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The performance of farmed ostrich chicks in eastern Australia

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Abstract

A prospective observational epidemiological study was undertaken in the south-eastern region of Queensland in eastern Australia to collect accurate information on the performance of farmed ostriches, and to identify the most important constraints facing on-farm production. This paper (the third in a series of three) focuses upon the performance of 394 chicks that hatched on 11 farms in this region from eggs laid between 1 July 1993 and 30 June 1994. Each chick was observed from hatch until dying, leaving the farm of origin or reaching 4 months of age (whichever occurred first). A total of 60.8% of the chicks survived to 4 months of age, with an overall crude mortality rate during the period of observation of 14.0 deaths per 100 chick-months at risk. The most common causes of death were the development of a lower-limb deformity (most frequently tibiotarsal rotation which accounted for 36% of all chick deaths), 'fading chick syndrome' (13%), and salmonellosis (11%). Only 83% of the chicks remained free of tibiotarsal rotation during the period of observation. This condition was generally first detected in chicks between 2 and 10 weeks after hatch, and the median survival time following diagnosis was 10 days. 'Fading chick syndrome' mainly affected chicks less than 3 weeks of age and did not appear to spread in a contagious manner. Chicks died following infection with *Salmonella typhimurium* on only one farm. Chick-level factors affecting survival during the 4 months following hatch were examined using the Cox proportional hazards regression model. After accounting for farm-level effects, risk factors for death or euthanasia during the first 4 months following hatch included the weight of the chick at hatch, and the development of tibiotarsal rotation. The need of the industry-wide development and adoption of objective measures of productivity is discussed, and some relevant measures are proposed.

Keywords: Ostriches; Australia; Chicks; Health and productivity profile; Productivity

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1. Introduction

Ostrich farming has attracted considerable international interest, and aims to fill a perceived international demand for high quality leather and meat. These commodities will be produced with the slaughter of young adult birds. It is understandable, therefore, that successful chick raising is integral to the on-farm productivity of a farmed ostrich flock.

There is a small but increasing amount of published information on aspects of the health and productivity of ostrich chicks (including aspects of nutrition (Gandini et al., 1986), management (Wade, 1995a), disease (Ley et al., 1986; Huchzermeyer et al., 1993; Terzich and Vanhooser, 1993; Bezuidenhout et al., 1994) and productivity (Deeming et al., 1993; Deeming and Ayres, 1994)). This information has mainly been collected from experimental studies, either on livestock research stations or during periods of lengthy quarantine. Observational studies from commercial flocks of farmed ostriches have not yet been described.

The main objectives of this study were to collect accurate information on the performance of ostrich chicks from hatch to 4 months of age on commercial farms in south-eastern Queensland, and to identify chick-level factors associated with the survival of these chicks.

2. Materials and methods

2.1. Study design, data collection and management

This work formed part of a larger study assessing the performance of ostriches in south-eastern Queensland. Information about the overall study design and general methods used for data collection, management and analysis are described elsewhere (More, 1996a). Briefly, a prospective longitudinal observational study was undertaken for 18 months from 1 July 1993 on a convenience sample of 12 study farms located within 100 km of Brisbane, Queensland. The focus of the overall research effort was upon defined cohorts of hens, eggs and chicks, and it is from these individuals that measurements were collected relating to productivity. This paper describes those aspects of this work relevant to the performance of ostrich chicks.

On each study farm, hens were enrolled into the 'hen cohort' if, at any time during the period 1 July 1993 to 30 June 1994, they were penned with at least one male bird for the purpose of producing fertile eggs. Enrolled birds were removed from the cohort if for any reason these conditions ceased to be met. The 'egg cohort' comprised all eggs laid by enrolled members of the hen cohort. These eggs remained under observation until each hatched, was permanently removed from the incubator unhatched, or reached the 46th day of incubation without hatching (whichever occurred first). Every chick which hatched from eggs within the egg cohort was then enrolled in the 'chick cohort' and was subsequently observed until dying, leaving the study farm of origin or reaching four months of age (whichever occurred first). The information that was collected for each chick included: identification and egg of origin, date of hatch, sex, weights during

growth, dates and types of disease event, dates and types of treatment event, date and reason for exit from the cohort, and whether and at what age the chick developed a lower-limb deformity which persisted until the chick left the cohort. With the exception of events evident during farm visits (for which a clinical diagnoses was made by the principal investigator) or for which a laboratory diagnosis was forthcoming following postmortem examination, the source of this data was either producer-generated records or information recalled by the producer at each farm visit. Chicks were individually identified using an implanted microchip and/or a velcro leg band.

