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03 CHAPTER

IMPORTANT ASPECTS OF MANAGING BUSTARDS IN CAPTIVITY

Tom Bailey and Olivier Combreau

"They eat quantities of green cabbage, lettuce, locusts, lizards, omelettes, grapes, meal wheat, all seeds, salt, humble bees, in fact almost anything"

Edward Meade-Waldo (1889)

[on the diet of captive houbara bustards in Tenerife]

3.1. Introduction

Bustards have been managed in menageries from historical times. In the nineteenth century great bustard eggs were frequently taken from the wild and hatched under domestic hens, so it is likely that this species was often found in captivity. Hopkinson (1926) noted that the first documented breeding of great bustards in captivity was in the Tyrol in 1858-1860. In 1889, a letter from Edward Meade-Waldo, an eminent ornithologist, to Herbert St Quintin, a well-known falconer describes the diet of captive houbara bustards kept in Tenerife (cited by Upton 2002). The earliest records of captive bustards being added to the collection at the Zoological Society of London (ZSL) are of houbara bustards caught in the Red Sea in December 1908 and in North Africa in May 1915 (Bradford 1908, Woodward 1915). However, it is likely that bustards were maintained at the ZSL before this as Beddard gave descriptions of the alimentary tract of dead bustards in 1898.

This chapter is not intended to be a reference on how to manage and breed bustards in captivity, as more comprehensive reviews are available elsewhere (Saint Jalme and van Heezik 1996, Sleigh and Samour 1996, Anderson 1998a, 1998b, 1998c; Hallager and Boylan 2004). Instead this chapter aims to give background information for the veterinarian who may be called on to provide advice on bustards that are maintained in breeding projects or zoological collections. This information on the biology and husbandry of bustards is important because disease and management are closely interrelated and the causes of the majority of diseases of captive bustards are multifactorial.

3.2. Nutrition

3.2.1. Diet of wild bustards

Emperor Frederick II was probably the first person to describe the feeding habits of wild bustards (1248, translated by Wood and Fyfe 1943). Frederick II commented that bustards when seeking their food: herbs, grains and worms, grasp it with their mandibles, taking it as it is found on the surface of the ground. Most bustards, including houbara bustards are opportunistic omnivores and in the wild their diet reflects the local and seasonal abundance of plants and small animals (Schulz and Seddon 1996, Tigar and Osborne 2000). Kori and black bellied bustards (*Lissotis malanogastor*) will even eat carrion and have been found at the road side eating corpses of birds (Collar 1996). Plants appear to be a more important source of food for houbara bustards during winter and early spring while animals, mostly invertebrates and small vertebrates are more likely to be consumed in the late spring and summer (Cramp and Simmons 1987, Johnsgard 1991). In the wild houbara

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bustard chicks are fed mainly on insects and small reptiles (Schulz and Seddon 1996). Field studies of the gut contents of bustards have shown that vegetation constitutes a very significant proportion of their diet (Collar 1996). In the case of the Vigor's bustard (*Eupodotis vigorsii*) animal material only makes up 6% of the aggregate volume and 12% of the aggregate mass of the intestinal contents (Collar 1996). Table 3.1 summarises what is known about the diets in the wild of the species most commonly kept in captivity.

Table 3.1. Summary of the wild dietary requirements of some bustard species that are kept in captivity (Rutgers and Norris 1970, Rahmani 1987, Johnsgard 1991, Bhushan and Rahmani 1992, Collar 1996, Cornes 1997, Snow and Perrins 1998, Tigar and Osborne 2000, Tourenq et al. 2003).

Species	Notes on diet in the wild
Arabian bustard	Chiefly grasshoppers, but also locusts when swarming. Other invertebrates include beetles, crickets and caterpillars. Small mammals, mice, nestling birds, grass, seeds, fruits of trees, succulent parts of plants and *Acacia* gum are also taken.
Australian bustard	A wide range of vegetable material and animals including shoots, roots, leaves, flowerheads, seeds, berries, molluscs, myriapods, arachnids, insects (grasshoppers, beetles, caterpillars), reptiles, young birds and rodents.
Buff-crested bustard	Diet is poorly studied, but it is known to eat seeds, green herbage, berries, *Acacia* gum and insects (*Tenebrionidae*, scarabs, beetle larvae, grasshoppers).
Black bustard	Diet is poorly studied, but it is known to eat vegetable matter, seeds, roots, shoots and insects.
Heuglin's bustard	Diet is poorly studied, but known to eat *Orthoptera*, small vertebrates, berries and vegetable matter.
Houbara bustard	Vegetable matter includes fruits, seeds, shoots, leaves, flowers. Animals eaten include mainly *Orthoptera, Coleoptera, Tenebrionidae,* as well as other invertebrates, small snakes, lizards and hatchlings of ground-nesting birds such as sandgrouse and larks.
Great bustard	Mainly plant material and invertebrates, although small mammals, amphibians and nestling birds are sometimes taken.
Great Indian bustard	Mainly insects including grasshoppers and beetles, but also scorpions, reptiles, bird eggs and small mammals. Favoured crop plants include groundnut, rocket salad, millet and Bengal gram.
Kori bustard	A wide range of vegetable material and animals including seeds, berries, bulbs, *Acacia* gum, snails, insects, locusts, grasshoppers, dung beetles, rodents, lizards, snakes and birds (eggs, nestlings and roadkills). Studies of the gut contents of kori bustards in Namibia have revealed mostly insects and very little plant material (T. Osborne, pers. comm.).
Little bustard	Animals eaten include beetles, grasshoppers and other terrestrial invertebrates. Plants eaten include shoots, clover, grain, leaves, flowers and seeds.
Nubian bustard	Invertebrates such as ants, locusts, beetles, caterpillars, grass seeds and vegetable matter, leaves, fruit and berries of desert plants and *Acacia* gum.
White-bellied bustard	Animals eaten include termites, locusts, caterpillars, beetles, spiders, scorpions, snails, snakes and lizards. Vegetable material includes green herbage, grass seeds, bulbs, berries and flowers.

3.2.2. Diets fed to bustards in captivity

In captivity, non-houbara species of bustards have been fed mice, mealworms, crickets, apple, cabbage, chopped greens and either bustard pellets (Abu Dhabi Food and Flour Mill, Anderson 1995), locally available game bird pellets, or a mixture of crane (Special Diet Services, Witham, Essex, UK) and ratite pellets (Special Diet Services) (Sleigh and Samour 1996). Captive bustards will also eat invertebrates attracted to vegetation in naturalistic aviaries (Figure 3.1).

Beef mince has been used to replace mice or mealworms if either component is unavailable. It should be noted that meat is perishable and, particularly in hot climates, needs to be handled carefully to prevent spoilage (Hallager and Boylan 2004). Table 3.2 presents the diet offered daily to adult non-houbara species of bustards at NARC (Anderson 1998a, 1998b, 1998c). Table 3.3 summarises the macronutrient composition of the production and maintenance diets for bustards. Table 3.4 summarises the nutrient composition of bustard pellets fed to houbara bustards at NARC.

3.1

3.1 A naturalistic aviary for medium-sized bustards with planted natural vegetation for cover and to attract invertebrates. In naturalistic aviaries up to 25% of the diet of captive bustards can come from the surroundings (Photo credit Tom Bailey).

Kori bustards kept in zoos in the United States (US) are fed horsemeat in addition to mice and the meat is supplemented with either crane and ratite pellets or game bird pellets (Boylan et al. 2001). The mixture is made into small meatballs and hand-tossed to each bird. This method of feeding facilitates close inspection of each bird as well as helps to form a trusting bond between the keeper and each bird. To encourage natural foraging behaviour, supplement the daily diet and provide a form of enrichment, chopped green beans, cherry tomatoes, hard-boiled egg, and blueberries are provided twice a week to kori bustards in US zoos (Bailey and Hallager 2003). Kori bustards at the San Diego zoo are fed on a mixture of a weight control diet for dogs (IAMS), zoo carnivore diet 5 (Natural Balance), mealworm larvae, crickets and whole adult mice (Edwards pers. comm.).

Other items fed at San Diego zoo to captive kori bustards have included giant grasshoppers, mincemeat, meatballs, lizards, feeder goldfish, cherry tomatoes, grapes, grains, shelled peanuts, sunflower seeds and honeysuckle flowers (Schneider 1992, Hallager and Boylan 2004). In addition, crushed oyster shells are dumped in their enclosure once a year as a calcium supplement.

In the 1990's a flock of great bustards was kept at Whipsnade Wild Animal Park in the UK. These birds were fed at various times on proprietary concentrate pellets, Zoo A diet (Mazuri Zoo Foods, UK), a proprietary crane diet and a formulated bustard diet (Special Diet Services) while fresh cabbage and cauliflower were fed ad-libitum (Flach 1995). Locusts, crickets, mice, dog food, insectivorous bird food, mealworms, spinach, cress, spring greens and sprouting broccoli were also fed in order to increase the condition of the birds (Bailey and Flach 2003). Great bustards maintained at the breeding centre in the University of Poznan in Poland are fed a diet consisting of ground horse or beef meat, ground pigeon (with feathers and bones), boiled hens eggs, barley gruel, barley grain, wheat grain, wheat bran, oat flakes, dry green forage, ground carrot and cut onion (Bereszynski and Graczyk 2000). Bereszynski and Graczyk (2000) estimate that adult great bustards consume 5-10% of their body mass a day.

Great Indian bustards at Jodhpur zoo have been provided with a diet comprised of meat (liver, species not specified), wheat flour, spinach, alfalfa and bread (Makwana et al. 1980). It was also observed that bustards caught and ate small birds, squirrels, lizards and insects in their enclosure.

At NARC and NWRC maintenance pellets (14% protein) are fed to houbara bustards outside the breeding season and productioner pellets (22% protein) are fed during the breeding season (Paillat and Gaucher 1996, Sleigh and Samour 1996). Additional live food such as mealworms or crickets is supplemented as part of taming protocols to reduce keeper-induced stress.

Food is presented in washable containers either once or twice a day. Water is provided ad-libitum. As long ago as 1932 Moody commented that houbara bustards are fond of fresh voles and field mice. Small mammals are still commonly fed to captive bustards. Pinkie mice are fed to smaller species of bustards, while fuzzie or adult mice are fed to the larger species such as kori bustards. Medication may be given to specific birds within favoured items such as mice.

Hard, insoluble grit may be necessary for the grinding of fibrous feed in the ventriculus. Free-living houbara and great bustards have been observed picking up small stones, gritty sand, quartz granules, clay shale and snail shells (Surahio 1985, Snow and Perrins 1998) and all

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bustard species examined post-mortem at NARC have stones of various sizes present in the ventriculi (Bailey et al. 1997d). These are probably ingested deliberately to assist with the grinding down of food (Bailey et al. 1997d). Calcium carbonate may be added to the fresh food mixture to compensate for the calcium imbalance that is caused by the addition of live food/mince. The feeding of sterilised bone fragments to growing ratites is recommended to reduce the incidence of leg deformities as they have the correct Ca:P ratio (Huchzermeyer 1998).

