State: Endangered (South), Vulnerable (North)

Federal: Endangered

IUCN: Vulnerable, declining population trend

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2013

Captive Management Guidelines for the Southern Cassowary

Casuarius casuarius johnsonii

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Cairns Tropical Zoo

Original Edition Cassowary Husbandry Manual, 1997 Currumbin Sanctuary Ed. Liz Romer

This Edition 2013 Cairns Tropical Zoo Ed. James R. Biggs

Captive Management Guidelines for the Southern Cassowary *Casuarius casuarius johnsonii*
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PREFACE & ACKNOWLEDGEMENTS

The text represents a compilation of the knowledge and experience of veterinarians, cassowary keepers and managers, and scientists involved in wild and captive cassowary conservation and is intended as a practical guide representing the current state of knowledge for managing *Casuarius casuarius johnsonii* in captivity. Significant portions of the original Cassowary Husbandry Manual (Romer 1997) are still relevant to Cassowary keeping and so are included in this edition. Areas where knowledge is lacking are also identified, but reference to similar species is offered where appropriate. New information will be included by chapter as it comes to light. Anyone keeping or interested in keeping Southern Cassowaries is encouraged to read this document and to contact the species coordinator with questions or comments.

Many people contributed their knowledge to this manual, including specialists with whom I have spent time in the field, expert keepers and captive managers from around the world, and regular everyday people throughout the North Queensland area. The manual relies heavily on many other people's work, and those that have been used are listed in the notes. It would certainly be unfair to select a few individuals for special thanks, so I would like to acknowledge and extend my sincerest appreciation to the following persons and organizations that have made their time, knowledge and skills available, and the completion of this edition of the manual possible.

Liz Romer; and to all those who contributed to that effort, namely Dr Katie Reid veterinarian at Currumbin Sanctuary who wrote the first edit health requirements section. Jonathon Wilcken undertook most of the analysis of the studbook and contributed a paper on Small Population Biology and Management. The first draft was reviewed by Des Spittall, Jeff McClure, Tony Gordon, Greg Thompson, Paul O'Callaghan, Mary Johnson, Zannah Gubler and Katie Reid. Des Spittall and David Westcott from CSIRO reviewed the second draft of the first edit. Jeff McKee reviewed the Health Requirements chapter.

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List of Acronyms

%RH	Percentage Relative Humidity
ARKS	Animal Record Keeping System
ASMP	Australasian Species Management Plan
AZA	Association of Zoos and Aquariums
BBC	British Broadcasting Corporation
BCS	Body condition score
CBSG	Conservation Breeding Specialist Group
CHW	Cassowary Husbandry Workshop
CTZ	Cairns Tropical Zoo
DEH	Department of Environment and Heritage
DERM	Department of Environment and Resource Management
DEWHA	Department of Environment, Water, Heritage and Arts
DPI	Department of Primary Industries
EAZA	European Association of Zoos and Aquaria
EPBC	Environmental Protection and Biodiversity Conservation
HCA	Hartley's Crocodile Adventures
IUCN	International Union for the Conservation of Nature
OZOO	Australia Zoo
QPWS	Queensland Parks and Wildlife Service
SEWPAC	Department of Sustainability
SHS/HSS	Hollow structural Section
TCS	Taronga Conservation Society
ZAA	Zoo and Aquarium Association
WOCC	White Oak Conservation Centre

INTRODUCTION

The cassowary (*casuarius spp*.) is a poorly known forest-dwelling bird which is currently represented by one species (*Casuarius casuarius johnsonii*) in Australian zoos. Despite a captive history dating back to Amsterdam in 1597 (Rothschild 1900), the husbandry of these birds has not always been approximated with the species natural history, likely due to the fact that even now, little is known about their natural history and few systematic studies have focused on the species.

Although land clearing has geared down considerably in North Queensland since the 1900's, landscapes continue to be modified at an alarming rate, and other significant threats such as vehicle strike and dog attack are still the cause for an alarming number of deaths in wild cassowary populations. As such, our obligation to mitigate these threats and identify the needs and status of this keystone species has never been more crucial to its survival.

Much debate surrounds the role of the captive industry in cassowary conservation, however it is well understood that zoos cannot contribute in isolation from *in situ* conservation efforts, and that captive breeding alone is not sufficient for indefinitely saving endangered taxa (Ebenhard 1995). There is a general consensus from the majority of stakeholders that captive breeding (for release) adjunct to *in-situ* cassowary conservation measures is unnecessary at this stage - that resources should be devoted to improving the resilience of the entire habitat, and acquiring the fundamental data needed to explore and explain population dynamics through DNA analyses and other studies. Garnett *et al*. (2011) estimate the total number of mature individuals to be around 2500, and although the IUCN recognises the potential contribution of zoos and other institutions that keep endangered animals in captivity (IUCN 2010) the union only recommends that vertebrate taxa numbering less than 1000 individuals in the wild should be considered for captive breeding (Ebenhard 1995).

The captive industry does have important roles in creating opportunities for education, encouraging action through community engagement, and in both scientific and husbandry research. Population managers must be cognisant of the intricacies of demographic and genetic management, and work cooperatively to further develop the much needed technical methods and tools that will be required, should wild populations fall victim to further human error, and environmental, demographic and genetic stochastic events.

In the future, field conservationists and captive breeding specialists will need to cooperate and make their efforts to save the species' complimentary (IUDZG/CBSG 1993). The important challenges include recognising when 'the time is right', identifying the precise role of the captive breeding efforts within the overall conservation action plan, and setting realistic targets (Leus 2011).

The impetus for revising the husbandry manual was to equip wildlife keepers and zoological institutions with the background knowledge to update and enhance the current captive management of the Southern Cassowary while stimulating readers to pursue further research by identifying where critical information is lacking, and listing future directives and avenues of research that will add to the growing body of knowledge of the species. The manual also aims to facilitate the development of techniques that will allow zoos to sustainably manage captive cassowary populations.

"Our knowledge of the species is doubtless still limited."

Hon. Walter Rothschild, 1899

NATURAL HISTORY

“The existence of a Cassowary inhabiting Australia was first made known in 1849 by the late Mr. Wm. Carron, Botanist to the Kennedy Expedition, who remarks in his ‘Narrative’ November 4th (1848) :- ‘This morning Jackey went to examine a scrub through which we wanted to pass, and while out, shot a fine Cassowary; it was very dark and heavy, not so long in the leg as the common Emu, and had a larger body, shorter neck with a large red, stiff horny comb on its head’ “ (North 1913).

"The first specimen of this bird was procured by Mr. Thomas Wall, naturalist to the late expedition commanded by Mr. Kennedy. 'This was shot near Cape York, in one of those almost inaccessible gullies which abound in that part of the Australian continent. The Cassowary, when erect, stands about 5 feet high. The head is without feathers, but covered with a blue skin, and, like the Emu, is almost without wings, having mere rudiments. The body is thickly covered with dark brown wiry feathers. On the head is a large protuberance or helmet of a bright red colour, and to the neck are attached, like bells, six or eight round fleshy balls of bright blue and scarlet, which give the bird a very beautiful appearance. The first, and indeed the only, specimen of the Australian Cassowary was unfortunately left at Weymouth Bay, and has not been recovered. Mr. Wall being most anxious for its preservation had secured it in a canvas bag and carried it with him to the spot where, unfortunately for himself and for science, it was lost. In the ravine where the bird was killed, as well as in other deep valleys of that neighbourhood, they were seen running in companies of seven or eight. On that part of the North-eastern coast, therefore, they are probably plentiful, and will be met with in all the deep gullies at the base of the high hills. The flesh of this bird was eaten, and was found to be delicious; a single leg afforded more substantial food than ten or twelve hungry men could dispose of at one meal. The Cassowary possesses great strength in its legs, and makes use of this strength in the same manner as the Emu. Their whole build is, however, more strong and heavy than that of the latter bird. They are very wary, but their presence may be easily detected by their utterance of a peculiarly loud note, which is taken up and echoed along the gullies; and it would be easy to kill them with a rifle."

This poor description, evidently made from memory, was published in the 'Illustrated Sydney Herald' of June 3rd, 1854, by Thomas Wall's brother, William Sheridan Wall (Rothschild 1900).

2.1 TAXONOMY

Cassowaries belong to a group of flightless birds called ratites (Latin *ratis* = raft) referring to the raft-like breast bone; these include the emu, ostrich, kiwi and rhea, which all lack a keel on their sternum (Pycraft 2009; Dawson 1996). The word cassowary is of papuan origin, from ‘kasu’ - horned and ‘weri’ - head (Boles 1987).

2.1.1 Nomenclature

Kingdom	Animalia
Phylum	Chordata
Class	Aves
Order	Struthioniformes
Family	Casuariidae
Genus	*Casuarius*
Species	*casuarius, unappendiculatus, bennetti*

2.1.2 Subspecies

Three extant species are recognised today (Kofron & Chapman 2006; Stocker & Irvine 1983) - the Southern Cassowary (*Casuarius casuarius*), Northern or Single-wattled Cassowary (*Casuarius unappendiculatus*), and the Dwarf or Bennett's Cassowary (*Casuarius bennetti*), belonging to a single genus - *Casuarius*. Several subspecies have been described for each, and these are listed below. Note that each of the subspecies has been described based on minor variations in wattle morphology and colour (Marchant & Higgins 1990) and the validity of each of the eight subspecies is not well established internationally (Department of the Environment, Water, Heritage and the Arts 2012), but are acknowledged by Garnett *et al*. (2011).

The Australian sub-species of the Southern Cassowary (*Casuarius casuarius johnsonii*) is the species on which this manual is based.

Table 2.1 - The Casuariiformes.

Common name	Genus/species	Subspecies	Distribution
Southern/ Double-wattled/ Australian	*Casuarius casuarius*	*casuarius*	Ceram
		aruensis	Aru Islands
		johnsonii	North Queensland
		sclateri	Southern New Guinea
		bicarunculatus	Western Vogelkop
		tricarunculatus	West Geelvink Bay
		bistriatus	North New Guinea, Geelvink Bay to Tana Mera
		lateralis	? locality
Northern/ Single-wattled	*Casuarius unappendiculatus*	*unappendiculatus*	Salawati & Western Vogelkop
		occipitalis	Japen Island & nearby coast (?)
		aurantiacus	Memberano to Sepik River
		philipi	Sepic River to Astrolabe Bay
Dwarf/Bennett's	*Casuarius bennetti*	*bennetti*	?
		papuanus	Vogelkop
		goodfellowi	Japen Island
		claudii	Nassau Mountains (south slopes)
		picticollis	South-east New Guinea
		hecki	Huon Peninsula to Sepik River
		shawnmeyer	Kratke Mountains
Total	**3**	***19***	

Source: Crome & Moore 1988b, Whitehead & Mason in: Romer 1997.

2.1.3 Synonyms

Cassowary, Australian Cassowary, Double-wattled Cassowary, Two-wattled Cassowary.

Table 2.2 - Indigenous names for the Cassowary.

Region	Aboriginal name	Tribe/clan	Location
Cape York	Kutani	Kaanju Pama	?
Wet Tropics	Boondarra	Djabugai/Tjapukai	Cairns, Port Douglas, Kuranda, Mareeba
	Gindaja	Yidinji	Edmonton, Cairns, Trinity Inlet, Admiralty Island
	Gumbulgan	Jirrbal	Ravenshoe, Herberton
		Ma:Mu	Innisfail, Murdering Point, Tolga
		Ngadjon-Jii	Malanda, Bellenden Ker, Atherton Tableland
	Gunduy	Banjin	Hinchinbrook
		Kuku Yalanji	Mossman, Daintree, Cooktown, Palmer River, Bloomfield
		Warrgamay	South of Cardwell to Ingham
	Punta:raa	Yirrganydji	Cairns, Port Douglas

2.2 PHYSICAL DESCRIPTION

The cassowary's large body is covered in coarse, black, hair-like feathers. Females can stand up to 1.7 metres tall, weighing in at up to 65kg. The wings are vestigial and rudimentary, and reduced to a few long hardened quills visible externally. Legs are muscular, terminating in three toes, of which the medial toenail is long and dagger-like. Skin on the wattles, neck, back and breast is ultimately naked, and brightly coloured with reds, blues and purples. Generally birds have two wattles hanging from the front of the neck. The casque, a distinguishable feature on their head generally skews slightly to the right. A more detailed physical description of the integument can be found in Chapter 7.

