EGGS OF XANTUS AND CRAVERI MURRELETS

WITH ONE ILLUSTRATION

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This paper is a report upon an examination of one hundred eggs of each of two species of murrelets. Its purpose is to describe the shells, to compare the two series, and, from the data so obtained, to study the relationships between the birds themselves.

A secondary motive actuated the investigation. An examination was made into the probable results of a research somewhat more elaborate than conventional measurements. As the methods here adopted developed they demonstrated that they could be made to show, negatively, that certain geographical groups of similar birds do not interchange matings with each other. The possibilities of positive inferences and of approximating degrees of relationship warrant the accumulation of further data. This paper is therefore drawn in a form susceptible of indefinite expansion and its scope is limited by practical considerations. The importance of laying a foundation for future extension seems to me to overshadow the objective itself.

Nesting. There are some facts connected with the laying of the eggs which have a direct bearing on the findings. These murrelets are insular breeders. Their instinct is to nest at the end of a natural burrow or crevice. The preference is for a recess two or three feet deep and not much larger in diameter than themselves—one which excludes all light and allows only a frontal approach. *Endomychura hypoleuca* breeds in the Pacific; *Endomychura craveri* in the Gulf of California.

Either from preference or because of the environment there exist minor differences in the nesting habits of the two races. Craveri are the more consistent. I have met with no exceptions to the rule that they lay in a burrow or crevice, and in the dark, and that they do nothing to improve the nest. Their eggs rest on rocks or pebbles or hard earth. On the other hand incubating Xantus often so expose themselves as to be visible to the passer-by. They frequently occupy caves and pot-holes and, if these have sandy floors, they scrape shallow depressions. It is not at all unusual to find their eggs above the surface, under thick vegetation. There is a suggested approach towards *Synthliboramphus*.

Determinations. Every egg was measured for length and width. The shells, dry and empty, were weighed individually. Each was then filled with distilled water and weighed twice, once in air and once suspended in water. Corrections for barometric pressure and for temperature were not considered advisable, and beverage distilled water was used because it is generally available.

Technique. Aside from the customary precautions incidental to delicate weighing, this is largely a contest with internal air bubbles. The best results follow if the shells are kept submerged as they are being filled and if they are allowed to rest, holes uppermost, for several days. Repetitions until duplicated figures agree with originals are an essential test. In my own case it was noticeable that the figures became more consistent as my experience increased.

Size.

Xantus, average 34.88 cc.
Craveri, average 32.93 cc.

These figures are intended to represent Xantus and Craveri eggs in general and not merely those of the series. For that reason I have dropped all but two of the calculated decimals. Even as it is, the last one is not significant and is retained only because it qualifies the other. The question of how many decimals to use is delicate and is answered more through judgment than through mathematics. It is my intention, in all cases, that the penult shall be fixed. That is, I do not intend to pass the point where the last figure but one would be altered a full unit

