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Effects of Pairing on Egg Laying in the Emu

By

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Summary：The emu is a ratite with marked environmental adaptability, bred in Abashiri City, Hokkaido mainly for oil (functional material) production. However, laying, fertility, and hatchability should be improved for mass breeding. Thus, in the present study, we investigated the relationship between pairing and laying to improve egg production. The laying period was seven months between November and May of the following year. Egg production was highest in February and March at 25.79 and 30.94%, respectively. The relationship between pairing and laying demonstrated that egg production in breeding groups of equal female-to-male ratios (18.50 eggs per female) was significantly higher than those of population breeding groups and breeding groups with unequal female-to-male ratios (6.55 and 9.51 eggs per female, respectively) ($p < 0.001$). The female-to-male ratio was altered in pairing, markedly decreasing the egg production from 20 to 1 the following year. For example, two females died as a result of an accident during transfer to a different pen, conducted to prevent pairing with the same male, while one female mated with two different males. Thus, some females continued to mate with the previous males, while the others mated with different males after laying. Fertility was 89.64 and 86.14% and hatchability was 67.34 and 64.64% in 2009-2010 and 2010-2011, respectively.

Key words：emu, pairing, compatibility, egg production

Introduction

The emu (*Dromaius novaehollandiae*) is the second largest ratite after the ostrich and native to Australia. Wild emus can be solitary or live in groups[1]. In the Southern Hemisphere, emus breed between October and May in short sunshine duration. In the Northern Hemisphere, in the United States, they lay eggs in winter between September and April. In Hokkaido, emus breed around October and generally lay eggs between December and April. A female emu lays one egg at 3-5-day intervals until laying a total of 10 eggs. In the wild, male emus brood the eggs. They fast for about two months until hatching, and lose 20 kg in weight. Emus can be monogamous or polyandrous[1].

Emu farming started in western Australia in 1970. Emu farming is attracting attention as a new industry, because emu oil is effective for the treatment of atopic dermatitis, burns and wounds, and bruises. Currently, emus are farmed in the United States and China, as well as in Australia[1].

In Hokkaido, emus were introduced in the 1980s. Emus can be bred relatively easily under diverse weather conditions even in Hokkaido, with its considerable temperature range. Emus are attracting attention as an oil-producing animal. However, in Japan, they lay only a small number of eggs (about 10 eggs). Thus, in the present study, to increase laying for mass breeding, we investigated the effects of pairing during breeding on laying.

Materials and Methods

Pairing

The effects of pairing on laying were investigated under the natural light condition between 2007 and 2008 and between 2010 and 2011. Emus were bred in breeding groups of equal female-to-male ratios (8 pairs in 1 : 1 area ; 10 pairs in 2 : 2 area ; 1 pair in 4 : 4 area) and unequal female-to-male ratios (2 pairs in 2 : 1 area ; 1 pair each in 5 : 2, 4 : 6, 5 : 10, and 3 : 2 areas) and population breeding groups (6 groups of 28, 50, 56, 63, 85, and 100 emus). We used adult emus aged 4-10 years. Laying dates and egg production were recorded for one pair each of the breeding groups of the female-to-male ratios of 1 : 1 and 2 : 1 and

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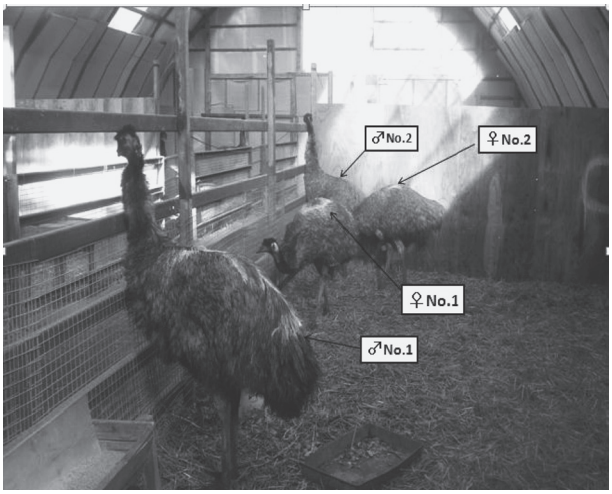

Fig. 1 Individual identification in each pen (identified with white paint).

four test areas of population breeding with 50 and 100 emus between 2007 and 2008 to be statistically analyzed. Fisher's least significant difference test was used for statistical analysis.

