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EVALUATION OF BILL FURROWS AS AGE INDICATOR IN THE TUFTED PUFFIN *LUNDA CIRRHATA**

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Abstract: Tufted Puffins (*Lunda cirrhata*) were divided into six stages (F(Y), F(0)–F(4)) according to the number of bill furrows formed in the reddish outer part of the upper bill. To clarify the morphological difference between sexes and among stages, eleven morphological measurements of the bills were made.

Males were significantly larger than females in most of the measurements. For example, if Tufted Puffins had a gape length longer than 44.0 mm there was a 72.5 percent chance that these birds would be male.

The variations of these measurements among the six stages of bill furrows were recognized to have three patterns; two measurements along the gape did not vary despite the stages, five measurements, two of which were connected with lower bill, found to be changed between F(Y) and F(0), and four measurements in terms of upper bill were found to be altered between F(Y) and F(0), and F(2) and F(3).

The number of bill furrows of the Tufted Puffin corresponded to six age groups on the analogy of the relationship reported between the number of bill furrows and the age in the Atlantic Puffin (*Fratercula arctica*) (A. PETERSEN: Ornis Scand., **7**, 185, 1976; M. P. HARRIS: Br. Birds, **74**, 246, 1981). The bill furrows of F(Y), F(0), F(1), F(2), and F(3) and F(4) would correspond to the age of 0 to 1, 1 to 2, 2 to 3, 3 to 4, and 5 or older, respectively.

1. Introduction

Age determination of wildlife is important to estimate their biomass and to understand their physiology and ecology. In the case of pelagic vertebrates, age determination for fishes and whales have been studied for resource management. The age determination of seabirds has not been clarified due to the lack of suitable body parts such as scales and otoliths for fishes and ear plugs and teeth for whales.

Generally, age determination of birds is based on plumage and coloration of soft parts, however, not all species show age specific plumage characteristics and, in those species which do, distinction is usually limited to immature *vs.* adult classes. Other methods based on weighing the bones (JANNETT, 1983) and counting the layers of the bones (VAN SOEST and VAN UTRECHT, 1971) have been reported. However, the results were not very satisfactory and practical application of these methods is not possible.

PETERSEN (1976) reported that the bill furrows of the Atlantic Puffin (*Fratercula arctica*) developed with age until at least their fifth year of life, when many may be old

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enough to breed. The Tufted Puffin (*Lunda cirrhata*) is closely related to the Atlantic Puffin, and the bill furrows are also present. This species is widespread in the North Pacific Ocean (SHUNTOV, 1972), and the total population is about 6–8 million birds (HARRIS, 1984).

Estimating the age of the Tufted Puffin is a must, not only to understand the physiology and the ecology but also to understand the population structure of this species. In this paper, we demonstrate the relationship between the furrow number and the growth of the bill, and discuss the suitability of the bill furrows as an age indicator in the Tufted Puffin.

2. Materials and Methods

The Tufted Puffins used in this study were obtained from an incidental catch in salmon gill-net sets in the northern North Pacific Ocean including the Bering Sea and the Sea of Okhotsk in the summer season from 1973 to 1982.

The samples were divided into six stages (F(Y), F(0)–F(4)) in accordance with the number of bill furrows formed in the reddish outer part of the upper bill. Each of the six stages consisted of 30 males and 30 females. A total of 360 birds were used in this study. The F(Y) stage has not developed a keratinous cere, and has a distinctive triangular blackish bill without a furrow. The birds of F(0), F(1), F(2), F(3) and F(4) have a developed cere, and have a deeper and more convex bill than in F(Y). There are 0, 1, 2, 3 and 4 furrows, respectively.