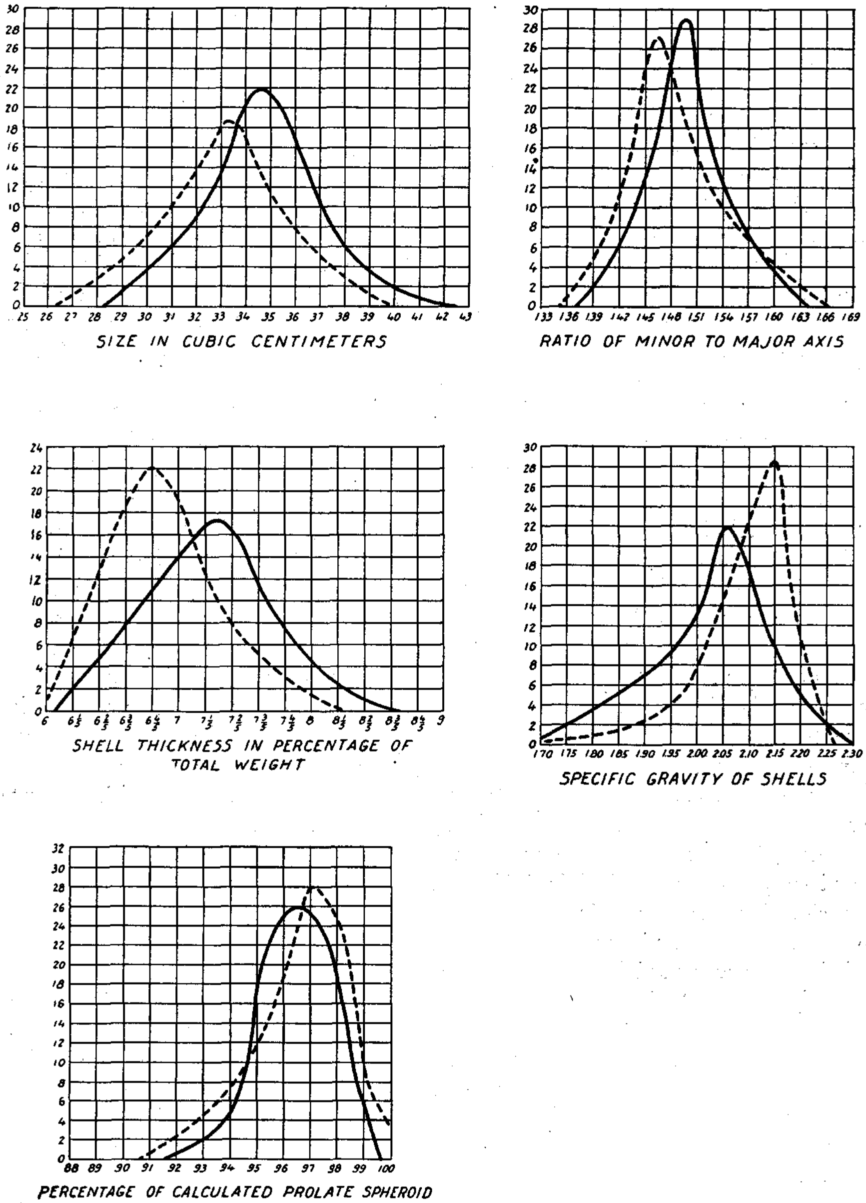

Fig. 91. Variations plotted for eggs of Xantus Murrelet (in solid lines) and Craveri Murrelet (in broken lines).

by any increase in the number of specimens on which it is based. If my surmise is correct in the case before us then we may regard as proven that the average external volume of eggs of the Craveri, for instance, is 32.9 cc. We may suspect that it approaches 32.93 more closely than 32.90 or 32.96, but on that refinement we have no certainty.

The distribution of the sizes is expressed with graphs[1] (fig. 91) in preference to the more customary use of extremes. The object is to minimize the influence of abnormalities. This work is predicated on the belief that, through averages, we can neutralize sports and technical errors and evolve normal types from a mass of irregularities, variations, and inconsistencies. Whatever can be learned by such means obviously is to be found in the centers, not on the edges, of the graphs.

The designation of sizes in cubic centimeters is a far better practice than the use of axial dimensions. It gives the values, in one set of figures, with an accuracy limited only by the patience of the observer. It forms a definite base both for the drawing of conclusions and for further calculations. So greatly am I impressed with its advantages that were this paper to result in nothing more than the adoption of cubic centimeters as the standard of size I would feel well repaid for the work.

The difference in the average volumes of the eggs of the two series is well marked and distinctive. It has been shown to be constant and therefore it precludes any present interchange of blood between the birds themselves. If the two races were not breeding as separate entities the differentiating characteristic could not maintain its distinctive inheritance. On the other hand the size of the egg could be, and most probably is, determined by the size of the mother. That, in turn, is subject to evolutionary selection and could therefore be altered in a biologically short space of time. So while we may be sure that Xantus and Craveri are now breeding independently of each other, the relative sizes of their eggs are not indicative of the length of the separation.

Axial dimensions. In deference to custom I give these in the conventional form.

Xantus, average 53.73 x 35.84 mm.
Craveri, average 52.37 x 35.21 mm.