A considerable amount of research has been conducted on ostriches to determine the energy, nutrient, mineral and vitamin requirements for ratites (Gandini et al. 1986b, Cilliers and Hayes 1996, Angel et al. 1996) and if we are to improve the nutrition of captive bustards similar studies are needed. Anatomical studies of the bustard alimentary tract have shown that buff-crested bustards show minor differences compared with the other bustards (comparatively larger ventriculi and longer small intestines) that may indicate dietary differences between the species (Bailey et al. 1997d). These differences may need to be reflected in modifications to the diet offered to captive bustards.

Table 3.2. The macronutrient composition of diets offered to non-houbara bustard species at the National Avian Research Center (Anderson 1998a, 1998b, 1998c).

Nutrient	Unit (%)	Maintenance diet	Breeding diet
Water	%	28.1	26.3
Protein	%	13.2	17.1
Fat	%	3.8	3.6
Carbohydrate	%	49.0	46.3
Ash	%	4.3	5.4
Calcium	%	1.1	0.8
Phosphorus (available)	%	0.5	0.5
Ca:P ratio		2.2	1.6

Table 3.3. Diet offered daily to adult kori (KB), white-bellied (WBB) and buff-crested bustards (BCB) at the National Avian Research Center (Anderson 1998a, 1998b, 1998c).

Food item	% of diet	Quantity per KB (g)	Quantity per WBB (g)	Quantity per BCB (g)
Bustard pellet*	75	292.5	46.8	34.1
Minced meat	9.7	37.8	6.05	4.4
Apple	9.7	37.8	6.05	4.4
Cabbage	4.8	18.9	3.02	2.2
Calcium carbonate	0.8	3	0.48	0.35
SA-37	**	0.5	0.08	0.06

*Bustard productioner pellet (Abu Dhabi Flour and Food Mill, Abu Dhabi, UAE).

**SA-37 (Intervet UK Ltd, UK) multivitamin supplement is provided on a bodyweight basis, not as a proportion of the diet.

Table 3.4. Composition of the pellets fed to houbara bustards at the National Avian Research Center (courtesy Olivier Combreau)

			Breeders		Non Breeders	
	Nutrient	**Unit**	**Male**	**Female**	**Starter**	**Maintenance**
Energy	ME Poultry	kcal/kg	2415.77	2367.52	2681.91	2210.00
	ME Layer	kcal/kg	2466.1	2424.88	2711.16	2232.00
Macronutrient	Moisture	%	11.85	11.22	11.8	11.97
	Protein	%	22.34	23.88	26.16	14.96
	Fat	%	3.9	4.09	2.68	3.40
	Fibre	%	7.45	6.38	3.99	11.00
	Carbohydrates	%	47.7	42.82	48.25	52.1
	Ash	%	6.76	11.61	7.12	6.57
	Ca	%	1.06	2.95	1.19	1.1
	P available	%	0.39	0.44	0.61	0.56
	Ca/P available		2.7	6.7	2.0	2.0
Amino acids	Methionine	%	0.38	0.45	0.67	0.54
	Lysine	%	1.13	1.27	1.54	1.26
	Tryptophan	%	0.29	0.3	0.32	0.28
	Threonin	%	0.83	0.9	0.99	0.87
Oligo-elements	Na	%	0.15	0.15	0.15	0.15
	Cl	%	0.26	0.26	0.24	0.18
	K	%	1.14	1.14	1.18	1.04
	Zn	ppm	183	183.32	132.15	175.86
	Cu	ppm	25	25	25	25
	Se	ppm	0.69	0.66	0.56	0.57
Vitamins	Vit E	ppm	336.5	336.5	28.5	300.00
	Vit A	UI	12850	12850	12850	12850
	Vit D3	UI	3000	3000	3000	3000

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3.2.3. Monitoring daily food consumption

Very often the first sign of clinical disease in individually-housed houbara bustards maintained under semi-intensive conditions is a decrease in food intake. Daily monitoring of individual food consumption is an important part of the husbandry of this species and is achieved by weighing food in and out of each pen. It is important to be aware that there is a seasonal variation in food intake in houbara bustards (Paillat and Gaucher 1996, Saint Jalme et al. 1996, Jacquet 1998). Food consumption is least at the end of the reproduction season, around May, and at the end of the moult, in the autumn. Food intake is greatest at the start of the breeding season and in the middle of the moult. Minimum and maximum quantity of food intake of pellets are 30-45 g/day and 40-60 g/day for female and male houbara bustards respectively (Paillat and Gaucher 1996).

3.2.4. Diets fed to bustard chicks in captivity

Stiévenart (2002) described the rearing procedure of houbara bustard chicks at NWRC. The diet for the first 45 days consists of:

- dry pellets (dry matter (DM) 88%, crude protein=22% DM, calcium=1.5% DM, phosphorus=0.8% DM),
- fresh alfalfa (dry matter 24%, crude protein=4.8% DM (Anderson 1995)),
- mealworms (*Tenebrio molitor*) (dry matter=42.2%, crude protein=22.3% DM (Jones et al. 1972))
- "Humid pellets" - SDS (Special Diet Services) pellets (crude protein=23.5% of dry matter) swollen by immersion in water enriched with a vitamin B complex solution and containing about 75% of water.
- Crickets (*Acheta domestica*) (dry matter 31.7%, crude protein=17.8% DM) (Anderson 1995).

Chicks are given mealworms (one meal every three hours from sunrise to sunset) upon entry to the nursery in order to stimulate pecking behaviour (Stiévenart 2002). This period of limited food supply ends after the first night. Afterwards, chicks are hand-fed with small pieces of humid pellets, mealworms, alfalfa and dry pellets. From one to ten days, chicks are given six meals per day, including these four food items and are progressively accustomed to feed independently. From ten days of age, chicks are able to pick up food items independently. They are stimulated to eat dry pellets, whilst fresh food is offered during taming activities at least four times a day. Fresh alfalfa, dry pellets and water should be available to the chicks *ad libitum* four days after rearing groups of chicks are formed.

Mealworms and crickets contain levels of calcium and phosphorus that are inappropriate for normal bone development in young animals (Allen and Oftedal 1989). Ca:P imbalances in the diets of growing animals result in metabolic bone disease which is discussed in Chapter 22. Anderson (1997) demonstrated that it is possible to improve the calcium status of mealworms and crickets by maintaining them in vitamin/mineral supplements for as little as 24 hours before they are fed to bustard chicks.

3.3. Vitamins

Vitamins are defined as natural food components that are present in minute quantities, are organic in nature and are essential for normal metabolism and health (Brue 1994). An insufficient or excessive intake of vitamins cause specific deficiency or toxicity syndromes. Table 3.5 (adapted from; Brue 1994, McWhirter 1994, Anderson 1995) summarises the biological importance of vitamins and vitamin-related syndromes in birds.

3.3.1. Vitamin E (α-tocopherol)

Adequate levels of fat-soluble vitamin E (α-tocopherol) are necessary for good health and successful reproduction in birds. Vitamin E deficiency in captive avian species (both domestic and non-domestic) has been associated with low fertility, low hatchability, immunosuppression, and specific clinical abnormalities such as encephalomalacia and muscular myopathies (Kling and Soares 1980, Scott et al. 1982, Dierenfeld 1989, Dierenfeld et al. 1993, Ullrey 1993). Data on the vitamin E status of avian species assist with the diagnosis of causes of morbidity and reproductive failure, and assist with assessment of the adequacy of diets for captive species. Plasma vitamin E assay is one method of assessing overall vitamin E status, although other dietary and environmental factors need to be taken into account when interpreting the results (Dierenfeld 1989). Vitamin E is dependent on blood lipid components for absorption and transportation, so it is important to evaluate blood vitamin E levels relative to blood lipid levels (Horwitt et al. 1972). Because blood cholesterol assay is a routine procedure, cholesterol levels are commonly used as an index of blood lipid levels, with blood α-tocopherol levels standardised by calculating α-tocopherol:cholesterol ratios. Plasma α-tocopherol and cholesterol concentrations have been measured in a wide range of captive avian species (Gulland et al. 1988, Dierenfeld et al. 1989, Schweigert et al. 1991, Dierenfeld and Traber 1992, Dierenfeld et al. 1993) including six species of bustards (Anderson et al. 2002). Table 3.6. presents a-tocopherol levels in bustards.

Table 3.6. Mean (±sem) plasma α-tocopherol and cholesterol concentrations in captive bustards at the National Avian Research Center, United Arab Emirates (Anderson et al. 2002).

Bustard species	Age[a]	Number of α-tocopherol samples	α-tocopherol (µg/ml)	Number of cholesterol samples	Cholesterol (mg/ml)	α-tocopherol: Cholesterol (µg/mg)
Houbara	Adult	32	11.07 ± 0.41	12	1.93 ± 0.10	6.09 ± 0.44
	Juvenile	12	6.33 ± 0.48	11	2.08 ± 0.09	2.94 ± 0.22
Kori	Adult	21	4.43 ± 0.42	20	1.23 ± 0.25	3.67 ± 0.44
	Juvenile	11	4.46 ± 0.26	11	1.28 ± 0.11	3.71 ± 0.36
Buff-crested	Adult	19	6.64 ± 0.33	18	1.22 ± 0.05	5.56 ± 0.32
White-bellied	Adult	8	7.75 ± 0.81	8	1.35 ± 0.13	5.83 ± 0.43
Black	Adult	2	10.08 ± 0.06	2	1.37 ± 0.04	7.36 ± 0.17
Heuglin's	Adult	4	6.08 ± 0.64	4	1.16 ± 0.09	5.39 ± 0.86

[a]Adult: ≥ 12 months; juvenile: 6-12 months.

The plasma α-tocopherol and cholesterol concentrations and α-tocopherol:cholesterol ratios of captive bustards reported by Anderson et al. (2002) cover similar ranges to those previously reported for omnivorous avian species such as Gruiformes and Galliformes (Dierenfeld et al. 1993).

Anderson et al. (2002) considered that the vitamin E status of adult bustards is influenced by environmental factors that varied due to species-specific husbandry regimes, but no clear relationship was seen with dietary vitamin E levels. As the species in this study were not maintained under similar management regimes the inter-specific differences observed between adult bustards in this study cannot be regarded as conclusive. Juvenile bustards did not have higher vitamin E levels than adults, despite being maintained on four-fold dietary vitamin E concentrations and in similar environmental conditions. Further research is required to determine which components of the identified environmental factors affect bustard vitamin E status and to confirm whether real differences exist between species independent of the variation in their management regimes.