The following clinical case definitions were used to categorise cases of lower-limb deformity (modified from Black (1993a) and Bezuidenhout and Burger (1993)): toe rolling was defined as an inward or outward rotation of the main digit along its long axis; club foot as deviation of the tarsometatarsal–phalangeal joint resulting in the normally medial surface of this joint becoming the weight-bearing surface; tibiotarsal rotation as an outward rotation of one or both pelvic limbs below the hock (tibiotarsal–tarsometatarsal joint) that resulted in limb deviation at rest and an altered gait once mobile; and leg bowing as either the inward or outward bending of the tarsometatarsal bone along its long axis.

A chick was considered to have died from 'fading chick syndrome' if it died following a period of inappetence and depression of at least 24 h in duration, and a definitive cause of death could not be reached.

2.2. Laboratory analyses

Producers were encouraged to submit cohort eggs that died for further examination. Producers were reimbursed for courier costs associated with the submission of chicks, and laboratory examinations were provided at no cost. All chicks were examined at Yeerongpilly Veterinary Laboratory (Queensland Department of Primary Industries, Yeerongpilly). Gross pathology, histopathology, bacteriology and parasitology was performed using routine methods when indicated.

Parasitological examination was performed on fresh faeces using methods previously described (More, 1996a) to detect coccidial oocysts, cryptosporidial cysts and helminth eggs. Faeces were collected during farm visits between August 1993 and October 1994 from pens containing chicks of varying ages. Some chicks were sampled on several occasions at consecutive farm visits.

2.3. Data analysis

Data analyses were performed using SAS release 6.04 (Statistical Analysis Systems Institute Inc., Cary, NC) and EGRET version 0.25.6 (Statistics and Epidemiology Research Corporation, Seattle, WA). The data were first examined using standard methods of descriptive statistics. Variables were described and subsequently handled appropriate to the result of a test for normality (using the Shapiro–Wilk statistic that tests the null hypothesis that the data were a random sample from a normal distribution). Confidence intervals of proportions were calculated using the exact binomial method. Standardisation of chick weights was undertaken with linear regression models after

obtaining measurements of three standard weights using a Sartorius electronic scale (Sartorius GmbH, Göttingen, Germany) and chick weighing scales on each farm. Incidence density morbidity and mortality rates were estimated using standard methods (Martin et al., 1987, pp. 48–52). The hypothesis that fading chick syndrome did not cluster in either time or space, or was more frequent in one sex than the other was examined using Fisher's exact test by comparing the farm of hatch, date of hatch and sex of chicks that did and did not develop this syndrome.

The following survival analyses were based on methods described by Lee, 1992 (pp. 66–130, 243–280). The cumulative proportion of chicks surviving to 4 months of age and surviving following the development of tibiotarsal rotation were calculated using the Kaplan–Meier method. A number of variables, each considered a putative prognostic factor for chick survival, were separately examined for association with chick survival time using the Kaplan–Meier method, and survival functions among the subgroups within each variable were compared using the logrank test. Variables associated with survival time at $P < 0.30$ were investigated further using the Cox proportional hazards regression model. The event of interest was chick death or euthanasia prior to reaching 4 months of age. A farm-identifying variable was forced into the model as a fixed effect. Other variables were then selected in a forward stepwise manner, and were retained if P remained at less than 0.05. Dummy variables were created for the categorical variables with more than two categories, and the variable describing the development of tibiotarsal rotation was offered as a time dependent covariate (coded 1 once tibiotarsal rotation was detected, and 0 otherwise). The assumption of proportional hazards (namely that the relative risk associated with each given level of a prognostic variable does not change with time (Tibshirani, 1982)) was tested (for each but the time dependent covariate) by extending the final model with an interaction term between the logarithm of time and each selected variable, as described by Anonymous (1993) and by assessing the effect of a $\log_e(-\log_e)$ transformation upon the survivorship function of all levels of each selected variable (Lee, 1992, pp. 261–263). Parametric models were produced based upon the Weibull, exponential, log-normal, log-logistic, gamma, normal and logistic distributions, with final model selection being based upon the model with the log likelihood statistic closest to zero.

