

J Ó Z E F H O R D O W S K I

OOMORPHOLOGICAL
CHARACTERISTICS OF THE BIRDS
OF KING GEORGE ISLAND

South Shetland Islands (Antarctic)



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Front cover: Colony Adélie penguin *Pygoscelis adeliae* in Admiralty Bay

Back cover: Gentoo penguin *Pygoscelis papua*

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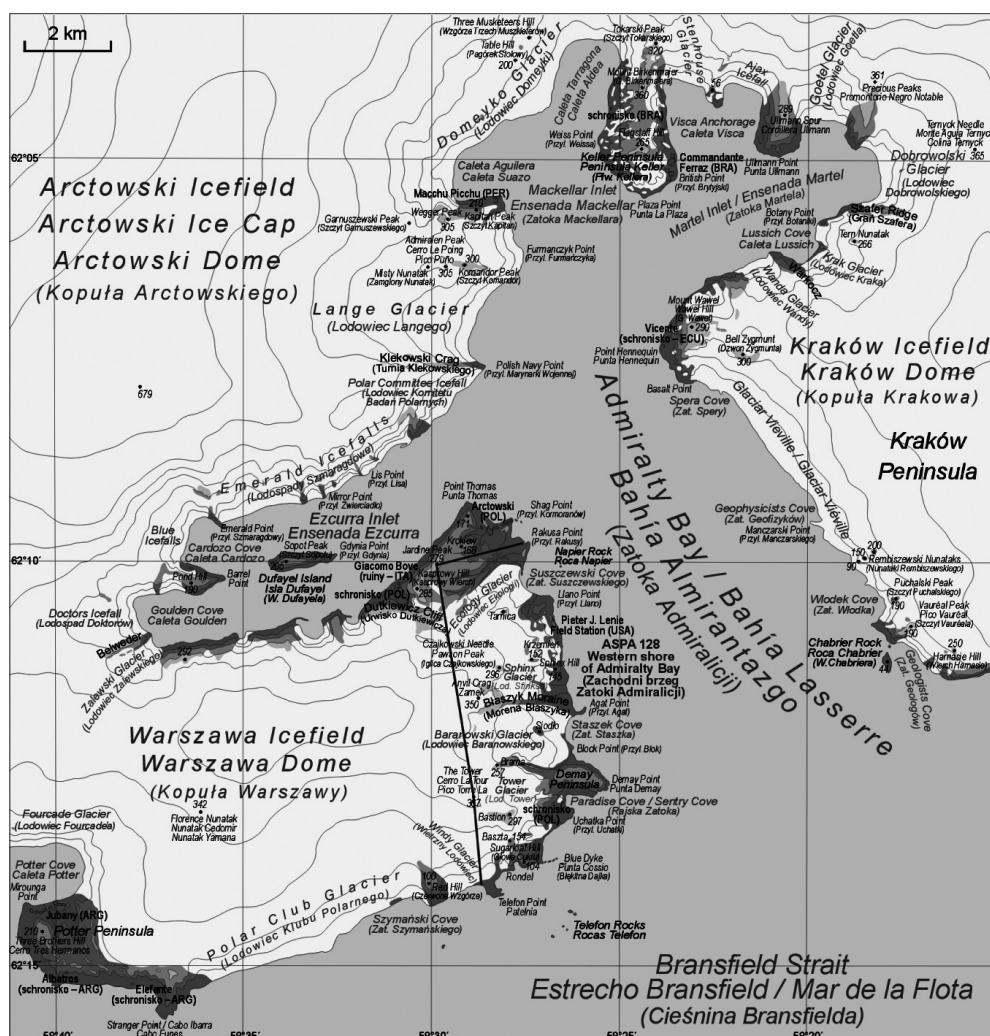
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Introduction

Until the 1960s there was very little data about the variety in size and colouring of the eggs of species of birds of the Antarctic (e.g. Clarke 1906, Gain 1914, Murphy 1936, Schonwetter 1960, 1962). However, from the 1950s on a number of polar research stations were established, thanks to which exploration of the region began in earnest. There are currently nine research stations on King George Island. Therefore, the contemporary birdlife of the island is known in detail. Thirteen species of birds are recorded as nesting in Admiralty Bay. Polish ornithologists have



Map of Admiralty Bay in the South Shetland Archipelago (wikipedia.org, © Aotearoa)

provided a comprehensive set of information based on research carried out since the late 1970s at the Polish “Henryk Arctowski” Antarctic Station (e.g. Jabłoński 1984, 1984a&b, 1986, 1987, 1995, Wasilewski 1986, Sierakowski 1991, Lesiński 1993, Rakusa–Suszczewski 2012). Other studies come from different parts of the island, e.g. Kamenev (1987), Trivelpiece et al. (1987), Hahn et al. (1998), Soave et al. (2000), Sander et al. (2005), Costa and Alves (2008).

The aim of this work is to present a detailed description of the oomorphological characteristics and the oomorphometry of the eggs of the nesting birds in Admiralty Bay on King George Island.

Material

The research was conducted on King George Island in the Admiralty Bay region. The island is situated in the oceanic climate zone of the Antarctic. The studies covered an area of some 400 km², of which 131 km² forms the area of Admiralty Bay and approximately 19 km² is an area free of ice (Rakusa–Suszczewski 1980). This area is located between Red Hill and Chabrier Rock. The total length of coastline in the area under study is approximately 91 km.

The material was collected by Dr Bolesław Jabłoński, who conducted research in Admiralty Bay on King George Island in the South Shetland Archipelago between 1978 and 1981. During his research Jabłoński recorded the measurements of 2185 eggs in total. The results from the first study season (N=583 eggs) were published in a work covering the birds of Admiralty Bay (Jabłoński 1986) and in a study discussing aspects of the reproductive biology of the Antarctic Tern (Jabłoński 1995). The material from the two subsequent seasons, i.e. 1979/1980 and 1980/1981, was not published. The egg samples gathered during the expeditions

TABLE 1 The equations from which the specific oological parameters were calculated

Variable		Reference
Egg length (mm)	measurements collected directly in the field	
Egg breadth (mm)		
Fresh egg weight (g)	$G = 0,542 \cdot \varphi \cdot A \cdot B^2 + 0,5 \cdot g$	Schonwetter 1985
Shell weight egg (g)	$g = 4,82 \cdot 10^{-2} \cdot C^{1,132}$	Paganelli et al. 1974
Volume egg (cm ³)	$V = 0,524 \cdot \varphi \cdot A \cdot B^2 / 1000$	Schonwetter 1985
Volume shell (cm ³)	$V_s = 2,48 \cdot 10^{-2} \cdot C^{1,118}$	Paganelli et al. 1974
Surface area egg (cm ²)	$O = 4,835 \cdot C^{0,662}$	Paganelli et al. 1974
Shell thickness (mm)	$d = (0,175 \cdot g / A \cdot B) \cdot 1000$	Schonwetter 1985
Large circumference (mm)	$U = (A + B) \cdot \pi / 2 \cdot x; [x = 1 + 1/4 \cdot (k - 1/k + 1)^2]$	Schonwetter 1985
No. pore/egg	$P = 278,6 \cdot C^{0,704}$	Whittow 1984
Factor shape k	$k = A/B$	
Relative egg weight %	$RG = 100 \cdot \text{egg weight} / \text{weight female}$	

were deposited in the Natural History Museum of the Institute of Systematics and Animal Evolution, Polish Academy of Sciences (PAN) in Kraków. The material from the field notebook is held in the Department of Polar Biology and Oceanobiology at the University of Łódź. The eggs were photographed in 2010. The eggs on Plate 1–12 are presented in their natural size.

The direct field measurements were made with callipers to an accuracy of 0.1 mm. However, the remaining characteristics were calculated from the equations presented in Table 1. The choice of these equations was aimed at sea and ocean birds (Whittow 1984).

The average weight of the female was taken from Dunning (2008). The classification and naming of the birds was based on Mielczarek&Kuziemko (2016).

Two fundamental factors affect the size of the eggs – the condition of the female and the availability of food. In the conditions of the Antarctic the richness of the habitat can vary greatly from year to year and so, in turn, there can be large swings in the size of the eggs (Weidinger 1996).

Acknowledgements

Particular thanks go to Dr Bolesław Jabłoński for his selfless agreement to the publication of his materials. I am grateful to Professor Janusz Siciński from the Department of Polar Biology and Oceanobiology, University of Łódź for access to relevant notes and literature and to Professor Zbigniew Bocheński from the Institute of Systematics and Animal Evolution, Polish Academy of Sciences (PAN) in Kraków for allowing access to the oological collections. I would like to thank Dr Narcyz Piórecki, Director of the Bolestraszyce Arboretum and Department of Physiography for his assistance in organising the research.

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Cape Petrel *Daption capense* (Linnaeus, 1758)

Abundance

Regularly breeding in various parts of the island (Sander et al. 2005). It nests in small, loose colonies, building its nest in shallow crevices, niches on shelves of rock, on high mounds of gravel, or among rocks, on cliffs (del Hoyo et al. 1992). It lays one egg which it incubates for around 41–50 days (Shirihai 2008).

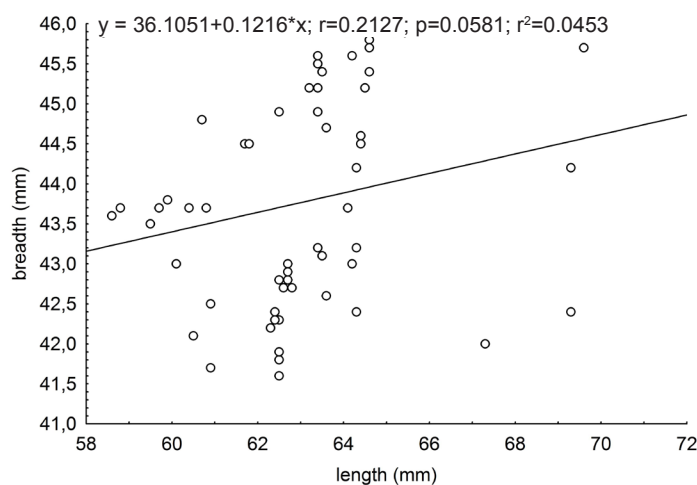
Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 2. The coefficient of variation and standard deviation was somewhat higher than those given by Weidinger (1996). Petrels, including the Cape Petrel, lay one large egg which represents approximately 15% of the weight of the female. The correlation between the length and breadth was low $r = 0.21$ and turned out to be statistically insignificant ($F_{1,78} = 3.6978$, $p = 0.0581$), while the regression equation between the breadth and length was $-B = 36.1051 + 0.1216 \cdot A$ (Fig. 1). What was statistically significant was the dependence between the breadth and length and the mass ($p < 0.05$) (Fig. 2). The largest eggs measured 69.6 x 45.7 mm, 64.6 x 45.8 mm, and the smallest 58.6 x 43.6 mm, 62.5 x 41.6 mm.

The seasonal differences in the volume of the eggs weren't large and came to 4.75 cm³: in 1980 – 61.2 cm³, in 1981 – 56.5 cm³. They were statistically insignificant ($F_{1,24} = 0.0158$, $p = 0.9009$). Weidinger (1996) observed a similar phenomenon on Nelson Island, but the differences in the volume of the eggs in 1990 and 1991 were smaller – just 1.5 cm³. However, Sagar (1979) and Sagar et al. (1996) on

TABLE 2 Morphometry of *Daption capense* eggs (N=80). *Explanations: N – sample size; x – Mean; min – Minimum; max – Maximum; CV – Coefficient of variation; SD – Standard deviation; Z = max [variable] – min [variable] / max [variable] – min [variable] * 100.*

Variable	x	min	max	CV	SD	Z
Egg length (mm)	63.22	58.8	69.6	3.59	2.27	8.58
Egg breadth (mm)	43.79	41.6	45.8	2.96	1.30	4.81
Fresh egg weight (g)	63.2	55.2	76.0	7.61	4.67	15.79
Shell weight egg (g)	5.27	4.52	6.49	8.61	0.44	17.83
Volume egg (cm ³)	58.6	51.3	70.5	7.57	4.31	15.71
Volume shell (cm ³)	1.75	1.53	2.11	7.61	0.13	15.79
Surface area egg (cm ²)	73.2	67.0	83.2	5.03	3.63	10.76
Shell thickness (mm)	0.32	0.28	0.35	5.07	0.02	11.21
Large circumference (mm)	168.7	161.6	181.9	2.66	4.73	5.92
No. pore/egg	5157	4695	5874	5.35	267.50	11.16
Factor shape k	1.44	1.34	1.63	4.17	0.07	9.75
Relative egg weight	15%					



Snares Island, located in notably better climatic conditions, recorded inter-year variations in egg volume of -0.7 g for the years 1985–1987.

Weidinger (1999) recorded the density of a freshly-laid egg at $1.096 \text{ g} \cdot \text{cm}^{-3}$. The total loss of water during incubation came to approximately 21% of the initial weight (Weidinger 1999). An average egg consists of 57.0% albumen, 31.8% yolk and 11.3% shell (Williams et al. 1982).

Oomorphology

SHAPE EGG. Heteropolar, ovoid, not very elongate, with a blunt, narrower end, oval, with blunt poles, sometimes however stretched and somewhat pointed. The shape factor of the egg $k=1.44$ also shows that the eggs are ovoid and slightly

TABLE 3 Geographical variation in egg size of *Daption capense*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Nelson Island	659	62.2	42.8	55.8	Weidinger 1996
Admiralty Bay King George Island	54	63.22	43.79	58.6	This study
Snares Island	130	61.27	42.5	54.2	Sagar et al. 1996
Signy Island	46	62.0	43.0	56.2	Pinder 1966
Terre Adélie	28	63.8	43.3	58.6	Mougin 1968
Laurie Island	15	61.7	43.2	56.4	Barreto 1997
South Orkneys Island	nume- rously	62.35	43.1	56.7	Clarke 1906
Haswell Island	30	64.0	44.0	60.7	Pryor 1968

elongated (Szielasko 1920). Weidinger (1996) on Nelson Island got almost the same result – $k = 1.46$ (Plate 1).

GRAIN & SHELL TEXTURE. The shell is matt or slightly shiny, coarse-grained, occasional samples covered with calcareous lumps.