3.3.2. Vitamin deficiencies and other vitamins

In birds the diagnosis of vitamin deficiencies (e.g. thiamine or vitamin E), has been based on clinical signs and the clinical response to supplementation. Thus, vitamin E and selenium deficiencies have been implicated in captive bustards with capture myopathy (Bailey et al. 1996a, 1996b) and encephalomalacia (Bailey et al. 1997b). However, it is important to note that α-tocopherol levels were not determined in these birds. Now that tests measuring vitamin levels in tissues and blood are becoming more widespread, the ability of veterinarians to diagnose deficiencies and to provide more rational supplementation will undoubtedly improve. Blood levels of vitamin A, B1, C and E in bustards are presented in Table 3.7 (Bailey unpublished data).

Table 3.7. Plasma vitamin A, B_1, C and E concentrations of healthy captive houbara bustards (n=15) in Dubai, United Arab Emirates (Bailey unpublished data).

Species	Vitamin B_1 (µg/l)	Vitamin E (µmol/l)	Vitamin C (mg/l)	Vitamin A (µmol/l)
Houbara bustard	[a]45.83 ± 1.87	[b]17.81 ± 1.03	4.06 ± 0.32	5.42 ± 0.23
	[c] (33 – 60)	(11.9 – 30.9)	(1.3 – 5.9)	(4.1 – 7.6)

[a]mean, [b]standard error of the mean, [c](range).

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3.3.3. Vitamin supplementation

Many diseases that are seen in young birds are due to inadequate nutrition of the parents in the months leading up to laying and during the laying period (Butterworth and Harcourt-Brown 1996). Captive houbara bustards may lay in excess of 20 eggs in a season and unless the diet is supplemented adequately with vitamins many eggs may fail to hatch, or may produce chicks that fail to thrive. In other species, chicks from nutritionally deprived eggs will fail to grow at the correct rate and will also have a greater incidence of abnormalities than chicks from normal eggs (Butterworth and Harcourt-Brown 1996).

Multivitamin solutions are added to the water twice a week at NWRC (Paillat and Gaucher 1996). In stressful situations (e.g. translocation, capture and heat stress) the requirements of certain vitamins may increase, while at the same time inappetance may lower the amount of vitamins ingested. Under such situations the supply of extra vitamins in the form of a soluble addition to the drinking water may be necessary. Many formulations are available and some of those used at NARC are listed in the formulary (Figure 3.2).

3.2

3.2 Nutritional and vitamin supplements used in bustard chick husbandry (Photo credit Tom Bailey).

Birds with vitamin E and selenium deficiencies, heat stress, trace element toxicity and parasitic infections may have increased requirement for vitamin C and in these situations parenteral supplementation is indicated (McWhirter 1994).

Bustard chicks, like those of other long-legged species, are susceptible to long-bone disorders and chick-rearing diets must be supplemented with Vitamin D3 (e.g. Nutrobal, Vetark). Vitamin D deficiencies are common in poultry kept indoors in an ultra-violet deficient environment with insufficient dietary vitamin D (Edwards et al. 1994) and a similar situation may occur in houbara bustards as management becomes ever more intensive. The concentration of 25-hydroxycholecalciferol in serum is currently considered to be a reliable indicator of the vitamin D status of animals (Stanford 2003a, 2003b) and levels below 50nmol/l may indicate deficiency in domestic poultry. As long bone disorders are common in bustard chicks studies on vitamin D requirements are warranted in the future.

3.4. Biosecurity Issues

3.4.1. The need for biosecurity in bustard projects

Free-living houbara bustards inhabit arid or semi-arid zones where rainfall rarely exceeds 200 mm a year and exist at low population densities (Schulz and Seddon 1996). Consequently, free-living bustards probably have few infectious diseases of their own with the exception of helminth parasites (Jones et al. 1996b, Wernery et al. 2001a). However, bustards maintained in captivity are susceptible to diseases of poultry, other birds and mammals. With concentrations of large numbers of bustards in captivity the danger of outbreaks of infectious disease is real and because of their incompletely developed immune systems, juveniles in rearing facilities are especially vulnerable. Consequently, it is necessary to protect bustard captive breeding projects, especially the rearing units, against the possible introduction of disease. The poultry industry has developed a series of procedures collectively termed 'biosecurity' which limit the occurrence and impact of disease (Shane and Minteer 1996). An overview of the methods of disease transmission is necessary in order to formulate appropriate biosecurity procedures for a bustard project. Pathogens can infect bustards by the following routes:

- Vertical transmission. Although bustards are susceptible to *Salmonella* and *Mycoplasma*, vertical transmission has not been demonstrated for these diseases as it has in poultry.
- Mechanical transmission on eggshells. In other species bacteria such as *Salmonella* and *Escherichia coli* can infect the surface of the egg as it passes through the cloaca.
- Direct transmission. Breeding birds could become chronic carriers of diseases agents such as reovirus, adenovirus, *Mycoplasma*, *Mycobacterium* and *Salmonella*. Stress factors such as capture, translocation, diet changes could result in activation of latent infections.
- Indirect infection is possible via vehicles, footwear, clothing, equipment etc.
- Insect vectors can transmit diseases such as avipox.
- Vermin such as rats and mice serve as reservoirs of diseases.

Many avian pathogens can readily spread through aerosol and feather particles. Air filtration systems that decrease particles and pathogens to the 0.1-1.0 mm range are recommended for use in incubation, nursery, hospital, quarantine and veterinary facilities. Ideally, veterinary hospitalisation and quarantine facilities should incorporate airflow systems that allow separation

of bustards with infectious diseases (Figure 3.3). Important biosecurity measures include the control of human movements, provision of protective clothing, footbaths/mats, footwear and decontamination facilities, strict exclusion of all poultry and pet birds, limiting or excluding visitors, predator and pest control, (Figures 3.4, 3.5), quarantine, disinfection programmes, the restriction of mammals like dogs and cats on-site to a minimum. Feed deliveries also constitute a way of introducing disease onto sites, particularly if the feed lorry has visited other poultry units or markets. Vehicles visiting breeding projects should drive through disinfectant wheel baths to reduce the risk of introducing pathogens.

3.4.2. Biosecurity programmes

Biosecurity may be defined as that part of management aimed at preventing the focal introduction, as well as the horizontal spread, of infectious diseases (viral, bacterial, fungal, parasitic) in an animal production system (Verwoerd and Temperly 1998). Ideally biosecurity principles should be incorporated into bustard projects from the initial inception and development of the project, and continued on a day-to-day basis, not as a reaction to emergencies. Investing in biosecurity is comparable to investing in an insurance policy, reducing the risks of disease outbreaks and facilitating the achievement of maximum production on a sustainable basis (Verwoerd and Temperly 1998).

The goal is to create a biosecurity culture within the staff of the project so that correct action is automatically taken by all staff all of the time. This can be achieved through leadership by example, training of all personnel in the correct execution of their daily tasks and educating them to have a basic understanding of disease and hygiene (Verwoerd and Temperly 1998). At NARC a review of biosecurity at the sites and facilities was combined with a training programme to raise awareness of hygiene in the staff. Microbiological screening conducted before and after the introduction of new disinfection protocols enables the effectiveness of new procedures to be measured (Forbes and Smith 2005).

3.3

3.4

3.5

3.3 The quarantine unit of the National Avian Research Center, UAE (Photo credit Tom Bailey).

3.4 Feral bird species such as these two house sparrows (*Passer domesticus*) in a naturalistic aviary can be a potential source of pathogenic agents for bustards. House sparrows have been implicated in avipox virus outbreaks at houbara bustard projects (Photo credit Tom Bailey).

3.5 A pigeon trap in a bustard aviary. Control of doves and pigeons is important in outdoor aviaries (Photo credit Tom Bailey).

3.4.3. Project layout

The incubation, rearing and breeding facilities should be separated and managed as distinct units. They should be located so that prevailing winds blow from the incubation unit and young chick areas to the breeder areas and not the other way round. All access by vehicles and visitors should be controlled and channelled to less sensitive areas, such as reception offices. All access points should be through an entrance and changing room where staff put on overalls and rubber boots before entering the units through a disinfectant footbath or foot mat. Where necessary, large access doors should be present to allow vehicles to enter for cleaning and maintenance. Water systems should be accessible to allow servicing, cleaning, medication, water quality monitoring and, if necessary, disinfection.

Incubation building design should separate the dirty area (egg receiving) from the clean area (egg storage and incubators/hatchers) and allow a logical flow of personnel between areas. Sufficient toilet, changing/washing/showering facilities along with locker space and changes of clothes should be provided. All

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inside surfaces should be white to show up dirt and they should be washable and accessible. Ideally the building should be under positive air pressure with sealed ceilings and sloping floors connected to a closed drainage system.

3.4.4. Choice of disinfectants

The recommended minimum criteria for the choice of disinfectant are as follows (Verwoerd and Temperly 1998);

- Substantiated efficacy spectrum including information on contact times and concentrations.
- Operator safety and side-effects on other animals.
- Absence of corrosiveness to surfaces and equipment such as incubators.
- Cost comparison based on price of working solution.

The following disinfectants can be used on bustard units: cresols, phenols, iodophors, quaternary ammonium compounds, chlorine compounds and formalin. The use of these agents in avicultural settings was reviewed by Shane and Minteer (1996). Biosecurity protocols were developed for NARC using the disinfectant F10 (Health and Hygiene, South Africa) and Virkon (Antec International, UK) after a biosecurity review in 2001. Protocols for F10 are presented in Appendix 26.2. Microbiological screening (settle plates and surface swabs) conducted in the NARC quarantine unit after these protocols were implemented demonstrated a measurable improvement in facility hygiene. Similar protocols are widely used in South Africa, Europe and N. America in a wide range of avicultural, veterinary and zoological facilities (Verwoerd 2001, 2002a, 2002b; Stanford 2003c, 2004; Forbes and Smith 2005).

A large bustard facility in the UAE has recently been fitted with a misting system through which F10 (1:250-1:500 dilution) is sprayed 2-4 times a day. This appears to have contributed towards reducing the incidence of a number of disease conditions (Bailey and Silvanose unpublished data 2004). Microbiological screening conducted before and after the introduction of the system demonstrated a reduction in the fungal colony counts in settle plates and reduced the isolation of pathogens from environmental swabs. Such misting systems may have an important role to play in the management of disease in rehabilitated bustards that have been exposed to infectious diseases.

3.4.5. Environmental and feed screening

Screening avicultural facilities for potentially pathogenic fungi and bacteria is an important part of project biosecurity (Figure 3.6). Animal feed and bedding become contaminated with pathogenic fungi in areas of warm temperatures and high humidity (Silvanose and Samour 1998). Incubators and hatchers are susceptible to contamination, since they provide suitable environmental conditions for the growth of bacterial and fungal pathogens. At NARC monthly screening comprises random samples from animal feed, nests, bedding, incubators, hatchers and the environment within live-food, chick rearing, food preparation and quarantine areas. In rooms it is important to consider sampling air-conditioning filters, drains and work surfaces. Samples from incubators should include water trays and egg incubating surfaces. Swabs of surfaces, as well as settle plates, should be included in any screening protocol. Wet surfaces in facilities should be screened with swabs and the results are expressed as colonies per cm3. Air samples are screened using settle plates exposed for 20 minutes. Silvanose (pers. comm.) classifies settle plates as follows: 1) normal environmental levels - 0-5 colonies of Aspergillus spp. in 90 mm agar settle plates/20 minutes; 2) poor hygienic status - 5-15 colonies of Aspergillus spp. in 90 mm agar settle plates/20 minutes and 3) unsuitable hygienic environment - >15 colonies of Aspergillus spp. in 90 mm agar settle plates/20 minutes.

