unconsciously make some allowance for it, which the instrument cannot do. We have not investigated any of these matters, having been concerned for the present chiefly to determine variations of gloss within a clutch or a series

of clutches of one species, and we believe the results here are strictly valid.

There are other points that come out in the analysis, but for these the typescript at Carnegie Museum should be consulted.

CONCLUSIONS

(1) Assuming that the available series of clutches are representative of the corresponding species (which seems probable), there is a systematic tendency for the "terminal" egg to be less glossy than the first egg in clutches of the following species: Great Skua, Laughing Gull, Common Tern, Black Guillemot, House Wren, and Robin. The test of "assorted eggs" indicates that this must be true of many other species, though the number of clutches examined of any one species is inadequate to show of which species it is true.

(2) The magnitude of this effect depends to a considerable extent on the parent as well as the species; the degree to which it is consistently independent of the individual parent is highest in the cases of the American Robin and House Wren.

(3) We have found no evidence of any such systematic tendency in available clutches of the Starling.

(4) In the clutches of three eggs which were tested, of the Laughing Gull and Common Tern, the first egg appears to be generally more glossy than the second. It is the third, or final egg, however, which differs most from the others.

(5) All the series tested containing no duplications of parentage show a systematic tendency for the gloss to vary with the parentage.

While "gloss" is a rather complicated concept, something agreeing quite closely with what we experience as gloss can be measured by purely physical (instrumental) means, and the instrumental readings confirm our subjective findings, though they are more sensitive in detecting small differences, and are quantitative in nature.

With these and previous papers it seems to be established that with many species the following things come to pass as the clutch sequence proceeds:

The eggs gradually become less glossy, usually with a great acceleration at the last egg. (This paper.)

In some species, such as the House Wren, the size of the egg increases as the clutch progresses (Kendeigh *et al.*, 1956); but in others such as the Herring Gull (*Larus argentatus*) and Lesser Black-backed Gull (*Larus fuscus*) (Paludan, 1951, quoted by Andersen, 1957), the Laughing Gull (Preston and Preston, 1953), the Common Tern (Gemperle and Preston, 1955), and the Velvet Scoter (*Melanitta fusca*)

(Koskimies, 1957, good bibliography), the breadth of the egg is significantly less in the last egg of the clutch. The shape changes, the two ends becoming more nearly alike (Preston and Preston, 1953).

The pigmentation declines, especially in the last egg of the clutch, (but the reverse is true of the Phoebe, *Sayornis phoebe*) and becomes differently distributed (Preston, 1957).

In general, if one egg differs substantially in any way from the rest, it is likely to be the last egg of the clutch.

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SUMMARY

1. Tests of eggs with a specially devised gloss-meter indicate that there is a systematic tendency for the last egg of a clutch to be less glossy than the first egg in the Great Skua, Laughing Gull, Common Tern, Black Guillemot, House Wren, and American Robin. This tendency was not found in the Starling.

2. Tests of one or two clutches of a number of other North American species, while statistically inadequate to show the situation in any one of such species, do suggest that the tendency for the terminal egg to be less glossy prevails generally, though it may not hold for all species or all clutches.

3. There is an apparent tendency for gloss to vary with parentage of the eggs.

4. The tendency for the last egg of the clutch to be less glossy is similar to previous findings that the last egg tends to differ in other respects, such as size, breadth, shape, and pigmentation.

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B.O.U. Centenary Celebration

The British Ornithologists' Union will celebrate its centenary from 20 to 23 March 1959 by a symposium with the theme "Progress and Prospects in Ornithology", at the University of Cambridge, England. Those interested in attending and wishing details should communicate with the Hon. Secretary of the B.O.U., Mr. Guy Mountfort, c/o Bird Room, British Museum (Natural History), Cromwell Road, London, S.W. 7, England.

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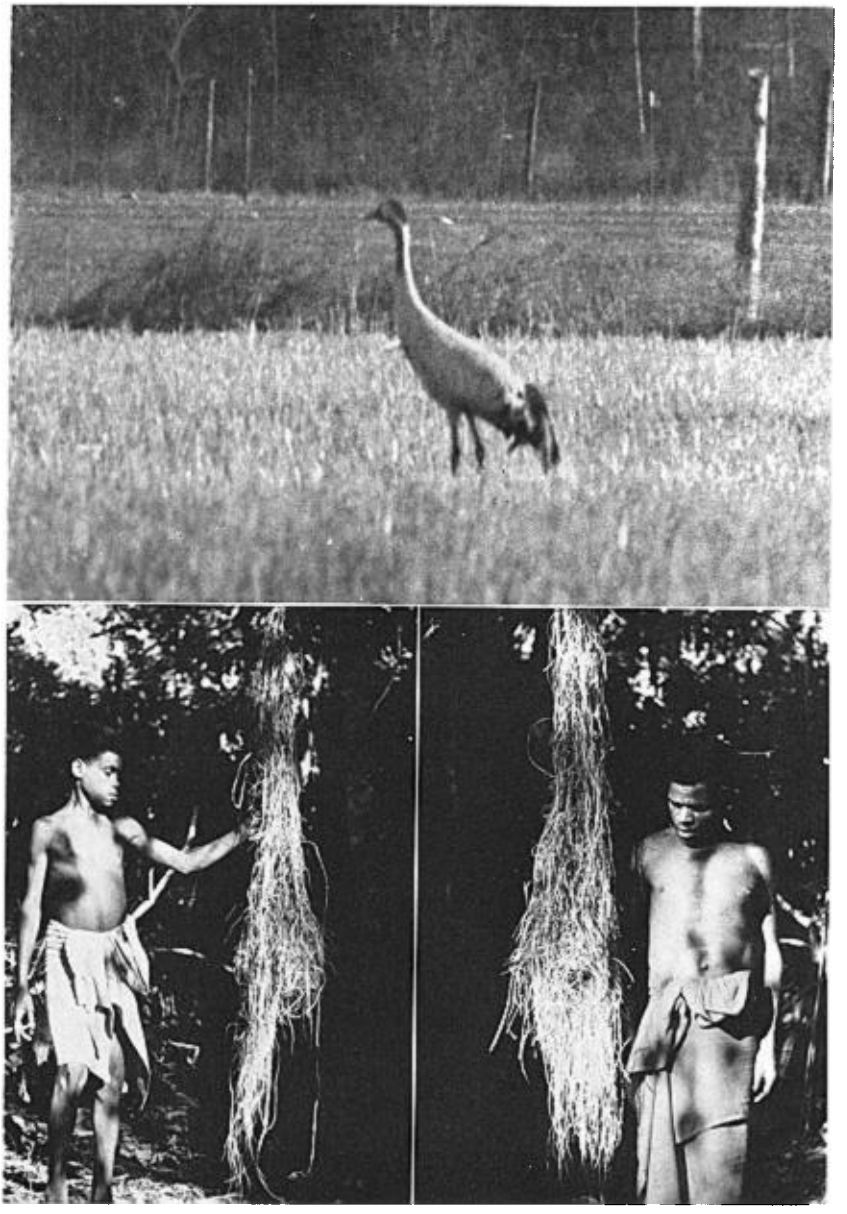

(*Above*) Common Crane, *Grus grus*, near Fairbanks, Alaska. Photo May 2, 1958 by Earl L. Schene.

(*Below*) Side and front view of nest of *Pomatostomus isidori*, Finisterre Mountains, New Guinea. Photos by E. Thomas Gilliard.