Pens of each test area were assembled using D-type agricultural fencing (Fig. 1). Emus were paired on November 1 in 2007–2010 and on November 6 in 2010–2011. The emus of each test area were identified by markings on their backs.

Records of egg-laying time, egg production, and laying dates

Eggs were collected at 30-minute intervals between 15 : 00 and 18 : 00, when emus lay more eggs, in order to prevent low-temperature injury. Eggs laid out of this time zone were used for food. The collected eggs were identified with test area symbols and laying dates.

Incubation

The identified eggs were incubated in an incubator, SHOWA FURANKI, TYPE : P3 (capacity : about 14 eggs), at 36.3℃, 32% relative humidity, and 12 egg rotations/day. Eggs on day 45 of incubation were transferred into an incubator (Ostrich Hatcher TYPE : SH10, SHOWA FURANKI, capacity : about 96 eggs) at 36.3℃ and 32% relative humidity.

Determination of fertilized eggs

Fertilized eggs were determined depending on embryonic development using an infrared projector (WIRELESS TSUKAMOTO CO. LTD, SM-56-850) and a ultrasensitive monochrome CCD camera monitor (WAT-902H2, Watec) on day 7 after the start of incubation. Those with embryonic development (black shadow on the monitor) were identified as fertilized eggs, while those without embryonic development were identified as unfertilized eggs (unpublished data).

Results and Discussion

Pairing and laying periods and laying

Emus were paired between 2008 and 2011 in the three test areas of equal and unequal female-to-male ratios and population breeding (Table 1). Laying was observed between November, when the pairing was started, and May of the following year. Laying peaked in February and March at 25.79 and 30.94%, respectively. Emus were paired between 2008 and 2011 in the three test areas of equal and unequal female-to-male ratios and population breeding (Table 1). Laying was observed between November, when the pairing was started, and May of the following year. Laying peaked in February and March at 25.79 and 30.94%, respectively.

Egg production per female varied with individuals : 2–28 eggs for the groups of equal female-to-male ratios, 3–22.2 eggs for the groups of unequal female-to-male ratios, and 4.2–13.26 eggs for the population breeding groups. Average egg production per female was significantly different between the groups with equal female-to-male ratios (18.5 eggs) and the other two groups (9.51 eggs for the groups of unequal female-to-male ratios ; 6.55 for the group of population breeding) ($p < 0.001$) (Table 2). Emu farms in Australia reported a high laying rate at the female-to-male ratio of 2 : 1[2]. However, SENTHIKUMAN and JAGATHEEAS (2012) reported egg production of 28.06 ± 2.56 eggs in the third-term breeding by pairing at a female-to-male ratio of 1 : 1. They suggested that laying might be improved by breeding at an equal female-to-male ratio. This is consistent with our results. Thus, breeding at an equal female-to-male ratio is recommended to select breeding emus with high-level egg production.

Of three pairs (A2-2, B, and D2), females of A2-2 died of old age at 18 years, and produced 18 eggs in the previous year between 2007 and 2008, and produced about 20 eggs every year for about 14 years. The remaining females of B and D2 died as a result of an accident (Table 1). No conspicuous trauma was noted. Thus, they may have suffocated to death by getting their necks stuck in a wire mesh fence during transfer to a different pen, conducted to prevent pairing after mating and laying, rather than through fighting. Emus breed in a monogynous or polygynous (polyandrous) form[3]. These accidental deaths may have involved polygamous individuals. Specifically, a female seeks a different male after mating with the previous one and laying. Like the No. 135 female, some females mated with two different males. They may have changed males after laying as described

Table 1 Laying period and egg production by month.