2.3 HABITAT

Generally restricted to dense tropical rainforest (Marchant & Higgins 1990; Stocker & Irvine 1983, Latch 2007; Westcott 1999; Crome & Moore 1990; Moore 2007; Sales 2009; Department of Environment and Heritage 2004), and associated vegetation (Marchant & Higgins 1990; Stocker & Irvine 1983; Latch 2007; Department of Environment and Heritage 2004), such as complex/non-complex notophyll/mesophyll forest and associated habitat such as mangrove Melaleuca (Department of Sustainability, Environment, Water, Population and Communities 2012; Crome & Moore 1990), eucalypt woodland (Department of Sustainability, Environment, Water, Population and Communities 2012, Crome & Moore 1990), swamp and swamp forest (Department of Sustainability, Environment, Water, Population and Communities 2012), savannas (Crome & Moore 1990) and disturbed habitats (Latch 2007) that provide a year-round supply of fleshy nutritious fruit (Crome 1976; Latch 2007). Such forest types occur in a relatively narrow and discontinuous strip along the north-eastern coast of Australia (Williams & Pearson 1997). Woodland, swamp and disturbed habitats are generally used as intermittent food sources and as connecting habitat between more suitable sites (Crome 1993; Bentrupperbäumer 1998). Birds appear to be most abundant in areas of relatively flat terrain with permanent fresh water (Department of Sustainability, Environment, Water, Population and Communities 2012), but are found at all altitudes (Marchant & Higgins 1990) with suitable habitat.

2.4 AUSTRALIAN DISTRIBUTION

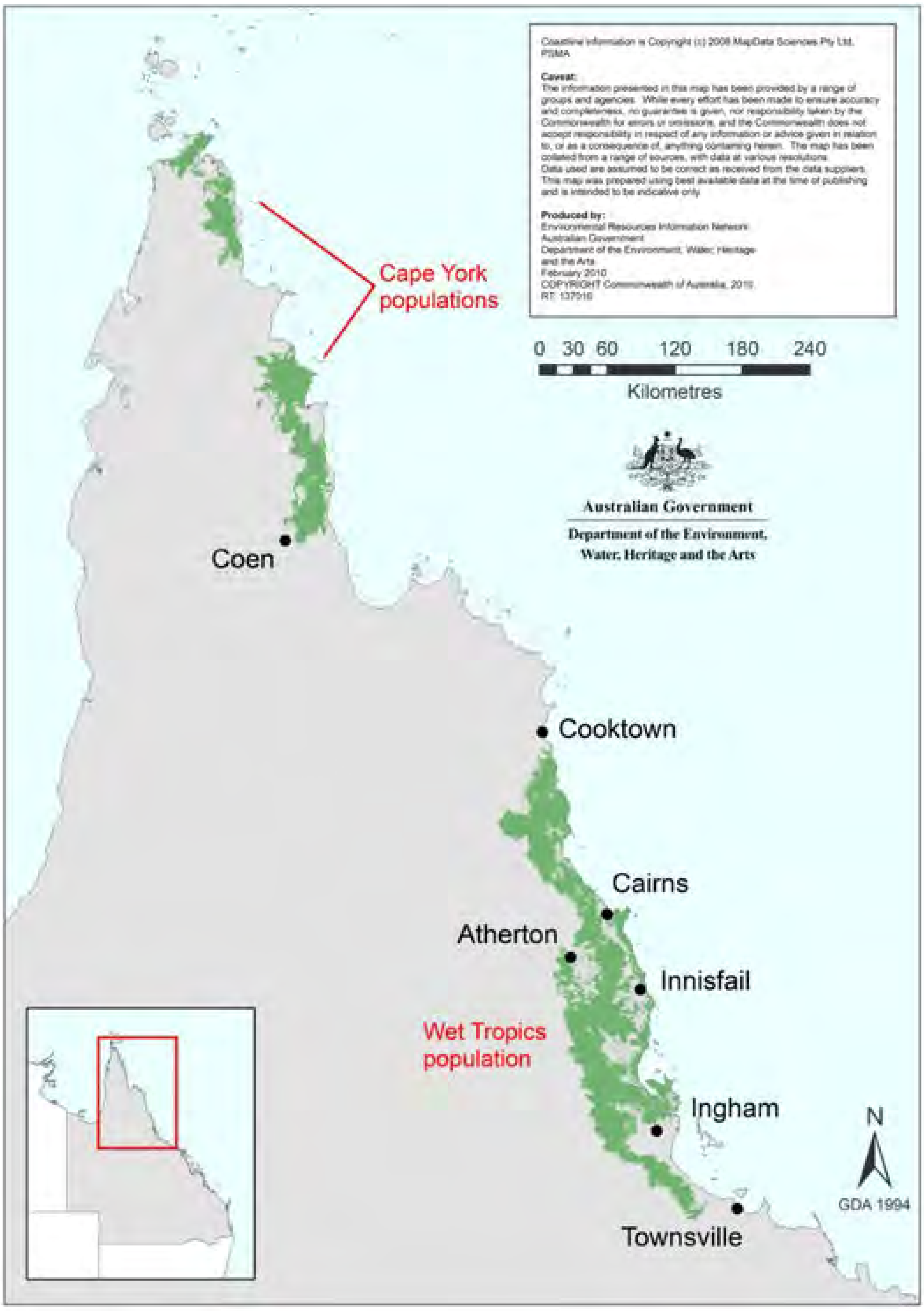


Figure 2.1 Australian distribution of southern cassowary habitat. *Source:* ***Latch 2007.***

Three broad populations of cassowary exist in two regions of northern Queensland (Kofron 1999; Queensland Parks and Wildlife Service 2002; Moore 2007) – two populations in Cape York, and one in the Wet Tropics (Figure 2.1).

Cape York, in the Northern Cape York Peninsula, centred on Shelburne Bay, and the Eastern Cape York Peninsula, in the Iron range/Mc Ilwraith Range area (Marchant & Higgins 1990; Department of Sustainability, Environment, Water, Population and Communities 2012; Latch 2007; Moore 2007).

Wet Tropics, in North Queensland centred on the Cairns region, between Cooktown and Townsville, throughout the coastal, hinterland and tableland areas south to the Bluewater Range (Marchant & Higgins 1990; Department of Sustainability, Environment, Water, Population and Communities 2012; Latch 2007; Moore 2007). While it is widely distributed in this area, it occurs patchily at both local and regional scales (Department of Sustainability, Environment, Water, Population and Communities 2012). The *Wet Tropics* World Heritage Area contains forests which have been growing for more than 100 million years, and are the oldest continually surviving rainforests on earth (Lane & McDonald 2002). Unfortunately the area is highly modified by people (Bellingham 2008) and has suffered extensive clearing, and from the cumulative effects of diverse incursion by roads, rail lines, powerlines, small mines, army training facilities, dams and urban development, and today less than half of the forest areas existing in 1850 remain (Lane & McDonald 2002).

The most comprehensive information regarding the Southern Cassowary's Australian distribution and population statistics is available from:

http://www.environment.gov.au/sprat

2.5 MOVEMENT PATTERNS

While early literature suggested seasonal altitudinal movement from the coastal rainforest into the foothills and over the Great Dividing Range (Frizelle in: White 1913), recent observations of birds in coastal habitat indicate that the species is probably sedentary though nomadic within a large home range (Bentrupperbäumer 1998, Marchant & Higgins 1990). Said home ranges may vary in size and shape both seasonally and from year to year, depending on environmental conditions and patterns of food abundance (Crome & Moore 1990; Bentrupperbäumer 1998). Little published information exists regarding individual movements; however, continued GPS-based tracking of rehabilitated birds may allude to any apparent patterns in habitat use. At this stage, rehabilitated translocated juvenile cassowaries appear to show high fidelity to release sites (Graham Lauridsen *personal communication*).

2.6 NATURAL DIET

Cassowaries are considered to be an effective seed disperser (Bradford & Westcott 2011) and have been recorded to consume fruits from 238 species of plant, including seven species of exotic plants commonly found in rainforests in the Wet Tropics Region Westcott *et al.* (2005) (See appendix 1). The gentle processing of fruits (Bradford & Westcott 2010) in the cassowary gastrointestinal tract often leaves fruit apparently unchanged (Stocker & Irvine 1983) with the flesh still attached and the seed still viable (Romer 1997). An apparently gentle digestive mechanism has been reported for other specialised frugivores and this probably serves to protect them from poisonous compounds in the seeds (McKey 1975 in: Gilbert & Raven). Bradford & Westcott (2010) concluded that cassowary gut passage can influence germination performance for individual species both during gut processing and subsequently in the way the seeds are deposited and that the effect is generally positive, although germination responses to cassowary handling and deposition are inconsistent across the range of plant species and seed types.

Protein in the form of vertebrate and invertebrate matter appears to have been an underestimated component of the cassowary diet in previous investigations. Additional foods such as fungi and non-fruit plant matter also occupy a significant portion of the diet, particularly after natural catastrophes such as cyclones (Graham Lauridsen *personal communication*).

Cassowaries generally eat food from the ground, but are also known to jump in order to reach low growing fruits.

2.7 SEXING

For the untrained eye, visually discriminating between the sexes is difficult, as morphological variations are minor and challenging to detect. Generally males are smaller than females and feathers at the rear of the body are longer and hang lower than in the female (Bentrupperbäumer 1998). Sexing chicks and sub-adults is impossible without physical handling. The sex of any age class older than a chick can be accurately determined by palpation of the genital prominence projecting from the ventral aspect of the proctodeum. See chapter 7 for appropriate sexing methods.

2.8 BREEDING

In nature, the home range of cassowaries between sexes overlaps significantly (Bentrupperbäumer (1998), and the home range of any single female may overlap that of a number or males, or vice-versa. Polyandrous and polygynous systems have been observed in this species.

Cassowaries are most frequently recorded breeding in the winter and spring months, both in the wild and in captivity. Generally aggressive female cassowaries appear to become more tolerant of males leading into and during the season, and conversely, some males appear to become bolder. Mating encompasses an intricate sequence of behaviours, usually starting with the male 'dancing' around the body of a sternally recumbent female, adjunct to throat swelling, rump scratching and gentle neck preening before copulation. If copulation is successful on each occasion, the female will lay an average of 4 eggs in a clutch and move on, leaving the male to incubate the eggs and rear the chicks. The incubation period is 47-54 days, during which time the male will rarely leave the nest.

Data from the ASMP studbook shows that males have been recorded breeding from age three to 37, and females from age two to 40 (See appendix 2). Given the meagreness of data, particularly for those over 20 years old, these data are not likely to represent the true reproductive limits of this species. No systematic records of the fecundity of wild birds exist, however anecdotal evidence indicates that they are capable of reproducing into their forties.

2.9 LONGEVITY

No formal records exist for wild birds, however captive cassowaries are long-lived, with a recent death of a bird recorded as being at least 48 years at Healesville Sanctuary (Hall 2011). Romer (1997) highlighted the death of a captive bird at Healesville Sanctuary whose age was estimated to be over 61 years. Stott (1948) suggested that because the controlling factors are manifold in each case, longevity records of wild birds seldom indicate the length of a physiologically 'normal' bird may attain if the conditions to which it is exposed are relatively ideal throughout its life. Birds maintained under captive conditions are not exposed to predators, nor are they, theoretically at least, subjected to the vicissitudes of weather and food supply (Stott 1948), so one can expect that the lifespan of a captive specimen would be equal to or greater than that of a wild bird. Anecdotal reports of wild birds suggest that reaching the age of 40 is not uncommon.

2.10 AGEING

The changes in plumage, skin colour and casque dimensions from hatching to adult occur at fairly constant ages and these can assist in aging young birds (Table 2.3).

Table 2.3 - Stages of the Cassowary life cycle

Life Stage	Age (years)	Description
Chick	***(0 - 1.5)***	***Hatching to the time chick is independent of male parent. Accompanied by male parent at all times.***
Young	0 - 0.4	Striped plumage – longitudinal dorsal black stripes and various shades of yellowish/cream brown; neck and body region covered with pale brown feathers; wattles very small and cream-coloured; casque absent. The time when chicks depend almost entirely on the male parent for provision and identification of food.
Old	0.5 - 1.5	Striped plumage replaced with a dull brown plumage on back of neck and body; cream-buff plumage on underside of neck and body; wattles still small, changing from cream to pale pink; casque visible and growing slowly. Continuing to lose close association between male parent and chick maintained, but independence developing in foraging strategies.
Subadult	***(0.7 - 4)***	***Young bird now fully independent of male parent.***
Young	0.7-2.4	Same physical characteristics as 'old' chick but during latter stages hints of blue appear around the head region; brown plumage increases in darkness on upper parts of the body while lighter brown plumage is maintained on the head and neck region and underside of the body; wattles pink; casque small.
Old	2.5-4	Body plumage black with brown tips; neck and head region blue and orange/red but still covered with fine black feathers; wattles pink/red, casque small.
Adult	***> 4***	***Fully mature plumage over whole of body – glossy black feathers, bare head, neck and wattle region brightly coloured in light and dark blue, red/orange and purple; wattles red; skin caruncluated; casque medium to large.***

Source: ***Adapted from Bentrupperbäumer 1998.***

POPULATION INFORMATION

3.1 WILD

3.1.1 Conservation Status

Endemic species have a high conservation priority and one of the primary reasons for the protection of the rainforests of the Australian wet tropics under World Heritage legislation is the high levels of regional endemism in both the flora and fauna (Williams & Pearson 1997).