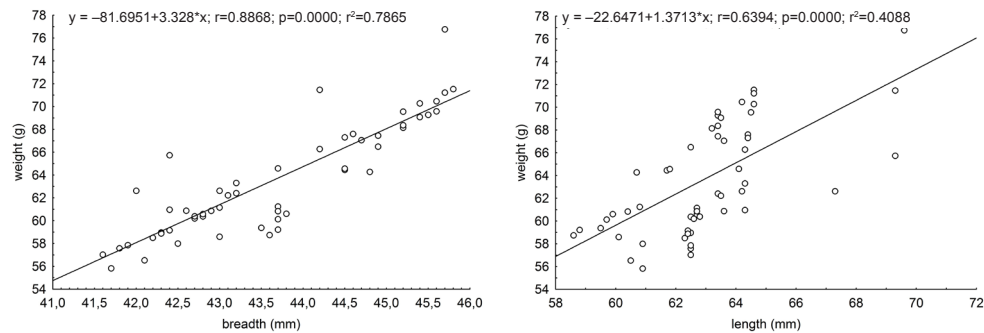
GROUND-COLOUR. The base colour of the shell is monochromatic white.

PATTERN OF EGG MARKINGS. None, but during incubation fat stains and dirty marks often appear.

PORES. Large and clear, deep, usually round, but occasionally elongated, sometimes 2–3 pores merge to form one large hole. An average-sized egg will have more than 5200 pores.

GEOGRAPHIC VARIATION. The eggs do not vary in shape or colour from eggs found in other regions. Weidinger (1996) claimed that the further south the latitude, the greater, proportionally, the volume of the eggs. Among the known dimensions, the largest eggs were found on Haswell Island 60.7 cm^3 and on King George Island

FIG. 2 Relationship between calculated egg-weight and breadth (left) and length (right) *Daption capense* eggs



Wilson's Storm-petrel *Oceanites oceanicus* (Kuhl, 1820)

Abundance

They nest in small numbers on the Island, in loose colonies, while they make their nests in burrows tunnelled into the soft clay or rock debris, in crevices on cliffs or even under loose lying rocks, or the bones of whales. The female lays one egg which is incubated for 33–59 days (del Hoyo et al. 1992, Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 4. The coefficient of variation of the breadth of the egg is surprisingly low at 0.92. Wilson's Storm-petrel produces one of the largest eggs of any birds relative to the size of the female, equivalent to approximately 30% of her body weight.

The correlation between the length and breadth was very low $r = 0.21$ and proved to be statistically significant ($F_{1,183} = 9.1385$, $p = 0.0029$) and the regression equation between the breadth and length was $B = 22.8208 + 0.0441 \cdot A$. (Fig. 3). The dependence between the breadth and length and the mass of the egg was statistically significant ($p < 0.05$) (Fig. 4). The largest eggs: 38.3 x 24.6 mm and 32.8 x 25.2 mm, while the smallest were 30.2 x 24.4 mm and 34.4 x 23.8 mm; 32 x 23 mm.

Seasonal variation in the volume of the eggs was minimal at 0.17 cm³: 1979 – 10.83 cm³, while in 1980 – 11.0 cm³ and was not statistically significant ($F_{1,39} = 0.3126$, $p = 0.5794$); the coefficients of variation were similar and came to

TABLE 4 Morphometry of *Oceanites oceanicus* eggs (N=185). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	35.05	30.2	38.3	3.16	1.11	11.82
Egg breadth (mm)	24.37	23.8	25.2	0.92	0.22	10.37
Fresh egg weight (g)	11.31	9.76	12.59	4.02	0.45	12.68
Shell weight egg (g)	0.75	0.64	0.85	4.56	0.03	14.33
Volume egg (cm ³)	10.6	9.1	11.8	4.01	0.42	12.63
Volume shell (cm ³)	0.31	0.27	0.35	4.02	0.01	12.68
Surface area egg (cm ²)	23.7	21.2	25.7	2.92	0.69	9.64
Shell thickness (mm)	0.154	0.149	0.160	1.33	0.00	3.56
Large circumference (mm)	94.0	86.2	99.7	2.02	1.90	7.23
No. pore/egg	1536	1385	1658	2.83	43.49	8.95
Factor shape k	1.44	1.24	1.56	3.07	0.04	11.42
Relative egg weight	30%					

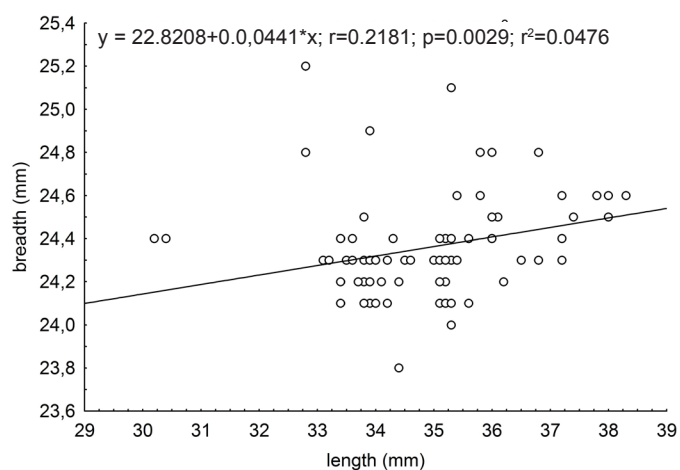


FIG. 3 Linear regression between the length and the breadth of *Oceanites oceanicus* eggs (N=185)

CV = 3.10 and 4.36 respectively. Relatively small variation was noted in a different area of King George Island, where between 1996 and 2003 the differences in volume were at most 0.38 cm^3 but in the years 1998–2002 were less at 0.12 cm^3 (Busser et al. 2004).

TABLE 5 Geographical variation in egg size of *Oceanites oceanicus*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm^3)	References
Kerguelen Island	9	32.8	23.5	9.2	Beck&Brown 1972
Bird Island	19	33.3	23.4	9.3	Copestake&Croxall 1985
Signy Island	15	34.8	24.7	10.8	Beck&Brown 1972
Argentine Island	12	33.6	23.5	9.4	Beck&Brown 1972
Terre Adelie	9	33.4	23.6	9.5	Mougin 1968
Admiralty Bay King George Island	131	35.05	24.37	10.6	This study
Crozet Island	16	31.5	22.9	8.4	Marchant&Higgins 1990
Tres Hermanos King George Island	72	33.5	23.9	9.7	Quillfeldt&Peter 2000
Haswell Island	10	33.9	23.4	9.4	Pryor 1968
Laurie Island South Orkneys Island	8	33.7	24.0	9.9	Clarke 1906
South Shetland	?	32.9	23.6	9.3	Murphy 1936
Tres Hermanos King George Island	915			9.21	Busser et al. 2004

Oomorphology

EGG SHAPE. Heteropolar, ovoid, not very elongated, with blunt ends, rarely close to spherical with strongly rounded poles. The shape factor of the egg $k = 1.44$ also indicates that the eggs have an ovoid, slightly elongated shape (Plate 1).

GRAIN & SHELL TEXTURE. The shell is slightly shiny, more rarely matt, medium and fine grained.

GROUND-COLOUR. The base colour of the shell is monochromatic, white, with occasional examples with small spots found most often near one of the ends.

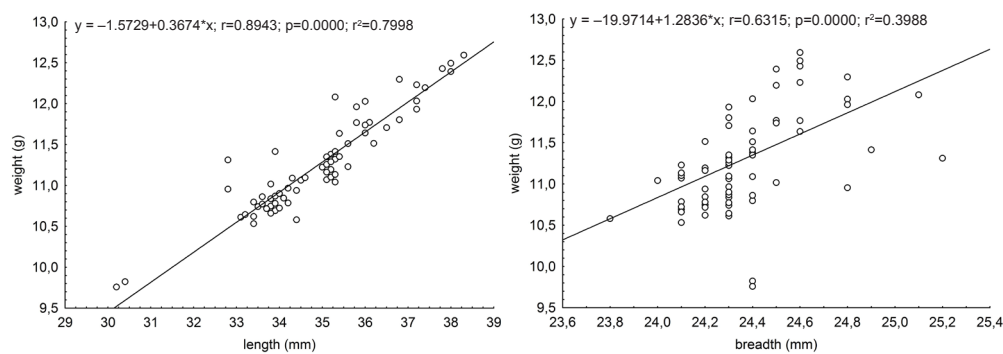
PATTERN OF EGG MARKINGS. Usually no markings, occasionally some eggs are marked, normally at the wider end, with a faint wreath composed of surface and deep stains. The surface markings are very fine while the deep marks can be a little bigger. As incubation progresses very often the eggs get dirty with fat stains and mud.

MARKINGS-COLOUR. The fine surface markings are brownish while the deep marks are in various shades of violet.

PORES. Easily visible and large, deep, of variable shapes, often oblong or circular. An average-sized egg will have around 1550 pores.

GEOGRAPHIC VARIATION. The Wilson's storm petrel eggs from King George Island didn't differ in shape or shell colour from eggs found elsewhere. The largest eggs were laid by the population inhabiting Signy Island – 10.8 cm^3 and Admiralty Bay 10.6 cm^3 , in other areas the eggs were smaller by around 1 cm^3 , the smallest on Kergulen Island and, interestingly, in another area of Admiralty Bay only 9.21 cm^3 (Table 5).

FIG. 4 Relationship between calculated egg-weight and breadth (right) and length (left) *Oceanites oceanicus* eggs



Southern Giant Petrel *Macronectes giganteus* (Gmelin, JF, 1789)

Abundance

Found on the island in small numbers, but regularly in small colonies (Lesiński 1993). It makes its nest on sandy or stony beaches and sea shores, on low moraine hills, lining the nest with small stones. The female lays just one egg, which she sits for 55–66 days (Shirihai 2008).

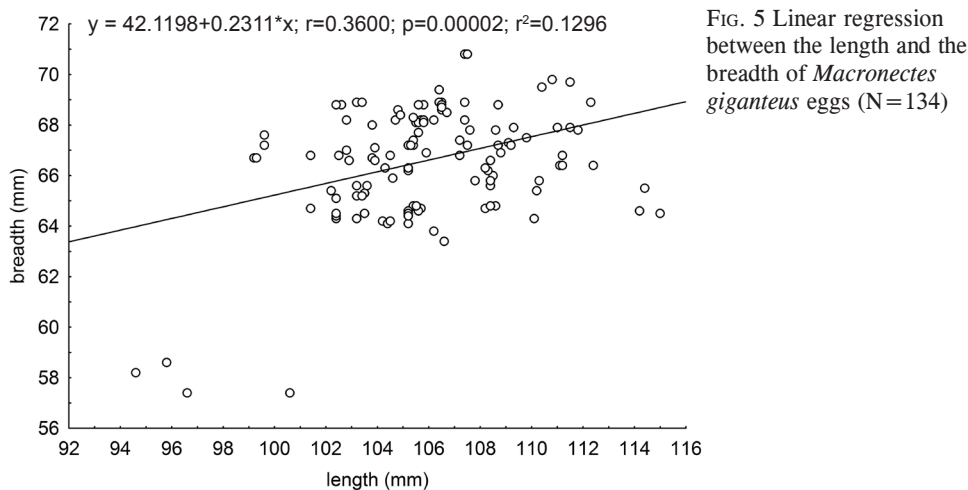
Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 6. The coefficient of variation of the breadth and length of the eggs was relatively low. The Southern Giant Petrel lays the largest eggs on King George Island, but the weight of the egg as a proportion of the female's body weight is small – at just 5.3%. On Signy island the egg is 6.8% of the female body weight (Conroy 1972). The density of the egg is on average 1.0728 g*cm³, while the density of the shell is 2.1006 g*cm³. During the incubation period, the egg absorbs around 36 litres of oxygen O₂ through its pores, and in the same period loses approx. 41 g of water (Rahn&Whittow 1988). In an average-sized egg weighing 253 g, the yolk makes up 32.2% of the contents, the albumen 51.1% and water 4.5% (Conroy 1972).

The correlation between the length and breadth was average $r = 0.36$ and proved to be statistically insignificant ($F_{1,132} = 1966.01$, $p = 0.0000$), and the regression equation between the breadth and length was $B = 42.1198 + 0.2311 \cdot A$ (Fig. 5). The dependence between the breadth, length and weight of the eggs was statistically significant ($p < 0.05$) (Fig. 6). The largest eggs were 115.0 x 64.5 mm,

TABLE 6 Morphometry of *Macronectes giganteus* eggs (N=134). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	105.91	94.6	115.0	3.32	3.52	9.73
Egg breadth (mm)	66.59	57.4	70.8	3.39	2.26	10.45
Fresh egg weight (g)	247.3	166.9	284.9	8.17	20.22	26.13
Shell weight egg (g)	24.69	15.81	28.97	9.17	2.26	29.39
Volume egg (cm ³)	227.8	154.1	262.3	8.13	18.52	25.98
Volume shell (cm ³)	6.86	4.63	7.90	8.17	0.56	26.13
Surface area egg (cm ²)	182.7	141.9	201.0	5.46	9.98	17.22
Shell thickness (mm)	0.61	0.50	0.66	4.47	0.03	14.06
Large circumference (mm)	271.8	240.9	285.5	2.78	7.57	8.47
No. pore/egg	13 476	10 223	14 899	5.88	792.80	18.61
Factor shape k	1.59	1.47	1.78	3.83	0.06	9.51
Relative egg weight	5.3%					



107.5 x 70.8 mm, whilst the smallest eggs were 94.6 x 58.2 mm and 96.6 x 57.4 mm. In South Georgia the eggs were larger and weighed 260.6 g – (Hunter 1984).

Oomorphology

EGG SHAPE. Heteropolar, ovoid, highly elongated, with rounded ends, rarely ovate. The shape factor of the egg $k = 1.52$ – shows the highly elongated shape of the eggs (Szielasko 1920).

GRAIN & SHELL TEXTURE. The shell is matt, coarse-grained and rough to the touch, sometimes the shell has little lumps of limestone.

GROUND-COLOUR. The base colour is monochrome white.