Years	Pairing	A	A2−2	B	C	D	E	G	Subtotal
		♂1 : ♀1	♂1 : ♀1	♂2 : ♀1	♂1 : ♀2	♂2 : ♀2	♂♀28	♂♀85	
2008~2009	Nov.	0	0	0	0	0	0	0	0
	Dec.	1	5	0	0	5	0	1	12
	Jan.	9	2	3	4	16	5	51	90
	Feb.	6	♀death	5	4	11	11	119	156
	Mar.	2		♀death	3	13	28	158	204
	Apr.	0			1	7	12	41	61
	May	0			0	2	3	1	6
	Total	18	7	8	12	54	59	371	529

Years	Pairing	A1	A2	A3	A4	D1	D2	D3	D4	H	Subtotal
		♂1 : ♀1	♂1 : ♀1	♂1 : ♀1	♂1 : ♀1	♂2 : ♀2	♂2 : ♀2	♂2 : ♀2	♂2 : ♀2	♂4 : ♀4	
2009~2010	Nov.	0	0	0	0	0	0	3	2	6	11
	Dec.	0	1	0	0	10	0	0	9	9	29
	Jan.	1	2	2	0	8	♀1death	10	7	18	48
	Feb.	3	5	10	0	5	1	12	7	17	60
	Mar.	9	8	7	4	5	4	13	8	14	72
	Apr.	8	6	4	4	8	1	11	8	19	69
	May	2	2	0	0	1	2	7	2	3	19
	Total	23	24	23	8	37	8	56	43	86	308

Years	Pairing	E1	E2	E3	E4	Subtotal
		♂♀63	♂2 : ♀5	♂1 : ♀1	♂1 : ♀1	
2009~2010	Nov.	1	0	0	0	1
	Dec.	13	1	0	0	14
	Jan.	74	5	2	1	82
	Feb.	117	5	4	4	130
	Mar.	141	0	0	3	144
	Apr.	50	4	0	0	54
	May	15	0	0	0	15
	Total	411	15	6	8	440

Years	Pairing	A*	B*	C*	D*	E*	F*
		♂2:♀2	♂2:♀2	♂2:♀2	♂2:♀2	♂2:♀2	♂2:♀2
2010~2011	Nov.	0	0	0	0	0	0
	Dec.	0	0	3	5	0	5
	Jan.	0	3	6	11	0	8
	Feb.	1	9	10	11	3	9
	Mar.	2	14	12	6	12	7
	Apr.	1	11	10	6	5	9
	May	0	13	10	2	0	13
	Total	4	50	51	41	20	51
	Pairing	G*	H*	I*	O*	Subtotal	The sum (%)
		♂6:♀4	♂10:♀5	♂2:♀3	♂♀56		
	Nov.	0	0	0	0	0	12(0.58)
	Dec.	6	0	0	12	31	86(4.14)
	Jan.	14	3	7	56	108	328(15.78)
	Feb.	14	23	10	100	190	536(25.79)
	Mar.	21	22	4	123	223	643(30.94)
	Apr.	20	18	0	86	166	350(16.84)
	May	11	0	0	34	83	123(5.92)
	Total	86	66	21	411	801	2,078

Confinement keeping (A, B, C, D, E, A1, A2, A3, A4, D1, D2, D3, D4, G, H, A*, B*, C*, D*, E*, F*, G*)

Confinement keeping with paddock (A2-2, E1, E2, E3, E4, H*, I*, O*)

Pairing days :2007～2008, 2008～2009 and 2009～2010 (1st in Nov.) , 2010～2011 (6th in Nov.)

2007~2008: (♂1:♀1, ♂1:2, ♂♀:50, ♂♀:100)

Table 2 Correlation between pairing and egg production.