State, Queensland (*Nature Conservation Act 1992*)

- Wet Tropics population (south) - Endangered
- Cape York populations (north) - Vulnerable

Federal, Australia (*Environment Protection and Biodiversity Conservation Act 1999*)

- Endangered

Action Plan for Australian Birds 2010 (Garnett *et al*. 2011)

- Vulnerable. Historical declines in habitat over the last three generations are thought to have caused a loss of >30% of the population in the last three generations (44 years), but the population is now almost stable.

IUCN 2012 (IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2)

- Vulnerable A2cde+3cde+4cde ver 3.1, declining population trend

3.1.2 Causes of Mortality

Since settlement, the primary causes of the species' decline are habitat loss, fragmentation and degradation, with motor vehicle strikes and dog attacks considered major threats for local populations (Kofron 1999; Crome & Moore 1990). Kofron and Chapman (2006) obtained data for 140 cassowary deaths from the years 1848-2004 from the Queensland Parks and Wildlife Service, local government councils and persons having experience with cassowaries. The majority of deaths were recorded to have occurred from 1986-2004 – 125 in total. Motor vehicle strike accounted for 49% of deaths, dog attack 16%, hunting 5%, shot or removed for attacking humans 3%, entanglement in wire 1%, natural causes 14%, and undetermined or unknown 12%.

133 cassowary deaths were reported to the Queensland Parks and Wildlife Service between 1992 and 2012. Of these, 103 were a result of car strike, 11 from illness/injury, 10 from dog attack, 6 from unknown causes, and 3 were killed in a pig trap.

3.1.3 Management Documentation

Key management documents for the southern cassowary include:

- *Recovery plan for the southern cassowary* Casuarius casuarius johnsonii (Latch 2007) (http://www.environment.gov.au/biodiversity/threatened/publications/recovery/southern-cassowary/pubs/sth-cassowary.pdf);

- *Threat Abatement Plan for Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs* (DEH 2005)

  (http://www.environment.gov.au/biodiversity/threatened/publications/tap/pubs/feral-pig-tap.pdf);

- *Threat Abatement Plan for Reduction in Impacts of Tramp Ants on Biodiversity in Australia and its Territories* (DEH 2006)

  (http://www.environment.gov.au/biodiversity/threatened/publications/tap/pubs/tramp-ants.pdf);

- *Significant Impact Guidelines for the endangered southern cassowary* (Casuarius casuarius johnsonii) *Wet Tropics Population. EPBC Act policy statement 3.15* (DEWHA 2009)

  (http://www.environment.gov.au/epbc/publications/pubs/casuarius-casuarius-johnsonii.pdf);

- *Survey Guidelines for Australia's Threatened Birds. EPBC Act survey guidelines 6.2* (DEWHA 2010)

  (http://www.environment.gov.au/epbc/publications/pubs/survey-guidelines-birds.pdf);

- *Distribution of Cassowary habitat in the Wet Tropics Bioregion, Queensland - Technical Report to Queensland Environment Protection Agency* (Kutt *et al*. 2004).

- *A framework to establish lowland habitat linkages for the Southern Cassowary (*Casuarius casuarius johnsonii*) between Cairns and Cardwell* (Biotropica Australia 2005).

- *Mission Beach Habitat Network Action Plan* (Hill *et al*. 2009).

3.1.4 Other Documentation

Other key documents for the Southern Cassowary include:

- http://www.environment.gov.au/sprat

3.1.5 Cassowary Recovery Team

The Cassowary Recovery Team is made up of representatives from a range of organizations whose primary function is to "Coordinate implementation of the Recovery Plan for the Southern Cassowary".

The objective of the recovery plan is to "protect cassowaries, habitats and corridors from threats through better planning, monitoring and community involvement"

The Team's website should be used as the primary source for up-to-date information regarding the southern cassowary.

- http://cassowaryrecoveryteam.org/

3.2 CAPTIVE

3.2.1 Status

A genetic and demographic review of the ASMP captive southern cassowary population is included in Appendix 2.

3.2.2 Causes of Mortality

Data from the Australasian regional Double-wattled Cassowary Studbook (Hall 2012) reveal that an alarming number of deaths (n = 42) are attributed to unknown causes, largely because no necropsy was planned. Associated infection, euthanasia, and injury from exhibit mate were the following lead causes (n = 9; n = 7; and n = 6 respectively).

These data highlight the need to place greater focus on thorough data collection, particularly during necropsy, to help increase our understanding of cassowary anatomy and physiology. A post mortem data collection form is included in appendix 3.

3.2.3 Management Documentation for ASMP Regional Population

Key management documents for the captive population of Southern Cassowary include:

- *Australasian regional Double-wattled Cassowary Studbook CASUARIUS CASUARIUS* (Hall 2011)
- *Program Outline: Southern Cassowary* (Hibbard 2001) See appendix 4.
- *Annual Report and Recommendations* (Biggs 2012; Biggs 2013)
- *Code of Practice of the Australasian Regional Association of Zoological Parks and Aquaria Minimum standards for exhibiting wildlife in Queensland* (*Department of Environment and Resource Management 2007*)
- *Captive Management Guidelines: Southern Cassowary* (Biggs 2013, this edition).

HOUSING REQUIREMENTS

To provide the best care for captive cassowaries, it is necessary to approximate the principal elements of their natural environment without compromising health or hygiene. Glatz & Miao (2008) point out that the housing of birds is considered by some authors to be one of the most important aspects of bird welfare. Meeting the requirements of their physical, social and psychological needs of the birds; satisfying security and safety concerns for humans and animals; and satisfying all other legislative requirements, are all crucial elements.

All recommendations listed henceforth are in line with the Queensland Department of Environment and Resource Management Code of Practice Minimum standards for exhibiting wildlife in Queensland, and offers suggestions that meet or exceed the minimum requirements.

The continued quiescence of the Australasian studbook remains the most significant issue facing the ZAA southern cassowary population. An hypotheses relating to the lack of mate-choice is being investigated however it is likely that a number of factors are involved as there are several pairs of 'compatible' birds which remain unproductive.

In nature, the home range of a female cassowary may loosely encompass that of several males (e.g. 2.1.0, 3.1.0, 4.1.0), however this observed social system has not been replicated in the captive setting, where traditionally one female is paired with one male when behavioural observations indicate receptiveness from both parties. This unit (constrained by standard 2-enclosure system in most institutions) is seldom encountered in the wild and has proven to be largely unsuccessful in captivity by limiting potential mate options to a single bird. Furthermore, birds housed at institutions have generally been kept as 'pairs' despite a number of years running without any signs of successfully reproducing. Providing a captive female with more than one male may encourage competition (and, optimistically, copulation and reproductive success for at least for one of the males), by giving the female options with whom to mate as opposed to offering her one male in perhaps sub-optimal condition.

Based on this, a new direction for the management of breeding birds in the Australasia region was established at the 2011 CHW which identified that ideally, breeding birds should be housed in a configuration of enclosures that allows birds to choose a mate.

A number of institutions are currently trialling a method whereby one female is given the opportunity to interact with two males simultaneously, but on an individual basis, in the hope that one of the males will meet her requirements and the 'pair' will go on successfully reproduce. The remaining (unsuccessful) bird is then available for a new pairing recommendation with an additional bird. Likewise, as males occasionally pair with more than one female in a given season, a scenario where one male is given the opportunity to interact with two females simultaneously, on an individual basis is also being trialled. Again, the remaining (unsuccessful) bird is made available for a new pairing recommendation. Despite the infancy of such trials, preliminary results look like progressing towards the establishment of successful pairings.

The lack of spaces in existing participating institutions limits such trials to larger establishments with the capacity to redevelop existing enclosures, or new establishments with the capacity to build the recommended enclosure configuration of three adjacent exhibits with a shared holding pen.

4.1 CONFIGURATION

Historically, most institutions have held 1.1.0 birds in separate enclosures. While these are acceptable for holding birds that are established as proven breeders, such enclosures are impractical for the managed program. This has been the root of stagnation in the captive population, as birds have been kept as 'pairs', despite consecutive years of non-success.

4.1.1 Configuration Recommendations

It is recommended that institutions with the capacity to hold more than 1.1.0 (i.e. 2.1.0 or 1.2.0) considers developing enclosures that allow for mate-choice to occur. Likewise, institutions who are able to assess existing enclosure dimensions and configurations should determine whether or not any minor adjustments might allow for mate-choice trials to occur.

A recommended minimum size enclosure for a trio of cassowaries is three adjacent enclosures, each measuring 18m x 12m. Safety passages at opposite ends of shared fence lines will provide a means for birds to safely escape potentially dangerous interactions, once they have been introduced in the breeding season (if behaviour of each individual allows for introduction). It is recommended that for the majority of the year, birds should be kept separate from one another due to natural aggression and have only partial visual access to one another. All three enclosures should be accessible from a shared holding pen of similar size (18 x 12m) which can also serve to hold any offspring for a period, post-independence and pre-placement at another institution.

For those establishments with a lesser capacity, a suggested minimum size enclosure for a pair of cassowaries is two adjacent enclosures, each measuring 18m x 12m (Romer 1997). Safety passages at opposite ends of shared fence lines will provide a means for birds to safely escape potentially dangerous interactions once they have been introduced in the breeding season (if behaviour of each individual allows for introduction). It is recommended that for the majority of the year, birds be separated from one another due to natural aggression and have only partial visual access to one another. Both enclosures should be accessible from a shared holding exhibit of similar size and again can serve to hold any offspring for the period post-independence and pre-placement at another institution.

4.2 PERIMETER DESIGN

Common sense is the key to designing an enclosure perimeter that safely contains any animal. A sound knowledge of species biology and capabilities will also assist in creating a suitable design.

The perimeter must confine the animal/s to the enclosure; minimize the risk of unauthorised entry by humans, conspecifics and other unwanted/incompatible animals; reasonably minimise predation of any animal kept in the enclosure; and, minimise health risks to the animal, including those arising from parasites and pests and other unwanted/incompatible animals entering the enclosure. Enclosures should also be constructed to reasonably prevent visitors from placing any part of their body within reach of a Cassowary (by means of a stand-off barrier).

Changes in the direction of fence lines should facilitate movement of the animals and avoid collision, entrapment and other hazards.

A fence containing a cassowary must meet or exceed 1.8m in height.

Support posts, rails, stays and straining wires for fencing should be on the outside of the enclosure barrier to provide a safe environment for the animal/s, and to minimise escape opportunities. Where this is not practical care should be taken to place them in a manner which minimises the risk of harm to the animal/s and the risk of escape.

Chain link fences are commonly and successfully used with Koppers logs as supports. Solid concrete rendered walls and tin fences have also been successfully used. Beak, wing and casque damage have occurred in all three of these as a result of pacing (MaryJo Willis *personal communication*). Horizontally tensioned wire strands have been effectively used at numerous zoos. In-hangs (with lightly tensioned wire or chain link fencing) are a widespread feature of many perimeter fences and significantly reduce the possibility of escape.

If used, mesh size should be carefully considered as heads can be pushed through larger mesh causing irreversible damage to the casque and further risk of neck breakage or decapitation. Additionally, kicks through the mesh can lead to torn and peeled leg scales and infections (Romer 1997).

Moats were tried unsuccessfully at L.A. Zoo, however Melbourne Zoo was successful in the use of a wet moat (Romer 1997).

Fence heights have varied from 1.4m to 1.98m. Several escapes have occurred at the lower height while one recorded escape has occurred at 1.8m, and one escape (into a stud pen) occurred at 1.98m (MaryJo Willis *personal communication*). Jump outs have generally been associated with interaction with conspecifics or aggression towards humans and are facilitated by perimeter fencing that do not incorporate either an in-hang or a solid top bar.

Foliage, particularly climbing plants, is planted along the external perimeters of enclosures at many institutions and provides good cover and protection.

Ideally routine feeding and watering should be possible without the need to enter exhibits.

4.2.1 Perimeter Design Recommendations

The fence should be of solid construction, and should follow the contour of the land.

It is recommended that posts be constructed from 50mm or larger SHS, with posts buried and concreted to a depth no shallower than 500mm. Alternatively, Koppers logs with a diameter of no less than 100mm or other similarly sturdy materials can be used.

The height of the posts should be no less than 1600mm from the surface of the ground with an additional in-hang increasing the total height of the fence to 1800mm. Posts should be spaced no more than 2000mm apart, be supported by a frame at the top and bottom made from 50mm or larger SHS.

The in-hang should be an extension of the fence posts, and should be angled inward at 45 degrees. Gently tensioned horizontal straining wires should join each post of the in-hang and be spaced no more than 200mm and no less than 150mm apart.

Where an in-hang is not possible, the height of the posts should meet or exceed 1800mm from the surface of the ground, be spaced no more than 2000mm apart, and be supported by a frame at the top and bottom made from 50mm or larger SHS. The bottom support frame should be flush with the internal ground level of the enclosure.