PATTERN OF EGG MARKINGS. Normally no markings, sometimes and only on some eggs there are indications of deep markings in the form of spots and larger

TABLE 7 Geographical variation in egg size of the *Macroneustes giganteus*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Nelson Island	14	102.9	66.5	220.3	Lumpe&Weidinger 2000
Admiralty Bay King George Island	134	105.91	66.59	227.8	This study
Marion Island	18	104.1	67.1	226.9	Marchant&Higgins 1990
South Georgia Island	49	105.1	65.8	220.3	Hunter 1984
Laurie Island South Orkneys Island	80	103.8	65.7	216.9	Clarke 1906
Falkland	4	101.7	64.7	206.1	Marchant&Higgins 1990
Signy Island	28	104.9	65.7	219.2	Conroy 1972
Crozet Island	12	105.0	68.0	235.1	Voisin 1968

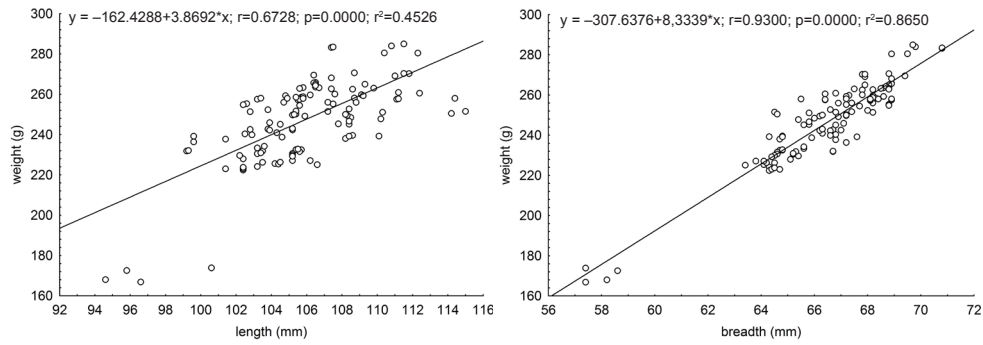
markings of irregular shape, spread in various places across the shell, often in the fatter end. There are often deep markings, usually evenly distributed over the shell. As incubation proceeds very often dirt appears in the form of fat and mud stains.

MARKINGS—COLOUR. The deep markings appear in various shades of violet.

PORES. Large and visible, quite shallow, of variable shape, usually irregular, close to spherical. An average-sized egg will have c. 13,500 pores.

GEOGRAPHIC VARIATION. The population on Crozet Island lays the largest eggs – at 235 cm³, then Admiralty Bay – 227 cm³, while the smallest come from the populations nesting in significantly warmer areas – 216 cm³ (Table 7). The relatively small sample size limits the possibilities for comparison.

FIG. 6 Relationship between calculated egg-weight and breadth (right) and length (left) eggs *Macronectes giganteus*



Black-bellied Storm-petrel *Fregetta tropica* (Gould, 1844)

Abundance

Small numbers in Admiralty Bay, they nest in loose colonies and they build their nests in rubble stones, between clumps of grass, rarely in burrows and crevices up to 50 cm deep. The female lays one egg which is sat on for 35–44 days (del Hoyo et al. 1992, Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 8. The coefficient of variation of the breadth and length of the eggs was relatively low. The Black-bellied Storm-petrel, after the Southern Giant Petrel, lays the largest egg relative to the weight of the female, reaching 28.5% of her body weight.

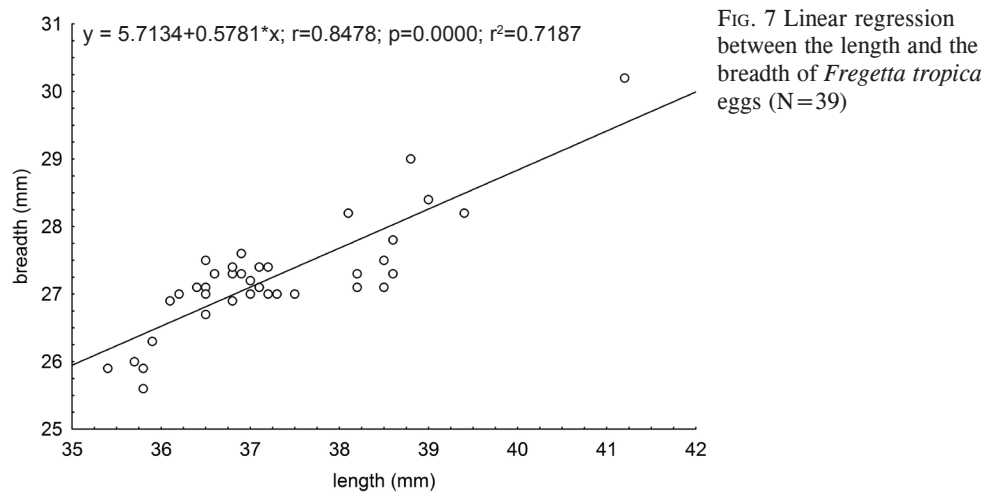
The correlation between the length and breadth was very high in comparison to other species $r = 0.84$ and statistically significant ($F_{1,38} = 8.0673$, $p = 0.006$), and the regression equation between the breadth and length was $B = 5.7134 + 0.5781 \cdot A$ (Fig. 7). The correlation coefficient between the weight of the egg and its length and breadth was very high and statistically significant ($p < 0.05$) (Fig. 8). The largest egg 41.2 x 30.2 mm, the smallest 35.4 x 25.9 mm and 35.8 x 25.6 mm.

Oomorphology

EGG SHAPE. Heteropolar, ovoid, with rounded ends, rarely somewhat spherical or elongated. The average shape factor $k = 1.37$ also shows that eggs typically have an ovoid shape (Plate 3).

TABLE 8 Morphometry of eggs *Fregetta tropica* (N=39). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	37.22	35.4	41.2	3.23	1.20	7.57
Egg breadth (mm)	27.23	25.6	30.2	3.01	0.82	8.24
Fresh egg weight (g)	15.2	12.9	20.7	9.28	1.41	23.22
Shell weight egg (g)	1.05	0.87	1.49	10.59	0.11	26.15
Volume egg (cm ³)	14.2	12.0	19.3	9.24	1.31	23.12
Volume shell (cm ³)	0.42	0.36	0.57	9.28	0.04	23.22
Surface area egg (cm ²)	28.8	25.9	35.3	6.06	1.74	15.45
Shell thickness (mm)	0.181	0.166	0.209	4.24	0.01	11.44
Large circumference (mm)	101.9	96.9	112.8	3.00	3.06	7.56
No. pore/egg	1891	1684	2350	6.43	121.55	16.50
Factor shape k	1.37	1.33	1.42	1.73	0.02	3.40
Relative egg weight	28.5%					



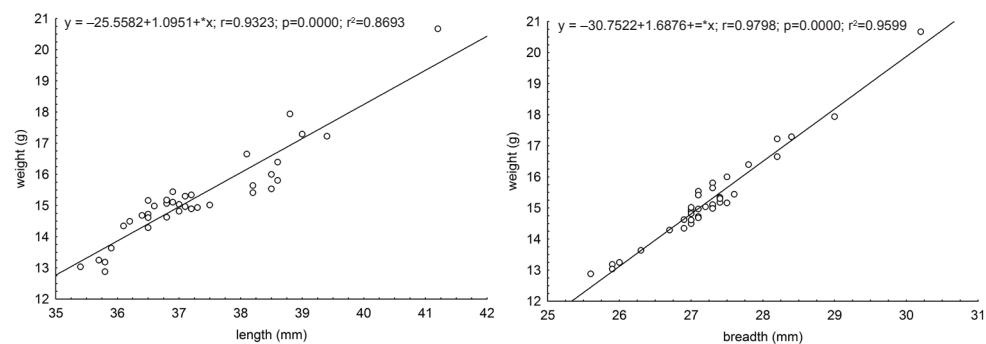
GRAIN & SHELL TEXTURE. The shell is slightly shiny, rarely matt, fine-grained and smooth to the touch.

GROUND-COLOUR. The base colour of the shell is pale, monochrome, off-white, sometimes dark white.

TABLE 9. Geographical variation in egg size of the *Fregetta tropica*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Signy Island	8	37.0	27.0	13.85	Beck&Brown 1971
Admiralty Bay King George Island	39	37.22	27.23	14.2	This study
King George Island	4	38.3	26.9	15.5	Hahn 1998

FIG. 8 Relationship between calculated egg-weight and breadth (right) and length (left) of the eggs of *Fregetta tropica*



Egg dimensions of *Fregetta tropica* from Admiralty Bay, King George Island

Length (mm)	Breadth (mm)	Calculated weight (g)
37	27.2	14.54
37.1	27.1	14.47
36.5	26.7	13.82
36.5	27.1	14.24
36.2	27	14.02
36.8	27.3	14.57
36.4	27.1	14.20
35.8	25.6	12.46
35.9	26.3	13.19
41.2	30.2	19.96
39	28.4	16.71
36.5	27	14.13
36.1	26.9	13.88
38.5	27.1	15.02
36.8	26.9	14.14
38.2	27.1	14.90
37.2	27	14.40
37.3	27	14.44
39.4	28.2	16.64
38.8	29	17.33
38.1	28.2	16.09

38.5	27.5	15.47
38.6	27.3	15.28
35.7	26	12.82
35.8	25.9	12.76
37.5	27	14.52
36.5	27.5	14.66
36.8	27.4	14.68
38.6	27.8	15.85
38.2	27.3	15.12
36.9	27.3	14.61
37.2	27.4	14.83
37.1	27.4	14.80
36.5	27	14.13
36.9	27.6	14.93
36.5	27	14.13
36.6	27.3	14.49
35.4	25.9	12.61
37	27	14.33
Other eggs		
36.0	25.5	Clarke 1906
38	27	Bennett 1927
35	25.2	Bennett 1927
32.5	19.0	Bennett 1927

PATTERN OF EGG MARKINGS. Typically on fresh eggs some staining and spotting can be seen; rarely short, indistinct streaks are found. Marking is concentrated typically at the fatter end of the egg, in the form of a clear, or dispersed wreath. There are examples of eggs without a visible marking, or with a marking made up of only poorly-visible deep stains. As incubation proceeds nearly always dirty marks appear from fat and mud stains.

MARKINGS—COLOUR. The small surface markings are brown, red, black, or red-dish-brown, while the deep markings are shades of violet.

PORES. Poorly visible and small, quite shallow, various shapes, normally elongated or round. An average-sized egg has around 1900 pores.

Antarctic Shag (Imperial Shag)
Phalacrocorax atriceps King, PP, 1828

Abundance

Breeds rarely in Admiralty Bay (Jabłoński 1984) in small colonies, nesting on cliffs, high rocks or boulders, padding the nest with seaweed, guano, moss, algae and grass. The female lays 2–3 eggs which are sat on for 40–45 days (Shirihai 2008). This area is nested in by the subspecies *P.a. bransfieldensis*.¹

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 10. The coefficient of variation of the breadth and length of the eggs was relatively low. The correlation between the length and breadth of the eggs was low $r = 0.34$ but statistically significant ($F_{1,80} = 10.1796$, $p = 0.0020$), and the regression equation between the breadth and length was $-B = 30.8537 + 0.1555 \cdot A$ (Fig. 9). The correlation coefficient between the weight of the egg and its length and breadth was very high and statistically significant ($p < 0.05$) (Fig. 10). The difference between the average weight of individuals and full clutches was large and came to 27.3%, on average 43.6 g (range 37.1 g), while the variation of

¹The systematics of this group of cormorants is very confusing (Orta et al. 2015). The taxus *albiventer* was formerly considered a separate species, but in the wide area where they cohabit alongside *atriceps*, mixed pairs are very often recorded. Apart from this there are no recorded differences in behaviour or osteology and maybe *albiventer* is only a subspecies or is only a morf. The subspecies *bransfieldensis*, *georgianus*, *nivalis*, *melanogenis* and *purpurascens* were also regarded as separate species, but the differences between them were not well documented. Therefore all these taxa are for now treated as one species *P. atriceps* (Dickinson&Remsen 2013, Orta et al. 2015, Mielczarek&Kuziemko 2016).

TABLE 10 Morphometry of *Phalacrocorax atriceps* eggs (N=82). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	64.84	57.7	69.8	4.78	3.10	9.49
Egg breadth (mm)	40.94	36.5	46.4	3.50	1.43	11.94
Fresh egg weight (g)	57.8	40.7	74.1	9.69	5.60	29.06
Shell weight egg (g)	4.77	3.20	6.31	10.96	0.52	32.63
Volume egg (cm ³)	53.7	37.9	68.7	9.64	5.18	28.92
Volume shell (cm ³)	1.60	1.13	2.05	9.69	0.16	29.06
Surface area egg (cm ²)	70.1	55.6	81.7	6.52	4.57	18.99
Shell thickness (mm)	0.313	0.266	0.367	4.73	0.01	15.93
Large circumference (mm)	167.0	148.8	177.0	3.63	6.06	8.65
No. pore/egg	4843	3788	5773	6.83	330.89	20.76
Factor shape k	1.58	1.39	1.83	4.84	0.08	13.85
Relative egg weight	3%					

TABLE 11 Mean mass $\pm$ SD of *Phalacrocorax atriceps* eggs in relation to clutch size and position in the sequence of laying (N=523 clutches) (Svigelj&Quintana 2011)

Clutch size	N	Position in sequence				Mean $\pm$ SD
		First	Second	Third	Fourth	
1	7	54.64 $\pm$ 1.77				54.64 $\pm$ 1.77
2	117	54.24 $\pm$ 0.44	53.78 $\pm$ 0.43			54.01 $\pm$ 0.31
3	389	55.21 $\pm$ 0.22	54.80 $\pm$ 0.23	52.55 $\pm$ 0.23		54.18 $\pm$ 0.13
4	10	55.47 $\pm$ 2.29	54.49 $\pm$ 2.16	54.50 $\pm$ 1.78	52.45 $\pm$ 2.02	54.23 $\pm$ 1.01

eggs where only one was laid came to 5.4 g, range 0.65 g – 11.1 g (N=23). The Antarctic Shag lays very small eggs in relation to the weight of the female – just 3%.

In the case of research conducted on a large number of sampled eggs (N=1588) the extreme dimensions were 53.97–72.49 x 34.83–45.74 mm (Svigelj&Quintana 2011). The mass of the eggs is slightly dependent on the order in which they are laid. The largest egg is the first, while the smallest is the second (Table 11, Punta et al. 2003). An average egg consists of 66.1% albumen, 20.7% yolk and 13.2% shell (Williams et al. 1982).

Oomorphology

EGG SHAPE. Heteropolar, sometimes homopolar, highly elongated, with rounded ends, sometimes pear-shaped and also strongly elongated. The average shape factor $k = 1.58$ also shows that the eggs have a strongly elongated shape (Szielasko 1920).

GRAIN & SHELL TEXTURE. The shell is matt, coarse-grained and very rough to the touch. Coated with a thick white calcareous deposits, sometimes the base colour is almost invisible (Plate 3).