Eleven measurements of the bill were made using a vernier caliper (Fig. 1): (1) the upper side straight length of the greenish inner part of the upper bill, (2) the upper side straight length of the reddish outer part of the upper bill, (3) the upper side straight length of the upper bill (culmen length), (4) the lower side straight length of the upper bill (gape length), (5) the upper side straight length of the lower bill, (6) the lower side

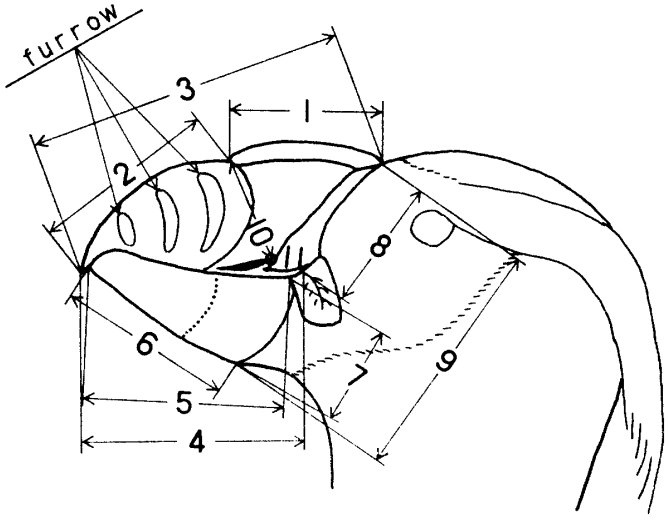

Fig. 1. Diagram showing the measurements made on the bill and the bill furrows formed in the reddish outer part of the upper bill of a Tufted Puffin Lunda cirrhata.

straight length of the lower bill, (7) the length of the lower bill depth, (8) the length of the upper bill depth, (9) the length of the bill depth, (10) the straight length from the posterior edge of the nostril to the anterior edge of (1), and (11) the bill width at the posterior edge of the nostril. The measurements are referred to as M-1 to M-11 in the following section.

3. Results and Discussion

3.1. Variations of measurements

HARRIS (1979) made three measurements of the bill, culmen length (M-3), gape length (M-4) and bill depth (M-9) in Atlantic Puffins from St Kilda and from the Isle of May. He showed that the birds from St Kilda were significantly smaller than those from the Isle of May. The coefficients of variation were less than 2.21% in the respective measurements from both areas. In this study, the coefficients of variation of M-3, M-4 and M-9 in the Tufted Puffins were found to be in the ranges of 2.80 to 4.84%, 2.94 to 3.73% and 3.89 to 6.81%, respectively (Table 1), and to be larger than those in the Atlantic Puffins. This might be caused by the fact that the Tufted Puffins were

Table 1. Mean, standard deviation (SD), coefficient of variation (CV %) and median of various measurements of Tufted Puffins Lunda cirrhata.

Measurement	Stage*	Male				Female			
		mean	SD	CV %	median	mean	SD	CV %	median
M-1	F (Y)	20.9	1.25	5.99	21.1	20.4	1.20	5.85	20.1
	F (0)	24.5	1.55	6.35	24.4	24.5	1.86	7.59	24.6
	F (1)	25.1	1.43	5.71	25.3	24.0	1.67	6.96	24.3
	F (2)	25.1	2.26	9.01	25.1	24.8	2.05	8.26	24.6
	F (3)	26.5	1.80	6.80	26.1	26.6	2.22	8.33	26.5
	F (4)	26.5	1.57	5.92	26.2	26.2	2.22	8.48	26.6
M-2	F (Y)	31.6	2.00	6.34	31.3	29.8	1.90	6.36	29.7
	F (0)	34.6	1.53	4.44	34.5	33.0	1.41	4.29	33.0
	F (1)	33.9	1.45	4.28	34.0	33.2	1.37	4.13	33.2
	F (2)	35.1	1.55	4.40	35.0	33.8	1.43	4.21	33.6
	F (3)	35.9	1.27	3.55	36.0	34.1	1.60	4.71	33.9
	F (4)	36.6	1.66	4.55	36.6	34.1	2.04	5.98	34.1
M-3	F (Y)	51.7	1.61	3.12	51.8	49.3	2.03	4.11	49.7
	F (0)	57.8	2.17	3.76	57.8	56.3	2.02	3.59	56.1
	F (1)	57.6	1.92	3.33	58.2	56.1	2.10	3.75	56.7
	F (2)	58.7	2.33	3.97	59.1	57.0	2.05	3.59	56.2
	F (3)	60.3	1.69	2.80	60.6	58.4	2.54	4.34	58.6
	F (4)	61.0	1.95	3.20	60.5	58.2	2.82	4.84	58.1
M-4	F (Y)	44.5	1.61	3.61	44.6	43.1	1.60	3.71	42.9
	F (0)	44.8	1.53	3.42	44.8	43.6	1.28	2.94	43.3
	F (1)	44.4	1.47	3.32	44.6	43.4	1.40	3.22	43.3
	F (2)	44.6	1.53	3.43	44.6	43.3	1.28	2.96	43.2
	F (3)	44.9	1.37	3.04	45.0	43.1	1.28	2.96	43.2
	F (4)	45.4	1.35	2.97	45.7	43.1	1.61	3.73	43.0