Chainlink is preferable to weld mesh. If used, chainlink openings should be no greater than 50mm x 50mm, and ideally be plastic coated. Wire diameter should be no less than 2.5mm excluding the plastic coating. Mesh should be attached to the internal side of the fence posts as per the manufacturer’s recommendations and be supported by horizontal straining wires.

As an alternative to chainlink mesh, horizontally tensioned wires spaced at 20cm have been successfully used as perimeter fencing, however are not recommended as a single means to contain a cassowary. Some beak/casque/head/wattle rubbing and other injuries have been associated with this method alone. Thought should be given to the addition of an in-hang and/or some form of electric deterrent.

Chicken wire is not recommended as toes can easily get caught in the small mesh and it is not strong enough to contain an adult bird if aggressive or frightened (Romer 1997). Vertical, spaced panels of any description must also be avoided due to the potential for whole legs and heads to get caught, and the possibility of bone breakage and decapitation.

Dry and/or wet moats are not recommended.

Electric barriers should not be used without visible backup barriers such as nonelectric fences in handling areas however may be used to supplement a primary barrier of an enclosure for an animal that climbs, jumps and/or is considered potentially dangerous.

Regardless of the design chosen, all internal fences should be free of obstacles, loose wires, protruding wires, hooks, nails, screws, plumbing or any other potentially dangerous items.

Where the park perimeter forms part of the enclosure perimeter provisions need to be made to protect the birds from outside disturbances such as the public, traffic and dogs to limit stress.

A standard double fence may be required if the bird/s is/are aggressive.

It is recommended that shared fence lines reach no less than 1800mm height, and be of similar construction to the perimeter. Shared fence lines should be heavily planted to allow only partial visual access.

4.3 GATES AND DOORS

Enclosure gates, doors, slides and other entry and exit devices must be designed, constructed, maintained and managed to: minimise risk of injury to the animal/s; allow safe access for, and operation by, staff; minimise risk of unauthorised entry; minimise risk of animal escape; and minimise risk of an animal from tampering with its effective operation or breaching its security.

Enclosure gates and doors should allow easy, calm movement of animals in and out of enclosures to minimise the stress of handling.

All gates, doors, slides and other entry and exit devices should provide: a clear view of other entry and exit points and the immediate surrounding area inside the enclosure; and, if mechanically operated (e.g. electric, air) easy manual operation without risk to the operator. They must also be able to be operated from areas that are secure from the animal/s.

All locking devices should indicate when gates and doors are locked or unlocked/open or closed. Access to enclosures containing Cassowaries should ideally be from an area capable of containing the animal/s should it escape through the access.

4.3.1 Gates and Doors Recommendations

Gates that are not slide gates should be inward swinging.

It is recommended that gates be constructed from 50mm SHS with 50 x 50mm weldmesh welded to the outer face of the gate. The height should be equal to the height of the perimeter fence and also contain an in-hang if an in-hang has been incorporated into the perimeter fence design.

Thought should be given to allowing a gate for vehicular access to facilitate easy transportation of birds, and to allow fast and easy enclosure maintenance. The recommended 3-enclosure configuration allows space for vehicular access to each enclosure via the holding pen.

It is recommended that each exhibit or holding pen includes capacity to attach a uniform transport crate to the perimeter to facilitate easy conditioning for transport, and for medical management (See appendix 9).

4.4 HOLDING AREA DESIGN

Every design for an enclosure housing a cassowary should include a service area, holding pen, indoor holding area or a secondary exhibit area that can be used to isolate individuals or separate a pair should the need arise.

Consideration should be placed on the intention of the holding area – the type of husbandry use intended, the general purpose of the area, and the duration that any animal will occupy the space. Such an area can be used as a feeding zone, and can be shut off from the birds for servicing to eliminate the risk of injury to staff. These may also act as a holding facility while the main exhibit is serviced, be used to separate birds if aggressive behaviours arise, to prevent breeding, and to isolate a female from an incubating/fathering male and his eggs/chicks.

Ideally routine feeding and watering should be possible without the need to enter the pen.

4.4.1 Service Areas, Holding Pens and Indoor Holding Area Recommendations

It is recommended that the holding pen perimeter be of similar construction to the main perimeter design. The height should be equal to the height of the perimeter fence and also contain an in-hang if an in-hang has been incorporated into the perimeter fence design.

It is recommended that birds are partial to no visual access between holding pens and any adjoining exhibits. Full auditory contact is ok.

It is recommended that the holding pen be connected to all adjoining exhibits to allow movement of birds for enclosure servicing and medical examination, temporary housing of individuals or juveniles/sub-adults.

It is recommended that each exhibit or holding pen includes capacity to attach a uniform transport crate to the perimeter to facilitate easy conditioning for transport, and for medical management (See appendix 9).

4.5 SPATIAL REQUIREMENTS

In a wild study site used by Bentrupperbäumer (1998), an average density of 2.5 birds per km^2 was observed for adults (breeding). Females have larger home ranges than males (Campbell *et.al* 2012) with female home ranges averaging 0.86km^2 and male home ranges of 0.65km^2 (Bentrupperbäumer 1998). Home ranges between sexes overlapped extensively (90-100%), and while same sex home ranges did overlap, shared areas were minimal (Bentrupperbäumer 1998; Campbell et. al 2012).

As required by law in Queensland, a single cassowary specimen must have 200 square metres. A further 100 square metres is required for each additional adult. No requirement is stipulated for any other age class.

Enclosure dimensions should allow for significant flight distance during agonistic interactions.

Cassowaries have successfully bred in enclosures as small as 200 square metres, however this was divided in half to separate the pair and additionally heavily planted (Hopton 1992 in: Romer 1997).

4.5.1 Spatial Requirements Recommendations

As cassowaries tend to occupy a limited territory, the quality of the space is likely to be more important than the quantity. It is recommended that enclosures be heavily planted with complex land contours and substrate combinations.

It is recommended that young chicks have daily access to a yard or run to stimulate and encourage exercise.

Large complex pens adhering to the recommended configuration should be used for introductions.

4.6 POSITION OF ENCLOSURES

Cassowary enclosures should be positioned such that they are free from draughts.

4.7 WEATHER PROTECTION/SHELTER

As a forest dwelling species, shelter and shade should be a major consideration in the design.

An artificial shelter may be necessary if the bird are in a climate that is significantly different to their natural environment and if few shade trees are available. Temperatures in their natural home range rarely drop below 10°C or above 37°C and conditions are often humid and wet. Philadelphia Zoo did however keep a bird outside with only a roof for shelter for a number of winters (Romer 1997).

4.7.1 Shelter Recommendations

Wherever possible, natural shade and shelter should be provided. For adults it is recommended that large trees, native to their home range be heavily incorporated into the design. These should preferably be fruiting trees (See appendix 1) to allow natural supplementation of the diet. The provision of a wind break area such as a large rock or buttress root may double as a safe nest site. For juveniles, it is recommended that numerous low shrubs and dense tussocks be incorporated into the design to allow safe hiding places.

In a case where climate requires that an artificial shelter be built, a two-walled structure (for a pair) should be built with a roof to a height of no less than 2.5-3m. This will allow hasty escape of a bird from any aggressive interactions with conspecifics. For a single specimen, a three-walled structure will provide more secure shelter. In the case of a pair, the shelter may also double as a suitable nest site and facilitate easier reproductive management. It is recommended that the shelter be constructed from similar materials as the perimeter fence, or other sturdy materials, including rendered brick, wood, or iron sheeting but should be free of obstacles, loose wires, protruding wires, hooks, nails, screws, plumbing or any other potentially dangerous item. The floor should have a non-slip surface, and may be constructed of natural substrate or concrete with rubber matting for ease of cleaning.

4.8 HEATING AND HUMIDITY REQUIREMENTS

Heat is required in very cold climates such as any area where snow is known to fall or where heavy winter frosts occur and temperatures commonly fall below 0°C. The provision of a heated shed or shelter will assist in alleviating cold stress.

Sprinklers or mist systems increase the humidity which reflect conditions in their natural habitat and may be necessary in dry areas to increase the humidity around eggs during incubation.

4.9 SUBSTRATES

Sandy, rocky, muddy, swampy, solid and organic substrates and ground covers are all encountered by wild cassowaries.

4.9.1 Substrates Recommendations

It is recommended that range of natural substrates and ground plantings should be incorporated into the design. Rocks or boulders incorporated into the design should be too large for birds to clamber up. Smaller boulders should not be piled because of their injury potential, especially when wet or covered in moss.

Other slippery surfaces such as polished concrete should not be used.

The land should be contoured to form an interesting and complex terrain.

4.10 FURNISHINGS

4.10.1 Furnishings Recommendations

It is recommended that every enclosure contain a combination of furniture such as logs, rocks, trees, shrubs, ponds and streams - not only to replicate the natural environment, but also to allow visual and physical separation if birds are feeling threatened, or during agonistic interactions. Placement of such obstacles should be avoided around the fence boundary to minimise opportunities for escape or injury. Complex furnishings also allow greater opportunities for enrichment.

Steep/loose rock piles, unless sturdily constructed, may cause injury and should be avoided.

4.11 PEST CONTROL

Minor pests in Australia include Indian Mynah's, turtle doves, and rats, which, apart from eating a small part of the diet offered, pose little threat.

The Cane Toad (*Bufo marinus*), which was introduced to North Queensland in 1935 has spread across the entire cassowary distribution range. The parotid gland on the neck of the toad secretes a toxin that is dangerous to many species. While no studies have been conducted on the effects of cane toad toxin on the cassowary, anecdotal evidence from numerous institutions with cane toad incursions suggest that no negative effects are encountered after eating toads. Post mortem results have identified amphibian skeletons in the stomachs of two captive birds (from the same institution, years apart), and although unconfirmed, were speculated to belong to

Bufo marinus which were subsequently recorded as the cause of death. No reports of cane toads causing death in wild birds have been made.

Wild crows have been observed killing hatchlings (Mike Taylor, *personal communication*) in North America.

Presenting food in raised troughs and under cover is the most appropriate means to prevent small pests from entering enclosures.

GENERAL HUSBANDRY

5.1 RECORD KEEPING

For long lived species, it is particularly important that consistent and accurate records be kept. Information should be recorded to provide for meaningful specimen histories and to be transferrable to other institutions.

The following records are particularly relevant for individual and genetic management and should be kept as a minimum:

- individual identification information (ARKS records etc, including descriptions of any distinctive markings;
- the origin (including details of the wild population or of the parents and their origin);
- transfers from previous locations;
- dates of acquisition and disposal (with details of circumstances and addresses);
- the date or estimated date of birth, and the basis on which the date is estimated;
- records from previous institutions;
- house name;
- pairings;
- breeding and details of any offspring (including transfer details);

Additional records that are particularly useful for developing a clinical health database for the species include, but are not limited to:

- medical treatments and outcomes;
- post mortem findings;
- egg post mortem findings;
- artificial incubation data;
- Serum biochemistry and haematology (to assist with the establishment of normal blood biochemistry ranges for this species);
- Individual genome sequence.

See Appendix 3, 5, 6, 7 & 8 for appropriate formats for recording information.

Electronic and hard copies of records should accompany any animal moving to a new location.

5.2 METHODS OF IDENTIFICATION

It is imperative that cassowaries are able to be individually identified on paper, and physically. Photographing and recording distinct variations in gross morphology (Figure 5.1) is the recommended form of identification and should be adjunct to individual specimen reports.

Figure 5.1 Distinct variations in gross morphology of the Southern Cassowary for use in individual identification.

For adult birds, sufficient variation in the following features allows accurate individual identification:

- Casque shape and orientation;
- Black keratin patterning on the front of the casque;
- Wattle size, shape and colour *patterning*;
- Yellow/white/black/blue integument *patterning* covering the infraorbital sinus;
- Yellow/white/black integument *patterning* on the maxillae, directly beneath the infraorbital sinus;
- Integument colour *patterning* on the back of the head and neck;
- Markings on beak or tissue damage;
- Body size;
- Footprint dimensions;
- Tail length;
- Leg scarring;

While the size and shape of the casque changes gradually throughout the bird's life, it is probably the most useful identification reference. Whatever the case, photographs should be updated regularly or as significant changes occur.

Feather colour and skin colour patterning (particularly in hatchlings, juveniles and sub-adults) are an ambiguous means of identification in young birds because growth is so rapid in the first few years of life, and colour patterning is steadily changing until adulthood. For birds up to the age of sub-adult, it is recommended that temporary marking be applied, particularly if more than one bird is housed in the same enclosure.

Depending on the disposition of an individual adult, colours may vary in intensity from season to season - or from hour to hour. On this basis, it is appropriate to play closer attention to the patterning of the colouration as opposed to the intensity of colouration.