TABLE 12 Geographical variation in egg size of the *Phalacrocorax atriceps*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Antarctic Peninsula	4	64.25	41.40	54.3	Nelson 2005
Admiralty Bay <i>brandsfieldensis</i>	82	64.84	40.94	53.7	This study
Punta León Argentina	1588	62.40	40.00	49.2	Svigelj&Quintana 2011
Isla Isabel and Galiano	742	61.8	39.8	48.3	Punta et al. 2003
South America	12	57.2	40.2	45.6	Pena 2013
Macquarie Island <i>purpurascens</i>	30	63.6	39.5	48.9	Brothers 1985
Macquarie Island <i>purpurascens</i>	130	64.0	40.0	50.5	Falla 1937
Marion Island <i>melanogenis</i>	204	62.9	39.4	48.1	Schonwetter 1988
subspecies <i>verrucosus</i>	34	60.9	38.5	44.5	Schonwetter 1988
Heard Island <i>nivalis</i>	107	63.6	40.3	50.9	Green 1997

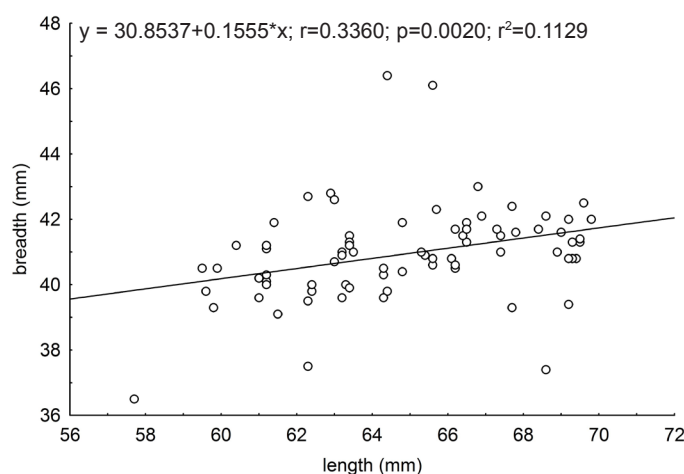
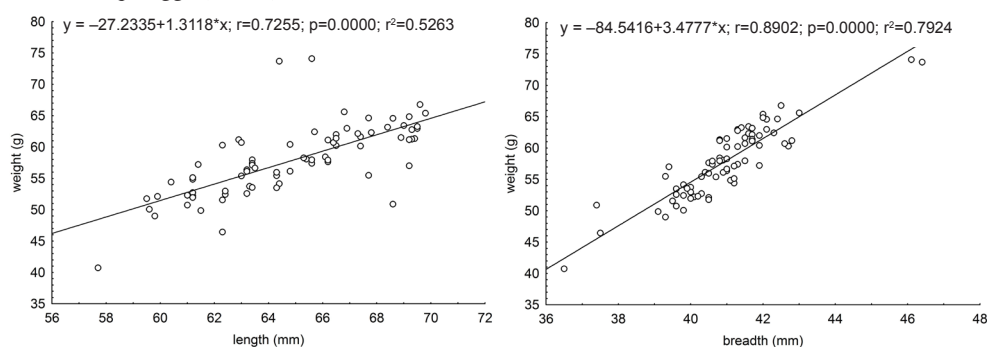


FIG. 9 Linear regression between the length and the breadth of *Phalacrocorax atriceps* (N=82)

FIG. 10 Relationship between calculated egg-weight and breadth (right) and length (left) of *Phalacrocorax atriceps* eggs (N=82)



GROUND-COLOUR. The base colour of the shell is light, monochrome, white or blueish-green. Sometimes because of the white chalky precipitate or fat covering the shell, the base colour is almost impossible to see.

PATTERN OF EGG MARKINGS. No markings, but as incubation proceeds, the eggs are completely covered in dirt and gradually turn a brown colour.

PORES. Because of the large amount of chalky deposit or fat stains, the pores are hard to see. But if the chalk is rubbed off they are increasingly visible. Generally small, quite shallow, of variable shape, normally elongated or round. An average-sized egg has some 4850 pores.

GEOGRAPHIC VARIATION. The largest eggs are laid by the subspecies *brandsfeldensis* on King George Island at over 53 cm³, slightly smaller are *atriceps*, *nivalis* and *purpurascens* at c. 50 cm³, while the smallest are *verrucosus* at around 45 cm³ (Table 12).

Snowy Sheathbill *Chionis albus* (Gmelin, JF, 1789)

Abundance

They breed in Admiralty Bay in small numbers, generally on their own near colonies of penguins or cormorants (several pairs), populating areas of rubble consisting of large boulders cut with deep crevices (Lesiński 1993). They make their nests in shallow burrows, crevices or rock falls, laying 2–3, occasionally 1–4 eggs which they sit for 28–32 days (Shirihai 2008).

Oomorphology

The sample from King George Island is small with just 16 eggs. The statistical description of the variation of different characteristics of the eggs is given in Table 13.

EGG SHAPE. Heteropolar, ovoid, usually slightly elongated, with a rounded narrower end, sporadically pear-shaped. The average shape factor of the egg, $k = 1.51$, shows that the eggs have a slightly elongated elliptical shape (Szielasko 1920). They are the most beautifully coloured eggs, after those of the Kelp Gull, to be found on the island (Plate 4).

GRAIN & SHELL TEXTURE. The shell is quite shiny, particularly towards the end of incubation, occasionally matt, medium-grained and quite rough to the touch.

GROUND-COLOUR. The background colour of the shell is quite pale creamy-white, brownish-white, sometimes almost completely white.

PATTERN OF EGG MARKINGS. Often the eggs have thick markings of varying sizes and irregular shape which are distributed relatively evenly; sometimes little marks and spots are found in elongated streaks along the long axis of the egg.

TABLE 13 Morphometry of eggs *Chionis albus* (N=16). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	57.76	54.3	60.1	3.09	1.78	5.07
Egg breadth (mm)	38.28	36.9	39.6	2.44	0.93	3.53
Fresh egg weight (g)	46.6	42.9	51.4	5.86	2.73	8.96
Shell weight egg (g)	3.73	3.4	4.17	6.64	0.25	10.14
Volume egg (cm ³)	43.4	39.9	47.8	5.83	2.53	8.92
Volume shell (cm ³)	1.24	1.15	1.37	5.83	0.07	8.92
Surface area egg (cm ²)	61.22	58.18	65.40	3.84	2.35	5.84
Shell thickness (mm)	0.295	0.281	0.309	3.14	0.01	4.66
Large circumference (mm)	151.6	146.7	157.1	2.10	3.18	3.41
No. pore/egg	4164	3931	4461	4.11	171.2	6.32
Factor shape k	1.51	1.40	1.58	3.97	0.06	5.93
Relative egg weight	7%					

The edges of the marks are generally sharp or only slightly fuzzy. Sometimes the markings at the fatter end are thick and create a little wreath or cap; other than this the markings can join up and create extensive smears. One can also find eggs with very thick markings covering the pale background, where the eggs give the impression of being very dark; or there can be eggs with very little, pale markings. The deep staining is generally abundant, but normally hard to see.

MARKINGS–COLOUR. The surface markings are in various shades of brown (from light– to dark brown), occasionally black or yellowish. The deep markings are pale, grey–brown, grey or violet grey.

PORES. The pores are quite dense but clearly visible. Normally they are small, shallow of varying shape. An average–sized egg will have around 4200 pores.

GEOGRAPHICAL VARIATION. The geographical variation appears to be very limited. Eggs from Admiralty Bay were slightly smaller than those found on the Antarctic Peninsular or on Signy Island (Table 14).

TABLE 14 Geographical variation in egg size of the *Chionis albus*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Antarctic Peninsula	141	57.4	38.4	43.3	Cordier 1983
Admiralty Bay King George Island	16	57.76	38.28	43.4	This study
Nelson Island	6	57.7	38.5	43.8	Lumpe&Weidinger 2000
Signy Island	103	57.6	38.5	43.7	Jones 1963

Length (mm)	Breadth (mm)	Calculated weight (g)	Egg dimensions <i>Chionis albus</i> from Admiralty Bay, King George Island		
57.3	36.9	41.31	59.2	37.6	44.32
58.3	36.9	42.04	58.4	38.8	46.56
59.2	37.6	44.32	58	39.7	48.41
55.4	38.2	42.81	59.2	37.9	45.03
59.1	39.1	47.85	57.4	38.5	45.05
54.3	38.7	43.06	54	38.6	42.61
60.1	39.4	49.40	57.3	38.1	44.05
58.7	39.6	48.74	58.3	36.9	42.04

Kelp Gull *Larus dominicanus* Lichtenstein, MHC, 1823

Abundance

Dozens of pairs nest in the Bay region (Lesiński 1993), normally in small, loose colonies, but sometimes in larger concentrations. They build their nests on the sea-cliffs and inaccessible rocks on the ridges of steep morains, lining them with moss, algae and seaweeds. They lay 2–3 eggs and sit for 24–30 days (Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 15. The mass of an individual egg in relation to the weight of the female was average, at 8.3%, while the whole clutch came to 20.7%. The correlation between the length and breadth was average $r = 0.47$ and statistically significant ($F_{1,198} = 57.2961$, $p = 0.00001$) (Fig. 11). The regression equation between the breadth and length was $-B = 29.6378 + 0.2751 \cdot A$. The correlation coefficient between the weight of the egg and its length and breadth was very high and statistically significant ($p < 0.05$) (Fig. 12). The largest egg: 82.9 x 51.5 mm, the smallest 59.7 x 41.0 mm. The variation between the eggs within the same clutch was not great, at 4% on average, range 0.09–18.4%. The loss of weight of the eggs during incubation was as much as 35–39%; during the first four days the weight loss is minimal, later roughly 1 g per day (Fordham 1964).

The difference between the average weight of the eggs in clutches of 2 and 3 eggs was 2.53 g: clutches of two – 93.05 g, clutches of 3 – 90.52 g, but the differences turned out to be statistically insignificant ($F_{1,27} = 0.3302$, $p = 0.5705$). The size of the eggs also changes with the order in which they are laid. In Southern Africa the first eggs were significantly heavier than the second and the third, the lightest – 93.2 g 90.5 g and 84.2 g respectively. However, in New Zealand the second egg was the largest – first 84.2 g, second 79.7 and third 72.9 g (Fordham 1964, Williams et al. 1984). The largest egg from the 1, 2 or 3-clutch nests is laid first in the two-egg

TABLE 15 Morphometry of *Larus dominicanus* eggs (N=202). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	71.39	61.4	80.0	3.77	2.69	13.15
Egg breadth (mm)	49.28	45.5	54.2	3.15	1.55	8.73
Fresh egg weight (g)	94.8	69.3	119.6	8.78	8.32	26.66
Shell weight egg (g)	8.34	5.84	10.84	9.94	0.83	29.97
Volume egg (cm ³)	87.8	64.3	110.7	8.73	7.67	26.52
Volume shell (cm ³)	2.63	1.92	3.32	8.78	0.24	26.66
Surface area egg (cm ²)	97.1	78.3	112.7	5.84	5.67	18.01
Shell thickness (mm)	0.414	0.366	0.470	4.30	0.02	12.44
Large circumference (mm)	190.2	168.5	205.7	3.06	5.81	9.94
No. pore/egg	6861	5505	8087	6.18	424.12	19.00
Factor shape k	1.45	1.29	1.61	3.57	0.05	10.88
Relative egg weight	8.3%					

clutches 91.61 cm³ (N=48), equally large is the first egg in the 3–egg clutches 90.16 cm³ (N=11), while the smallest is the third egg in 3–egg clutches 79.13 cm³ (N=11) and in nests with one egg 81.82 cm³ (N=10) (Prellvitz et al. 2009).

An average egg consists of 61.4% albumen, 29% yolk and 9,5% shell (Williams et al. 1982).

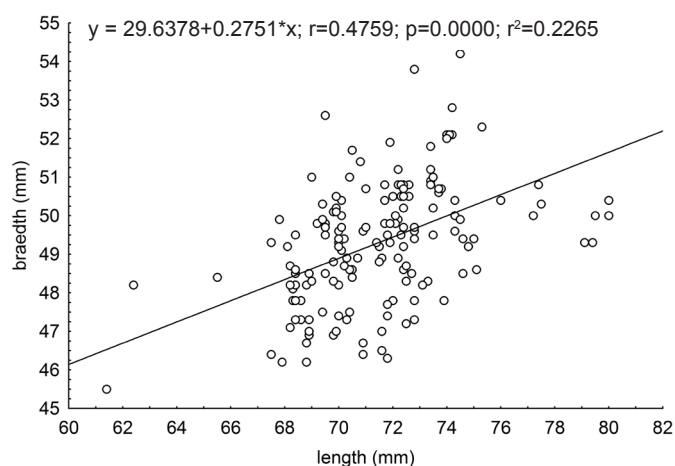


FIG. 11 Linear regression between the length and the breadth of *Larus dominicanus* (N=202)

TABLE 16 Geographical variation in egg size of the *Larus dominicanus*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
San Jorge Gulf Argentina	443	71.1	48.6	84.9	Yorio&Borboroglu 2002
Admiralty Bay	202	71.39	49.28	87.8	This study
Keller Peninsula King George Island	55	72.0	51.0	94.7	Branco et al. 2009
Gulf Algoa, South Africa	58	72.0	48.2	84.6	Williams et al. 1984
Saldanha Bay, South Africa	119	70.4	48.5	83.7	Williams et al. 1984
Marion Island	38	70.1	47.9	81.3	Williams et al. 1984
Kerguelen Island	14	69.0	49.2	84.5	Williams et al. 1984
Somes Island	798	69.2	47.0	77.3	Fordham 1964
Deception Island	13	74.7	49.7	93.3	Gain 1914
Falkland	12	72.5	51.0	95.3	Murphy 1936
Tamboretes Island, Brazil	164	71.7	49.1	87.4	Branco et al. 2009
Itacolomis Island, Brazil	94	71.8	48.3	84.7	Branco et al. 2009
Deserta Island, Brazil	300	71.5	48.9	86.4	Branco et al. 2009
Moleques Island, Brazil	744	70.1	48.3	82.7	Branco et al. 2009
Lobos, Brazil	142	71.2	48.7	85.3	Branco et al. 2009
Parana coast, Brazil	29	70.73	49.86	88.9	Krull 2004
Parana coast, Brazil	67	70.89	49.30	83.92	Carniel 2008
Nelson Island	22	70.2	48.2	82.5	Lumpe&Weidinger 2000

Oomorphology

EGG SHAPE. Heteropolar, ovoid, normally slightly elongated with a rounded narrow end, sometimes close to pear-shaped. The average shape factor $k = 1.45$ shows that the eggs have a typically elliptical shape. Alongside the Snowy Shearwater, they are the most beautifully coloured eggs on the island (Plate 5).