3. Results

3.1. General comments about ostrich chick management

Three hundred and ninety four chicks (116 males, 121 females and 157 unsexed birds) from eleven of the study farms were enrolled into the chick cohort. No chicks were hatched on the twelfth farm. On these farms, chicks were raised in facilities that were isolated from the adult breeding stock. On the ten farms with on-site incubation, all chicks were removed from the hatcher within 2 days of hatching and placed in a brooding area with supplementary heating equipment. On the other farm, chicks returned from the farm of hatch within 2 days after hatching and were placed directly into a

Table 1
Survival of 394 ostrich chicks enrolled into the chick cohort on 11 farms in south-eastern Queensland in 1993/1994

	No. of chicks		Proportion surviving		
	Total	Died [a]	30 days	60 days	120 days
All members of the chick cohort	394	146	0.82	0.72	0.61
The chicks that hatched on farm [b]					
A	22	11	0.68	0.59	0.50
B	21	6	0.81	0.81	0.71
C	29	23	0.71	0.36	0.14
D	8	3	1.00	0.63	0.63
E	113	13	0.91	0.90	0.88
G	49	32	0.90	0.64	0.21
H	13	1	1.00	0.92	0.92
I	68	43	0.59	0.43	0.36
J	63	7	0.95	0.93	0.87
K	3	3	0.67	0.67	0.67
L	5	4	0.20	0.20	0.20

[a] Includes chicks that were killed and those that died without human intervention, each prior to reaching 4 months of age.
[b] On farm F, no chicks were enrolled into the chick cohort.

brooding area. Although not quantified during this study, depending upon weather conditions, all producers attempted to provide brooding chicks with access to pasture, and to increase the length of this access as chicks grew. While ensuring that each pen contained chicks of similar ages, all farms moved chicks from the brooding pen through a series of juvenile pens of increasing size. The juvenile pens each contained an

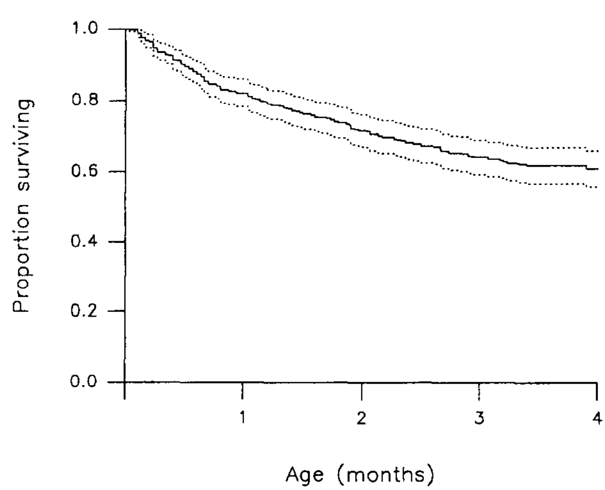

Fig. 1. The survival of ostrich chicks on 11 farms in south-eastern Queensland during 1993/1994 (dotted lines represent the 95% confidence interval).

Table 2
The overall crude chick mortality rate during the first 4 months following hatch, and the distribution of the crude chick mortality rates on 11 ostrich farms in south-eastern Queensland during 1993/1994

Period of observation	Crude chick mortality rate (no. of deaths per 100 chick-months at risk) [a]				
	Overall	Farm-specific			
		25th percentile	Median	75th percentile	Range
Limited					
During the first 30 days following hatching	19.9	5.0	21.6	45.5	0–214.3
During the 2nd month after hatching	13.9	0	8.2	33.0	0–66.5
During the 3rd and 4th months after hatching	8.9	0	6.5	49.2	0–181.8
Complete					
During the first 4 months after hatching	14.0	3.6	20.6	44.8	2.1–82.2

[a] Includes chicks that were killed and those that died without human intervention.

enclosed area—where the chicks were housed at night and during inclement weather—and an area of pasture.

3.2. Chick performance

Two hundred and ninety one chicks were weighed on the day of hatch (mean 822.8 g, median 819 g, range 464–1300 g) and, for all but three chicks, the calculated egg weight at the beginning of incubation was also available. Newly hatched chicks weighed an average of 62.3% (median 63.3%, range 35.8–83.1%) of the egg weight at set.

One hundred and forty six (37.1%) chicks subsequently died or were killed prior to reaching 4 months of age (with 38 (26.0%) of these (including 35 that died and three that were killed) being submitted for laboratory examination), 133 (33.8%) left the farm of origin before reaching this age, and 115 (29.2%) chicks remained until at least 4 months of age on the farm of origin.

Notes to Table 3:
[a] *Salmonella typhimurium* serotype 64 was isolated from these chicks; *Pseudomonas aeruginosa* was also isolated from one chick.
[b] *Escherichia coli* was isolated from two chicks; *Streptococcus faecalis*, *E. coli* and a *Bacillus* sp., and a mixed infection of Gram-positive cocci and Gram-negative rods were each isolated from one of the other three chicks.
[c] *Acinetobacter calcoaticus*, *E. coli* and *P. aeruginosa* were each isolated from one of the three chicks.
[d] *P. aeruginosa* was isolated.
[e] *Aspergillus fumigatus* was isolated.
[f] No culture was performed.
[g] No organism was isolated.
[h] The case definitions for these lower-limb deformities are described in Section 2.
[i] The case definition is described in Section 2.
[j] This chick developed apparent blindness and star gazing; it remained ambulatory for 25 days after this time prior to slaughter.