Table 1 (continued).

Measurement	Stage*	Male				Female			
		mean	SD	CV %	median	mean	SD	CV %	median
M-5	F (Y)	41.1	1.26	3.07	41.0	39.2	1.34	3.40	39.2
	F (0)	41.2	1.52	3.70	41.2	40.3	1.20	2.99	40.1
	F (1)	41.1	1.59	3.87	41.0	39.9	0.99	2.47	39.9
	F (2)	41.1	1.38	3.34	40.9	40.1	1.23	3.08	39.7
	F (3)	40.8	1.25	3.06	40.8	39.2	1.00	2.55	39.2
	F (4)	41.9	1.29	3.08	41.9	39.6	1.48	3.74	39.5
M-6	F (Y)	34.7	2.54	7.33	34.6	32.2	1.54	4.80	32.6
	F (0)	38.0	1.77	4.66	38.2	36.4	1.65	4.53	36.2
	F (1)	37.6	1.79	4.75	37.7	36.0	1.73	4.82	36.0
	F (2)	38.8	1.92	4.94	38.6	36.1	1.62	4.48	35.8
	F (3)	38.9	1.76	4.51	39.2	36.4	1.65	4.52	36.4
	F (4)	39.4	2.08	5.29	39.2	36.6	2.10	5.75	36.8
M-7	F (Y)	16.6	0.69	4.15	16.6	16.0	1.00	6.24	15.9
	F (0)	18.8	1.16	6.17	19.0	18.2	0.85	4.67	18.5
	F (1)	19.0	1.13	5.95	19.2	18.1	1.02	5.65	18.5
	F (2)	19.1	1.25	6.54	19.0	18.7	0.98	5.26	18.7
	F (3)	19.9	1.28	6.40	19.9	18.9	1.14	6.03	18.7
	F (4)	20.4	0.97	4.77	20.2	19.1	0.99	5.19	19.2
M-8	F (Y)	20.3	0.85	4.18	20.3	19.4	0.76	3.92	19.4
	F (0)	26.0	1.43	5.52	26.3	25.2	0.98	3.87	25.2
	F (1)	26.1	1.22	4.68	26.5	25.0	2.18	8.72	25.5
	F (2)	26.4	1.18	4.46	26.3	25.6	1.34	5.25	25.7
	F (3)	26.9	2.10	7.80	26.7	25.9	2.23	8.60	25.7
	F (4)	27.4	1.27	4.62	27.6	26.4	1.59	6.04	26.8
M-9	F (Y)	33.6	1.51	4.49	33.8	32.5	1.50	4.61	32.7
	F (0)	42.6	1.96	4.59	42.7	41.3	2.01	4.86	41.7
	F (1)	42.7	2.02	4.74	43.0	41.1	2.80	6.81	42.2
	F (2)	43.1	2.05	4.76	43.1	41.9	2.11	5.04	42.1
	F (3)	45.4	2.32	5.11	45.4	43.6	2.52	5.78	43.9
	F (4)	45.7	1.77	3.89	45.5	43.5	1.92	4.41	43.5
M-10	F (Y)	17.1	0.65	3.80	17.3	16.7	0.83	4.99	16.5
	F (0)	19.8	0.77	3.90	19.9	19.2	0.83	4.30	19.1
	F (1)	20.0	0.83	4.14	19.9	19.1	0.73	3.82	19.1
	F (2)	20.1	0.96	4.78	20.0	19.7	0.97	4.94	19.6
	F (3)	21.3	1.11	5.20	21.2	20.6	1.02	4.94	20.5
	F (4)	21.1	0.68	3.22	21.1	20.2	1.00	4.95	20.3
M-11	F (Y)	15.7	0.71	4.55	15.8	15.1	0.69	4.56	15.0
	F (0)	17.6	0.80	4.54	17.6	16.6	0.86	5.17	16.7
	F (1)	17.5	0.77	4.41	17.7	16.7	0.58	3.45	16.9
	F (2)	17.7	0.77	4.35	17.6	16.9	0.67	3.96	16.8
	F (3)	17.7	0.88	4.98	17.4	17.2	0.70	4.09	17.1
	F (4)	17.8	0.80	4.52	17.9	17.1	0.76	4.43	17.1