GRAIN & SHELL TEXTURE. The shell is shiny, particularly by the end of incubation, very occasionally matt, medium-grained and quite rough to the touch.

GROUND-COLOUR. The eggs from King George Island had base shell colours in greenish-yellow and pale brown, more rarely creamy-white or grey-white. Frodham (1964) after examining 818 eggs, identified 9 types of base shell colour, although two types were dominant (accounting for 80.6% in total), i.e. greyish and greyish-green, more rarely greenish (12.1%).

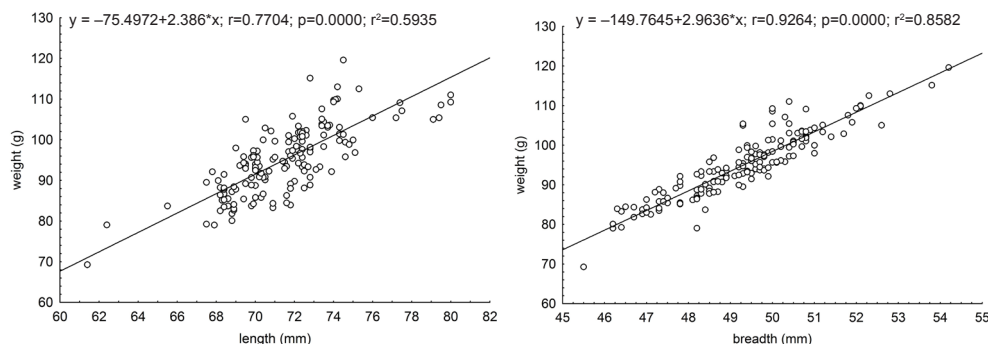
PATTERN OF EGG MARKINGS. The eggs have markings of various sizes, usually quite small and relatively sparsely distributed and of irregular shape, more densely concentrated in the fatter end of the egg; rarely eggs can be found with several large markings randomly dispersed over the shell. The edges of the markings are usually sharp or only slightly blurred. Sometimes the markings at the fatter end are very dense and form a cap. One can also find eggs with small pale markings. The deep markings are usually abundant but hard to see, only on eggs with a pale base shell colour are they very clearly visible in the form of irregular small or medium-sized marks.

MARKINGS-COLOUR. The surface markings are in various shades of brown (from pale- to dark-brown), more rarely black or yellowish, while the deep markings are pale grey-brown, grey or violet-grey.

PORES. The pores are hard to see, small and shallow, of variable shape, usually round. An average sized egg will have around 6800 pores.

GEOGRAPHICAL VARIATION. If we look at sample sizes of over 30 eggs, the largest eggs were found among the population inhabiting the Keller peninsular on King George Island – 94.7 cm^3 , quite large eggs were found in the Admiralty Bay population – 87.7 cm^3 (data below); on the Brazilian coast gulls lay eggs of similar size – 82.7 cm^3 – 87.4 cm^3 (Branco et al. 2009); whilst the smallest appear in another part of the world in New Zealand only 77.3 cm^3 (Frodham 1964) (Tab. 16).

FIG. 12 Relationship between calculated egg-weight and breadth (right) and length (left) of *Larus dominicanus* eggs (N=202)



Antarctic Tern *Sterna vittata* Gmelin, JF, 1789

Abundance

Nesting in colonies of up to 40 pairs, rarely up to 1000 pairs, the colonies in the area of Admiralty Bay were found on the morains and gentle slopes covered with fine-grained shingle; nests are most often found in recesses in the earth or sand or among small stones, usually lined with fine, delicate stones; they lay 1–2 eggs, which are sat on for 23–25 days (Jabłoński 1995, Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 17. The weight of an individual egg relative to the weight of the female, at 19%, was average, while the whole clutch came to 50%. The correlation between the length and breadth was low $r = 0.21$ and statistically significant ($F_{1\ 476} = 11.9393$, $p = 0.0007$) (Fig. 13), but statistically significant ($p < 0.05$). The regression equation between the breadth and the length came to $-B = 29.1653 + 0.0962 \cdot A$. The correlation coefficient between the weight of the egg and its length and breadth was very high and statistically significant ($p < 0.05$) (Fig. 14).

Eggs from 1 and 2 egg clutches weigh on average the same, e.g. on Snares Island 24.56 g (Sagar et al. 2003). As the nesting season progresses the eggs laid are somewhat smaller (Jabłoński 1995): 25–30 XI 46.7 x 33.1 mm; 26 XII – 3 I 44.5 x 33.4 mm; 9–14 I 43.0 x 33.5 mm.

TABLE 17 Morphometry of eggs *Sterna vittata* (N=479). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	45.25	41.5	51.5	3.34	1.51	10.75
Egg breadth (mm)	33.54	31.1	43.5	2.43	0.81	16.62
Fresh egg weight (g)	28.97	23.54	32.37	5.74	1.60	15.81
Shell weight egg (g)	2.09	1.72	2.47	6.49	0.14	17.85
Volume egg (cm ³)	26.0	22.9	30.1	5.71	1.49	15.73
Volume shell (cm ³)	0.78	0.65	0.90	5.74	0.04	15.81
Surface area egg (cm ²)	43.1	38.3	48.1	3.92	1.69	11.33
Shell thickness (mm)	0.241	0.219	0.259	2.70	0.01	8.46
Large circumference (mm)	124.3	116.3	134.6	2.28	2.83	7.32
No. pore/egg	2906	2574	3222	4.05	117.65	11.18
Factor shape k	1.35	1.07	1.53	3.64	0.05	17.58
Relative egg weight	19%					

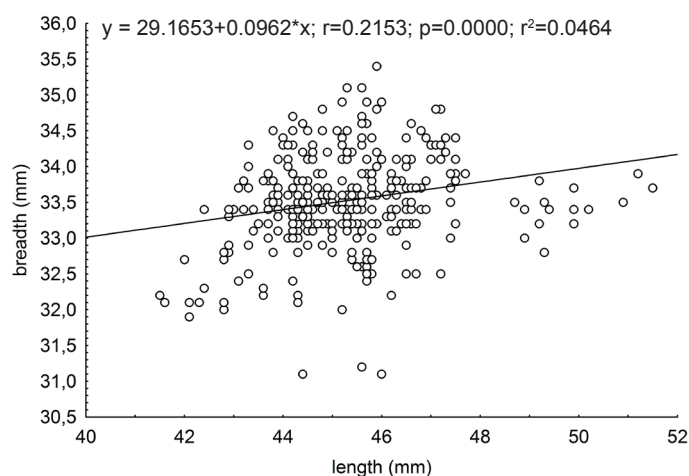


FIG. 13 Linear regression between the length and the breadth of *Sterna vittata* (N=479)

Oomorphology

EGG SHAPE. Heteropolar, ovoid, not very elongated with a rounded narrow end, sometimes pear-shaped or rounded. The average shape factor $k = 1.35$ shows that the eggs have a typical elliptical shape (Table 6).

GRAIN & SHELL TEXTURE. The shell is shiny, particularly by the end of incubation, very occasionally matt, fine-grained, smooth to the touch.

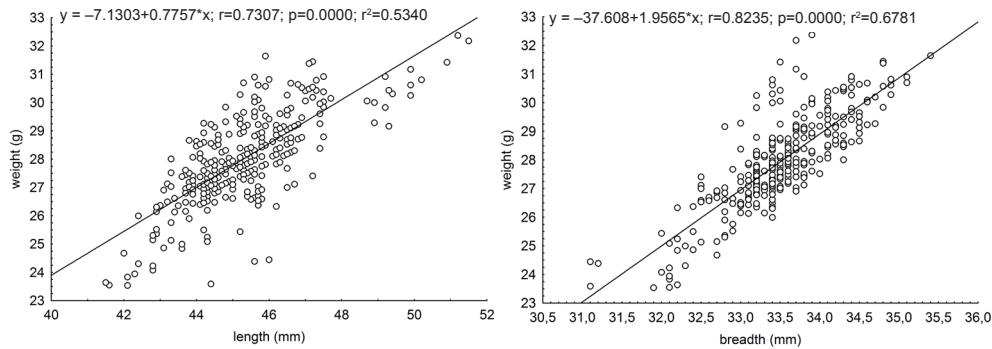
GROUND-COLOUR. The base colour is usually greenish-brown, more rarely brown in shades from pale to dark (approx. 30% of the egg) (Jabłoński 1995).

PATTERN OF EGG MARKINGS. The eggs have various sizes of markings, more or less evenly distributed over the egg, irregular in shape. The markings are often concentrated at the fatter end, creating a wreath or cap. The edges of the markin-

TABLE 18 Geographical variation in egg size of the *Sterna vittata*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Admiralty Bay King George Island	479	45.25	33.54	26.0	This study
King George Island	57	45.13	33.6	26.1	Ayala&Felippe 2012
Kerguelen Island	19	46.7	33.0	26.1	Sagar 1991
Crozet Island	5	43.8	31.8	22.7	Despin et al. 1972
Tristan da Cunha	10	45.7	31.5	23.2	Jabłoński 1995
Snares Island	14	46.2	32.1	24.4	Jabłoński 1995
Snares Island	153	45.75	32.2	24.3	Sager et al. 2003
Antarctic Peninsula	69	46.0	32.8	25.4	Cordier et al. 1983
Nelson Island	132	45.1	33.1	25.3	Lumpe&Weidinger 2000
King George Island	650	44.7	32.9	24.8	Peter et al. 1988

FIG. 14 Relationship between calculated egg-weight and breadth (right) and length (left) of *Sterna vittata* eggs (N=479)



gs are normally sharp or have only slightly blurred edges. Some eggs have quite small, pale markings, when often the fatter end has a large, dark cap. The deep markings are normally abundant and on pale eggs are particularly easy to see in the form of irregular small or medium-sized markings.

MARKINGS-COLOUR. The surface markings are normally dark brown (from pale- to dark-brown), rarely brownish-black, while the deep markings are pale grey-brown, normally smaller than the surface markings, the majority distributed evenly, rarely concentrated at one end.

PORES. The pores are hard to see or invisible, small and shallow, variously shaped, normally round. An average-sized egg has approximately 2900 pores.

GEOGRAPHICAL VARIATION. When analysing samples of more than 30 eggs, the largest have been found among the population nesting in the most southerly regions, i.e. on Nelson Island and the Antarctic Peninsula – 25.3 cm³, on King George Island – 26.0 cm³, and the smallest on the most northerly Snares Island – 24.3 cm³ (Table 18).

South Polar Skua *Catharacta maccormicki* Saunders, H, 1893

Abundance

The most common skua on King George Island, nesting in loose colonies, on rocks, moraine hills (Lesiński 1993), lined with grasses, little stones and blocks and moss; it lays 1–2 eggs which are sat on for 28–31 days (Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 19. The correlation between the length and the breadth was quite low $r = 0.33$ and statistically significant ($F_{1,38} = 4.4137$, $p = 0.0425$), while the regression equation between the breadth and length was $B = 39.9201 + 0.1436 \cdot A$ (Fig. 15). The dependence between the breadth and length and weight of the eggs also turned out to be statistically significant ($p < 0.05$) (Fig. 16). The first egg laid is normally heavier than the second – on average by 3.9 cm^3 (Wang&Norman 1993). At Palmer Station the average volumes when food was scarce during egg formation was 81.5 cm^3 ($67.5\text{--}97.3 \text{ cm}^3$; 58 clutches); when more food is readily available – 84.5 cm^3 ($74.6\text{--}99.1 \text{ cm}^3$; 40 clutches) (Higgins&Davies 1996).

Oomorphology

EGG SHAPE. The eggs are heteropolar, ovoid, little elongated with a rounded narrow end, sometimes cracked. The average shape factor $k = 1.43$ shows that the eggs have a typical elliptical shape (Plate 7).

TABLE 19 Morphometry of *Stercorarius maccormicki* eggs (N=39). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	72.25	64.9	79.9	4.00	2.89	10.36
Egg breadth (mm)	50.30	48.5	55.2	2.53	1.27	6.46
Fresh egg weight (g)	97.4	85.7	108.2	7.59	5.63	11.57
Shell weight egg (g)	8.59	7.44	9.68	8.63	0.56	13.08
Volume egg (cm^3)	90.2	79.5	100.1	7.55	5.19	11.51
Volume shell (cm^3)	2.70	2.38	3.00	7.59	0.16	11.57
Surface area egg (cm^2)	98.6	90.1	107.0	5.09	4.03	8.60
Shell thickness (mm)	0.42	0.40	0.44	3.48	0.01	4.81
Large circumference (mm)	191.9	180.5	204.6	2.88	5.08	6.25
No. pore/egg	6993	6396	7533	5.29	284.80	8.16
Factor shape k	1.44	1.31	1.61	3.98	0.06	10.56
Relative egg weight	7.8%					

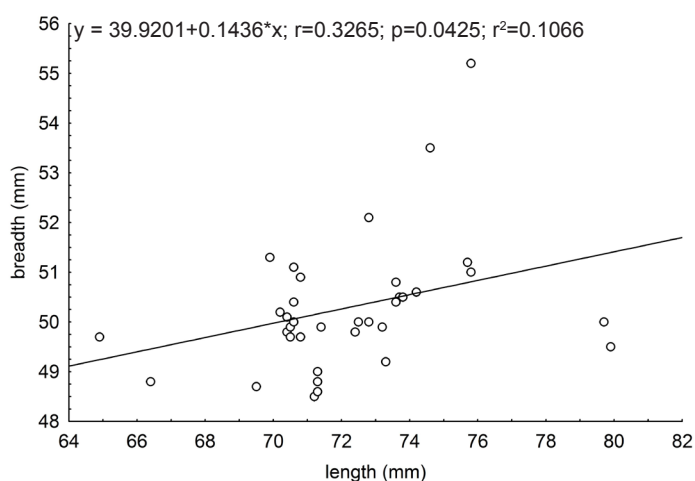


FIG. 15 Linear regression between the length and the breadth of *Catharacta maccormicki* (N=39)

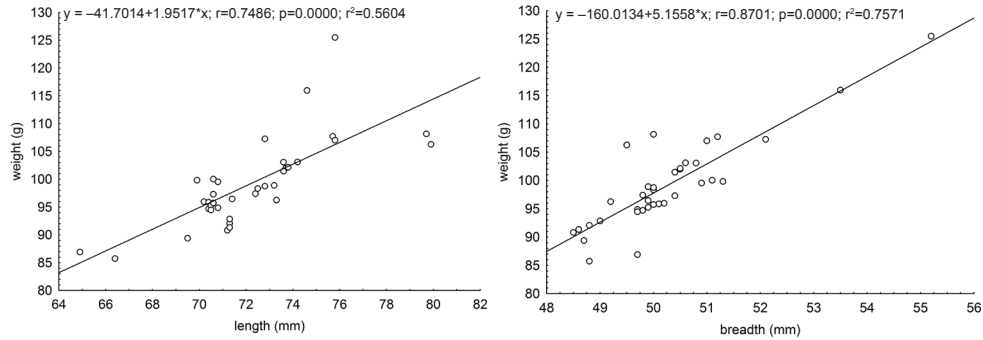
GRAIN & SHELL TEXTURE. The shell is shiny, particularly towards the end of incubation, very rarely matt, medium-grained, smooth to the touch, although sometimes it can feel slightly rough; sometimes it is covered in calcareous lumps.