Three (0.8%) chicks from three different study farms had congenital defects. Two chicks had unilateral anophthalmia and one chick had micrognathia.

In this cohort, 60.8% of the chicks survived to 4 months of age (Table 1, Fig. 1). There was a significant difference between the survival curves from each farm (logrank test $P < 0.001$). The overall crude mortality rate during the first 4 months following hatch was 14.0 deaths per 100 chick-months at risk. The overall crude chick mortality, and the distribution of the crude chick mortality rates on 11 ostrich farms is shown in

Table 3
Reasons for the death of 146 ostrich chicks less than 4 months of age on 11 farms in south-eastern Queensland during 1993/1994

Reason for death	Chicks affected		No. examined	Cause-specific deaths in chicks aged:							
				< 1 month		1–2 months		2–3 months		3–4 months	
	No.	%		No.	%	No.	%	No.	%	No.	%
Infectious cause											
Salmonellosis [a]	16	11.0	16	13	18.6	3	7.5				
Omphalitis [b]	5	3.4	5	5	7.1						
Bacteraemia [c]	3	2.1	3	3	4.3						
Severe keratitis [d]	2	1.4	2	1	1.4	1	2.5				
Aspergillosis [e]	1	0.7	1	1	1.4						
Aspiration pneumonia	1	0.7	0	1	1.4						
Pleurisy [d]	1	0.7			1	1	2.5				
Peritonitis [f]	1	0.7	1	1	1.4						
Thymitis [g]	1	0.7	1	1	1.4						
Lower-limb deformities [h]											
Toe roll	1	0.7								1	11.1
Hyperkeratosis of the footpad	1	0.7	1							1	11.1
Club foot	7	4.8	0			5	12.5	2	7.4		
Tibiotarsal rotation	52	35.6	2	9	12.9	19	47.5	20	74.1	4	44.4
Leg bowing	5	3.4	0	1	1.4	1	2.5	2	7.4	1	11.1
Swollen hock joint	1	0.7	0					1	3.7		
Undefined lower-limb deformity	1	0.7	0 1			2.5					
Misadventure	5	3.4	0	3	4.3	1	2.5			1	11.1
Miscellaneous											
Fading chick [i]	19	13.0	2	18	25.7	1	2.5				
Sudden death	12	8.2	0	7	10.0	4	10.0			1	11.1
Gut impaction	2	1.4	0			2	5.0				
Severe perinatal oedema	1	0.7	0	1	1.4						
Diarrhoea	1	0.7	0			1	2.5				
Gout	1	0.7	1	1	1.4						
Neurological condition [j]	1	0.7	0					1	3.7		
Micrognathia	1	0.7	0					1	3.7		
Cause undetermined	4	2.7	2	4	5.7						

Table 4
Types of permanent lower-limb deformities and the subsequent outcome for 98 ostrich chicks on 11 farms in south-eastern Queensland in 1993/1994

Type of deformity [a]	No.	Outcome		
		Died without human intervention	Killed	Survived [b]
Toe roll [c]	5	0	1	4
Hyperkeratosis of the footpad	3	1	0	2
Club foot	9	0	7	2
Tibiotarsal rotation [d]	68	2	50	16
Leg bowing	11	0	5	6
Swollen hock joint	1	0	1	0
Undefined lower-limb deformity	1	0	1	0

[a] The case definitions for these lower-limb deformities are described in Section 2.
[b] Chicks that either left the property of origin prior to reaching 4 months of age, or chicks that remained on the study farm until reaching at least this age.
[c] Includes one chick with a probable fracture of the main digit.
[d] The right limb was affected in 26 chicks, and the left in 42 chicks.

Table 2. The development of tibiotarsal rotation was the most frequent cause of death, particularly in chicks more than 1 month of age, although infections and 'fading chicks' were the most common causes of death in very young chicks (Table 3).

Ninety eight chicks developed a lower-limb deformity that persisted until the chick died, reached 4 months of age or was prematurely withdrawn from the cohort (Table 4), with an overall incidence rate during the 4 months following hatch of 10.1 cases per 100 chick-months at risk. Tibiotarsal rotation was the most common lower-limb deformity detected in this cohort (affecting 68 chicks of which 52 subsequently died or were killed). The overall incidence rate of this condition in this cohort during the 4 months following hatch was 6.8 cases per 100 chick-months at risk. The age at which producers first recorded the development of tibiotarsal rotation in the 68 chicks, and their subsequent survival is shown in Figs. 2 and 3, respectively. The median survival time of chicks following a diagnosis of tibiotarsal rotation was only 10 days. There was a significant difference between the survival of chicks following the development of tibiotarsal rotation when more than 60 days of age in comparison to those that developed this condition whilst 60 days of age or less (median survival times of 14.5 and 7 days, respectively; logrank test $P = 0.050$).