Pairing type (♂:♀)	Same ratio	Different ratio	Colony breeding
Pair number	19	6	6
Average egg production per ♀1	18.50 [a]	9.51 [b]	6.55 [b]

(Fisher's LSD, protected LSD) ; A significant difference was recognized between different mark ($p < 0.001$).

above. The other females mated with the previous males. In the wild, when a male starts to brood, a female leaves the male to mate with a different one[3,4].

Subsequently, the effects of pairing between 2009 and 2010 and between 2010 and 2011 on laying were examined (Table 3). As a result, the laying of the No. 134 female was markedly decreased from 20 to 1 the following year. This may have resulted from female-to-male incompatibility during pairing. Like the No. 131 female, some females showed decreased laying even after

Table 3 Comparison of egg production in each female emu when changed pairing partner.

Years	Pairing	A (A4 and D4)		B (A2 and D4)		C (A1 and A3)		D (D3)	
		♂(131)	♂(134)	♂(132)	♂(140)	♂(135)	♂(133)	♂(138)	♂(139)
		♀1(131)	♀2(134)	♀1(132)	♀2(140)	♀1(135)	♀2(133)	♀1(138)	♀2(139)
2009~2010	Nov.	0	1	0	1	0	0	2	1
	Dec.	0	4	1	5	0	0	0	0
	Jan.	0	3	2	4	1	2	4	6
	Feb.	0	3	5	4	3	10	8	4
	Mar.	4	4	8	5	9	7	7	5
	Apr.	4	4	6	5	8	4	7	4
	May	0	1	2	1	2	0	3	4
	Total	8	20	24	25	23	23	31	24
	Pairing	A (A＊)※		B (B＊)		C (F＊)		D (D＊)	
		♂1(138)	♂2(150)	♂2(139)	♂1(189)	♂1(149) ♂2(136)	♂2(136)	♂1(148)	♂2(131)
		♀1(131)	♀2(134)	♀1(132)	♀2(140)	♀1(135)	♀2(133)	♀1(138)	♀2(139)
2010~2011	Nov.	0	0	0	0	0	0	0	0
	Dec.	0	0	0	0	0	3	3	2
	Jan.	0	0	3	0	0	6	6	5
	Feb.	0	1	7	2	6	4	7	4
	Mar.	2	0	4	10	6	6	4	2
	Apr.	1	0	5	6	4	6	3	3
	May	0	0	6	7	5	5	1	1
	Total	3	1	25	25	21	30	24	17

※：There was in serious trouble when introduce in breeding pen.

First day of pairing：2009～2010 years （Nov. 1st）、2010~2011 years (Nov. 6th)

Last day of pairing: May 31th

Table 4 Fertility and hatchability in each pairing.

Years	Pairing	A1	A2	A3	A4	D1	D2 ＊1	D3	D4	H	Total
		♂1:♀1	♂1:♀1	♂1:♀1	♂1:♀1	♂2:♀2	♂2:♀2	♂2:♀2	♂2:♀2	♂4:♀4	
2009~2010	Egg production	23	24	23	8	37	8	56	43	86	308
	No. of haching egg	15	18	15	5	27	5	37	34	66	222
	Fertilized ovum	15	17	15	4	22	3	35	30	58	199
	No. of hatching chick	13	12	8	1	18	0	24	22	36	134
	Fertility (%)	100	94.44	100	80.00	81.48	60.00	94.59	88.24	87.88	89.64
	Hatchability(%)	86.67	70.59	53.33	25.00	81.82	0	68.57	73.33	62.07	67.34