Micro chipping is one of two approved permanent identification methods in Australia, and is frequently used by many institutions. This method provides a permanent form of identification which can be useful when inter-institutional movements become regular.

Microchips should be inserted sub-cutaneous at the back of the neck or in the left lateral thigh when the bird is at least three months of age. However, unless conditioned to receive a microchip reader in these areas, it may become increasingly difficult to do so as the bird grows older.

The second approved method is wing-tagging, however due to the delicate nature of the anatomical structures within the wing, this method is not recommended.

Due to their size and construction, permanent leg bands are ungainly and have a high potential to damage skin and joints, so are not recommended. At institutions where they have been used, bands have been placed above the hock joint.

5.3 ROUTINE DATA COLLECTION

Routine data collection can facilitate proper identification of illness, injury or disease in captive birds and hence, provide a solid baseline for treatment and subsequent data collection.

A routine data collection sheet (Appendix 5) is attached for use and should be filled out on a monthly basis for 12 months and seasonally after that to assist with identifying seasonal trends in appetite, body condition and weight.

5.4 HYGIENE AND CLEANING

No document specifically lists hygiene and cleaning requirements that are required in order to provide adequate housing for Southern Cassowaries. In any case, enclosures should be cleaned to ensure the health of the animal/s.

Watering points should be regularly cleaned, flushed and/or replaced. Enclosures that allow it should be spot cleaned as necessary. Uneaten food should be removed daily and feeding receptacles should be cleaned with an appropriate disinfectant at each feed. If two feeds are offered daily, uneaten food from the first meal should be removed and the receptacle cleaned prior to offering new food.

For keeper hygiene, gloves should be worn when removing faecal matter to prevent the potential transmission of pathogens.

HANDLING & TRANSPORT

Cassowaries, because of their inherent defensive anatomical structures and ability to kick forward and sideways even when sedated, should be handled with the utmost care by suitably qualified personnel only. Manual handling and restraint of Cassowaries is potentially dangerous and poses a serious threat to both handlers and birds. Personnel involved require a working knowledge of the individual bird, its behavioural characteristics and the species capabilities.

In contrast, incorrect handling techniques can also cause injury to the bird. In ostriches, the relatively high centre of gravity, weight and muscular conformation renders these birds susceptible to injury when incorrectly restrained (Wade in: Tully & Shane 1996) and most of the problems in the restraint and handling of emus are due to underestimating the strength and activity of the bird or alternatively applying excessive force (Mouser in: Tully & Shane 1996).

Any restraint procedure of a potentially dangerous animal should be carefully planned in advance to minimise the risk of stress and/or injury to both animals and handlers. Such procedures should only take place in conjunction with or under the supervision or direction of a registered veterinarian and a suitably qualified senior member of wildlife staff.

The strategies listed here were developed through trial and error and each has a number of scenarios for which they are most appropriate. These are by no means the only methods suitable for cassowary capture and restraint.

The nature of the procedure to be performed (whether for enclosure maintenance, a medical procedure, or transport) will determine the type of capture and restraint technique utilized. Confinement by conditioning, hands-on physical restraint, administration of sedatives or a combination of each, all have their benefits and drawbacks, discussed throughout this section.

6.1 SAFETY

When undertaking any capture and restraint procedure, safety is paramount. Plans should be carefully thought out and precisely executed to minimise patient contact time and stress. Removable hazards should be eliminated, and risks mitigated where possible. Occupation health and safety standards for your region/locality/workplace should be observed when performing any dangerous task. If the options mentioned here do not satisfy your institutional regulations and requirements, then you are urged to develop a strategy that does.

The following factors should dictate capture and restraint procedures:

- Reason for capture;
- Environmental factors such as enclosure size & topography, ambient temperature;
- Previous capture experience of personnel involved;
- Number of personnel available;
- Duration of procedures to be conducted including room for error;

- Availability of personnel available for post-procedure monitoring.

6.2 CONDITIONING

6.2.1 Conditioning for Enclosure Maintenance, examination or transport

Ratites can be conditioned to move from enclosure to adjoining enclosure, den or crate. As cassowaries are known to forage throughout the day, strict weight management is not necessary. To achieve reliable results, keepers should use food items favoured by the individual. A verbal cue can be added however generally the sound of a slide gate, door, lock, or the movement of a keeper towards a holding pen is enough to prompt investigation by the bird, however motivation may be lacking leading up to and during the breeding season.

6.3 IMPORTANT CONSIDERATIONS FOR HANDLING

6.3.1 Physical condition

The physical condition of a bird should be a primary concern when attempting any capture or restraint procedure. See Appendix 10.

6.3.2 Timing

Adult ratites should not be transported during the breeding season as birds may be more prone to higher stress levels at this time.

6.3.3 Location

Capture procedures should be conducted in areas that are familiar to the bird, particularly if anaesthetics are to be used. The area should be free of potentially hazardous obstacles. Holding exhibits or large flat areas are ideal for handling procedures.

6.3.4 Duration

The duration of any handling exercise should be kept to a minimum. Thorough planning prior to engaging in any handling procedures can eliminate any time waste.

6.3.5 Release

Release should be conducted in areas that are familiar to the bird. If the bird is new to the collection, releasing in a quarantine pen with dense vegetation will allow the bird hide if necessary. If the bird has been anesthetised, all ponds should be dropped to prevent drowning, and drinking water should be offered from an appropriately sized tub only.

6.4 CAPTURE AND RESTRAINT TECHNIQUES

6.4.1 General, weighing and examination

Ordinarily, a general health check can be completed without restraint, regardless of age, through visual observation and a thorough review of the birds' medical history, keeper observations and routine data collection sheets (Appendix 5). As a baseline, staff working with cassowaries should complete a routine data collection sheet on at least a seasonal basis to provide a baseline for subsequent examinations.

6.4.2 Medical Procedures/Examination

Whenever possible, procedures should take place during the cooler parts of the day, for example early morning or late afternoon, particularly in the tropics or other warm environments.

For hands-on physical manipulation or procedures involving chemical immobilization, veterinarians generally suggest fasting the bird for up to 24 hours prior to the procedure, or offering only a small amount of food due to the risk of regurgitation; however this option may be impracticable if the procedure requires emergency attention. Given the rapid gastrointestinal transit time observed in cassowaries, feeding a bird pre-may not prove to be an issue.

Care must be taken that the wings are not injured through forceful handling and handlers should always be aware that even a sedated and/or restrained cassowary can kick out with its feet and potentially inflict serious damage.

6.4.2.1 Up to 6 months

For juveniles aged up to 6 months, the most challenging part of the procedure is separating the individual in question from the protective sire. Use can be made of the juvenile's natural curiosity to tempt the bird into a race or holding pen. Favourite food items, such as protein, may prove useful in this instance.

Capture and restraint can be safely and easily achieved by slowly approaching from behind or gently coercing a bird into a corner and scooping the bird up with one arm between the legs such that the hocks are separated, minimising the risk of injury. The scooping hand should be placed on the sternum. As the birds are naturally inclined to stretch the head and neck forward at this stage, the free hand should be used control the head and neck to prevent contact with any thrashing legs. The handler should also be conscious of their own head and arm placement during this procedure to also prevent contact with legs.

A similar method exists, whereby the handler approaches from the side and first controls the head and neck, quickly followed by swiftly scooping the bird up from behind between the legs, again placing the hand on the sternum. This method is not as safe as the first method for the handler due to the side positioning of the handler and the proximity of the torso to the thrashing legs. It is however, more appropriate for birds up to 3 months of age.

Alternatively, and possibly the safest method requires two handlers. The first can first control the body (push into a sternally recumbent position by putting weight squarely on the back). The second can secure the tarsus of each leg, while the first handler secures the head and neck, rolls the bird onto its side while applying downward pressure to the body and then gently lifts the bird to a position allowing the second handler to pick up the bird.

During any restraint procedure, it should be noted that juvenile birds will generally evacuate their bowels, so the vent should be directed away from oneself and from other handlers.

Younger birds often sprint back and forth along a single fence line once they recognize that a capture is taking place. Watching the bird's repetitive behaviour for a moment can facilitate straightforward catching. These birds are capable of jumping to considerable heights, and have been observed surging vertically up fences constructed of 50 x 50 mesh, using the links as foot supports. Enclosures used for capture procedures should take this into account.

Careful consideration should be placed on what techniques are utilised for safe capture and restraint - even at 6 months of age. If any uncertainty exists, or if risks are deemed too high, consider the following method.

6.4.2.2 Any age (Up to 18 months if anaesthetic is not an option)

Manual restraint without anaesthetic is generally most suitable for birds up to 18 months. Three to four people holding baffle boards, hessian, shade cloth or other similar materials can coax a bird into a corner or a race. Once in a position to do so, the bird can be grabbed from behind. By placing pressure squarely on the birds back, it will sink into a crouched position. The same handlers can then secure the lower tarsus of each leg while maintaining downward pressure on the bird's back with their body weight. This can be achieved in less than 30 seconds. The risks of physical injury to the bird and handlers using this method are considerably increased if using the technique with adult birds.

6.4.2.3 Over 18 months - long procedures

The use of chemical restraint should always be considered when it is necessary to perform a physical examination. For ostriches, anaesthesia is recommended for even superficial operative procedures of short duration (Wade in: Tully & Shane 1996).

For a detailed or lengthy examination in birds aged 18+ months, mild-heavy sedation is acceptable. Ideally (depending on the health status of the bird and the reason for restraint) the bird should be sedated prior to entry into the enclosure, either by pole injection or blow dart, however successful capture and restraint procedures have been performed on adult birds without chemical restraint.

Sedation should be administered to the bird in an enclosure in which the bird is comfortable, and one which has few obstacles or furnishings that may injure the bird. Once the sedative has taken effect, the capture and restraint procedure can begin.

In a new technique established by Graham Lauridsen, the sedating drug is allowed to exert its full effect before any restraint is applied. Zoletil is the drug of choice.

A team of experienced, physically fit, confident handlers should be carefully selected to perform the procedure and include site staff for crowd control, gate guarding and emergency communications. This team should be led by one person from whom all directions will come. The plan, along with the physical abilities of the bird, should be discussed prior to entry into the enclosure, and should clearly outline the role of each team member and a protocol to abort the procedure. Any changes to the plan, once in operation, should be made only by the team leader in a loud, clear voice.

This new procedure requires that handlers delay any physical restraint until the bird has reached full lateral recumbency. At this point, a rope is placed on each leg and gentle tension applied from a distance to allow some control if any degree of reflex is encountered. For additional restraint, pressure can be placed on the thorax.

Upon successful restraint, a complete physical examination should be performed (See Chapter 10 for detailed physical examination procedure). Heavy focus should be placed on the Monitoring and Anaesthesia form (Appendix 8).

Although peroneal nerve paralysis is a regular feature in ostriches held in lateral recumbency for extended periods, it has not been observed in cassowaries with use of this technique (Graham Lauridsen *personal communication*), Graham highlights the importance of having a dark transport box available for recovery of the bird – allowing the bird to fully wake up before release will result in the best outcomes.

6.4.2.4 Over 18 months – medium procedures

For general blood sampling, abdominal examination and urogenital examination in birds aged 18+ months, mild sedation is acceptable and widely practiced with ratites.

Sedation should be administered to the bird in an enclosure in which the bird is comfortable, and one which has few obstacles or furnishings that may injure the bird. Once the sedative has taken effect, the capture and restraint procedure can begin.

A team of experienced, physically fit, confident handlers should be carefully selected to perform the procedure and include site staff for crowd control, gate guarding and emergency communications. This team should be led by one person from whom all directions will come. The plan, along with the physical abilities of the bird, should be discussed prior to entry into the enclosure, and should clearly outline the role of each team member and a protocol to abort the procedure. Any changes to the plan, once in operation, should be made only by the team leader in a loud, clear voice.

Once the sedative has started to take effect, a small team will lead the bird with hessian or padded boards to an area of the enclosure where the procedure can be safely initiated (against a smooth fence line with no protrusions, next to a tree, a smaller section of the enclosure or a crate). The bird can be effectively captured by grabbing it from behind and putting weight squarely on its back until it drops into a crouched position. Birds will often fight this type of restraint and the potential risks of this procedure to both staff and bird should never be underestimated. At this stage, the lower tarsus of each leg must then be secured by persons from the rear of the bird, taking care to hold the legs close to the body while adding weight to the birds back. Care must be taken of the legs to ensure they are not broken or dislocated. This should all be done quickly to limit stress and potential hyperthermia and/or myopathy.

The head should also be held upright to prevent possible choking as a result of gastric reflux caused by stress or medical reaction. Enough pressure should be placed on the birds back to prevent jumping whilst the procedure is taking place.

The use of a hood is not recommended as it does not have the same calming effect as in other ratites. If any sort of visual barrier is to be used, a simple tea-towel or cloth is adequate, and can be easily removed if the desired effect is not produced.