During the study, 19 chicks died from fading chick syndrome. The chicks were hatched on seven different farms, and 18 (95%) died before reaching 21 days of age. One chick died 36 days after hatching. Only two of these chicks were submitted for laboratory examination. In comparison to the chicks within the cohort that did not develop fading chick syndrome, there was no evidence to suggest clustering of the syndrome either in space (Fisher's exact test (two-tailed) $P = 0.463$, using a table with separate categories for chicks hatching on farms A/B/C/D, E, G/H, I, J/K/L) or time (Fisher's exact test (two-tailed) $P = 0.175$, using a table with separate categories for chicks hatching in bimonthly groupings between July 1993 and August 1994). There

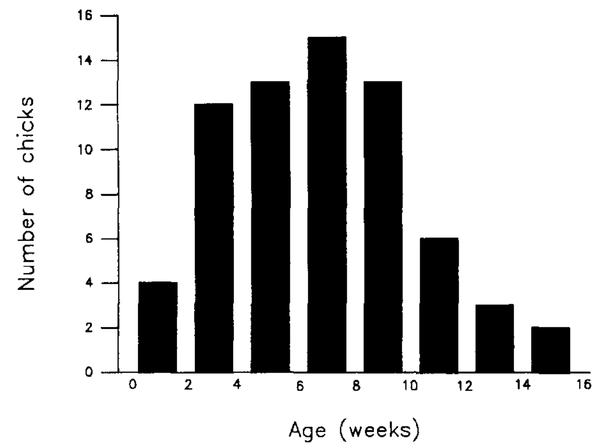

Fig. 2. The distribution of ages of 68 chicks when signs of tibiotarsal rotation were first detected by producers on 11 farms in south-eastern Queensland.

was a significant difference between the sex of chicks affected and not affected with fading chick syndrome (Fisher's exact test (two-tailed) $P < 0.001$ using a table with separate categories for males, females and unsexed chicks).

Salmonellosis was considered the cause of death of 16 chicks during the study; however, all known cases were confined to only one of the study farms. *Salmonella* spp. Group B4 was isolated from all cases, with further serotyping of 14 isolates resulting in the identification of *Salmonella typhimurium* serotype 64 in each case. At death, the affected chicks were between 4 and 43 days of age (mean 18.3 days, median 14.5 days),

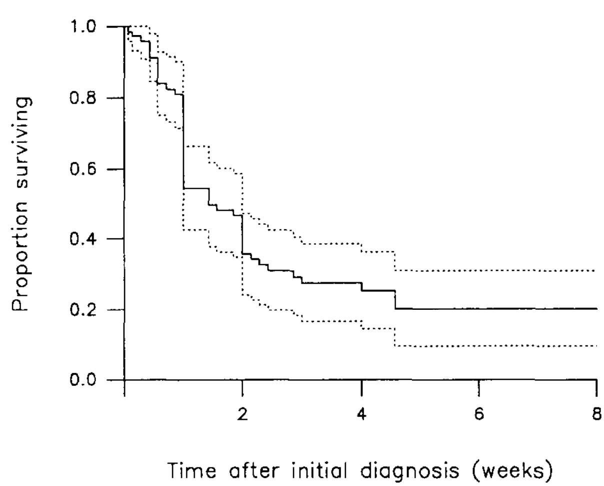

Fig. 3. The survival of 68 ostrich chicks following the development of tibiotarsal rotation on 11 farms in south-eastern Queensland (dotted lines represent the 95% confidence interval). Five chicks remained under observation for 8 weeks after the condition was first detected.

with the index case being a 7-day-old chick. The affected chicks originated from eggs laid by four different hens. All eggs had been fumigated with formaldehyde gas prior to set. The sex of all affected chicks were unknown. Deaths from salmonellosis occurred over a 123 day period during January–May 1994, ceasing when the chick rearing operation was transferred to new facilities. If the at-risk population is considered as being all chicks reared in the original facility between the dates of the index and last case whilst each remained less than 2 months of age, the salmonellosis-specific mortality rate on this farm during this period was 31.4 deaths per 100 chick-months at risk.

Data relating to morbidity and treatment events were incomplete, and are not presented here. Healthy, untreated chicks could not be clearly identified using the available recorded data, and for this reason chick growth curves were not constructed.