Extremes. Xantus, *57.8* x 35.4, 57.0 x *38.0*, *49.3* x 34.2, 53.0 x *34.0*.
Craveri, *57.0* x 35.2, *49.0* x *32.6*, 54.8 x *38.1*

Shape. Of the possible mathematical expressions of shape I have selected two. One is the ratio between the major and the minor axes.[2] It represents the length of the shell in terms of the width.

Axial ratio of Xantus, average 1.499
Axial ratio of Craveri, average 1.488

If we calculate the cubic contents of a prolate spheroid having axes the same as those of a given egg, and if we then ascertain the actual size of that egg, we can determine its percentage of the spheroid.[3] These percentages vary with the degree to which the egg is rounded and more particularly with the average areas of the cross-sections. They represent shape in terms of fullness of form.

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[1] Data for graph of sizes. Xantus, 29=1; 30=3; 31=1; 32=10; 33=10; 34=22; 35=12; 36=19; 37=11; 38=6; 39=2; 40=2; 42=1. Total = 100. Craveri, 27=2; 28=4; 29=3; 30=10; 31=9; 32=10; 33=18; 34=17; 35=14; 36=7; 37=5; 39=1. Total = 100.

[2] Data for graph of axial ratios. Xantus, 1.39=1; 1.41=4; 1.43=3; 1.44=5; 1.45=3; 1.46=5; 1.47=9; 1.48=12; 1.49=8; 1.50=10; 1.51=4; 1.52=7; 1.53=7; 1.54=5; 1.55=5; 1.56=2; 1.57=2; 1.58=1; 1.59=1; 1.60=3; 1.61=1; 1.62=1; 1.63=1. Total = 100. Craveri, 136=1; 139=1; 140=1; 141=3; 142=4; 143=2; 144=11; 145=8; 146=8; 147=8; 148=5; 149=8; 150=8; 151=6; 152=5; 153=2; 154=5; 155=2; 156=5; 157=2; 159=1; 161=2; 165=1; 166=1. Total = 100.

[3] Data for graph of spheroidal percentages. Xantus, 92=1; 93=2; 94=3; 95=19; 96=25; 97=25; 98=19; 99=6. Total = 100. Craveri, 91=1; 92=3; 93=4; 94=2; 95=17; 96=15; 97=28; 98=17; 99=10; 100=3. Total = 100.

Xantus, average 96.46%
Craveri, average 96.64%

The differences in these shapes are relatively small. The axial ratio for horned owls, for instance, is 1.20 to 1.25, for cormorants about 1.80. Percentages of prolate spheroids will probably prove to be about 90 for murres and 97 for auklets. Considering the extent of the possible range and the fluctuations as the tabulations were compiled as well as my rather crude technique, I am forced to the conclusion that, while there probably exists a slight difference in ellipticity, none has been proven as to the other standard of shape. The evidence demonstrates, in so far as form is concerned, that communal inheritances are strongly predominant and possibly coincident.

Surface. There are no visible distinctions in the textures of the shells of the two species. The surfaces are smooth and glossy. If we were to arrange the eggs of North American birds in arbitrary classes with reference either to frictional resistance or to reflection of light, those of *Endomychura* would be placed but a few groups below the smoothest or the brightest, as the case might be.

Ground color. The determinations were based on Ridgway's "Color Standards and Color Nomenclature." Every egg was referred to the printed color which it most closely resembles. The results, of course, were approximations. For instance twelve eggs are listed as "white". In each of them a tinge is readily perceptible and yet every one more closely approaches pure white than any color that Ridgway gives.

	Xantus	Craveri
White	3	9
Pale Olive Buff	25	44
Pale Smoke Gray	10	7
Tilleul Buff	5	8
Olive Buff	17	18
Smoke Gray	3	3
Vinaceous Buff	5	4
Avellaneous	11	4
Deep Olive Buff	13	3
Buffy Brown	6	0
Army Brown	2	0
Total	100	100

Pigmentation. The markings are virtually confined to two colors and both are to be found on every egg. There is the basic Light Olive Gray which occasionally shades into Smoke Gray. Superimposed upon it and dominating the coloration of the entire collection is Bone Brown. That, too, has its modifications in occasional Olive Brown, Buffy Brown, or Isabella Color.