GROUND-COLOUR. The base colour of the shell is usually greenish-brown, occasionally brown in light to dark shades.

TABLE 20 Geographical variation in egg size of the *Catharacta maccormicki*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Prydz Bay, Antarctica	21	70.02	49.91	87.6	Wang&Norman 1993
Admiralty Bay King George Island	39	72.25	50.3	90.2	This study
Signy Island	27	71.3	49.6	88.1	Hemmings 1984
Pointe Geologie	13	71.0	50.7	91.7	Hemmings 1984
Cape Denison	12	70.6	51.5	94.1	Hemmings 1984
Antarctic Peninsula	10	71.9	49.0	86.8	Gain 1914
McMurdo Sound	11	70.9	49.7	88.0	Wilson 1907
Hop Island	62	72.8	51.2	95.9	Norman&Ward 1999
Graham Land	69	69.41	49.11	84.1	Peklo 2011
Haswell Island	7	69.3	51.2	91.3	Starck 1980
S Shetland Island	118	71.2	50.5	91.2	Peter et al. 1990
Terre Adelie	21	71.45	50.7	92.3	Higgins&Davies 1996
C. Denison	12	70.6	51.5	94.1	Higgins&Davies 1996
Palmer Station	175	70.9	49.2	86.2	Higgins&Davies 1996

FIG. 16 Relationship between calculated egg-weight and breadth (right) and length (left) of *Catharacta maccormicki* eggs (N=39)



PATTERN OF EGG MARKINGS. The eggs have spots of different sizes, evenly distributed over the shell of irregular shape. The markings are usually sparse and small. Sometimes the spots are concentrated at the fatter end and create a cap; occasionally eggs have several larger spots randomly distributed over the shell. The edges of the spots are normally sharp or have only slightly blurred edges. One can find eggs with a pale base colour, through which one can clearly see the deep markings.

MARKINGS-COLOUR. The surface spots are usually dark brown (from pale to dark brown), rarely brownish-black, while the deep spots are pale grey-brown, violet-grey, normally smaller than the surface spots, the majority are distributed evenly, rarely concentrated at one of the ends.

PORES. The pores are hard to see, small and shallow or variable shape, usually round. An average egg will have c. 7000 pores.

GEOGRAPHICAL VARIATION. Because of the small number of measured eggs (in samples greater than 30 eggs) it is difficult to make a broader comparison, but one usually refers to two measurements, taken in different parts of Antarctica – specifically on Hop Island – 95.9 cm³ and on Graham Land and Palmer Station – more than 10 cm³ smaller (Norman&Ward 1999, Peklo 2011); the eggs on King George Island are quite large with volume of 92 cm³ (Table 20).

Brown Skua *Catharacta antarctica* (Lesson, 1831)

Abundance

One of the most common skuas, nesting in loose colonies, it builds its nest on sea shores, beaches, on shingle and stones with small recesses lined with moss and grass; they lay 1–2 eggs (larger clutches are laid by 2 or more females) and sitting lasts 28–32 days (Shirihai 2008). King George Island is inhabited by the subspecies *C.a. lonnbergi*.²

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 21. The correlation between the length and breadth was low $r = 0.21$ and statistically significant ($F_{1,99} = 4.4823$, $p = 0.0368$). The regression equation between the breadth and length was $B = 42.1801 + 0.1097 \cdot A$ (Fig. 17). The dependence between the breadth and length and weight of the egg was also statistically significant ($p < 0.05$) (Fig. 18). The maximum difference between the eggs in a clutch was 18 g. In over 37% of the clutches the difference was more than 2.5 g, while in the remainder the differences were greater (Williams 1980). The first egg laid is heavier than the second, 105.1 g and 99.2 g respectively, while the composition of the eggs is as follows – first and second respectively: shell 11.8 g and 10.8 g, yolk 28.3 g and 32.0 g, albumen 65.0 g and 56.4 g, water content 76.0 g and 70.7 g (Williams 1980a).

² Formerly included in the *Catharacta skua* species, but tests on mitochondrial DNA, features of the plumage and biometrics show that the differences between *C. antarctica* and *C. skua* are sufficiently clear that they should be treated as separate species. Currently three subspecies are recognised: *lonnbergi*, *clarkei* and *intercedens* (Furness&Bonan 2016).

TABLE 21 Morphometry of eggs *Catharacta antarctica lonnbergi* (N=101). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	73.15	64.6	81.4	3.43	2.51	11.51
Egg breadth (mm)	51.20	46.9	55.5	2.58	1.32	8.40
Fresh egg weight (g)	105.7	87.0	125.9	6.76	7.10	18.26
Shell weight egg (g)	9.43	7.56	11.48	7.65	0.72	20.61
Volume egg (cm ³)	99.9	80.6	116.4	6.72	6.53	18.16
Volume shell (cm ³)	2.93	2.41	3.49	6.76	0.20	18.26
Surface area egg (cm ²)	104.4	90.7	116.4	4.52	4.76	12.33
Shell thickness (mm)	0.438	0.406	0.486	3.42	0.01	9.01
Large circumference (mm)	196.4	179.9	211.0	2.47	5.23	7.96
No. pore/egg	7410	6462	8381	4.77	349.16	12.93
Factor shape k	1.43	1.30	1.57	3.82	0.05	9.31
Relative egg weight	6.9%					

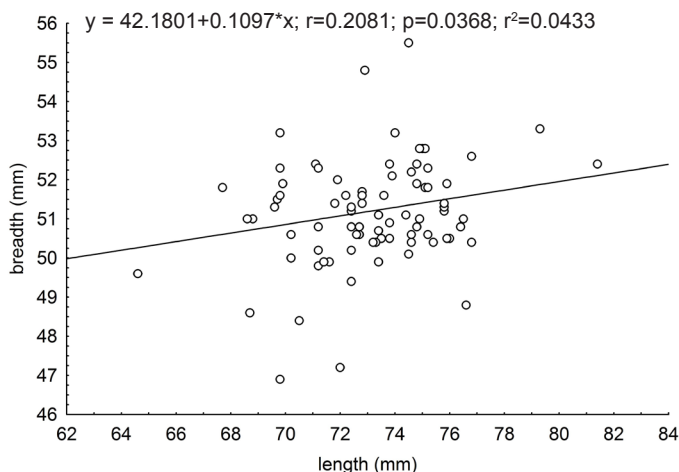


FIG. 17 Linear regression between the length and the breadth of *Catharacta antarctica lonnbergi* (N=101)

Oomorphology

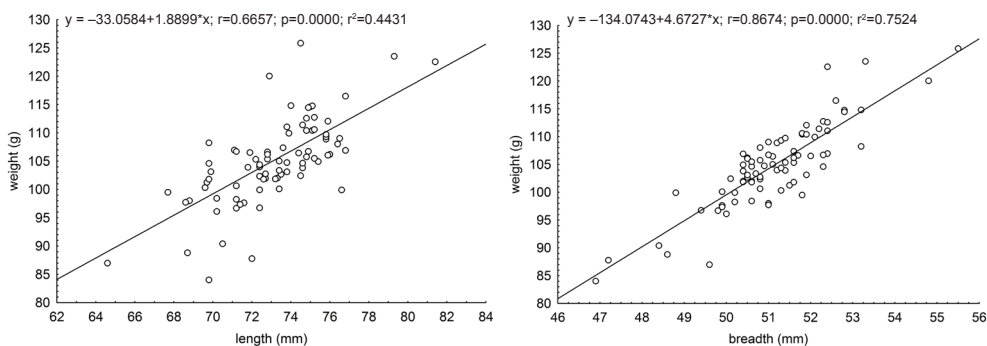
EGG SHAPE. Heteropolar, ovoid, slightly elongated, with a rounded narrow end, occasionally cracked. The average shape factor $k = 1.44$ shows the eggs have a typical elliptical shape (Plate 8).

GRAIN & SHELL TEXTURE. The shell is shiny, particularly by the end of incubation, very rarely matt, medium-grained, sometimes coarse-grained, slightly rough to the touch, but sometimes smooth, especially fully-incubated eggs.

GROUND-COLOUR. The base colour of the shell is typically brown, more rarely dark brown or greenish-brown. The eggs are generally clean, unsoiled, sometimes with traces of excreme.

PATTERN OF EGG MARKINGS. The eggs have different sized markings, evenly distributed over the shell, of irregular shape, mainly round. Normally the markings are

FIG. 18 Relationship between calculated egg-weight and breadth (right) and length (left) of *Catharacta antarctica lonnbergi* eggs (N=101)



sparse and limited, but some eggs have markings in the form of dots along the axis of the egg; sometimes the markings are concentrated at the fatter end and create a cap. The edges of the markings are usually sharp or have only slightly blurred edges. There can be eggs with a pale base colour, under which the deep markings can be clearly seen, often very extensively. The spots are typically irregularly shaped and randomly distributed over the shell but sometimes are concentrated at the fatter end creating a clear streak, which is rare for deep markings.

MARKINGS-COLOUR. The surface markings are normally dark-brown (from pale- to dark-), rarely brownish-black or black, while the deep markings are pale grey-brown, violet-brown.

PORES. Hard to see, small and shallow, of variable shape, normally round. An average-sized egg has c. 7400 pores.

GEOGRAPHICAL VARIATION. It appears that the variation in measurements of eggs in the Antarctic is relatively small (102–108 cm³), and the smallest eggs are laid by the population from Admiralty Bay on King George Island – 99.9 cm³ and the northern island of Tristan da Cunha 91.8 cm³ and Falkland 95.4 cm³ (Table 22).

TABLE 22 Geographical variation in egg size of the *Catharacta antarctica*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Admiralty Bay King George Island	101	73.15	51.20	99.9	This study
Signy Island	39	73.8	52.3	102.4	Hemmings 1984
Snares Island	16	73.6	53.4	106.5	Miskelly et al. 2001
Tristan da Cunha	22	70.1	50.8	91.8	Schonwetter 1988
Marion Island	43	76.6	52.6	107.5	Rand 1954
Marion Island	136	76.4	52.7	107.6	Williams 1980a
Antipodes Island	20	74.8	53.0	106.6	Moors 1980
South Georgia	20	75.5	53.2	108.4	Stonehouse 1956
Chatham Island	154	74.3	51.9	101.5	Hemmings 1989
Anvers Island	16	73.6	53.1	105.3	Higgins&Davies 1996
Crozet Island	20	76.5	52.9	108.6	Higgins&Davies 1996
Kerguelen Island	17	75.2	53.3	108.4	Higgins&Davies 1996
South Shetland Island	80	74.2	52.0	101.8	Peter et al. 1990
Tristan da Cunha& Gough Island <i>hamiltoni</i>	25	69.5	50.7	90.6	Williams 1980b
Falkland <i>antarctica</i>	14	69.8	51.9	95.4	Williams 1980b

Catharacta antarctica lonnbergi
Catharacta maccormicki (hybrid)

Abundance

In places with populations of both species mixed clutches can occur. On King George Island mixed pairs can make up 10–12% of all the pairs of skuas on the island (McCarthy 2006, Ritz et al. 2006), and the resulting offspring are fertile (Hemmings 1984, Peter et al. 1990).

Oomorphometry

The readings were taken from a small number of eggs (N=17) and therefore may have only an approximate value (Table 23, Plate 9). The eggs from the mixed pairs are more or less of average size – 94.7 cm³, the largest *C.a. lonnbergi* – 97.4 cm³, and the smallest *C. maccormicki* – 91.2 cm³. The results presented by Peter et al. (1990) are almost the same: the volume of the eggs from mixed pairs was 92.9 cm³, (N=21), for *C.a. lonnbergi* – 95.9 cm³ (N=80), while for *C. maccormicki* – 85.4 cm³ (N=118). The remaining measurements of the eggs of the mixed pairs are presented in Table 24.

TABLE 23 Morphometry of eggs *Catharacta antarctica lonnbergi* *Catharacta maccormicki* (N=17).
 Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	72.53	66.70	74.80	3.91	2.84	5.72
Egg breadth (mm)	50.83	48.80	53.80	2.82	1.43	4.87
Fresh egg weight (g)	102.3	88.4	118.1	8.63	8.83	14.35
Shell weight egg (g)	9.09	7.70	10.69	9.77	0.89	16.22
Volume egg (cm ³)	94.7	82.0	109.2	8.58	8.13	14.27
Volume shell (cm ³)	2.84	2.45	3.27	8.63	3.00	96.65
Surface area egg (cm ²)	101.9	92.4	111.8	5.79	5.90	9.53
Shell thickness (mm)	0.43	0.41	0.46	3.96	0.02	6.85
Large circumference (mm)	194.4	184.3	202.6	3.13	6.09	4.73
No. pore/egg	7240	6538	8013	6.07	439.70	10.14
Factor shape k	1.43	1.33	1.50	3.22	0.05	6.22

TABLE 24 Geographical variation in egg size of the *Catharacta antarctica lonnbergi* *Catharacta maccormicki*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Admiralty Bay King George Island	17	72.53	50.83	94.7	This study
Signy Island	6	73.8	51.8	99.9	Hemmings 1984
South Shetland Island	21	72.4	51.8	98.0	Peter et al. 1990
Palmer Station	4	74.5	53.3	106.8	Higgins&Davies 1996

Adelie Penguin *Pygoscelis adeliae* (Hombron & Jacquinot, 1841)

Abundance

15,000 pairs nest in the Admiralty Bay area (Rakusa-Suszczewski 2012). The female carves out a modest nest on an ice free piece of land and lays two, or very occasionally three eggs (Shirihai 2008).