* Each of the six stages consists of 30 males and 30 females having different number of bill furrows (see text).

collected from a wide area of the northern North Pacific. The wide coefficient of variation suggests that the bill size of Tufted Puffins from different populations differ from one another.

3.2. *Sexual difference*

The differences of the medians of the measurements between sexes were analyzed using the Mann-Whitney's U test, and the results are shown in Table 2. Most of the measurements excluding M-1 were significantly larger in males than in females ($P<0.05$). However, the significance of sexual differences was slightly lower in the measurements related with bill depth, as in M-7, M-8, M-9 and M-10 than in other measurements. This indicates that males had the bill more triangular in shape than that of females.

CORKHILL (1972) measured the gape length (M-4) and bill depth (M-9) in Atlantic Puffins on Skomer Island. He used a discriminant analysis to calculate a line (formula: $M\text{-}9 = -0.439 \times M\text{-}4 + 47.82$) to separate male from female in adult birds, which resulted in 10% of the males and 12% of the females being misclassified. HARRIS (1979) also reported sexing adult Atlantic Puffins using bill measurements with 90% certainty on the Isle of May and St Kilda. In the case of the Tufted Puffin, if a bird had an M-4 longer than 44.0 mm there was a 72.5% chance that it would be a male and if the M-4 was shorter than 44.0 mm it would be a female with a chance of 72.0%. Similarly, a bird with the M-5 longer than 40.2 mm had a 73.8% chance of being a male, and with the M-5 shorter than 40.2 mm had a 74.6% chance of being a female. The certainty of sexing is lower for Tufted Puffins than in the reports of CORKHILL (1972) and HARRIS (1979) for Atlantic Puffins. However, the M-4 and M-5 could be well adopted for sexing of both adults and juveniles of Tufted Puffins. The bill measurements of M-4 and M-5 would be useful sexing indices for Tufted Puffins because few other morphological differences exist between sexes during their growth phase.

Table 2. Mann-Whitney's U test for difference between sexes in various measurements of the bill of Tufted Puffins Lunda cirrhata.

Stage*	Measurement										
	1	2	3	4	5	6	7	8	9	10	11
F(Y)		**	**	**	**	**	**	**	**	*	**
F(0)		**	**	**	*	**	*	**	*	**	**
F(1)	**	*	**	**	**	**	**	*	*	**	**
F(2)		**	**	**	**	**		*			**
F(3)		**	**	**	**	**	**		**	*	*
F(4)		**	**	**	**	**	**	*	**	**	**

*: See footnote of Table 1. *: $0.05>p>0.01$, **: $p<0.01$.