3.6

3.6 Microbiology screening of egg incubators. It is a routine biosecurity procedure in artifical incubation units (Photo credit Tom Bailey).

Feed should be regularly screened for fungal contamination and at NARC this was done once a month. Silvanose (pers. comm.) classifies fungal contamination of pellet feed as follows: 1) normal hygienic status - 0-10 colonies *Aspergillus* spp., 2) poor hygienic status - >10 colonies *Aspergillus* spp. Feed samples can also be tested for the presence of aflatoxins using commercially available ELISA kits (R-Biopharm, Germany). Silvanose (pers. comm.) classifies aflatoxin contamination of pellet feed as follows: 1) <50 ng aflatoxins/kg feed is considered normal, 2) 50-100 ng aflatoxins/kg feed is considered poor hygienic status and 3) >100 ng aflatoxins/kg feed is considered unacceptable hygienic status.

Aflatoxin B_1 is the most toxic of the aflatoxins and is a well known hepatotoxin, causing poor weight gain, anorexia and hepatomegaly (Hoefer 1997). Pellets containing toxins should not be fed to bustards because of the risk of developing liver disorders. Other fresh food items (e.g. mince and live food) and water should also be tested. Meat and live food can act as source of *Pseudomonas* spp, *Salmonella* spp. and *Clostridium* spp. *Pseudomonas* spp. and *Salmonella* spp. can also be transmitted through the water.

3.4.6. Predator and pest control

Predator control is an important aspect of captive bustard management (Figure 3.5). Birds in outdoor aviaries can be frightened by predators and injure or kill themselves by flying into the fences. Cats, foxes and even monitor lizards have caused problems in 'overly' naturalistic enclosures in the Middle East. While the outer fences of naturalistic aviaries should be predator-proof, ideally the perimeter of breeding units should be protected by 2 m high predator-proof fencing. Outside units should be surrounded by a frame supporting 1.5 cm square mesh to prevent small birds such as sparrows from entering aviaries and introducing diseases.

Wild birds and rodents are potential and frequent carriers of pathogens (Shane and Minteer 1996). Ad-libitum feeding in naturalistic aviaries attracts large numbers of wild birds and they could be an important source of infection for avian influenza, PMV-1, mycoplasmosis and chlamydophilosis for other types of captive managed domestic and exotic avian species (Huchzemeyer 1998). The problem can be solved by feeding the larger bustards from custom-made hoppers that exclude smaller wild birds such as doves and sparrows. Rodents, flies and reptiles often carry *Salmonella* spp. (Shane and Minteer 1996). Rodents and other small mammals can also carry ticks into naturalistic aviaries. General cleanliness helps to control flies and rodents. Trapping of vermin is favoured over the use of rodenticides, as bustards are at risk of succumbing to secondary rodenticide toxicity if they consume dead or dying rodents.

Rodents and invertebrates can infest environmentally controlled buildings. While rodents and invertebrates can spread disease, invertebrates can also be intermediate or paratenic hosts for helminth parasites. Paratenic or transport hosts are animals that act as substitute intermediate hosts of parasites, usually having acquired the parasite by ingestion of the original host (Blood and Studdert 2000). Fire ants (*Solenopsis geminata*) have been recorded as entering a hatcher and going through the external pip hole to kill a hatching kori bustard chick. Subsequent to this event, benches on which hatchers are placed stand away from the wall and their legs stand in bowls of water that act as moats to prevent ants climbing up the legs. Petroleum jelly can be smeared around electric cables that lead to hatchers to prevent ants from climbing along the walls or along cables. Paillat and Gaucher (1996) describe the use of long-acting insecticides sprayed around aviary walls to form a protective barrier against ants and beetles.

Unfortunately, many private collections in the Middle East release pinioned wild caught bustards into the walled grounds of large properties. This results, particularly during the migration season, in large numbers of raptors, such as eagle owls (*Bubo bubo ascalaphus*), harriers (*Circus* spp.) and eagles (*Aquila* spp.) being attracted to what is a source of easy prey. Many collections then have teams of staff who shoot these raptors (Anonymous 2005). The logic of importing wild bustards into the Middle East, contributing to population declines in their countries of origin, and then destroying large numbers of raptors, many of which are species under population pressures of their own to protect mutilated 'exotic' bustards is a senseless form of predator control.

3.4.7. Quarantine

All projects should have a quarantine facility that is appropriate for the size of the breeding centre. Naldo et al. (1997a) consider that a quarantine facility should:

- be located a safe distance away from the breeding centre and from any neighbouring residential or agricultural areas. Special attention should be paid to the direction of prevailing winds and nearby poultry facilities.
- be protected from stray animals and predators.
- have a central unit fully equipped to carry out clinical laboratory and post-mortem work.
- have at least two separate wards so that two groups of birds can be accommodated at the same time.
- have a buffer zone between the central unit and the wards.
- have facilities for personal hygiene.
- have facilities for disinfecting car tyres and boots.
- be able to be maintained at a required temperature and humidity.
- have enclosures that get the maximum benefit of sunlight, be spacious and easy to clean.
- be possible to observe birds form the corridor without causing disturbance.
- have facilities so that birds can be moved between pens minimising contact with personnel inside the enclosure.
- be possible to separate a bird from the group to facilitate catching and handling.

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3.5. Management of Captive Birds

3.5.1. Capture

Correct methods must be used to catch and handle bustards to avoid injuries (Figures 3.7a-b, 3.8, 3.9, 3.10a-c). For birds maintained in outside aviaries in arid and semi-arid regions, captures are usually carried out early in the morning to reduce the risk of heat stress. In the Middle East multivitamin solutions are given in the water for 5-7 days before large captures to reduce the potential for capture-related myopathies. The specific methods for catching birds depend on the species, the age, the level of tameness, the aviary size, the size of the cage/enclosure and the environment that is within this and the reason for the catch (translocation, medication, artificial insemination).

3.7a

3.7b

3.8

3.9

3.10b

3.10c

3.10a

3.7a/b Large species of bustards can be caught by a) pushing them towards a corner and b) grabbing them when they pass between the handler and the side of an enclosure when they try to break back past the catcher. Reprinted by kind permission from Samour, J.H. (ed), *Avian Medicine*. Mosby, London. Pp 181-186; 2000 (Photo credit Tom Bailey).

3.8 A capture-corral for catching bustards housed in large naturalistic aviaries (Photo credit Tom Bailey).

3.9 Hand-catching a houbara bustard in a small pen involves herding the bird into a corner and then grabbing it swiftly (Photo credit Tom Bailey).

3.10a/b/c When restraining small-medium-sized bustards, the limbs can be; a) tucked under the birds body, b) held extended behind the bird, but c) care should be taken when restraining bustards to keep a finger between the hock joints, to keep control of the feet and avoid friction injuries (Reproduced by kind permission of the Avicultural Society, *Avicultural Magazine*, 109: (1); 1-8. Note that falconers hoods can be used in houbara and other medium sized bustard species (Photo credit Tom Bailey).

Single small- or medium-sized birds in small aviaries can be captured by hand by one person if the bird is tame, or using a net by one or more people if it is nervous. Nets may be used either with or without a handle. The decision whether or not to use a handle will depend on the available space within the aviary. The catcher should push the bird into a corner before closing in and netting the bird. If the bird attempts to run or fly past the catchers the net should be placed in front of it so the bird runs or flies into it. Care should be taken when netting flying birds not to cause any injuries. Once netted the bird should be carefully removed and either held in the hands or placed in a box or carrier. While removing the bird from the net, special attention should be paid to the feet, head and carpo-metacarpal joints to ensure that they are not entangled in the netting as the bird is pulled out.

Single tame bustards in small indoor aviaries can also be caught by hand by one person, after herding the bird into a corner. Larger species like kori bustards housed in small enclosures can be caught by slowly guiding them into a small-darkened shed, cornering them and grabbing by hand around the body.

Flocks of birds in large aviaries are often able to escape by flying or running and they may be captured using nets or corrals. These are a blind-ended funnels, often made of shade cloth with a wide mouth and a circular catching area at the blind end. Some larger species, like kori bustards may best be captured by cornering and grabbing around the body by hand. However, even with such large birds a net placed over their head and upper body makes capture easier and therefore less stressful for the bird.

3.5.2. Handling

Once captured, darkness has a quietening effect on bustards. This can be achieved by placing the bird in its capture crate into a dark room or by placing a hood over the head of a bird that is being handled (Figure 3.11). Falconry hoods are commonly used for medium-sized bustards, such as houbara and white-bellied bustards. Cotton bags may be placed over the head of the larger species of bustards, such as kori bustards and socks with holes have even been used in emergency situations! Cotton bags should have an opening over the nostrils to allow breathing. Restraint harnesses are also useful for restraining hooded small- to medium-sized bustards and are particularly useful in birds that are recovering from anaesthesia. Bustards that are captured for handling should always be weighed (Figure 3.12).

3.11

3.12

3.11 A small cloth sack can be used to cover the head of medium-large sized bustard species. It is important to have a hole so that the nares are not covered (Photo credit Tom Bailey).

3.12 An aviculturalist weighing a kori bustard. Such measurement should be taken whenever a bird is captured (Photo credit Tom Bailey).

The main aims when restraining bustards are to immobilise the wings, and to control the legs and heads of the larger species. Lifting bustards by their wings or legs is not recommended because their legs and wings are fragile and feathers can tear easily. Degloving injuries of the skin over the legs can occur in birds that struggle and kick and that are not properly restrained. White-bellied bustards appear to be susceptible to this injury as they tend to kick vigorously when restrained. Bustards should be held firmly against the handler's body, the wings should be fully closed and the legs held together, but prevented from rubbing against each other by positioning fingers between them. Legs can be held so that they are bent at the tibiotarsal joint. Some movement of the leg is allowed without letting the bird kick uncontrollably. Birds should be kept as sternal as possible while being held as this reduces stress levels. Wrapping birds in towels is also helpful to reduce trauma and feather loss. Time spent practising techniques, along with a dose of patience, are essential prerequisites to minimise the possibility of injury and stress to both the bird and handler.

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Bustards are highly sensitive to stress and incorrect handling can cause:

- temporary or permanent neural damage.
- hyperthermia.
- fractures of legs or wings.
- skin lacerations, bruising and feather loss.
- luxation of the tibiotarsal bones.
- dislocation of the cervical vertebrae.
- compression of the trachea and internal organs.
- stress and the progression of a disease process and even death.