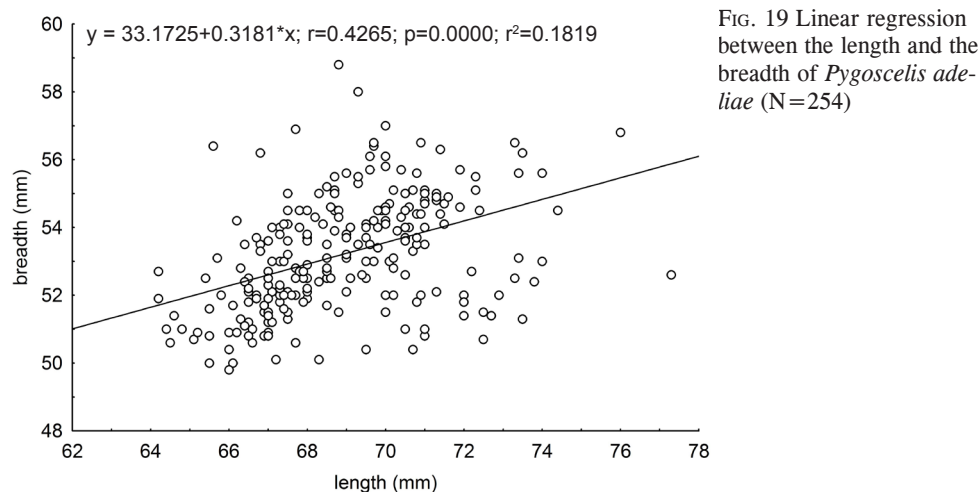
Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 25. In two-egg clutches the first egg is significantly larger than the second: 120.8 g and 113.2 g respectively (Lishman 1985). The calculated value of the shell thickness of 0.471 mm is smaller than that given by Tyler (1965) and Thompson&Goldie (1990) – 0.57 mm. The largest egg weighed 185 g and measured 81.4 x 64.5 mm; the smallest 36.8 x 31.0 mm (the weight of the smallest eggs 31 g – 58 g). Both the smallest and the largest eggs are not incubated (Ainley 2002). The small eggs are almost certainly laid by sexually immature or sick birds. The younger females lay eggs which are on average smaller than older birds (Ainley 2002).

The correlation between the length and breadth was average $r = 0.42$ and statistically significant ($p < 0.05$). The regression equation between the breadth and length was $B = 33.1725 + 0.3181 \cdot A$ (Fig. 19). The correlation coefficient between the mass of the egg and its length and breadth was very high and statistically significant ($p < 0.05$) (Fig. 20).

TABLE 25 Morphometry of eggs *Pygoscelis adeliae* (N=254). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	68,92	64,2	77,3	3,26	2,25	9,26
Egg breadth (mm)	53,21	49,8	58,0	3,15	1,68	18,58
Fresh egg weight (g)	110,2	92,38	138,7	8,30	9,13	20,04
Shell weight egg (g)	9,89	8,09	12,82	9,41	0,93	22,6
Volume egg (cm ³)	102,0	85,6	128,22	8,26	8,4	19,94
Volume shell (cm ³)	3,24	2,96	3,59	8,30	0,17	9,5
Surface area egg (cm ²)	107,25	95,62	125,4	5,45	5,84	13,48
Shell thickness (mm)	0,471	0,431	0,527	4,24	0,02	10,03
Large circumference (mm)	192,17	181,26	209,13	2,72	5,23	7,14
No. pore/egg	7627	6741	8974	5,84	444,2	14,21
Factor shape k	1,3	1,19	1,47	3,43	0,04	10,57
Relative egg weight	2.3%					



At Cape Royds on Ross Island the dimensions and weight of the first, second and third eggs laid by 10 specially marked birds was on average 122.5 g and 68.8 x 55.6 mm for the first egg, 115.5 g and 68.6 x 54.4 mm for the second egg and 102 g and 65.9 x 51.8 mm for the third egg (Taylor 1962). The volume of the eggs in single egg nests was $V=106.3$ ml and is lower for the second egg than the first in two-egg clutches – the first egg volume was 111.2 ml and the second 108.5 ml (Yates 1968).

The inter-year variation (Yeates 1968) for 1964/1965 was – 1 egg 70.51 x 55.23 mm; 2 eggs 69.18 x 54.49 mm (N=33), while for 1965/1966 – 1 egg 69.79 x 54.79 mm; 2 eggs 69.00 x 54.20 mm (N=33). In Admiralty Bay in 1978/1979 – 69.89 x 54.47 mm G=111.9 g (N=138), while for the years 1979/1980 – 70.67 x 54.99 mm, G=115.2 g (N=134) (own results).

Three egg nests in Admiralty Bay are on average slightly smaller than the eggs in two egg nests (1978–1980), 69.91 x 54.19 mm, G=110.7 g (N=8 clutch) and 70.27 x 54.72 mm, G=113.6 g (N=86 clutch).

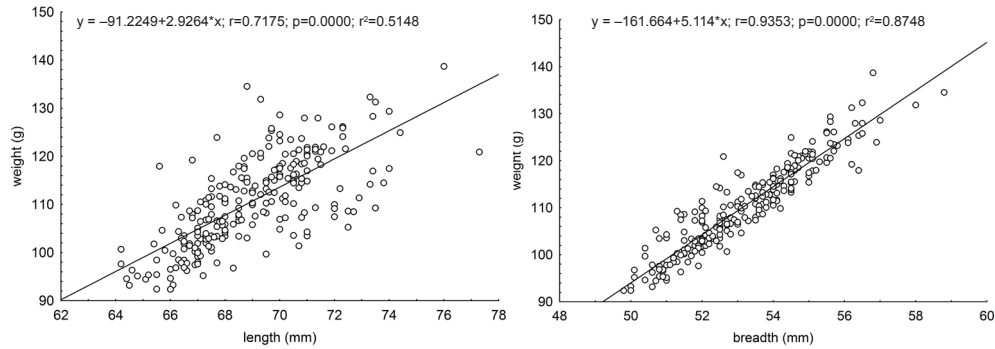
An average egg consists of 65.4% albumen, 21.6% yolk and 13.0% shell (Williams et al. 1982). Ancel and Beaulieu (2009) gave the formula for calculating the fresh mass of an egg $G=0.564 \cdot LW^2$.

The weight of eggs in relation to their order of laying (Taylor 1962)

- 1st egg (N=32): G=124 g (105–145); 69.8 mm (70.4–73.6) x 55.8 mm (52.5–60.2)
- 2nd egg (N=21): G=115 g (90–135); 68.7 mm (70.0–72.3) x 54.5 mm (48.1–58.1)
- 3rd egg (N=12): G=101 g (70–125); 66.1 mm (63.4–71.0) x 51.4 mm (44.5–55.0)
- Single-egg nests (N=10): G=117 g (95–130); 69.2 mm (65.4–74.3) x 54.1 mm (49.5–57.5).

Research on the penguins shows that birds nesting in the inside of large colonies on average raise more young, lay more eggs than birds nesting on the edge

FIG. 20 Relationship between calculated egg-weight and breadth (right) and length (left) eggs *Pygoscelis adeliae* (N=254)



of such colonies or in small colonies or nesting alone (e.g. Penney 1968, Tenaza 1971, Barbosa et al. 1997). It is assumed that mainly adult penguins nest in the middle of such colonies while juveniles and first-time breeders are at the edges. The dimensions of eggs gathered from four penguin colonies in Admiralty Bay in 1978–1980 show that females from the inside of the colonies on average lay significantly larger eggs $G=111.8$ g, 70.78×54.11 mm ($N=127$), while those from the outside were significantly smaller $G=101.5$ g, 67.43×52.82 mm ($N=145$).

During incubation 125 g Penguin eggs lose about 447 mg of water per day, resulting in an overall estimated loss, during 35 days of incubation, of 13% of their initial mass. The eggshell conductance of $13.1 \text{ mg H}_2\text{O} \cdot \text{day}^{-1} \cdot \text{torr}^{-1}$ occurs from 9100 pores with an effective radius and pore length of 11 μm and 600 μm , respectively (Rahn&Hammel 1982).

Table 26 Geographical variation in egg size of the *Pygoscelis adeliae*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Admiralty Bay King George Island	254	68.92	53.21	102.0	This study
Signy Island	73	68.8	54.75	107.8	Lishman 1985
Ross Island	6	68.6	55.8	111.7	Thompson&Goldie 1990
Cape Royds Ross Island	677	68.58	53.48	102.6	Ainley 2002
Signy Island	161	68.3	54.5	106.1	Ainley 2002
Cape Crozier Ross Island	132	69.25	55.35	110.9	Ainley 2002
Iles des Pétrels Adélie Land	25	70.44	54.87	110.9	Ancel&Beaulieu 2009

Oomorphology

SHAPE EGG. Heteropolar, occasionally homopolar, not very elongated or cracked with strongly rounded sides of the egg. The average shape factor $k = 1.29$ shows that the eggs are almost spherical in shape (Plate 10).

GRAIN & SHELL TEXTURE. The shell is matt, coarse-grained, rough to the touch, slightly smoother towards the end of the incubation period; covered in a thick calcareous deposit as well as lumps and bumps. During incubation the majority of the eggs become extremely dirty from mud and excrement. As with other penguins, the shell has a cuticle, i.e. an irregular layer of calcium. However, some of the eggs have an even thinner layer evenly covering the shell (Tyler 1965). Its thickness was estimated by Thompson&Goldie (1990) at $48\text{ }\mu\text{m}$.

GROUND-COLOUR. The base colour of the shell is monochrome – white or whitish-green.

PATTERN OF EGG MARKINGS. None, but usually numerous dirt stains or yellow fat stains are visible.

PORES. Easily visible, large and deep, variable shape, usually round; no difference in the shape of the cross-section through the poles or flat through the middle of the egg. An average sized egg has approx. 7600 pores. The cross-section of a pore has the shape of an hourglass. The narrowest part of the pore is 20–40% from the internal surface of the shell (Thompson&Goldie 1990).

GEOGRAPHIC VARIATION. The eggs laid by the population living at Admiralty Bay are the smallest amongst those investigated – 102 cm^3 , similar sized eggs were found at Cape Royds Ross Island – 102.6 cm^3 , but another population on the same island in the region of Cape Crozier laid the largest eggs 110.9 cm^3 (Ainley 2002) (Table 26).

Gentoo Penguin *Pygoscelis papua* (Forster, JR, 1781)

Abundance

Regularly recorded on the island, but the least numerous species of penguin found in the Admiralty Bay region (Korczak–Abshire et al. 2013). It normally nests in small colonies, the nest made from a small pile of stones and it lays two eggs (Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 27. The coefficient of variation between the breadth and length of the egg was low, but the standard deviation was slightly higher than that found by Stonehouse (1970).

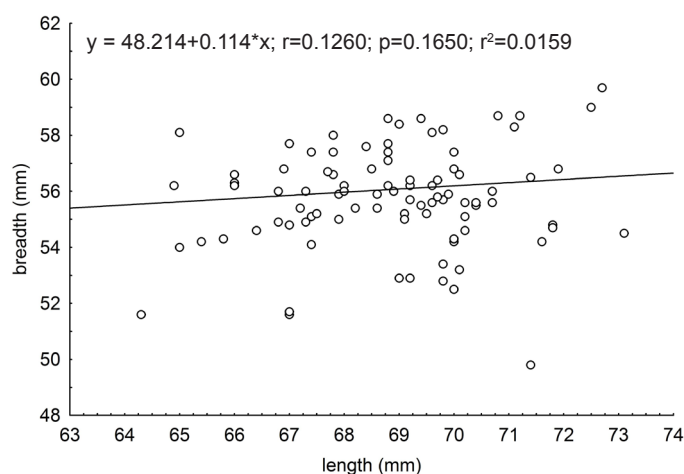
The calculated shell thickness, at 0.504 mm, is slightly smaller than that given by Tyler (1965) – 0.567 mm. The correlation between the length and breadth of the eggs was very low $r = 0.12$ and statistically insignificant ($F_{1\ 122} = 2.4112$, $p = 0.1231$) (Fig. 21). The regression equation between the breadth and length was $B = 48.214 + 0.114 \cdot A$. While the dependence between the breadth and length and the weight of the eggs was statistically significant ($p < 0.05$) (Fig. 22).

The young females lay significantly smaller eggs than older, 7–8 year old birds; the weight of a clutch from 2-year old females was 238.1 g, 3-year olds 245.4 g, 7–8 year olds 274.7 g (Williams 1980c) (Table 29). The first egg laid is slightly larger than the second, 115.0 cm³ (67.7 x 57.6 mm) and 113.5 cm³ (67.6 x 57.3 mm), respectively; on average the smallest eggs are found in nests with only one egg – 105.7 cm³ (68.2 x 55.1 mm) (Lescroel et al. 2009). An average egg consists of 61.8% albumen, 24.7% yolk and 13.5% shell (Williams et al. 1982).

In the 1970s it was established that there was an increase in the residual DDT (pp'DDE) and the almost complete disappearance of pp'DDT (a derivative of DDT breakdown) (Łukowski 1983).

TABLE 27 Morphometry of *Pygoscelis papua* eggs (N=123). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	68.71	64.3	73.1	2.87	1.97	6.40
Egg breadth (mm)	56.05	49.8	59.7	3.18	1.78	9.04
Fresh egg weight (g)	122.2	96.7	146.6	7.30	8.92	20.54
Shell weight egg (g)	11.11	8.52	13.65	8.25	0.92	23.16
Volume egg (cm ³)	113.0	89.5	135.5	7.26	8.21	20.43
Volume shell (cm ³)	3.39	2.68	4.07	7.30	0.25	20.54
Surface area egg (cm ²)	114.3	98.0	129.0	4.74	5.42	13.63
Shell thickness (mm)	0.504	0.436	0.551	4.12	0.02	11.65
Large circumference (mm)	196.4	182.5	208.4	2.25	4.42	6.62
No. pore/egg	8204	6960	9333	5.16	423.35	14.57
Factor shape k	1.23	1.12	1.43	4.10	0.05	12.34
Relative egg weight	2.6%					



Oomorphology

SHAPE EGG. Heteropolar, occasionally homopolar, slightly elongated or cracked, with strongly rounded sides, almost spherical. The average shape factor $k = 1.23$ shows that the eggs are almost ball-shaped (Plate 11).

GRAIN & SHELL TEXTURE. The shell is matt, coarse-grained, rough to the touch, slightly smoother by the end of sitting; covered in a thick calcerous coating, as well as lumps and bumps. During incubation the majority of the eggs become extremely dirty from mud and excrement. When held up to the light the shell is whitey-green with a blueish-green tinge.