This procedure can be used for birds from 18 months or older; however the use of chemical restraint should be at the discretion of the consultant veterinarian and is usually not necessary in birds under this age. The amount of force required for a sub-adult is less than that required for an adult and extra care should be taken that excessive force is not used.

6.4.2.5 Over 18 months - short procedures

Alternatively, follow Section 6.4.2.3 to the point where pressure is applied to the birds back and the bird is in a sternally recumbent position, each leg can be secured individually with ropes using a noose style knot. Birds can then be rolled into a laterally recumbent position whilst pressure is maintained on the body. The ropes allow some degree of leg control by handlers and generally are used to lift the legs slightly off the ground to prevent the bird from spinning if kicking is observed. These should remain separate, allowing greater manoeuvrability. Leg ropes minimize the need for protective (and generally restrictive) clothing worn by some handlers during restraint procedures.

To terminate the procedure, legs are drawn back into the body by the rope handler and ropes removed to the hands of the handler, such that both legs can be released at the same time.

6.4.2.6 All ages – for transport

In many cases sedatives are not necessary and numerous transports have occurred successfully without their use, however if the event appears to be particularly stressful, consideration should be made to very mildly sedate or calm the bird for the initial transport period.

Large padded plywood sheets or baffle boards have been successfully used to guide adult cassowaries into smaller enclosures or crates for transport, however significant stress levels are observed in some cases. Handlers should be acutely aware that a stressed cassowary will resist this type of handling, and as such, should be prepared to endure a substantial blow to the baffle board at all times.

A nervous adult male was successfully transported from Rockhampton Zoological Gardens to Adelaide Zoo, and was boxed using the aforementioned method (Graeme Strachan *personal communication*).

Alternatively, if time permits, birds can be easily conditioned to voluntarily enter a crate or transport box in a similar manner to conditioning a bird to a holding pen or adjoining enclosure.

Atchison & Sumner (1991) state that a pair of cassowaries were moved to a new enclosure within the zoo (Taronga Zoo) by placing a box measuring 160cm x 50cm x 135cm high with sliding doors at each end in an access gate between their two yards. The birds were enticed (one at a time) by a favourite food item into the box until the birds' confidence with the box was gained and then the doors on either end dropped. Once boxed the birds were injected with 10mg of Valium through a gap at the top of the box and transported without event.

Hartley's Creek Crocodile Adventures (formerly Hartley's Creek Crocodile Farm and former cassowary rehabilitation facility) in North Queensland observed an uneventful transport of an adult male to Dreamworld on the Gold Coast (approximately 2000km away). This was made possible by conditioning the bird to voluntarily enter a box and offering mild sedation. The box was placed inside the enclosure and a hessian race constructed with a 90 degree corner; the race narrowing toward the box. The corner of the race was an advantage in that minor adjustments could be made to the box without the bird seeing. Over a period of three weeks, the bird was conditioned to feed closer and closer to the box, and eventually in the box.

Two injections were given by slightly raising the rear door, these were 1mL Azaperone as Stresnil to mildly sedate the bird, and 8mL vitamin E as E-Se (50mg/mL). The bird was released 5 hours later in good condition although it took approximately 1 week for the bird to resume its normal feeding habits.

A juvenile female was also safely transported from Hartley's Crocodile Adventures to Billabong Sanctuary (400km away) using this method. On the day of transport, the bird was waiting inside the transport box before the keepers arrived (Kirra Stout *personal communication*). The conditioning procedure took six days.

Two juveniles were uneventfully moved from Cairns Tropical Zoo to Taronga Zoo by physically restraining the birds using the techniques listed for birds under 6 months, administering mild sedation and carefully loading into individual boxes.

6.5 TRANSPORT REQUIREMENTS

6.5.1 Box design

IATA regulations do not seem appropriate due to the large box size which causes the bird to thrash around and injure itself, and the requirements for water containers which can easily cause injury to the bird (Romer 1997). However, such regulations must be observed during international transport.

Romer (1997) recommends a box constructed of structural ply, 900mm high, 650mm wide and 1200mm long. DERM utilizes a standard box for birds of all ages with slightly larger dimensions to this.

Transport boxes should be large enough to prevent cramping but not large enough to predispose the bird to injury through excessive movement and should be sturdy enough to prevent escape during transport. It should be slightly higher than the height of the bird and wide enough to allow the bird to sit comfortably. The box should have sliding doors at both ends and should be screwed in place for the journey. It should also be dark, while still providing adequate ventilation. The roof should be padded to prevent head and neck injuries, and the floor should be covered with a soft, non-slip, absorbent material providing adequate grip for the bird’s feet. Framing should be on the outside of the box and there should be no internal protrusions that could cause injury.

See Appendix 9.

6.5.1.1 Furnishings

It is recommended that the ceiling of the box be covered with soft bedding foam of 2-3 inches depth.

The floor of the box should be covered with non-slip matting, such as fine corrugated rubber matting, fake grass or clean straw/hay.

For transport inside Australia, food and water bowls should not be included in the design because of their capacity to injure birds during transport.

6.5.1.2 Water and food

For transport periods lasting fewer than 12 hours, it is suggested that birds travel with a few of their favourite food items, placed loosely on the floor of the box.

6.5.2 Transport

Special consideration should be placed on the means by which a bird is transported to ensure welfare of the bird and safety of the handler are not compromised.

For long distance travel, juvenile (over 12 weeks of age), sub-adult and adult birds should be transported individually.

During transport, the birds should be protected from excessive noise, exhaust gases, rain, wind, humidity and extremes of temperature.

Journeys should be as short as possible, and if travelling by road, bumpy roads should be avoided.

6.5.2.1 Release from box

See section 6.3.5

ANATOMY

7.1 INTRODUCTION

To date, few documents have been produced pertaining specifically to cassowary anatomy, and data that are collected are simply focused on identifying the cause of death of an individual, with little energy put into collecting valuable anatomical or physiological data for the species.

This chapter reviews the available literature on Southern Cassowary anatomy, and presents new data collected during the gross anatomical survey of two deceased specimens. Specimen A, a wild adult female of unknown age; and specimen B, a wild born, long-term captive adult male of unknown age. The right wing and leg of both specimens were disarticulated and examined. The thoracic ribs were removed and the thoraco-abdominal and cervical regions explored. Particular attention was paid to the muscular, skeletal and digestive systems because of their importance in clinical medicine and in the captive management of the species. Thorough analysis of the urogenital system is yet to be conducted. Comparisons are made with other ratite species. Notes of interest on the casque are also included. Where relevant, clinical applications are offered.

The purpose of this chapter is to provide species specific data and tips to veterinarians and those involved in captive cassowary management to allow familiarity with the anatomical structures of the Cassowary.

The author recognizes that i) although there is a basic typical design for each vertebrate class, or order, or family, no two animals, however closely related, have exactly the same conformation in the minute structure of all organ systems (Berger 1956); and ii) although sporadic dissections are useful for identifying unique anatomical features, the physiological mechanisms of regulation cannot be easily detected (Hildebrandt *et al*. 2000) by this method alone.

7.2 METHODS

Specimen A was obtained through the Department of Environment and Resource Management (DERM) in conjunction with Windfall Productions (BBC). The specimen was struck by a vehicle in Bramston Beach during the 2010 natural breeding season and sustained a compound fracture to the left tarsometatarsus and a ruptured liver. She was euthanized due to irreparable injuries – her body kept in cold storage for five months prior to the dissection. The dissection was led by Dr Lauridsen, and was intended for the television production “Inside Nature’s Giants”. This cursory examination was conducted over the course of a day and was limited to areas of interest to the production crew.

Specimen B was a founder to the current Australasian Species Management Program (ASMP). Obtained from the wild in 1994 and held in captivity at Cairns Tropical Zoo since then. The bird was presented with lethargy and inappetance, with a concentrated urate component in several stools. Rapid deterioration lead to acute death. Post mortem examination was conducted within two hours of death. Examination of the carcass ensued over a number of months.

The right wing of both specimens was disarticulated at the scapula. Musculature and fat layering were examined. The right leg of both specimens was disarticulated at the synsacrum. Major musculature and circulatory instruments with the potential for use in everyday clinical management were examined. Musculature and fat layering were observed over the remainder of the body. Identifiable organs were examined. The gastrointestinal tract of Specimen B was removed intact for examination. The proctodeum and related urogenital structures were not examined, nor were the synsacrum and pygostyle.

7.3 RESULTS AND DISCUSSION

7.3.1 General

Female cassowaries can grow to around 1.7 metres in height and can reach up to 70kg in weight. Generally males are smaller and feathers at the rear of the body are longer and hang lower than in the female (Bentrupperbäumer 1998). Skin colouration at the intersection of the breast and neck extends further along the body in females than in males (Graham Lauridsen *personal communication*) however is not visible without parting feathers. The possession of a phallus which is visible during defaecation (Bentrupperbäumer 1998) also offers a means to positively identify males.

7.3.2 Head

The fused premaxillae are large and houses a large right and left nasal apertures and septum. The lower mandibles are also fused and terminate almost directly beneath the termination of the premaxillae. The elongated nares are located rostrally within the premaxillae and are surrounded by delicate black skin which extends caudally over the nasal passage. Integument covering the infraorbital sinus differs in colour and patterning between birds and can be used by keepers to identify individual birds.

The bill is laterally compressed with the culmen curving downward towards the tip (Rothschild 1900).

Large eyes sit directly above the rictus, are slightly forward-facing and are protected somewhat from small particles falling from above by modified feathers analogous to mammalian eyebrows. The large tympanic cavities to the ears are located caudally to the rictus and are filled with fine modified feathers, which possibly also serve some protective function against small foreign bodies.

7.3.3 Integument

Adult birds are covered in coarse, glossy black plumage, each feather (Figure 7.1) comprised of a double rachis and appearing more like hair than common feathers due to the lack of barbules to stabilize the filaments attached to the central rachis (Fowler 1991).

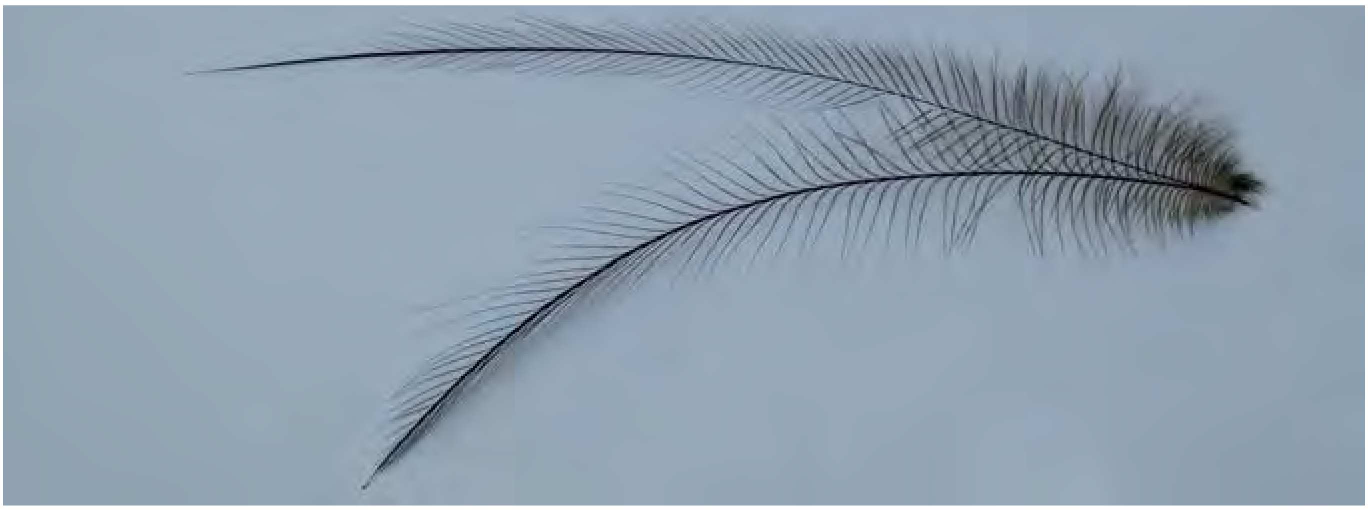


Figure 7.1 - Feather comprised of double rachis, lacking barbules.

Chick and juvenile feathers also have a double rachis. The plumage has high insulating properties but also readily holds beaded water, which can assist in cooling. Leg feathering terminates proximal to the tibiotarsal-tarsometatarsal joint. Sparse, very fine feathering is observed on the head and neck, around the ear patch, nape, eyes and wattles.

The cassowary's old feathers are soon shed after being pushed up from the skin; the loss of old feathers is a gradual one over the whole body of the bird; and there is no great subcuteaneous development of the new feather prior to its pushing out the old (Rand 1950). In captivity, moult roughly corresponds with the non-breeding season and appears to vary in intensity each year. It occurs patchily over the body and is augmented by higher than usual levels of preening.