3.3. *Change of the bill shape with increasing the number of bill furrows*

The variations of eleven morphological measurements among the six stages of bill furrows were categorized into the following three patterns.

i) No changes with increasing number of bill furrows

The M-4 and M-5 along the gape were constant despite the growth of bill. This

might improve the usability of M-4 and M-5 as sexing indicators.

ii) Changes occurred only from F(Y) to F(0), and thereafter constant

The M-2, M-6, M-7, M-8 and M-11 changed markedly between F(Y) and F(0). The medians of these measurements in both sexes were larger in F(0) than F(Y), which were significant at $P<0.01$ (Mann-Whitney's U test). The M-5, M-6 and M-7 of the lower bill did not change after F(0).

iii) Changes which occurred first between F(Y) and F(0), and second between F(2) and F(3)

The M-1, M-3, M-9 and M-10 were found to be altered between F(Y) and F(0), and F(2) and F(3). The medians of these measurements in both sexes were significantly larger in F(0) than in F(Y) and in F(3) than in F(2) ($P<0.01$, but in the case of M-3 and M-9 in female, $P<0.05$). Because these measurements were related to the upper bill, it can be said that the growth of the upper bill continues up to F(3).

Owing to the three patterns of the bill measurement variations, the bill did not increase in gape length but became deeper and thicker when changing from F(Y) to F(0), and the upper bill became more convex when changing from F(2) to F(3).

Breeding Tufted Puffins, as determined from the examination of over 100 birds collected in June and having brood patches, always had three or four furrows. In the case of Atlantic Puffins, breeding birds had more than two furrows (HARRIS, 1981). The furrow numbers of three for Tufted Puffins and two for Atlantic Puffins must correspond with sexual maturation. This suggests that the bill is used in display when breeding and the furrows presumably have some sexual importance in Tufted Puffins and similarly in Atlantic Puffins (HARRIS, 1981). The change of bill shape from F(2) to F(3) would mark the occurrence of a secondary sex character.

3.4. Relationship between the bill furrows and the age

In Atlantic Puffins of known age, the relationship between the number of bill furrows and the age has been studied. PETERSEN (1976) showed that the birds from Westmann Island, Iceland, developed furrows as follows: two-year-olds had one very shallow broad furrow, three-year-olds had one deep plus one shallow and broad furrow, most four-year-olds had two plus a half or more of a third furrow, and five-year-olds had more than two furrows. Older birds had usually three deep furrows. HARRIS (1981) found the furrow patterns in birds from the Isle of May as follows: the three one-year-olds had only a trace of a furrow, two-year-olds mostly had one or less than one furrow, most three-year-olds had one plus a half or more of a second furrow, and most four-year-olds and half of the five-year-olds had two furrows and trace of third. In fact, 83% of the breeding birds had more than two furrows.

The above relationships between the number of bill furrows and the age in Atlantic Puffins were applied to those in Tufted Puffins. The ages of Tufted Puffins were arranged as follows:

F(Y): 0 to 1 year old
F(0): 1 to 2 years old
F(1): 2 to 3 years old
F(2): 3 to 4 years old
F(3) and F(4): 5 or more years old.

This relationship is based on inference, but it corresponds to the change of bill measurements with increasing number of bill furrows. Though it is not possible to make age determination of the Tufted Puffin accurately, it will be possible to divide three or four age groups; F(Y), F(0)–F(2), and F(3)–F(4) or F(Y), F(0), F(1)–F(2), and F(3)–F(4).

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References

CORKHILL, P. (1972): Measurements of Puffins as criteria of sex and age. Bird Study, **19**, 193–201.

HARRIS, M. P. (1979): Measurements and weights of British Puffin. Bird Study, **26**, 179–186.

HARRIS, M. P. (1981): Age determination and first breeding of British Puffin. Br. Birds, **74**, 246–256.

HARRIS, M. P. (1984): The Puffin. Calton, T & AD Poyser, 224 p.

JANNETT, F. J., Jr. (1983): A quantitative method for age determination of adult birds. Am. Midl. Nat., **109**, 145–151.

PETERSEN, A. (1976): Size variables in Puffins *Fratercula arctica* from Iceland, and bill features as criteria of age. Ornis Scand., **7**, 185–195.

SHUNTOV, V. P. (1972): Sea Birds and Biological Structure of the Ocean. Transl. from Russian. TT74-55032, Springfield, NTIS, U.S. Dep. Commer., 560 p.

VAN SOEST, R. W. M. and VAN UTRECHT, W. L. (1971): The layered structure of bones of birds as a possible indication of age. Bijdr. Dierkd., **41**, 61–66.

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