TABLE 28 Geographical variation in egg size of the *Pygoscelis papua*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Admiralty Bay King George Island	123	68.71	56.05	113.0	This study
South Georgia	160	68.0	57.0	115.5	Stonehouse 1970
Port Lockroy Petermann Island	20	69.0	57.0	117.2	Stonehouse 1970
Macquarie Island	68	67.0	56.0	109.9	Marchant&Higgins 1990
Kerguelen Island	52	67.6	57.2	115.6	Cordier et al. 1983
Estacade, Kerguelen Island	80	67.83	56.67	113.9	Lescroel et al. 2009
Crozet/Marion Island	104	67.5	57.1	115.1	Williams 1980c
Falkland Island	50	69.9	59.1	127.7	Schonwetter 1988
Heard Island	26	70.0	58.5	125.3	Marchant&Higgins 1990
Possession Island Crozet Island	26	68.6	58.9	124.5	Marchant&Higgins 1990
Marion Island	80	68.1	57.7	118.6	Marchant&Higgins 1990
subspecies <i>ellsworthi</i>	61	68.9	56.2	113.8	Schonwetter 1988

TABLE 29 Variation in egg weights in Gentoo Penguins of known age, breeding experience and breeding location within the colony, Bird Island (Williams 1980c) Sample size in parentheses.

	First egg/N	Second egg/N	Total clutch
2-years old	119.8 (28)	119.0 (21)	238.1 (21)
3-years old	121.3 (19)	123.7 (15)	245.4 (15)
7–8-years old	136.6 (8)	138.4 (7)	274.7 (7)
First-time breeders	118.9 (13)	120.5 (13)	239.5 (13)
Established breeders	130.6 (42)	132.6 (42)	263.2 (42)
Tussock area	120.0 (10)	119.9 (10)	239.9 (10)
Sub-colony	129.6 (39)	131.5 (39)	261.1 (39)
Main colony	129.6 (133)	131.7 (133)	261.3 (133)

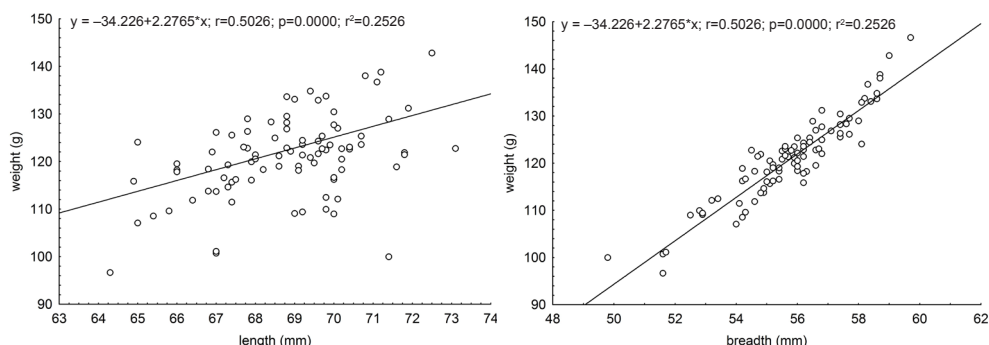
GROUND-COLOUR. The base colour of the shell is monochrome – white or greenish–white.

PATTERN OF EGG MARKINGS. None, but usually plenty of dirt smudges or yellow fat stains are visible.

PORES. The pores are easily visible, large and deep, variable shape, usually round. An average-sized egg will have nearly 8200 pores.

GEOGRAPHIC VARIATION. The largest eggs are laid by penguin populations on lone, mid-ocean islands e.g. Crozet Island and Falkland – over 120 cm³, while on Macquarie Island one finds the smaller eggs at 110 cm³; on average slightly smaller eggs are laid by penguins nesting on islands close to Antarctica, whilst the smallest are on Antarctica and its closest islands, e.g. King George Island, South Island, which are inhabited by the smaller subspecies *ellsworthi* (Martinez et al. 2016) (Table 28).

FIG. 22 Relationship between calculated egg-weight and breadth (right) and length (left) eggs *Pygoscelis papua* (N=123)



Chinstrap Penguin *Pygoscelis antarcticus* (Forster, JR, 1781)

Abundance

The third most numerous species of penguin in Admiralty Bay (Lesiński 1993, Korczak–Abshire&Chwedorzewska 2013). It builds its nest from stones and the female lays two eggs, occasionally only 1 or 3 (Shirihai 2008).

Oomorphometry

The statistical description of the variation of different characteristics of the eggs is given in Table 30. The calculated thickness of the shell was 0.448 mm and was less than that given by Tyler (1965) – 0.56 mm. The largest egg measured 77.0 mm by 54.0 mm and the smallest 44.3 x 39.2 mm. The correlation between the length and breadth was very low $r = 0.14$ but statistically significant ($F_{1,430} = 8.1415, p = 0.00452$) (Fig. 23). The regression equation between the breadth and length was $B = 44.6618 + 0.101 * A$. Meanwhile the high dependence between the breadth and length and the weight of the egg was statistically significant ($p < 0.05$) (Fig.24).

Oomorphology

Very similar to the two previous species of penguin, only with slightly more elongated shape factor $k = 1.33$. The pores are easily visible, large and deep, of variable shape, usually round and elliptical. An average-sized egg has some 7200 pores (Plate 12).

The two larger sets of measurements suggest that penguins from different areas lay similar eggs. The measurements taken by Gain (1914) may pertain to a different species (Table 31).

TABLE 30 Morphometry of *Pygoscelis antarcticus* eggs (N=434). Explanations table 2

Variable	x	min	max	CV	SD	Z
Egg length (mm)	68.34	60.2	79.4	4.37	2.84	13.75
Egg breadth (mm)	51.56	41.9	61.4	4.16	2.08	18.88
Fresh egg weight (g)	101.9	68.7	152.0	9.78	9.84	37.77
Shell weight egg (g)	9.05	5.79	14.23	11.04	0.99	42.17
Volume egg (cm ³)	94.4	63.7	140.5	9.72	9.07	37.58
Volume shell (cm ³)	2.83	1.90	4.22	9.78	0.27	37.77
Surface area egg (cm ²)	101.7	78.4	117.0	6.39	6.37	18.43
Shell thickness (mm)	0.448	0.346	0.564	5.39	0.02	23.96
Large circumference (mm)	188.9	166.1	209.7	3.20	5.90	11.60
No. pore/egg	7217	5472	9574	6.92	491.12	27.26
Factor shape k	1.33	1.16	1.82	6.11	0.07	22.14
Relative egg weight	2.5%					

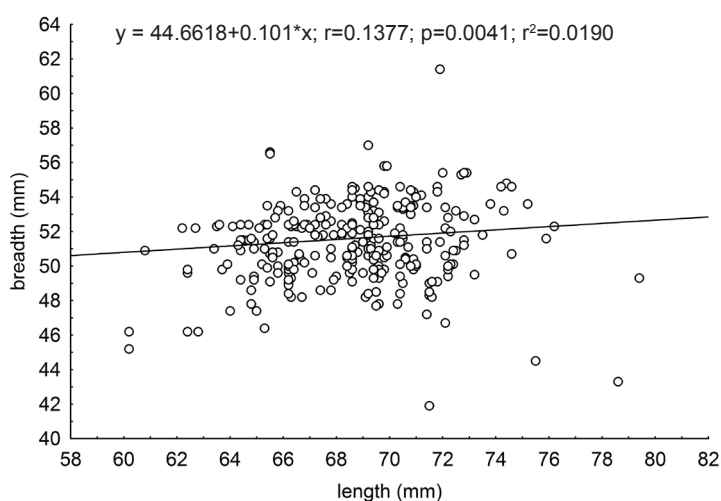


FIG. 23 Linear regression between the length and the breadth of *Pygoscelis antarcticus* (N=434)

FIG. 24 Relationship between calculated egg-weight and breadth (right) and length (left) eggs *Pygoscelis antarcticus* (N=434)

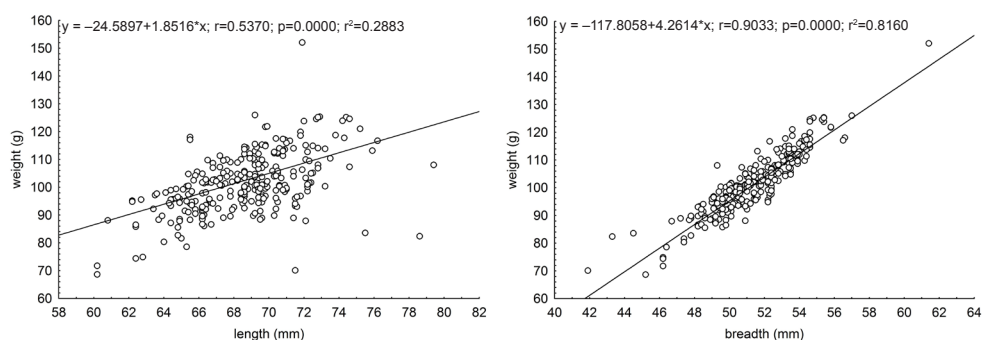


Table 31 Geographical variation in egg size of the *Pygoscelis antarcticus*

Geographic region	N	Length (mm)	Breadth (mm)	Volume (cm ³)	References
Admiralty Bay King George Island	434	68.34	51.56	94.4	This study
Elephant Island	51	67.39	51.96	94.3	Conroy et al. 1975
Deception Island	10	60.25	45.35	64.22	Gain 1914
Deception Island 1995/96	74	67	52.2	94.2	Belliure et al. 1999
Deception Island 1991/1992	102	?	?	90.1	Moreno et al. 1994

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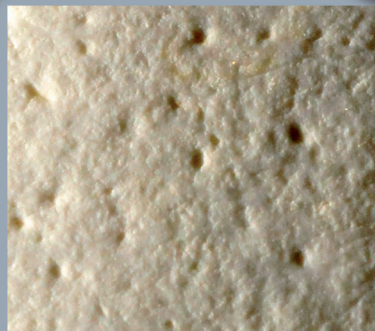
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PLATE 1



*DAPTION
CAPENSE*



OCEANITES OCEANICUS



PLATE 2



MACRONEUSTES GIGANTEUS

PLATE 3



FREGETTA TROPICA



PHALACROCORAX ATRICEPS

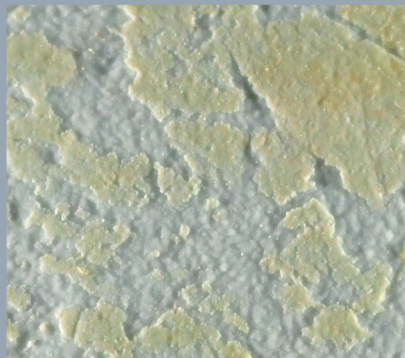


PLATE 4



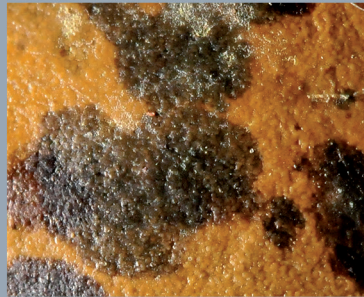
CHIONIS ALBUS

PLATE 5



LARUS DOMINICANUS

PLATE 6



STERNA VITTATA

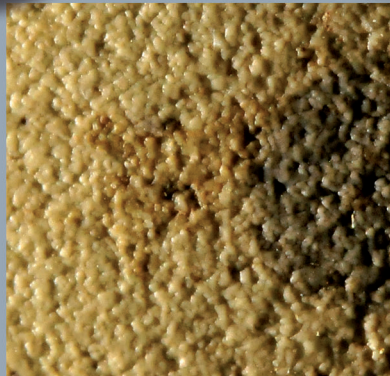


PLATE 8



CATHARACTA ANTARCTICA

PLATE 9



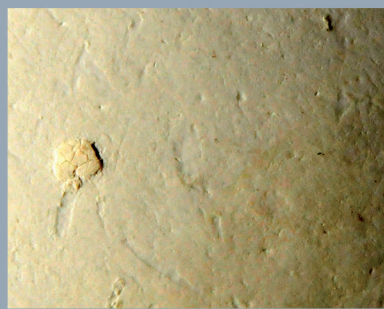
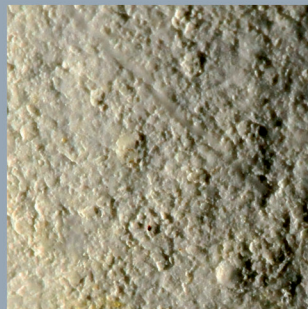
C. ANTARCTICA LONNBERGI x *C. MACCORMICKI* (HYBRID)

PLATE 10



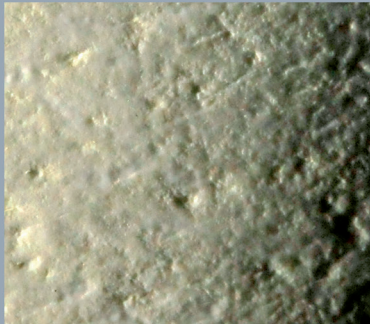
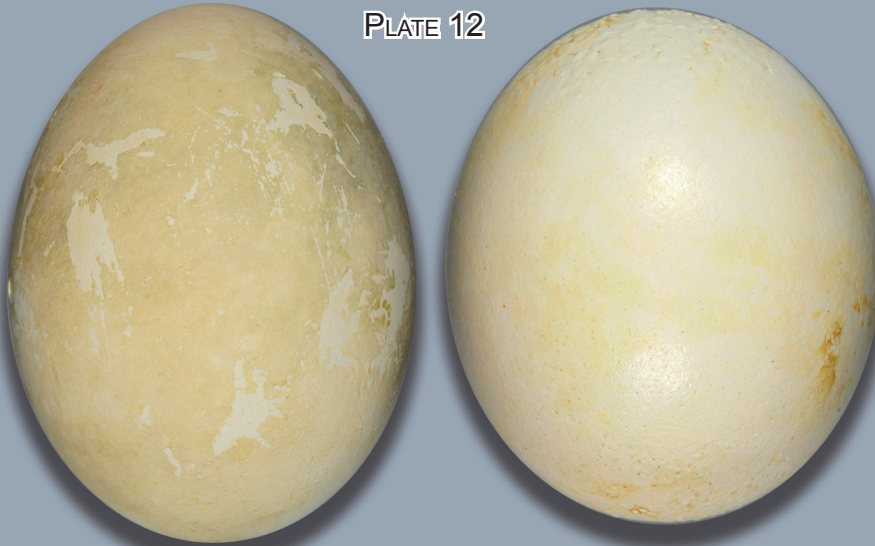
PYGOSCELIS ADELIAE

PLATE 11



PYGOSCELIS PAPUA

PLATE 12



PYGOSCELIS ANTARCTICUS