Figure 7.2 – Medial aspect of right wing tip showing modified wing feathering & reptilian claw (attached to fused remnant phalanges).

Projecting from the radius of each wing are 5-6 modified feathers, each with a large black single-shafted rachis which, when fully grown, generally lacks barbs and barbules. A claw is attached to the second digit of each wing Heilmann in: Fisher 1940) (Figure 7.2). Like all feathers, these are comprised of keratin and are also subject to wear. These shafts may serve a protective function when birds move through dense thorny vegetation – able to hold tendrils away from the body – which becomes apparent upon inspection of damaged and broken shafts of live and deceased birds.

Apteria found along the lateral body wall in the ostrich are lacking in the cassowary.

Skin over the legs and body is thick and greyish white with flecks of orange and blue. On the neck, upper back and breast, skin is brightly coloured, highly vascularised and soft. The caudal aspect of the neck and the dorso-cranial and cranio-lateral regions of the body are covered in furrows and ridges. Skin on the head, neck, and upper body varies in colour to include white, blue, purple, pink, red and orange. Coloured skin is also seen on the rump. In some birds, the coloured skin parts become more vivid or intense under excitement or emotional stress (Davis 1935), and observations of individuals in numerous captive institutions confirms this change in the cassowary.

The two wattles of the cassowary do not appear to be an organ of sexual dimorphism, and vary greatly in size and colour between and amongst sexes. Colours range from blue at the proximal intersection on the neck, to orange, pink or violet distally. A bird with three wattles has been observed in Queensland (Graham Lauridsen *personal communication*).

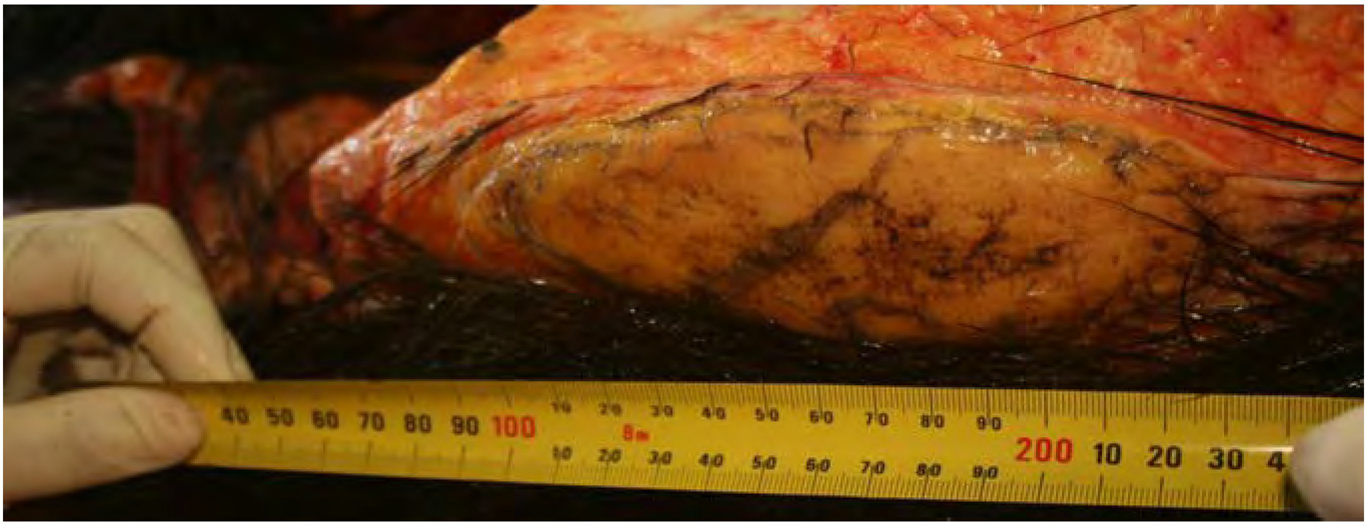


Figure 7.3 - Sternal callosity, ventral aspect.

A beige sternal callosity in the shape of an inverted teardrop exists where the sternum of a recumbent adult bird contacts the ground (Figure 7.3). The callosity observed on Specimen A measured approximately 150 x 65mm, and 140 x 61mm on Specimen B. The callosities appear to be keratinized and layered in thick flakes. Unlike the ostrich, cassowaries lack a ventral callosity.

Figure 7.4 - Right tarsometatarsus, dorsal aspect showing reticula and overlapping scutes.

Figure 7.5 - Right tarsometatarsus, plantar aspect showing sharp scutella.

Thick scales and tendons on the plantar aspect of the hock joint allow cassowaries to remain fully sternally recumbent or poised on the tarsometatarsus for long periods.

Scales are present on the legs and feet only, and begin proximal to the hock joint on both legs, roughly in line with the termination of leg feathering. Scutes extend along the dorasal surface of the tarsometatarsus (Figure 7.4) from the distal aspect and terminate at the proximal end of the first phalange on each digit. Additional scutes extend from mid-proximal first phalange along the dorsal surface of the digits. All scutes are slightly overlapping. Scutella cover the posterior aspect of the tarsometatarsus (Figure 7.5) apart from the hock. Scutella capable of inflicting damage to handlers and should be handled cautiously.

Figure 7.6 (top) - Right tarsometatarsus (integument partially removed), medial aspect. White line marks Tendo m. gastroc. Cnemial crest on the medial proximal aspect of the tibiotarsus circled. Arrows show possible movement of tendon over crest – Left (dorsal) lifts foot, Right (plantar) drops foot.

(bottom) - Right tarsometatarsus, medial aspect externally visualising medial metatarsal vein (black). White marks location of Tendo m. gastroc.

7.3.4 Musculo-skeletal System

Belonging to the family Ratitae, cassowaries are grouped based on the shape of their raft-like sternum which lacks a prominent keel for the attachment of significant flight muscles. The sternum is roughly concave dorsally and convex ventrally (Fowler 1991). A layer of fat conceals the breast muscles which are significantly reduced, consisting of rudimentary pectoralis and suracoracoideus muscles. The coracoids and scapula bones are fused, however these were not observed to be additionally fused to the sternum in either of the examined specimens, as is the case in the ostrich (Fowler 1991). Despite this non-fusion, the level of moveability is minimal. Cartilaginous extensions of the sternum, ventral to the attachment of the coracoids-scapula found in the ostrich are also present in the Cassowary.

Rib bones are pneumatized, containing fine trabecular bone.

Similarly to ostriches and emus, muscles in the ventral midline area of the abdomen are minimal and consist largely of the aponeuroses of the abdominal muscles. In both specimens, the muscles were covered by a thin layer of fat.

The wings of cassowaries are vestigial and rudimentary. Muscles in the wings are heavily reduced and the fat:muscle ratio appears to be around 70:30. One downward curving claw, analogous to a middle phalange reptilian claw exists at the wing tip, attached to fused remnant phalanges (Figure 7.2).

The loss of flight is substituted with the ability to swiftly move through the forest at speed. Abourachid & Renous (2000) conclude that the posterior position of the hip in comparison to other ratites allows greater rocking of the trunk which can be useful in the closed environment of the rainforest. Leg muscles, particularly the iliotibialis, gastrocnemius and fibularis muscle groups are enormous and are suitable sites for intra-muscular injection. Muscles around the tarsometatarsus are greatly reduced and comprised principally of long flattened tendons and the aponeuroses of the extensor, abductor and flexor muscles.

A cnemial crest on the medial proximal aspect of the tibiotarsus (Tuberositas m. fib. brevis?) inserts on a tendon (Tendo m. gastroc.?) attached to the distal tarsometatarsus. The flicking action of this tendon either to the anterior or posterior aspect of the crest (Figure 7.6) coupled with flexion or extension of the enormous muscles associated with the tibiotarsus and femur, facilitates the formidable barging and kicking ability of cassowaries.

No patella was observed in either of specimens.

Figure 7.7 - Right foot, dorsal aspect showing overlapping scutes and medial claw.

Cassowary feet are tridactylie, the legs terminating in three digits – digits two, three, and four, all of which have claws (Cho *et al*. 1984) (Figure 7.7). The medial claw is a spike, up to 15cm long, evolved for defence (Fowler 1991) and when coupled with the immense kicking strength, is capable of inflicting serious damage such as lacerations, puncture wounds and ruptures of internal organs (Kofron 1999).

In both specimens, a fat layer extended over the muscles of the back, and was between 0.5-3 inches thick, tapering cranially, caudally and laterally with the thickest area covering the dorsal-most region behind the thighs. The thinner areas of fat under which epaxial musculature exists are an additional recommended site for intra-muscular injection.

Natural seasonal variation in body condition is observed in adult birds, and varies significantly between individuals. Breast muscles are reduced to mere rudiments however significant fatty deposits are usually located in this area. As such, the area can still be palpated to determine the general condition of the bird. Cassowaries lack a prominent keel, so it may be difficult to make an assessment unless the handling personnel are familiar with normal cassowary anatomy.

Fat loss and muscle deterioration over the back and rump can be visually identified using the body scoring system (Appendix 10), without having to palpate the bird. The scoring system is intended to provide a more consistent means of evaluating a bird's body condition and, through regular evaluation, will allow personnel to identify what is normal body condition for an individual bird throughout the year. Score will vary between individuals and season – it is subjective determination to be evaluated in the context of the time of year and the overall health of the bird – if an increase in weight does not correspond with an increase in back score, consider behavioural observations to determine whether or not there is a health problem (Brown & King 2005).

Procedures lasting more than one hour in ostriches held in lateral recumbency have resulted in peroneal nerve paralysis however cassowaries can lie sternally recumbent for long periods, and it appears that symptoms caused by extended periods of lateral recumbency are less pronounced (Graham Lauridsen *personal communication*).

7.3.5 Respiratory System

The nasal cavity is divided into the left and right septum, which communicates with the oropharynx via the choana, located in the roof of the upper rostrum, ventral to the nares. The location of the infraorbital sinus is visible externally, rostro-ventrally to the eye, and is particularly visible if either of the nares or septum are congested.

The laryngeal mound projects into the floor of the oropharynx. Paired cartilages surround and protect the slit-like opening of the glottis, which is closed during the swallowing of food and water.

The trachea is comprised of dorso-ventrally flattened, complete cartilaginous rings, and accompanies the esophagus through the cervical region. Bifurcation takes place deep within the thoracic viscera. The tympanum starts approximately two inches cranial to the tracheal bifurcation, and is comprised of more circular-rigid cartilaginous rings than the trachea proper. The pessulus is located at the bifurcation. The right and left tympaniform membranes are located within their respective bronchi and are enclosed by a series of complete and incomplete cartilaginous rings. The primary bronchi are also comprised of both complete and incomplete rings. The longitudinal cleft in the trachea of the emu responsible for the booming sound is absent in the cassowary.

Contrary to what was observed in other ratites by Heard (1997), air sacs are extensive in the cassowary (Graham Lauridsen *personal communication*). They are comprised of a very thin, markedly expansible material (Smallwood 2010), and although generally deflated, extend into the cervical, thoracic, clavicular and cranial thoracic regions, and further extend into the rib bones. The distinct visceral outlines created by the airsacs in the radiographs of psittacines are not present in ratites (Stewart in: Ritchie *et al*. 1994). The motion of expansion and compression of the air sacs can be seen in live Cassowaries prior to and upon initiation of the distinct booming vocalization.

The lungs are small in relation to body size and confined to the deepest cranio-dorsal aspect of the thoraco-abdominal cavity, embedded ventral to the notarium and next to the thoracic ribs. The respiratory rate of a resting adult Cassowary in mild ambient temperature varies from 10-18 breaths per minute. Respiratory rate can be monitored visually in some birds through observation of chest movement or subtle motion of skin covering the infraorbital sinus.