3.5.3. Identifying bustards

As soon as possible after hatching, the chicks are given individual numbered and/or coloured plastic leg rings. Microchips, passive induced transponders (PITs), are implanted before two months of age (Figures 3.13, 3.14). These are placed subcutaneously in the inner crural region of the leg. Coloured spiral coil rings can be used for subadult kori bustards.

3.13

3.14

3.13 NARC staff member reading a microchip in a houbara bustard. At NARC birds are uniquely identified with rings and microchips (Photo credit Tom Bailey).

3.14 Morphometric measurements taken from a houbara bustard. Whenever bustards are handled every opportunity should be taken to collect such biomedical data (Photo credit Tom Bailey).

Adults of the larger species of bustards such as kori bustards, have been identified with Darvic rings, which are strips of laminated PVC moulded into rings. Each ring has a two letter code engraved so that the letters show black through a yellow laminate layer. This is attached above the tibiotarsal joint for visual identification of individuals. It is important to regularly check ringed birds, especially juvenile birds with plastic rings, to ensure that rings are not too tight, causing constrictions of the limb and resulting in necrosis.

3.5.4. Transportation

Bustards should be transported in secure, darkened and well-ventilated containers, with holes low on their sides (to minimise light at eye level) and a new piece of carpet, rubber matting (which has the advantage that it can be disinfected and reused), or similar material on the floor to allow the bird adequate grip. Straw, peat or hay should be avoided as bedding because of the risk of *Aspergillus* contamination. The container must be free of sharp edges or protrusions, which may cause injury. Padding the ceiling and sides of a container can reduce injuries. The bird should be maintained at an ambient temperature of 21° C to 28° C and should never be left unattended. The size of the container should not permit wing flapping, but must allow the bird to stand up in a natural position and turn around.

Small bustards (up to 2 kg) can be transported in commercial pet carriers or cardboard boxes. Larger bustards, such as kori bustards can be transported individually in transport crates. Carrier specifications for international air transportation of birds are set by the International Air Transport Association (IATA 1998).

Containers that have been previously used to transport birds must be cleaned and disinfected before reuse. Wooden boxes are not recommended for transporting birds as they can allow the bird to damage itself as it flaps around and they are difficult to disinfect. The dangers involved in transporting bustards include overheating, dehydration, injury and death. Sick, or injured or weak bustards should not be transported except to receive treatment.

3.5.5. Routine health care

Bustards in the Middle East have succumbed to a variety of diseases, notably trichomoniasis, Newcastle disease caused by paramyxovirus type 1 (PMV-1) and avian pox. Preventive medicine programmes include annual vaccination with inactivated PMV-1 vaccine, live canary pox vaccine and regular (2-3 times a year dependant on risk) anthelmintic and antiprotozoal medication given in the water or food. Vaccines are given during health-assessment catches held 1-2 months before the breeding season and during the cool season in the Middle East. Preventive medicine programmes for bustards are fully covered in Chapter 14. Within the United States, internal

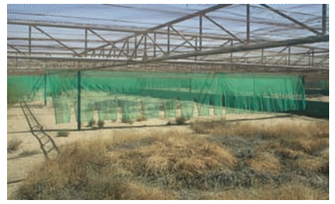
parasites are commonly detected and avian pox has been reported in two kori bustard chicks (Hallager pers. comm.). Vaccines are not routinely administered in the United States. Kori bustards in zoo settings need to be carefully monitored for signs of impaction and zinc toxicity as they have a particular tendency to consume items thrown into their enclosures (e.g. pennies, camera batteries, nails, etc) by visitors (Boylan et al. 2001). Daily inspection of pens and the removal of foreign material are important.

3.5.6. Reducing trauma in captivity

Frederick II described the escape responses of bustards in his chapter on *Avian means of offence and defence* in *Arte Venandi cum Avibus* (1248, translated by Wood and Fyfe 1943): "*There are birds that springing up from the ground, attempt to throw an attacking bird of prey beneath them, among these are the large bustards and the lesser bustard.*" Similarly Moody in 1932 commented that little bustards damage their heads by their habit of springing up in the air when alarmed. These predator-escape responses make bustards vulnerable to traumatic injuries in captivity. Male buff-crested bustards also have spectacular aerial displays (Johnsgard 1991) and trauma has occurred in these birds during the breeding season, presumably by damaging themselves against the roof of their pens.

Captive bustards, particularly birds originating from the wild as adults, are highly susceptible to trauma-related death or injury. This can be minimised through corrective husbandry; well-considered design of aviaries, minimisation of unnecessary disturbance and the implementation of protocols to diminish the sensitivity of birds to stress. In a study at NARC traumatic causes of death (intra-specific trauma, fractured neck, euthanasia due to fresh fractures, and dislocations and aviary-related trauma) were responsible for 23.5% of the deaths of captive adult houbara bustards, and 57.1% of the deaths of captive adult buff-crested bustards (Bailey et al. 1996a, 1996b). Some 60% of deaths of captive adult houbara bustards at the NWRC were caused by trauma (NWRC 1993, Ostrowski and Combreau 1995). Stressed birds and birds that have not been pinioned or had their primary flight feathers clipped appear to be particularly susceptible to trauma. Disturbed or frightened buff-crested bustards have been observed to fly vertically and are prone to breaking their necks. Consequently, attention to the design of facilities and the behaviour of staff working with the birds is important to minimise trauma-related problems. Trauma can be reduced by:

- Using plastic coated foam padding to surround the sides of cages or pens, for example in areas where birds are regularly caught such as in hospital or quarantine pens. This minimises abrasion injuries to wingtips.
- Using shade-cloth or tension netting on the roof and sides of aviaries to cushion the impact resulting from birds flying within a pen (Figure 3.15).
- Modifying behaviour by taming nervous individuals or housing such birds in naturalistic pens with cover.
- Ensuring that stock that has not been pinioned is regularly feather cut.
- Preventing stress by reducing the number of non-essential people who visit the birds.



3.15

3.15 Hanging shade cloth in a large outdoor aviary. This system can help reduce trauma in large aviaries housing nervous rehabilitated houbara bustards (Photo credit Tom Bailey).

Additionally, it is thought that houbara bustards derived from migratory populations, such as the captive stock originating from Kazakhstan at NARC, may be more restless during the migratory season and more vulnerable to trauma related deaths (Combreau pers. comm.). In the future chemical modification of behaviour, a technique widely used in mammalian wildlife species may be an option for managing confiscated wild-caught bustards that are being rehabilitated. However, in our experience wild-caught houbara bustards appear to be refractory to even high doses of tranquillisers such as haloperidol, zuclopenthixol acetate and perphenazine that have been successfully used to modify behaviour in psittacines (Chitty 2003, haloperidol) and game species (Swan 1993, haloperidol, zuclopenthixol acetate and perpehazine). It remains to be seen if tamer captive-reared houbara bustards are susceptible to the effects of behaviour-modifying tranquillisers.

Kori bustards are also trauma-susceptible and Schneider (1992) reported that 18% of the gene pool in the USA was lost over a two and a half year period due to deaths caused by improper handling, shipping and an incorrect captive environment. Schneider (1992) commented that the use of man-made sight barriers within aviaries is helpful in reducing the stress in this species. These barriers exploit one of the common defensive behaviours of kori bustards, which is to walk away from threats and to hide under the cover of trees or to blend in with any object that will hide their outline.

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3.5.7. Pinioning and feather clipping

These are procedures that are performed to prevent bustards from flying. Samour (2000) describes various methods for pinioning and feather clipping birds. Feather clipping is carried out by cutting short the primary feathers of one wing using scissors (Figures 3.16a-b). Feathers should be fully (i.e. not in blood) grown and for a more natural appearance the first two primary feathers can be left uncut. The disadvantage of cutting feathers is that flight is only impaired until the next moult. Surgical techniques to pinion bustards are discussed in Chapter 10 (Figures 3.17a-c).

3.16a

3.16b

3.16a/b Technique for feather cutting the primary feathers of a houbara bustard. Wing clipping is carried out by cutting short the primary feathers of one wing using a stout pair of scissors. The main disadvantage of this procedure is that flight is impaired for only a short period (Photo credit Tom Bailey).

3.17a

3.17b

3.17c

3.17a/b/c Pinioning a 2 day old kori bustard chick. The operation involves a) disinfecting the wing, b) amputating the wing tip just below the carpal joint using scissors and c) controlling haemorrhage by applying surgical glue to the cut stump (Photo credit Tom Bailey).

Whether or not to pinion bustards is a contentious issue amongst aviculturists. Some believe that birds should not be pinioned or have their primary feathers clipped, and rely more on the quality/safety of the environment and de-stressing procedures to avoid trauma (Ostrowski pers. comm.). Some avoid pinioning and clip primary feathers, and some practice pinioning. At NWRC pinioning is not practiced, but clipping of primary feathers on both wings is routinely carried out (Ostrowski pers. comm.). Bereszynski and Graczyk (2000) reported that adult and young great bustards at a breeding station were feather cut 2-4 times a year to avoid birds damaging themselves in aviaries. White (1985) found that captive Australian bustards with both wings pinioned have fewer injuries and retain balance better.

In the UAE adult bustards, and many other species of wild-caught birds (e.g. stone curlew), are pinioned.

Many owners of private collections wish to release birds in the grounds of their properties and consider that pinioning is the only way to stop birds from flying away. Many birds are pinioned without anaesthesia using hot knives by non-veterinary staff. Animal welfare and the concept that birds feel pain are poorly recognised concepts in the Middle East and the absence of regional veterinary organisations with the ability to lobby governments greatly retards the promotion of better standards of animal care.

3.6. Housing

3.6.1. Housing of captive bustards

Differences exist in the housing of bustards both between and within species and according to the region in which the birds are maintained in captivity (Figures 3.18a-c, 3.19). Paillat and Gaucher (1996) comprehensively reviewed the type and design of facilities for breeding houbara bustards at NWRC, Saudi Arabia. The traditional cages for keeping houbara that are maintained in isolation for artificial insemination are based on a type used at NWRC. The medium-sized cages (6mx4mx2.3m) are laid out in blocks of 20. In Morocco and Saudi Arabia these are outdoor units, while in Abu Dhabi, because of the extreme climatic conditions, these units are built within environmentally controlled buildings. Birds maintained in outside units should have overhead panels to provide shelter from heavy rain and sun.

3.18a

3.18b

3.18c

3.19

3.18a/b/c a) Indoor early rearing unit, b) indoor intermediate stage rearing room, and c) outdoor intermediate stage rearing room for houbara bustards at ECWP in Morocco (Photo credit Tom Bailey).