3.3. Parasitological results

Seventy seven chick faecal samples (32 from chicks 0–1 month of age, 22 from chicks 1–2 months, 22 from chicks 2–3 months and one sample from chicks 3–4 months; with chick age here being considered the age midway between the oldest and youngest chick in each pen at the time of sampling) were collected during the study, including some from each of the 11 farms. All samples were examined for nematode eggs, 76 (98.7%) for coccidial oocysts and 63 (81.8%) for cryptosporidia. Coccidial oocysts and cryptosporidia were not detected in any samples (upper 95% confidence limits of 4.7 and 5.7%, respectively), and evidence of nematode infection was detected

Table 5
Association between potential prognostic variables and survival to 4 months of age of 394 farmed ostrich chicks on 11 farms in south-eastern Queensland in 1993/1994

Variable	No. of chicks		Proportion surviving			Logrank test
	Total	Died [a]	30 days	60 days	120 days	P
Season of lay						
Early (June–Aug.)	86	30	0.85	0.80	0.63	0.19
Mid (Sept.–Feb.)	257	101	0.80	0.67	0.59	
Late (Mar.–May)	51	15	0.88	0.72	0.70	
Weight at hatch [b]						
≤ 819 g	147	68	0.74	0.60	0.51	< 0.001
> 819 g	144	38	0.87	0.79	0.73	
Sex						
Male	116	13	0.97	0.97	0.88	0.53
Female	121	10	0.99	0.97	0.91	
Development of tibiotarsal rotation						
No	326	94	0.81	0.74	0.70	< 0.001
Yes	68	52	0.87	0.58	0.18	

[a] Includes chicks that were killed and those that died without human intervention, each prior to reaching 4 months of age.
[b] Data were missing for 103 chicks not weighed on the day of hatch.

Table 6
Risk factors associated with death or euthanasia of 291 ostrich chicks prior to reaching 4 months of age on eight farms in south-eastern Queensland in 1993/1994

Explanatory variable	Regression coefficient	P	Relative risk(95% CI)
Farm [a]			
B vs. A	−0.37	0.65	0.69 (0.14–3.45)
C vs. A	−0.28	0.58	0.75 (0.28–2.06)
E vs. A	−1.50	0.003	0.22 (0.08–0.59)
G vs. A	−0.75	0.11	0.47 (0.19–1.12)
I vs. A	0.11	0.80	1.11 (0.49–2.51)
J vs. A	−1.87	0.001	0.15 (0.049–0.49)
K vs. A	2.06	0.07	7.82 (0.87–70.3)
Development of tibiotarsal rotation	3.21	< 0.001	29.9 (14.5–42.9)
Hatch weights (100 g increments)	−0.38	0.01	0.69 (0.51–0.91)

Cox proportional hazards regression model: Deviance = 920.4. Data from 291 chicks on eight farms with hatch weight data were used in this model[a] Forced into the model.

on a single occasion (95% confidence interval 0.03–7.0%) when a single strongyle-type egg was found following faecal flotation of a bulked sample collected in May 1994 from two pens on one farm holding chicks of 0–1 month and 1–2 months of age. No further evidence of nematode infection was found when these and other chicks from this farm were sampled 1 and 5 months later, nor was *Libyostrongylus douglassi* detected in faecal samples from adult birds held on this property during July to September 1993.

3.4. Factors affecting chick survival

Four chick-level variables were considered plausibly related to chick survival: the season of lay, chick hatch weight, chick sex and the development of tibiotarsal rotation whike the chick remained under observation. Witht he exception of sex, each of these variables was unconditionally associated with chick survival time at $P < 0.30$ (Table 5). The hatch weight of 103 (26%) chicks was not recorded; as a consequence, data from 291 chicks on 8 farms was used in the Cox proportional hazards regression model. In this model after accounting for farm-level effects, chick survival was conditionally associated with the weight of chicks at hatch and with the development of tibiotarsal rotation, but not witht he season of lay (Table 6).

4. Discussion

Chick wastage (particularly during the first 8 weeks of life) was probably the most important on-farm constraint to productivity for producers on the ostrich farms within this study. Although the losses varied greatly between study farms, on most farms the rate of chick death was unacceptably high. Chick wastage also appears to be a considerable problem in US ostrich flocks, where the problem has also been described (Smith, 1993; Wade, 1995a).

The chick mortality data in Table 3 provides a useful picture of causes of mortality in ostrich chicks. It was collected from a relatively large group of birds run under commercial conditions, and birds within this study can be considered representative of all birds within the reference population (More, 1996a). It could be argued that the validity of some of this information is questionable because laboratory examinations were only undertaken on 26% of the dead chicks. However, most recorded causes of death would fairly represent the true cause of death given that nearly half of all deaths were the result of a lower-limb deformity which was diagnosed with clinical (and not postmortem) evidence. Furthermore, broad, clinically based and relatively non-specific categories were used throughout this study to describe the cause of death of those chicks not submitted for laboratory examination.