Markings. The table below refers to the relative proportions of the surfaces which are covered with markings. The references in this and in the succeeding table are to the bodies of the eggs as distinguished from the wreaths about the larger ends.

	Xantus	Craveri
Almost plain	8	9
Lightly marked	5	19
Medium	16	39
Well marked	24	24
Heavily marked	47	9
Total	100	100

The markings themselves fall into five classes. As all of the designs are present, in varying degrees, on every egg the tabulation is based on predominating characteristics.

	Xantus	Craveri
Streaks	2	0
Fine dots	8	14
Spots	13	28
Small blotches	42	39
Medium blotches	35	19
Total	100	100

Within my experience every egg of either murrelet has a tendency to gather the markings about the larger end. Usually a distinct wreath is formed. A tabulation of these wreaths showed them to be about equally divided between suggested, decided, medium, and heavy, and to be virtually the same for both Xantus and Craveri.

With the two hundred eggs spread upon the table it was clear that, individually, the eggs of the two species were not distinguishable. Yet the groups were distinctive. As would be surmised from the tables the eggs of Xantus show the wider range in color and markings. In the aggregate they are more bold, more brilliant and more striking. Contrasts are greater. The importance of these facts is emphasized because of their bearing on the relative antiquity of the two races. It should be noted, too, that they are directly opposed to the status of plumages. The following statement by van Rossem (Condor, XXVIII, 1926, pp. 80-83) is fully supported by my own observation. "*Craverii* is thus seen to be a highly variable species, in the case of the newly hatched young as well as in adults, while *hypoleucus* is stable and exhibits little or no variation."

It is safe to assert that, at least during the present geological era, neither the pigmentation itself nor its design has exerted any influence on the probabilities of the survival of the chick. Therefore it is to Mendel rather than to Darwin that we must turn for an interpretation of the color differences. Of themselves they throw no light on antiquity because they have come about, not through gradual change, but as the direct result of one of, or, more probably, a series of, the little understood mutations. They are manifestations of pure heredity, and as such demonstrate at once close relationships and clear lines of cleavage.

Shell weights. It must be understood that in all references to weights of shells, membranes are included. There seems to be no feasible means of removing the lining without destroying the specimen. Sometimes the membrane comes out during preparation. Its presence or absence is averaged or neutralized and has little effect on the comparative value of the final figures.

Our interest in the thickness of the shell is purely relative. In order to compare eggs of various sizes the expression adopted is the proportionate weights of the shell when empty and when filled with distilled water. The weight of the shell is given as a percentage of the whole.[4]

Xantus, average 7.22%
Craveri, average 6.82%

The specific gravity of the shells is, of course, subject to the same qualifications as the weight.[5]

[4] Data for graph of shell percentages. Xantus, 6.2=2; 6.4=6; 6.6=7; 6.8=12; 7.0=13; 7.2=17; 7.4=16; 7.6=9; 7.8=11; 8.0=2; 8.2=2; 8.4=2; 8.6=1. Total = 100. Craveri, 6.0=1; 6.2=7; 6.4=13; 6.6=19; 6.8=22; 7.0=17; 7.2=12; 7.4=4; 7.8=3; 8.0=1; 8.2=1. Total = 100.

[5] Data for graph of specific gravities. Xantus, 1.50=1; 1.55=1; 1.65=1; 1.75=2; 1.80=5; 1.85=6; 1.90=6; 1.95=8; 2.00=10; 2.05=22; 2.10=14; 2.15=13; 2.20=5; 2.25=5; 2.30=1. Total = 100. Craveri, 1.70=1; 1.80=1; 1.85=1; 1.90=4; 1.95=5; 2.00=4; 2.05=17; 2.10=24; 2.15=29; 2.20=10; 2.25=1; 2.30=1; 2.35=1; 2.50=1. Total = 100.