3.19 Breeding aviaries for houbara bustards at the NWRC in Saudi Arabia (Photo credit Tom Bailey).

3.6.2. Naturalistic aviaries

Great bustards in the UK have been kept as single sex groups in 20 x 30m grass paddocks topped with nylon netting and as a mixed-sex flock in a large four hectare paddock (Flach 1995). In the United States, kori bustards are maintained in outdoor pens, which are equipped with heated shed areas, where the birds are housed during periods of inclement winter weather. The ground on which bustards are kept should be well drained. In Europe small-to medium-sized species such as the buff-crested, houbara and white-bellied bustards are kept in both indoor and outdoor aviaries and should be provided with supplemental heat during the winter months if housed outdoors and/or moved into winter holding facilities (Rutgers and Norris 1970). The provision of shade and shelter are important for birds managed outdoors in tropical and temperate climates respectively, as is the use of predator-proof fencing material. All species of bustard are susceptible to frostbite and supplemental heat must be supplied when temperatures drop below 4ºC. Outdoor aviaries may have alfalfa beds in addition to natural vegetation. This provides birds with a direct food source, with cover to hide in, and also encourages foraging for invertebrates attracted to the vegetation. Trauma is an important cause of morbidity and mortality for all captive bustards, so great attention is paid to using ‘soft’ materials when pens

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are constructed. Additionally, pinioning of chicks or feather cutting (primaries) of adults are important management tools to reduce the potential for self-inflicted injuries. Pinioning of chicks is preferred as this eliminates the need to routinely catch adults for feather clipping. Smaller bustard species can be exhibited in mixed aviaries. Kori bustards should preferably be housed by themselves to facilitate breeding, but if necessary, can be maintained in mixed species exhibits with non-aggressive hoofstock (e.g. gerenuk or dik-dik) (Bailey and Hallagher 2003).

3.6.3. Substrates

Substrates of outdoor naturalistic aviaries comprise sand, gravel or grass (UK). Impaction does not appear to be a problem with adult bustards in naturalistic aviaries. However, ingestion of foreign bodies including nails, galvanised wire and pieces of plastic-coated chain-linked fencing is not uncommon in kori and houbara bustards. Bustards also dust bath frequently and provision for this should be made available.

3.6.4. Hospitalisation facilities

Quarantine facilities have been discussed elsewhere. There should be hospitalisation facilities at sites where bustards are maintained. These need not be elaborate or expensive. In larger pens in naturalistic aviaries, small holding pens (6 m x 6 m) made of shadecloth are suitable for isolating both large and small bustards. These can be effective for birds that have minor injuries and need occasional monitoring, and being further away form routine human activity, such pens are less stressful for 'nervous' birds. Blocks of hospital pens next to veterinary facilities are also useful for hospitalising bustards that need more attention.

3.7. Veterinary Aspects of Breeding Management

A detailed description of breeding management of bustards is beyond the scope of this book, but veterinarians who work with bustards should be aware of the following important avicultural issues.

3.7.1. Life span of bustards in captivity

The average lifespan of great bustards is at least 12 years in the wild and 28 to 50 years in captivity (Carey and Judge 2000, Osborne and Martin 2001). Osborne and Martin (2001) comment that most animals have a short life expectancy in the wild and cease breeding before reaching the maximum age reached in captivity, the maximum reproductive age of great bustards is considered to be 20 years. Flower (1925) reported examples of a great, a Nubian and a white-bellied bustard living for at least 27, 10 and 9 years respectively. So far, the record for longevity in kori bustards is a 26 year old female bird currently alive in a zoo in the USA (Hallager pers. comm., 2005). In 2004 this individual was still laying eggs.

3.7.2. Composition of breeding flocks

While houbara bustards caught as adults from the wild can be maintained in captivity they remain sensitive to stress and rarely breed unless they are housed undisturbed in large aviaries (Rhamadan-Jaradi and Rhamadan-Jaradi 1989). The successful houbara bustard captive breeding projects use hand-reared birds, which are more suitable for intensive production efforts utilising artificial insemination (Paillat and Gaucher 1996).

3.7.3. Egg Collecting

Egg collection for houbara bustard projects is described by Paillat and Gaucher (1996) and Jarrett (1995) and the logistics will not be discussed further. Egg collecting expeditions for any bustard species should have a veterinary contribution that includes the provision of first aid kits for any chicks hatched under field conditions and clear procedures for quarantine and health screening of birds derived from wild populations before their incorporation into captive flocks. Such expeditions also represent a unique opportunity to acquire information on the health status of wild bustard populations.

3.7.4. Sexing

Adult bustards show sexual dimorphism. Jarrett and Warren (1999) presented morphometric data to guide age and sex determination in houbara bustards. It is important to remember that there is a seasonal variation in bodyweight and food intake in some species, including houbara and Australian bustards. Houbara bustards are heaviest in winter, progressively losing weight towards summer (Jacquet 1997). Male Australian bustards have a 50% increase in bodyweight at the end of winter before they begin to display (Fitzherbert 1983). Some smaller species such as white-bellied bustards can be sexed by differences in head and throat plumage. Larger species show strong adult sexual dimorphism. Kori bustards are easily sexed at one year of age, for although the plumage of both sexes is similar, males are considerably larger than females. Juvenile bustards can also be sexed using endoscopy after about 6 months of age. Molecular sexing offers many advantages, being non-invasive and if done from feathers or blood collected from freshly hatched chicks, it can allow different sexes to be reared under different protocols (D'Aloia and Griffiths 1999).

3.7.5. Breeding strategies

Bustards are generally long-lived species with a low reproductive output. Management strategies for breeding vary according to the species, but there are basically three regimes (Table 3.8). In most species, males and females do not establish a true pair-bond, and

depend instead on a dispersed lek breeding system in which the males advertise themselves in traditional areas (Collar 1996). Male bustards perform elaborate displays to attract females and maintain a dominance hierarchy. The females are left alone to undertake nesting, incubation, and rearing of the young. In captivity, houbara bustards managed as pairs or as mixed sex groups rarely, if ever, breed. Similarly, houbara bustards caught as adults remain sensitive to stress and in most cases fail to breed. Successful houbara bustard breeding projects use hand-reared birds, which are more suitable for intensive production efforts utilizing artificial insemination. White-bellied bustards are monogamous and adults are maintained in pairs. Buff-crested bustards tend to be bred in captivity as pairs, but in the 1980's and early 1990s they were successfully bred at Al Ain Zoo in polygynous breeding groups of three females and a number of males in a large aviary. Kori bustards are managed in mixed-sex flocks, but can be managed as trios.

Table 3.8. Examples of management strategies of bustards. Reproduced by kind permission of the Avicultural Society, *Avicultural Magazine*, 109: (1); 1-8, 2003.

Strategy	Bustard species	Age	Social Grouping
Isolated for artificial insemination	Houbara	Adult	Singles
		Juvenile	Small groups (≤5)
Pairs	White-bellied and Buff-crested Adult	Adult	Pairs
		Juvenile	Small groups (≤5)
Heterosexual groups	Kori	Adult	Large group (~25)
		Adult	1 male and 2 females
		Juvenile	Large group (~15)

Rainfall plays a strong role in the breeding success of free-living kori bustards, with breeding greatly reduced during time of drought. At NWRC van Heezik et al. (2002) considered that low fecundity in the captive houbara bustard flock in 2000 was related to a warm winter. Cooler winters were correlated with high proportions of females laying and more eggs being laid and the timing of the first rainfall of the season also stimulated some birds to breed (Van Heezik et al. 2002).

Gonadotrophins have been used to try to stimulate reproductive development in houbara bustards at NARC, but preliminary trials were of limited success and the work has been discontinued (Jacquet 1996a, 1996b).

3.7.6. Selection of breeding stock

Successful breeding is more than the production of chicks, it also involves a process of genetic selection to improve the captive stock. Proper selection can only take place in an environment where the parents of each chick are known, where records are kept and performance of breeding stock and progeny can be compared and where ultimately pedigrees can be established. The future of bustard breeding projects depends on the development of proper breeding strategies and selection criteria. Criteria can be morphological (colour, shape, size, soundness) or production-related (egg production, egg size, hatchability, growth rate, chick survival, etc). Behavioural traits such as tameness should also be considered. In this case progeny should be compared with the parents as part of the selection process. Genetic (DNA) fingerprinting can be undertaken to establish the degree of relatedness to aid in the management of breeding stock.

3.7.7. Captive population management and studbooks

There are only a few reports of successful breeding of bustards historically. Quintin (1904) and Moody (1932) reported the first breeding success of the great bustard at Scampton Aviaries in the UK in 1901. Hopkinson (1926) reported that a little bustard was bred in Scampton Aviaries in 1915 and great bustards were bred in the Tyrol in 1858-1860. Great bustard eggs collected from the wild were prized in the eighteenth century for the purpose of hatching out under domestic hens (Swann, 1913). However, it is only relatively recently that houbara bustards have been bred in low numbers in

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captive breeding projects in Uzbekistan (Flint et al. 1992b), at the Dubai Wildlife and Research Centre (Platt 1985), at Al Ain Zoo (Rhamadan-Jaradi and Rhamadan-Jaradi 1981, 1989) and at Tel Aviv University (Mendelssohn 1979). However, it was not until the 1990's that NWRC started to breed this species in large numbers.

Many of the breeding populations managed by NARC, including the white-bellied, kori and buff-crested bustards were founded from very few birds (Anderson 1998a, 1998b, 1998c). This is also the case for many of the projects breeding Heuglin's, kori and buff-crested bustard in zoos and private collections in the Middle East. Van Heezik et al. (1999c) recommended a strategy to minimise inbreeding in the NWRC flock by not breeding from inbred birds, minimising insemination using multiple fathers and obtaining new breeding stock from the wild.

Small captive populations of bustards are vulnerable to demographic stochasticity, which can lead to the population being unable to recover or persist (Princée 1999, Paresce 2000). Loss of genetic variability presents another risk to these populations, as the smaller a population becomes the greater is the frequency of matings between close relatives (Primack 1993). Small captive populations of wildlife have limited genetic diversity, and poor captive breeding can result in further genetic loss (Foose and Ballou 1988). In captivity, small populations should be managed according to demographic and genetic principles to minimise these problems (Foose and Ballou 1988, Seal et al. 1994). Captive breeding projects for bustards should aim to incorporate established demographic and genetic principles to achieve the following aims (Anderson 1998a, 1998b, 1998c):

- To establish a population with a stable age and sex structure.
- To maximise and maintain genetic diversity within the population
- To maximise the genetically effective population size.

Sustaining healthy populations of bustards in captivity requires careful assessment and manipulation of genetic and demographic information and in order to accomplish this effectively it is necessary to have accurate information on a population in a standard format that can easily be analysed (Wilcken and Lees 1998). Studbooks contain records of the history in captivity of a species and are an important tool in the management of CBRPs (Wilcken and Lees 1998). The computer programme SPARKS is the programme endorsed by the World Association of Zoos and Aquaria for recording studbook data and is used by many bustard projects and zoos keeping bustards.

Maintaining studbook records and conducting analysis on the breeding records of each species using studbook analysis software enables demographic and genetic imbalances to be detected. This is essential for the management of the species, both at a collection level and at a regional or global population level. Anderson (1998a) reviewed the demographics of the kori bustard captive population at NARC and concluded that a target population size of 50 was required in order to maintain a viable long-term captive breeding population. Conducting these reviews is necessary so that managers can plan strategy and allocate the necessary resources that will be needed in the long term (Hallager and Ballou 2001).