Errors in the measurement of some events affecting chicks in the cohort may limit the usefulness of part of this study. All producers recorded key on-farm events relevant to the chick cohort including identification and egg of origin, date of hatch and weights during growth (if weighed). However, some producers did not record the dates that chicks developed tibiotarsal rotation or left the cohort. If data was not available from other sources (such as sale records), in these circumstances I relied upon the information recalled by producers. It is inevitable that these producers sometimes recalled incorrect and possibly biased information. Nonetheless, because farm visits were frequent and the size of the chick cohort on each farm at any point in time was generally small, these errors are likely to be minor. This issue should be considered when interpreting relevant results.

There is little published information on the incidence of tibiotarsal rotation in either farmed or wild ostrich chicks, although Bezuidenhout and Burger (1993) did report a 6.3% incidence risk in chicks hatched over two seasons on an experimental farm in South Africa compared with the 6.8 cases per 100 chick-months at risk in my study. Miller and Sullivan (1994) reported that tibiotarsal rotation represented only 0.7% of chick, juvenile and adult ostrich submissions to a veterinary laboratory, during a period covered by this study, and from a clientele who also included the reference population of this work. These figures clearly reflect the frequency of referral, and cannot be considered a measure of occurrence of tibiotarsal rotation in farmed ostrich populations in this region.

The cause of tibiotarsal rotation is not well understood either in avian species (including turkeys, chickens and guinea fowl); however, there is considerable expert opinion suggesting that it is probably multifactorial in nature (Gandini et al., 1986; Jensen et al., 1992, pp. 24–25; Black, 1993a; Bezuidenhout and Burger, 1993; Bezuidenhout et al., 1994; Wade, 1995b). Factors such as genetics, nutrition (including excessive growth rates of young chicks, overfeeding, diets with an improper calcium:phosphorus ratio and with inappropriate levels of energy and protein), management (including inadequate levels of exercise), underlying disease resulting in malnutrition and malabsorption, and trauma to the proximal tibiotarsus are each considered to contribute to the development of tibiotarsal rotation in ostriches.

Fading chick syndrome, also known as 'ostrich chick fading syndrome' (Terzich and Vanhooser, 1993) and 'ostrich fading syndrome' (Anonymous, 1995, p. 21; Button, 1995), has been reported in Australia, the US, Canada and South Africa (Anonymous,

1995, p. 21). It has previously been identified as a major cause of chick wastage (Smith, 1993; Terzich and Vanhooser, 1993)—as it was here. The condition is poorly understood; also, as a result of differing case definitions between published reports, it is possible that these syndromes may refer to more than one clinical condition. Terzich and Vanhooser (1993) considered the condition to be an infectious process, with multiply-resistant *Escherichia coli* and/or *Klebsiella pneumoniae* isolated from all affected chicks. Affected chicks were mainly less than 3 weeks of age, and the condition was characterised by depression, anorexia and death. During an important outbreak of ostrich fading syndrome in Australia during 1995, although no aetiological agent(s) could be identified, the spread of the condition was suggestive of a propagating epidemic (Button, 1995). The condition caused severe emaciation and death and mainly affected chicks aged between 2 weeks and 5 months. In contrast to these two reports, my findings provide some evidence for a condition that did not spread in a contagious manner. No attempt was made to control for variables that confounded the relationship between the sex of the chicks and the occurrence of this condition, and for this reason the role of sex must be viewed with caution. For example, a number of factors (including the farm of origin, length of survival, and likelihood (for those chicks that died prematurely) of being submitted to a laboratory for further examination) each influenced the chances of a chick being sexed. I acknowledge that some of these affected chicks may have died for specific reasons including omphalitis; however, this could not be confirmed by laboratory examination.

Although salmonellosis was the third most common cause of mortality of chicks in this study, all known cases were confined to a single farm. On this farm the outbreak was both serious and prolonged; however, upon the owner's specific instructions, steps could not be undertaken to confirm either the source of the outbreak or the method of spread. A wide range of domestic and wild bird and animal species were present on this property and may have served as vectors. Vertical egg-based transmission seems unlikely given the varying parentage of the affected chicks, and the coincident cessation of the outbreak with the commissioning of the new chick-rearing facilities. I believe that disease spread was probably encouraged as a result of inadequate hygienic practices in the original chick raising facilities, although the situation may have been exacerbated by the presence of persistently infected chicks. The floor of the old facility was smoothed concrete which the producer felt probably predisposed chicks to the development of lower-limb deformities. Large carpet squares were used to overcome this problem but were difficult to disinfect. These problems were overcome with the use of a low-slip yet easily cleaned concrete floor with a 'roughened' surface in the new facility.