Xantus, average 2.02
Craveri, average 2.10

As will be seen from the graphs the differences are quite constant. They constitute the outstanding divergence between the eggs of the two birds. Their importance impels me to support them by calculating the medians; the latter are less directly affected by technical errors.

Xantus, shell percentage 7.23; specific gravity 2.05
Craveri, shell percentage 6.80; specific gravity 2.11

I have before me quite an array of figures on the eggs of other Pygopodes, tabulations too incomplete and fragmentary to permit publication. They include, to date, several hundred eggs and they are sufficiently extensive to prove that the overwhelming factor in determining the thickness and the specific gravity of shells is heredity. Just as protective coloration, disuse, and other suggestive contributory causes are overwhelmed by genetic relations in so far as pigmentation is concerned, so do food and temperatures and necessities fail to dislodge inheritance as the prime, if not the only, determinant of shell structure.

The extent of the variations in their shell weights, as compared with other birds whose separation of descent is more obvious, is sufficient to show that the murrelets under consideration are far more independent of each other than has been supposed. The most plausible reconciliation of the figures under this heading with those previously discussed is the theory that the communal life of these birds ceased long ago, and that, since the severance, neither has undergone much alteration.

Sets. These murrelets normally lay a clutch of two. So nearly universal is the rule that exceptions are to be looked upon with suspicion. The eggs within a set of *Endomychura* exhibit on the average a greater variation from each other in ground color than do those of any other North American bird. Of the forty-one sets in each of the series under consideration 23 Xantus and 18 Craveri (exactly one half of the total) contain eggs distinctive enough from each other to have been assigned separate shades in the color tabulation.

The two eggs of a set are always to be distinguished from each other by referring to one as having heavier and the other the more lightly tinted ground color. The relation between this fact and primogeniture is one which, with the material available, can be approached only through analogy. I assembled 24 sets of eggs of domestic pigeons in which the order of laying was known. The following table lists the characteristics of the murrelets according to the egg having the darker ground color and the pigeons according to the egg which was first laid. The numerical equivalents are the percentages of the excess of the darker or, in the case of the pigeons, the first laid egg. To illustrate, the first figure given, 42, means that in 42% of the sets of Xantus the darker of the two eggs is the larger. The last figure, 38, means that in 38% of the pigeon sets it is the first laid egg whose percentage of a true prolate spheroid is the greater.

	Xantus	Craveri	Pigeon
Size	42	22	25
% of shell	88	80	80
Sp. gr. of shell	58	47	87
Major axis	41	35	29
Minor axis	48	30	25
Axial ratio	59	43	46
% pro. sph.	51	38	38

It is quite obvious, from the tabulation, that the first laid pigeon egg normally has the heavier shell. It is also clear that exceptions are not rare enough to be regarded as sports. If the murrelet eggs follow those of the pigeons then the darker egg is normally the heavier shelled and the first laid. We can see that it is not always the heavier shelled, and the figures suggest, though they do not prove, that there are also exceptions to the rule that it is the first to be laid.

There is not sufficient variation or consistency for us to conclude other than that primogeniture and shape have little in common. In the matter of size there appears quite a tendency for the last laid egg to be the larger. The specific gravity of the shell does not, in the case of the murrelets, appear to be related either to shell thickness or to ground color. On the other hand its relation to primogeniture with the pigeons gives the most constant figure I have obtained.

The shells thicken progressively as the ground colors become darker. This is only because the darker eggs of a set have the heavier shells. *Per se* there is no relation between the weight of one and the color of the other. The fact is demonstrated by the table below, which lists the two eggs of each set in separate columns and gives the average percentage of the shells according to ground color.