	Pairing	A(♂2:♀2)※		B(♂2:♀2)		C(♂2:♀2)		D(♂2:♀2)	
		♀No.1	♀No.2	♀No.1	♀No.2	♀No.1	♀No.2	♀No.1	♀No.2
	Egg production	3	1	25	25	21	30	24	17
	No. of haching egg	3	1	25	25	21	30	24	17
	Fertilized ovum	1	0	24	25	21	24	20	14
	No. of hatching chick	1	0	14	16	16	10	9	2
2010~2011	Fertility (%)	33.33	0	96.00	100	100	80.00	83.33	82.35
	Hatchability(%)	100	0	58.33	64.00	76.19	41.67	45.00	14.29

Pairing	E	F	G	H	I	O	Total
	♂2 : ♀2	♂2 : ♀2	♂6 : ♀4	♂10 : ♀5	♂2 : ♀3	♂♀56	
Egg production	20	51	86	66	21	411	801
No. of haching egg	20	51	86	66	21	411	801
Fertilized ovum	16	48	82	59	19	337	690
No. of hatching chick	4	39	54	44	11	226	446
Fertility (%)	80.00	94.12	95.35	89.39	90.48	82.00	86.14
Hatchability(%)	25.00	81.25	65.85	74.58	57.89	67.06	64.64

＊1：♀1 died

Egg production showed number, egg was collected in p.m.15：00～18：30.

※：There was in serious trouble when introduce in breeding pen.

changing males. In contrast, the No. 133 female showed increased egg production from 23 to 30 after changing males. The egg production may have been influenced by laying performance and female-to-male compatibility.

Pairing, fertility, and hatchability

Improved hatchability is the most critical point for emu breeding. Thus, the effects of pairing on egg production and hatchability were investigated (Table 4). Of

the pairings with a large number of cases, the average fertility between 2009 and 2010 was as high as 89.64%, while the hatchability was low, except for the A1 and D1 pairings (86.67 and 81.82%, respectively), and the average hatchability was 67.34%. Between 2010 and 2011, the average fertility was 86.14%, while the hatchability was low, except for the F pairing (81.25%), and the average hatchability was 64.64%. Boopathi *et al.* (2012) reported 100% fertility and 63.6% hatchability. This hatchability was almost the same as our results.

In both years, the fertility varied from 33.33 to 100%, while the hatchability varied from 14.29 to 86.67%. The cause of this is unknown. Besides genetic characteristics, the environmental conditions of long-term incubation between January and July and storage time after incubation may be involved. During this period, the period of fertilized egg collection was limited due to very cold weather in Abashiri City. The improved egg collection time and intervals significantly increased the fertility from 40–50 to 80%.

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エミューの産卵に及ぼすペアリング効果

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要約：エミューは環境適用性に優れた走鳥類で，北海道・網走市ではオイル（機能性物質）生産を主要目的に飼育・増殖されている。しかし，生産家禽として扱うためには，産卵性，受精率，孵化率等に関して改善しなければならい課題が多い。そこで，本研究ではエミューの産卵数の向上を目的として，ペアリングと産卵性との関連を調査した。

産卵期間は，11 月から翌年 5 月までの 7 カ月であった。最も産卵数の多い時期は 2 月と 3 月で，それぞれ 25.79％と 30.94％であった。ペアリングと産卵性の関係について，雌・雄同比率繁殖群の産卵数（雌 1 羽当たりの産卵数が 18.50 個）は，集団及び雌・雄異比率繁殖群（それぞれ雌 1 羽当たり 6.55 個と 9.51 個）に比べ有意に高かった（$p<0.001$）。ペアリングでは，雄と雌の組み合わせを変更して，産卵数 20 個が翌年に 1 個に激減した例，同一雄とのペアリングを解消するためペンからの移動を試みた時の事故死例（2 例），また 2 羽の雄と交尾した例（1 羽）が観察された。これらから，雌には，同一雄とペアリングを継続するタイプと産卵後に雄を交換するタイプが存在すると推察された。受精率は，2009～2010 年と 2010～2011 年で，それぞれ 89.64％と 86.14％で，孵化率はそれぞれ 67.34％と 64.64％であった。

キーワード：エミュー，ペアリング，相性，産卵数，受精率，孵化率

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