Producers and their veterinarians would be better able to address the issue of chick wastage if farm and chick-level factors most closely associated with this problem were better understood. Unfortunately only general information on likely factors is currently available, making it very difficult for veterinarians to present solutions to producers in other than general terms. The influence of general aspects of chick management and husbandry upon chick survival has been emphasised (Jensen et al., 1992; Alldredge, 1993; Wade, 1995a) suggesting that probably a range of farm-level factors are associated with chick survival. A range of chick-level factors are also likely to be important.

For example, Deeming and Ayres (1994) provide some evidence that chick survival is adversely affected if chicks are helped to pip and hatch.

Only a small number of study farms were involved in this current study, and no attempt was made to identify farm-level factors associated with chick wastage. Data were collected from each of the chicks under observation, and the univariable and multivariable analyses were therefore conducted to examine the effect of a range of chick-level factors upon chicken wastage. A farm-level variabel was forced into the Cox proportional hazards regression model because farm-level efects were expected (McDermott and Schukken, 1994). These analyses have identified two factors that were conditionally associated with chick-survival int his study population, namely the weight of chicks at hatch (the risk of death increased 1.45 times for each 100 g decrease in hatch weight) and the development of tibiotarsal rotation (affected chicks being 24.9 times more likely to die than unaffected chicks). Although there is an obvious association between chick weight at hatch, the initial egg weight and the loss of egg weight during incubation (Deeming and Ayres, 1994), manipulation of these latter two variables may not necessarily improve chick productivity. Egg weight loss can be minimised during incubation, however, this may prove counterproductive because of the close (curvilinear) relationship between egg weight loss and hatchability (More, 1996b). Increased initial egg weights would probably result in improved egg hatchability (More, 1996b) as well as chick survival, however, practical methods to achieve this in farmed ostriches are not yet known. In this study population, the prognosis for chicks following the development of tibiotarsal rotation was extremely poor. It was not surprising, therefore that this factor was identified as an important risk factor for chick survival. As discussed previously, the cause(s) of tibiotarsal rotation are poorly understood. Treatment is rarely sucessful (Black, 1993b), and further work is needed to identify methods to prevent this condition.

At present there is little published information on infectious diseases of ostriches, nor of the role that ostriches may play in harbouring pathogens of other poultry species. The need for such information has been expressed (Terzich and Vanhooser, 1993) and became very apparent with the development of risk assessment documentation concerning the importation of live ostriches and fertile eggs into Australia (Anonymous, 1992; Gilchrist, 1993), and with the isolation of avian influenza virus from clinically affected ostriches in southern Africa (Allwright et al., 1993). Unfortunately, producer concern regarding the jugular bleeding of the chicks steadily increased as the study progressed and, as a consequence, the intended serological phase of this study was abandoned. The collection of baseline serological information should remain a priority for this industry.

There is a real need within this industry for the development and utilisation of simple farm records and for the development and industry-wide adoption of objective measures of productivity. Clearly defined measures of livability, production and hatchability have been developed for the commercial poultry industries (R.J. Jenner, personal communication); however, their direct application to the ostrich industry is limited due to its current emphasis on the performance of individual birds or breeding units. This emphasis will likely persist even once the breeding phase of industry development has been passed. Four measures of production—number of eggs laid per hen per year, fertility percentage, hatchability percentage and rate of chick survival to 4 months of age—are easily

measured within existing industry practices, and would provide obvious and practical measures of hen or farm productivity. The number of mature chicks raised per hen per year is one omnibus measure of productivity, directly derived from these four production parameters, that has the added advantage during both the developmental and commercial phases of this industry of being closely linked to the economic viability of individual farms.

Although future prospective observational studies about farmed ostrich health and productivity are obviously warranted, researchers should carefully consider methods to overcome the problems of data collection and quality encountered during this study. In particular, researchers may need to examine ways to encourage producers to record some information that in normal circumstances they would not. Attempting more focused objectives within a single study, and increasing the frequency of contact with participating producers (with increased farm visits and/or project personnel) should both be considered. Studies examining aspects of health may benefit from the use of data recording methods adapted from work described by Christensen et al. (1994). Regular and timely written reports would also encourage producer participation, particularly if the information could be used to support on-farm decision making (Martin, 1993). Data collection may become less difficult as this industry matures because increasing numbers of producers should appreciate and adopt rational, on-farm monitoring programs.

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