	Xantus		Craveri	
	Darker egg	Lighter egg	Darker egg	Lighter egg
White	1=6.08	2=7.02	3=6.79	6=6.68
Pale Olive Buff	5=7.45	14=7.03	15=6.93	24=6.71
Pale Smoke Gray	4=6.99	5=6.70	2=6.52	3=6.84
Tilleul Buff	....	3=7.08	4=6.82	2=6.56
Olive Buff	8=7.84	7=7.09	7=7.05	6=6.49
Smoke Gray	2=7.55	1=8.16	3=7.12	....
Vinaceous Buff	3=7.06	....	3=7.41	....
Avellaneous	3=7.71	4=6.84	2=7.33	....
Deep Olive Buff	8=7.34	4=6.96	2=6.53	....
Buffy Brown	6=7.54	....	....	....
Army Brown	1=7.48	1=7.32	....	....
Total	41=7.44	41=7.01	41=6.98	41=6.67

Sex. Again I was compelled to turn to analogy among the pigeons. Fifteen pairs of juveniles were sexed. It was known in every case which bird had hatched from the first-laid egg. The results showed no relationship whatever between sex and either primogeniture, shell-thickness, or specific gravity.

Both eggs hatched male birds in	3 cases
Both eggs hatched female birds in	4 cases
The first was male, the second female, in	3 cases
The first was female, the second male, in	5 cases
Total	15

Comparison. In order to obtain perspective a comparison is made with eggs of the Ancient Murrelet and the Pigeon Guillemot. These birds immediately precede and succeed *Endomychura* in the A. O. U. sequence, except *Cepphus columba* was preferred to *C. grylle* because of geographical juxtaposition. Only 16 eggs of the guillemot were available, but their averages are sufficiently definite for the present purpose. The figures for *Synthliboramphus antiquus* are based on 55 specimens.

The four species under consideration have the common characteristic of laying, normally, two eggs. In shell texture the Ancient Murrelet eggs closely approximate those of Xantus and Craveri, but the guillemot's are much duller and rougher. The ground color of *Cepphus* is a dull bluish white; in no phase does its pigmentation resemble that of murrelets. *Synthliboramphus*, on the other hand, is typically and consistently a pale olive buff. The range of shade is small and exceptional markings rare. It is particularly noteworthy that there is no tendency to form wreaths and but a slight variation between the eggs of a set. The darker egg is the larger in 68% of the sets and has the heavier shell in 62%. In 71% of the sets the heavier shell has the greater specific gravity.

The following table indicates the determined relations between the eggs.

	Ancient Murrelet	Xantus Murrelet	Craveri Murrelet	Pigeon Guillemot
Size	44.87	34.88	32.93	52.88 cc.
% of shell	6.50	7.22	6.82	8.82 %
Axial ratio	1.605	1.499	1.488	1.436
Sp. gr. of shell	1.88	2.02	2.10	2.08
% of prolate spheroid	96.61	96.46	96.64	96.50 %

Conclusion. We have seen that, in shape, the eggs in the two species of *Endomychura* virtually coincide with each other. In ground-color, markings, and pigmentation there is a close parallel, with *craveri* always lagging behind. In shell thickness and in specific gravity there is clear-cut separation. The deviation from *Synthliboramphus* is impressive. From *Cepphus* it is still greater. Resemblance in one case is virtually confined to the surface of the shell and in the other to shape.

Of course, at some period these four birds had common ancestors. There is much evidence here to support the contention that the first division came between the guillemots and the murrelets and the second between *Synthliboramphus* and *Endomychura*. In color and in shell thickness the Craveri Murrelet approaches the Ancient more closely than does the Xantus. The reverse is true with regard to ellipticity and specific gravity. Size, in this connection, is relatively unimportant. If we consider as proven that the two species of *Endomychura* have not varied greatly since their separation from each other then necessarily they did not directly break away from *Synthliboramphus*. The former existence of one or more now extinct forms is necessary to complete the chain.

It does not follow, in this particular case, that the evidence has thrown any new light on an old subject, nor would it be safe, in a preliminary survey, to carry conjecture farther. Nevertheless I believe it has been shown that physical properties of egg shells are entitled to consideration in any scheme of avian classification. I believe it is safe to go farther and to maintain that, if egg data were assembled with the conscientious thoroughness that has been accorded other characteristics, they would assume a position of prime importance. They are our oldest manifestation of heredity. Long after the selective processes induced by the struggle for existence have brought about anatomical modifications in the structure of the birds we may expect to find the eggs unaltered. Except in size alone there simply exists no reason why they should change.

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