Projects maintaining captive populations of bustards should not only keep good records, they should also contribute data to international studbooks for each species. Sara Hallager from the National Zoological Park, Smithsonian Institution manages International Studbooks for the buff-crested and kori bustard (Hallager 1999, 2001). Such studbooks are the only way that species can be usefully managed in the medium to long-term.

3.7.8. Health risks of artificial insemination and cryopreservation programmes

Artificial insemination (AI) is practised routinely for the intensive production of houbara bustards (Figures 3.20, 3.21, 3.22) and has been successfully used to breed buff-crested bustards at NARC in 1997 (Anderson 1998c). Gaucher et al. (1993) and Saint Jalme et al. (1994) provide detailed descriptions of semen collection and of insemination in the hen houbara bustard. Wishart and Wilson (1999) investigated the effect of temperature on the motility of houbara bustard spermatozoa. Hartley et al. (1999) reported a simple technique of cryopreserving semen from houbara bustards using dimethylacetamide as a cryoprotectant. Cryobanking of semen represents a useful technique for both routine management and for long-term banking of founder stock (Bailey 2002b).

3.20

3.21

3.22

3.20 Collecting semen from imprinted male houbara bustards at ECWP in Morocco (Photo credit Tom Bailey).

3.21 Artificial insemination of a female houbara bustard at ECWP in Morocco (Photo credit Tom Bailey).

3.22 Dummy female houbara bustard for semen collection from imprinted males (Photo credit Tom Bailey).

The risk of disease transfer with semen used for AI, both fresh and stored has not been adequately investigated in non-domestic species, including bustards. Infections of the reproductive tract of female bustards that have been artificially inseminated should be a consideration for veterinarians working on breeding projects. Bacteria (*Enterococcus faecalis* and *Staphylococcus* spp.) have been isolated from frozen-thawed falcon semen samples used for AI (Bailey 2002b, Bailey et al. 2003). *Enterococcus faecalis* is a common avian faecal contaminant, while *Staphylococcus* spp. could have been either a contaminant from the falcons or from the handlers. In addition to the risks of disease transfer from active or latent infections being carried by the semen donors, there is also potential for contamination of semen samples at each stage of the pathway from collection to use of semen. Silvanose (pers. comm.) has also isolated *Enterococcus spp.* from semen samples of houbara bustards. Perek et al. (1969) demonstrated that bacteria including *Staphylococcus* spp. are frequently transmitted in the semen from cockerels, while Ferrier et al. (1981) showed that *Mycoplasma meleagridis* can survive cryopreservation and can be transmitted in frozen turkey semen. The transfer of *Chlamydophila* sp. infections is of concern to avian CBRPs and Bodetti et al. (2002) recently described how koala (*Phascolartos cinereus*) semen was screened for this organism. In the poultry industry antibiotic mixtures that do not decrease fertility are added to semen extenders to prevent bacterial contamination and this may have potential for non-domestic bird species too (Sexton et al. 1980, Gee and Sexton 1990). In a recent review of disease control measures for genetic resource banks, Kirkwood and Colenbrander (2001) concluded that stringent codes and regulations developed for domesticated species should be adapted for wildlife species. Further studies are warranted to screen bustard semen for infectious diseases and projects initiating cryopreservation would be wise to develop hygiene protocols to deal with this issue.

Attempts were made at NARC to collect semen from kori bustards using manual restraint, but outcome was unsuccessful and the male donor died as a consequence of traumatic injuries. If AI is to be tried in larger bustard species, trained imprinted birds should be used, or semen collection procedures should be performed under general anaesthesia to minimise trauma.

3.7.9. Egg hygiene

To prevent contamination of the eggs, clean sand should be used in the places which bustards have chosen as nesting sites. The value of environmental screening has been discussed previously. People handling the eggs should clean their hands thoroughly and/or wear sterile disposable gloves. The receptacles used for transporting the eggs, usually made of plastic foam with hollows to hold individual eggs, should be lined with disposable paper towels to prevent further contamination. Bustard eggs can become contaminated by bacteria and fungi before and during incubation. Incubators can provide an optimum environment for the growth of micro-organisms. The stages and sources of egg contamination are summarised in Table 3.9. Contamination is enhanced by the presence of faeces, moisture on the shell and damage to the shell (Anderson 1996).

Bacterial contamination through the shell is an important cause of embryo mortality and yolk sac infection and contamination can be reduced by following good

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Table 3.9. Summary of the sources of microbial contamination of bustard eggs (Anderson 1996).

Stage of contamination	Source of contamination
Pre-lay	Transovarian and transoviductal (e.g. *Salmonella enteritidis*)
Post-lay	Nest environment
	Artificial incubation environment
	Improper handling, cleaning and disinfection

handling, cleaning and disinfection procedures and maintaining good incubation hygiene. The purpose of cleaning is to remove organic material from the shell surface before disinfection, while the purpose of disinfection is to destroy micro-organisms present on the shell.

Eggs can be disinfected by fumigation with formalin and potassium permanganate, by dipping in a disinfectant solution, by spraying or with ultraviolet lights (Anderson 1996). The quantities of fumigant for the former depend on the volume of the area to be fumigated. For one cubic metre of airspace 40 ml undiluted formalin (40% formaldehyde) and 20g potassium permanganate are needed. The liquid is poured into a dish in the fumigation chamber, and the crystals are added at the last minute. The chamber is left for 20-30 minutes, before the fumigant is ventilated out.

3.7.10. Incubation hygiene

Hygiene in the incubation facilities consists of thorough cleaning and disinfection of incubators, hatchers and implements. Movement of personnel through the hatching areas must be controlled to avoid recontamination of clean and disinfected areas. Incubators with eggs inside can be periodically cold fogged with disinfectant, but this can only be done in incubators specifically designed for this procedure. After cleaning and disinfection the incubators and hatchers are rapidly recontaminated by dust that is sucked into ventilation and air-conditioning systems. To reduce the contamination, dust can be precipitated out of the air by ionisers, or by filtering incoming air.

3.7.11. Infertile eggs

All infertile eggs and those with dead embryos should be removed from the incubator. Eggs should be subjected to a post-mortem examination (Chapter 11). At NWRC van Heezik and Ostrowski (2001) estimated that 53% of fertile eggs survive. Consequently, research to identify the causes of this wastage during incubation could have a great impact in the production of houbara bustards. There is no accurate figure for fertility in captive houbara bustards, due to the difficulty to differentiate between infertile eggs and fertile eggs with early dead embryos (van Heezik , 2000). As a consequence it is often hard to assess whether egg loss is a problem of fertility or hatchability.

3.8. Rearing

3.8.1. Free-living bustards

Free-living houbara bustard chicks are precocial and nidifugous at hatching (Schulz and Seddon 1996) and are brooded by the female for the first 24 hours. Live food is offered to the chicks bill-to-bill and by two to three days of age the females drop prey on the ground to be retrieved by the chicks hatching (Schulz and Seddon 1996). By days five to six the chicks are feeding independently and by four weeks the birds are fully feathered and have started flying short distances. Free-living houbara males have never been observed incubating eggs or feeding chicks (Schulz and Seddon 1996).

3.8.2. Captive-reared chicks

In a review of a large sample of captive-bred houbara bustards at NWRC several factors including: sex, year of hatch (i.e. different management practices) and size of group, were found to cause variability in growth rates between years (van Heezik and Seddon 2001). Houbara chicks kept in groups of eight had slower growth rates until fledging compared with chicks reared in groups of five (van Heezik and Seddon 2001). In the early days of NARC bustard chicks were reared singly and this may have been an important stress factor for these birds (Deeming, 1995). This may have also contributed to the poor growth rates and susceptibility to diseases seen in these birds. It is thought that early differences in growth rate may have long-term effects on reproductive performance, although further studies are required to demonstrate this. Interestingly, houbara chicks that were regularly weighed had a reduced risk of mortality during their time in the rearing unit (van Heezik and Seddon 2001). Regular weighing is thought to accustom birds to handling and human presence and may make birds less flighty and prone to trauma. Anderson (1998c) reports that musculoskeletal problems were seen in buff-crested bustards that had growth rates in excess of 10% during one season and as a consequence target growth rates for this species are recommended at less than 10%. Rearing

regimens may also influence long-term reproductive performance and this is another important area for consideration by bustard projects aiming to improve productivity and lower costs.

Standard incandescent bulbs should not be used for brooding birds, as at least three chicks reared under incandescent bulbs at NARC in 1993 developed cataracts. No cases of cataracts were observed subsequently with chicks reared under ceramic dull-emitter bulbs. Interestingly, rearing partridge chicks under ceramic dull-emitter bulbs results in excessive foraging behaviour (O'Donovan pers. comm.).

3.8.3. Intestinal flora and competitive exclusion

While the early establishment of a normal intestinal flora will occur in naturally-reared bustards, colonisation will differ in artificially-reared chicks hatched from fumigated eggs in a disinfected incubator and placed on disinfected artificial surfaces. Such chicks do not have the chance to come into contact with the bacteria needed for the normal functioning of their digestive system.

A normal intestinal flora has two main functions;

- Competitively excluding the establishment of pathogenic bacteria by occupying available attachment sites in the gut.
- Assisting in the digestion of fibre.

The failure to acquire the correct intestinal flora plays an important role in the epidemiology and pathogenesis of enteritis in young ratites (Huchzemeyer 1998).

Competitive exclusion of bacterial pathogens by dosing them with a normal flora has been investigated in poultry (Corrier et al. 1993). In poultry the addition of lactose to the starter diet helps to establish a healthy intestinal flora by allowing the anaerobic flora to produce volatile fatty acids, which are bacteriostatic and discourage colonisation by *Salmonella* spp. (Hinton et al. 1990). Several probiotic preparations developed for exotic avian species can be used to help with the initial intestinal colonisation of bustard chicks. In ratites even fresh yoghurt is successfully used to dose chicks on day 1, while by day 4 clean substrate such as soil is scattered on the floor of the rearing pens so that ostrich chicks acquire a larger variety of bacteria (Huchzemeyer 1998). McKinney (pers. comm.) has used 'transfaunation' of bustard intestinal flora in bustard chicks following antibiotic therapy and this technique may be worth attempting with artificially-reared bustard chicks.

3.8.4. Coprophagy

Bustard chicks are coprophagic and when chicks are reared on bare flooring they will often ingest faeces. If one chick is infected with harmful bacteria, this behaviour will lead to the rapid spread of infection through the group, irrespective of how well the rearing coops are cleaned. Sick chicks should be isolated. This behaviour in bustards could be because of lack of environmental stimulation. Coprophagy in ratites is not considered to be normal behaviour and is considered to occur because of lack of parental teaching and the fact that the chicks are in a confined coop where the faeces are present on a bare floor surface (Huchzemeyer 1998).

3.9. Climate Adaptability

3.9.1. Adverse environmental conditions and bustards

Environmental factors (air temperature, photoperiod, food availability) control the reproductive cycle of many birds, including bustards and the climatic suitability of the facility chosen to locate a breeding project should be critically assessed. In a review of the veterinary problems of great bustards maintained at Whipsnade Wild Animal Park (WWAP), UK, low condition accounted for 30% of the clinical findings and was associated with periods of cold wet weather during the winter and spring at WWAP (Bailey and Flach 2003). The use of Portuguese birds, considered genetically different from the historic British populations and not as well suited to the British climate may have been a factor in the poor adaptation of the bustards to WWAP (Osborne and Martin 2001). Low condition in great bustards was often a problem in early spring when the birds should have ideally been in good condition before breeding. Periods of low condition during poor weather may have predisposed the elderly WWAP bustards to health problems.

The houbara bustard has a wide geographic range from North Africa and the Middle East through Central Asia to China and while this species has a certain capability to adjust to a wide range of climatic conditions, it probably does best in drier climates. Just as periods of low condition during poor weather predisposed elderly great bustards to health problems in the UK, elderly houbara bustards maintained in outdoor aviaries at Al Ain Zoo in the UAE appeared to be more susceptible to secondary infections during times of environmental stress, particularly during summer when temperatures and humidity are extremely high.

3.9.2. Hypothermia

For the first couple of months of their life bustard chicks are also sensitive to cold. Care must be taken to provide sufficient heating especially to debilitated chicks that are hospitalised. Under sub-optimal temperature conditions, bustard chicks and even juvenile bustards can suffer from hypothermia. In the Middle East this usually occurs when heat lamps fail overnight in the cooler winter months. Hypothermic bustards will not feed until the body temperature has returned to normal again.

Table 3.5. A summary of the biological role of vitamins and vitamin-related syndromes in avian species (adapted from; Brue 1994, McWhirter 1994, Anderson 1995).

Vitamin	Physiology in avian species	Vitamin related syndromes
A	Fat soluble vitamin essential for growth and differentiation of epithelial tissues, mucopolysaccharide formation, stability of cell membranes, growth of bones and normal reproduction. Also improves the immune system. It is stored in the liver and has the potential to act as a cumulative toxicant. Deficiencies can result from insufficient dietary fat, insufficient antioxidant protection or disorders that interfere with fat digestion or absorption. Liver disease may reduce the bird's ability to store vitamin A.	**Deficiency** - Embryo mortality and abnormalities, susceptibility to respiratory infections, visual disorders, squamous metaplasia of mucous membranes, hyperkeratosis, decreased testes size and testosterone levels, urate deposits in the kidneys and ureters, egg binding, poorly formed eggs. **Toxicity** - bone abnormalities, spontaneous fractures, conjunctivitis, enteritis, suppressed keratinisation, internal haemorrhages, fatty liver and kidneys and secondary deficiencies of other fat-soluble vitamins.
D_3	Fat soluble vitamin essential for the absorption of calcium and consequently normal bone and eggshell formation. It is destroyed by excess radiation with ultraviolet light and oxidation in the presence of rancidifying fatty acids. There are two forms of this vitamin, ergocalciferol (D_2), a plant derivative and cholecalciferol (D_3) produced in the bird's body. Vitamin D_3 is synthesised in avian skin exposed to ultraviolet light and is 30-40 times more potent than vitamin D_2. A dietary source of Vitamin D_3 is needed by animals that do not have access to ultraviolet light.	**Deficiency** – thin, soft-shelled eggs, embryonic abnormalities and mortality, metabolic bone disease, leg weakness, seizures, pathological bone fractures, poor feathering. Can be induced by high dietary vitamin A or E levels. **Toxicity** – reduced fertility, decreased eggshell quality, soft tissue calcification, renal and artery calcification, bone demineralisation and muscular atrophy.
E	Fat soluble vitamin that provides natural anti-oxidation protection for cells, fatty acids and other fat soluble vitamins. Working in conjunction with vitamin E are several metalloenzymes, which incorporate manganese, zinc, copper, iron and selenium. The selenium containing glutathione peroxidase is the most important of these enzymes. Because of their similar activity, selenium and vitamin E tend to have a sparing effect on each other. Vitamin E is active in several metabolic systems including cellular respiration, normal phosphorylation reactions, ascorbic acid synthesis, sulphur amino acid synthesis. It also has effects on immunity by increasing phagocytosis and antibody production, as well as stimulating macrophage and lymphocyte activity.	**Deficiency** - low fertility, embryonic mortality, low hatchability, immunosuppression, testicular degeneration, and specific clinical abnormalities such as encephalomalacia, exudative diathesis and muscular myopathies. May be predisposed by giardiosis. **Toxicity** – enlarged fatty livers, waxy feathers. High levels can cause secondary deficiency signs of bone demineralisation or blood clotting failure if vitamins D_3 and K are marginal.

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K	Fat soluble vitamin essential for normal blood clotting. It comes from 3 sources: 1) green plants, 2) bacteria, and 3) synthetic forms. The microbial synthesis in the intestinal tract is significant in most species. The requirements of this vitamin vary according to the extent different species use the synthesised vitamin K and to which they practise coprophagy. It is destroyed by oxidation, alkaline conditions, strong acids, ultraviolet light, and some sulphur drugs. Vitamin K also requires the presence of dietary fats and bile salts for absorption from the gut, so decreased pancreatic and biliary function can impair normal absorption.	**Deficiency –** embryonic mortality, haemorrhaging, anaemia, altered bone metabolism. Can be induced by high dietary levels of vitamins A or E or by prolonged antibiotic treatment. **Toxicity** – high levels can cause chick mortality and anaemia.
B_1	Thiamine is a water soluble vitamin essential for enzyme activity and cellular respiratory control, as well as being involved in nerve activity. It is common in plant and animal food sources, but generally at low concentration. Several compounds in nature possess anti-thiamine activity. These include amprolium which inhibits thiamine absorption from the intestine, thiaminases which are found in raw fish and thiamine antagonists such as tannic acid. Thiamine is not stored in the body for a long time.	**Deficiency –** embryonic mortality, muscular paralysis, ataxia, convulsions, neurological signs, organ atrophy. **Toxicity** – not studied in birds. High levels in mammals can cause depression of the respiratory centre and blockage of nerve transmission.
B_2	Riboflavin is a water soluble vitamin essential for enzyme activity, carbohydrate utilisation, cellular metabolism and respiration, uric acid formation, amino acid breakdown and drug metabolism. It is destroyed by ultraviolet light and alkaline solutions. Very little riboflavin is stored in the body and it is rapidly excreted.	**Deficiency –** embryonic abnormalities and mortality, chick mortality, curled toe paralysis and other neuromuscular disorders, dermatitis, poor feather pigmentation, splayed legs, fatty liver and dermatitis. **Toxicity** – not reported in birds. Toxicity not thought to be a risk because it is not well absorbed from the gut.
B_6	Pyridoxine is a water soluble vitamin involved in a number of enzyme systems as a coenzyme. It is required in all areas of amino acid utilisation, the synthesis of niacin and in the formation of antibodies. It is destroyed by oxidation.	**Deficiency –** reduced hatchability, ataxia, neuromuscular disorders, perosis, haemorrhaging and gizzard erosion. **Toxicity** – not reported in birds.
B_{12}	Cyanocobalamin is a product of bacterial biosynthesis and therefore must be obtained by consuming a bacterial source or animal tissues that accumulate the vitamin. It is a critical component of many metabolic pathways and is involved in the synthesis of nucleic acids and protein as well as carbohydrates and fats. Most vitamin B_{12} in the body is found in the liver, with secondary stores in the muscles. Vitamin B_{12} is stored efficiently with a long biological half-life of one year in humans.	**Deficiency –** embryo abnormalities and mortality, chick mortality, gizzard erosion and poor feathering.

Biotin	Biotin is a water soluble vitamin that is an active part of four different carboxylase enzymes in the body that are involved in the metabolism of energy, glucose, lipids and some amino acids. It is destroyed by strong acids and bases, oxidising agents and by the protein avidin in raw egg albumin. Biotin is widely distributed in foods at low concentrations. The synthesis of biotin by intestinal microflora may be important.	**Deficiency –** embryo abnormalities and mortality, poor growth, dermatitis, perosis and leg abnormalities, fatty liver-kidney syndrome. **Toxicity** – not reported in birds.
Choline	Choline is a water soluble vitamin that has four important metabolic functions: 1) as a component of phospholipids and therefore in maintaining cell integrity, 2) maturation of the cartilage matrix of bone, 3) fat metabolism in the liver, and 4) it is acetylated to form the neurotransmitter acetylcholine. While most animals synthesise choline young animals cannot synthesise enough to meet the demands for growth.	**Deficiency –** reduced hatchability, perosis and enlarged hocks, hepatic steatitis, fatty liver syndrome. **Toxicity** – not reported in birds.
Folic acid	Folic acid is a water soluble vitamin that is involved in amino acid metabolism and bioconversion and in the synthesis of nucleotides. It is involved in red blood cell maturation, white cell production, functioning of the immune system, uric acid formation. It is also essential for normal growth. Some sulphur drugs increase folic acid requirements. Zinc deficiency can decrease the absorption of folic acid by reducing activity of the mucosal enzyme that creates an absorbable form of folic acid. Enzyme inhibitors are present in some foods such as cabbage, oranges, beans and peas	**Deficiency –** embryo abnormalities and mortality, perosis, macrocytic anaemia, poor feathering and loss of feather pigmentation. **Toxicity** – not reported in birds.
Niacin	Niacin is a water soluble vitamin that is an important component of coenzymes NAD and NADP that are involved in carbohydrate, fat and protein metabolism.	**Deficiency –** dermatitis, perosis, stomatitis, perosis and enlarged hocks, anaemia, digestive disorders, general muscular weakness. **Toxicity** – course dense feathering and anteriorly-directed short legs in chickens.
C	Ascorbic acid has not been demonstrated to be a required nutrient for most avian species. It is easily manufactured in the liver and kidneys of birds, but biosynthesis can be inhibited by deficiencies of vitamins A, E and biotin. Ascorbic acid is involved in the synthesis of collagen, is an excellent antioxidant and can regenerate vitamin E.	**Deficiency –** Signs of vitamin C deficiency have not been documented in birds.
Pantothenic acid	Pantothenic acid is a water soluble vitamin that is a structural component of coenzyme A, one of the most critical coenzymes in tissue metabolism. As such it is involved in fatty acid biosynthesis and degradation, and the formation of cholesterol, triglycerides, phospholipids and steroid hormones. It is destroyed by heat, acids and bases.	**Deficiency –** embryonic mortality, dermatitis, perosis, poor feathering, poor growth, fatty liver-kidney syndrome, ataxia and reduced semen volume and fertility. **Toxicity** – not reported in birds.