7.3.6 Circulatory System

The heart is located cranial to the liver in the thoraco-abdominal cavity. Inspection of Specimen B revealed that the right jugular vein is not significantly larger than the left as is seen in most avian

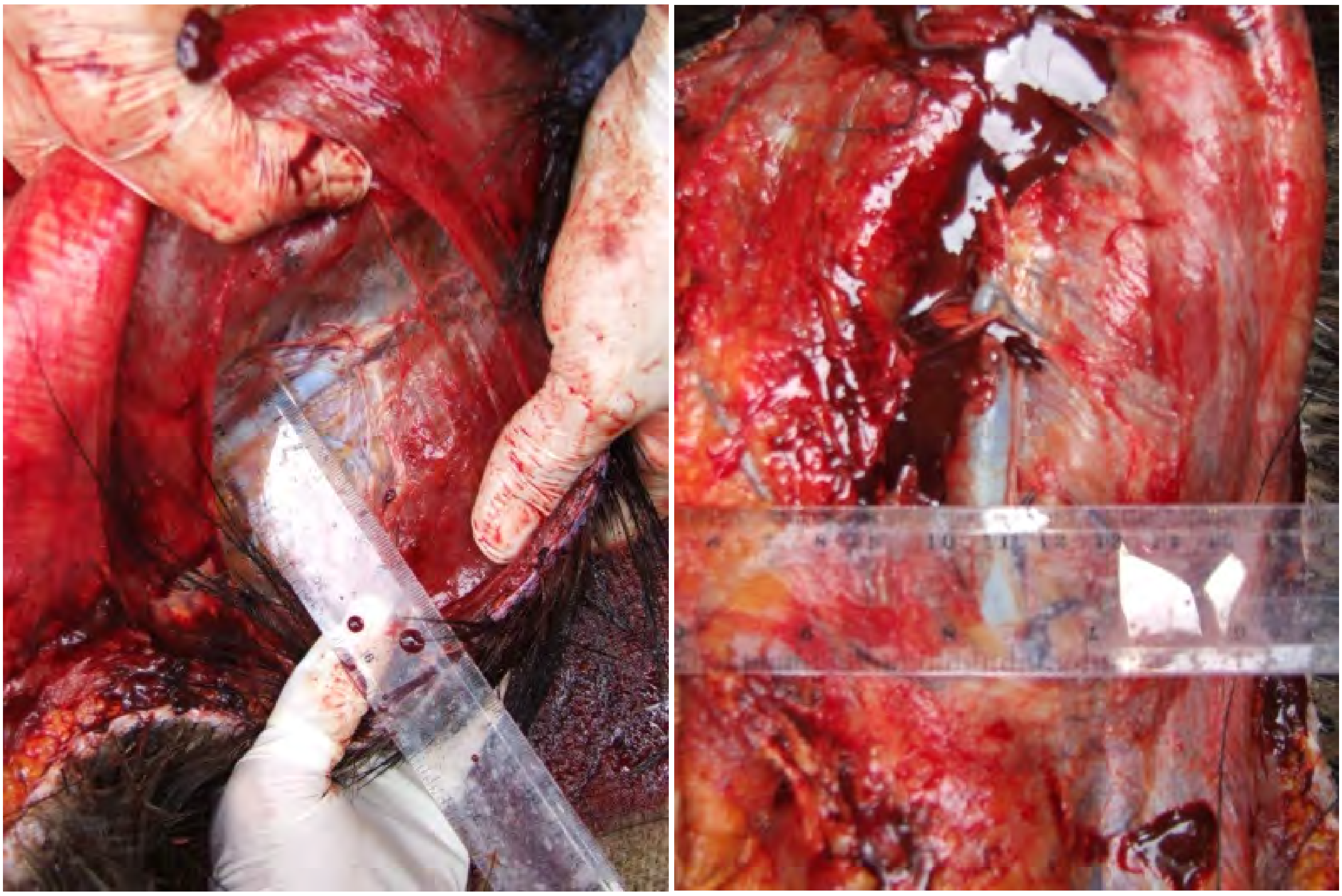


Figure 7.8 - Left and right jugular veins.

species (Figure 7.8). When located, either vein may be useful as a primary site for blood collection and intravenous injection. Extreme caution must be exercised when using the jugular for these purposes as any abrupt movement by an inadequately immobilized bird will increase the risk of laceration, haematoma formation and even fatality. Prior to the death of Specimen B, blood was collected from the right jugular, and good haemostasis was achieved with pressure applied for one minute, however up to two minutes may be required. The resting heart rate is difficult to detect visually, but can occasionally be observed by monitoring the movement of feathering above the sternum while the bird is standing.

Figure 7.9 - Right wing (integument removed), medial aspect showing brachial vein.

The brachial vein was not easily identified in either specimen (Figure 7.9), as it is in other ratites (Fowler in: Tully & Shane 1996) however it has been used successfully to collect a sufficient quantity of blood to run full biochemistry panel from birds presenting the wing for a voluntary blood draw (Cindy Pinger *personal communication*). The medial metatarsal vein is accessible only in the sedated or immobilized bird (Fowler in: Tully & Shane 1996) and although this is a preferred site for blood collection by some veterinarians, a higher pain response is observed in this area compared with the jugular vein (Graham Lauridsen *personal communication*).

Figure 7.10 - Right tarsometatarsus, medial aspect showing location of medial metatarsal vein at boundary of large reticula on dorsal aspect of tarsometatarsus and smaller reticula on medial aspect.

The medial metatarsal vein is located on the medial aspect of the tarsometatarsus (Figure 7.10), in a furrow formed by the dorso-medial aspect of the same bone, and the tendon inserting on the cnemial crest of the tibiotarsus. The vein does not protrude externally due to the thick scaling, however it is generally marked by the boundary of large reticula on the dorsal aspect of the tarsometatarsus and the immediate change to significantly smaller reticula on the medial aspect of the same bone.

Fowler in: Tully & Shane (1996) advise that the shape and location of the spleen is important for evaluating radiographs, at surgery, and at necropsy. Although some variation can be expected, generally the cassowary spleen is flattened and shaped like an irregular polygon (Cho *et al*. 1984). The spleen was not positively identified in either of the dissected specimens.

Fowler (1991) speculated that the renal portal system might affect the concentration of nephrotoxic drugs reaching the kidneys if administered in the leg muscles suggesting that drugs that are typically excreted via the kidney tubules may be expelled before reaching the general circulation, precluding the calculated effect. Stewart (in: Ritchie *et. al* 1994) however, found that in Ostrich, drug concentrations observed in the blood remained the same regardless of the injection site.

7.3.7 Digestive System

The oropharynx is large and allows birds to consume sizeable food items without manipulation. The tomia of the mandibles and maxillae are characterized by fine serrations beginning beneath the nares and terminating at the rounded tip. The tongue is compressed laterally, has a serrated edge and rests on the ventral aspect at the rear of the oropharynx.

The large oesophagus (Duke 1997) transverses the right side of the neck and is comprised of a thin elastic membrane of delicate longitudinal muscles. It is highly moveable and has a markedly expansible diameter (Fowler 1991; *personal observation*). The oesophagus enters the proventriculus prior to reaching the thoracic cavity. It is imperative that personnel attempting to gavage feed an ailing cassowary is aware of the delicate nature of this structure to prevent injury.

The proventriculus is a spindle-shaped swelling surrounding the central lumen of the digestive tract (Cho *et al*. 1984; Fowler 1991). The crop is absent (Sales 2002; Angel 1996), however the thin-walled expanded proventriculus appears to serve a storage function (Cooper & Mahroze 2004). The size and shape of the food items consumed can be noted even when the proventriculus remains intact. Fowler (in: Tully & Shane 1996) noted that the glandular area responsible for the secretion of digestive enzymes in the cassowary proventriculus extends over the dorsal and ventral internal aspects, and this was confirmed upon inspection of Specimen B. Very little demarcation of food is observed in this area.

The Cassowary ventriculus is not a heavily muscular organ and lacks the keratin-like lining (Griner in: Cho *et al*. 1984) found in emu's. It is comprised of a thin muscle (1.5cm +/- 0.5cm) surrounding another membrane responsible for further excretion of digestive enzymes. The ventriculus in both specimens was more muscular than the proventriculus, contrary to what was found by Stewart (in: Ritchie *et al*. 1994). The ventriculus in Specimen B was less muscular compared with that of Specimen A, probably owing to the composition of a long term captive diet of commercially available fruit, which are generally softer and contain less fibre than what is found in the native diet.

In contrast to the emu (Figure 7.11), the diameter of the small intestine is large (>6cm), likely an adaptation to the large food items consumed, and is significantly shorter than in the ostrich.

The caeca are paired in ratites, and are vestigial and non-functional in cassowaries (Fowler 1991).

The large intestine is relatively short in comparison to the emu and offers a rapid gastrointestinal transit time of food consumed. Due to their diet composition, significant intestinal length is not required in the cassowary (Cho *et al*. 1984).

The asymmetrical bi-lobed liver is located cranial to the ventriculus and ventral to the heart.

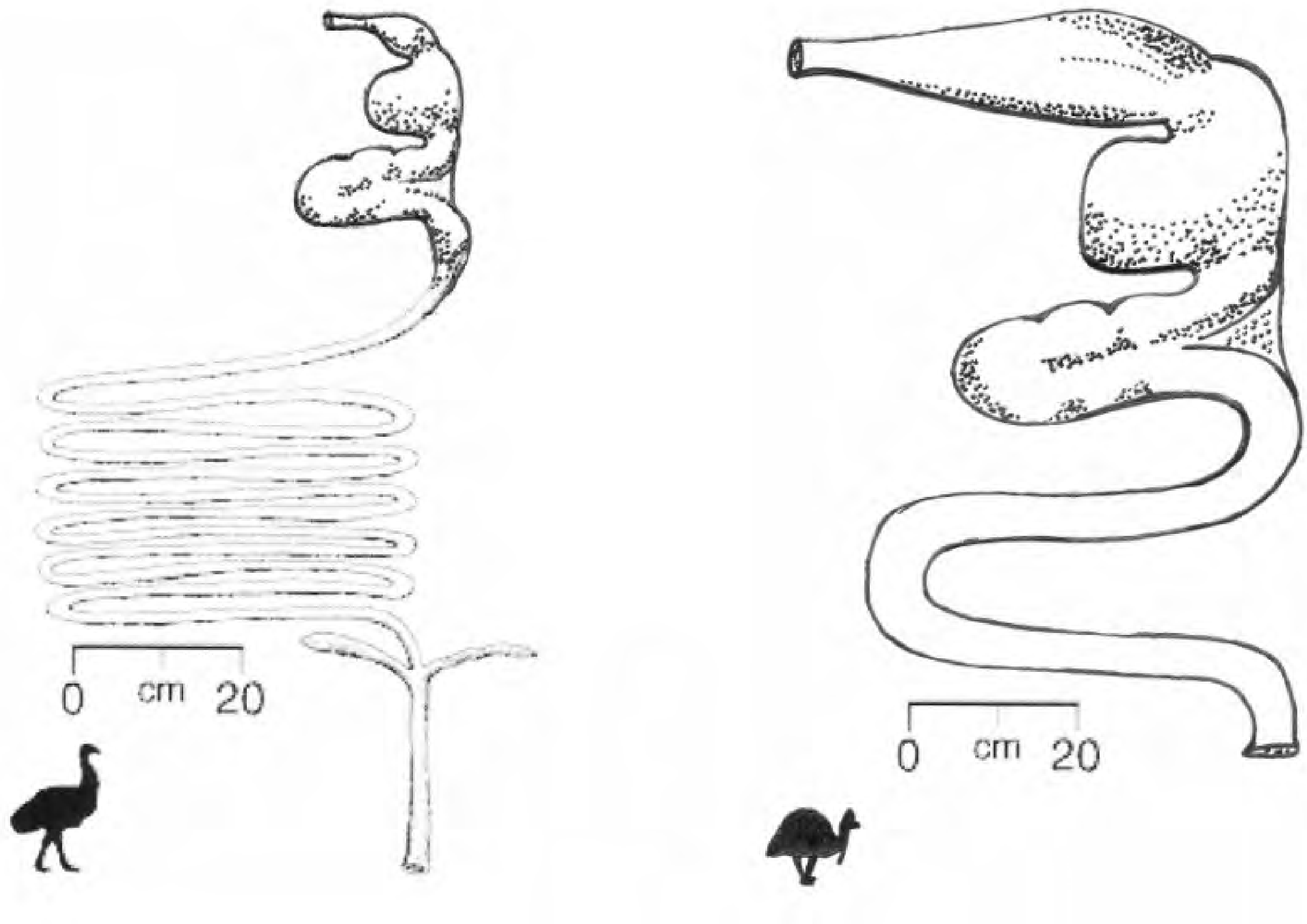


Figure 7.11 - (left) Emu digestive arrangement Source: Stevens & Hume (1995). (right) Cassowary digestive arrangement.

The arrangement of the digestive organs is similar to other ratites, although the organ dimensions are distinctly different.

7.3.8 Reproductive System

All female ratites have a single left ovary and oviduct (Stewart in: Ritchie *et al*. 1994; Fowler in: Tully & Shane 1996). An active cluster of ova and follicles were examined in Specimen A. Ova varied in diameter from 0.5-6cm, and it was evident that at least two had been released into the oviduct for oviposition prior to death.

Paired testes are tan in the cassowary and enlarge during the breeding season (Graham Lauridsen *personal communication*). They are located intra-abdominally, ventral to the kidneys. The left testicle of Specimen B was six times the size of the right (L = 0.06kg; R = 0.01kg). Further studies will confirm whether or not this is the norm.

Male cassowaries have an intromittent organ referred to as a phallus which contains a cavity that serves to transport semen from the ejaculatory ducts in the cloaca of the male to the cloaca of the female. The erect phallus is short, curved slightly to the left and tapers toward the end. It is contained by a partially inverted sleeve that everts during erection, and an attachment at the base of the blind pouch prevents full eversion (Fowler in: Tully & Shane 1996).

7.3.8.1 Sexing Methods

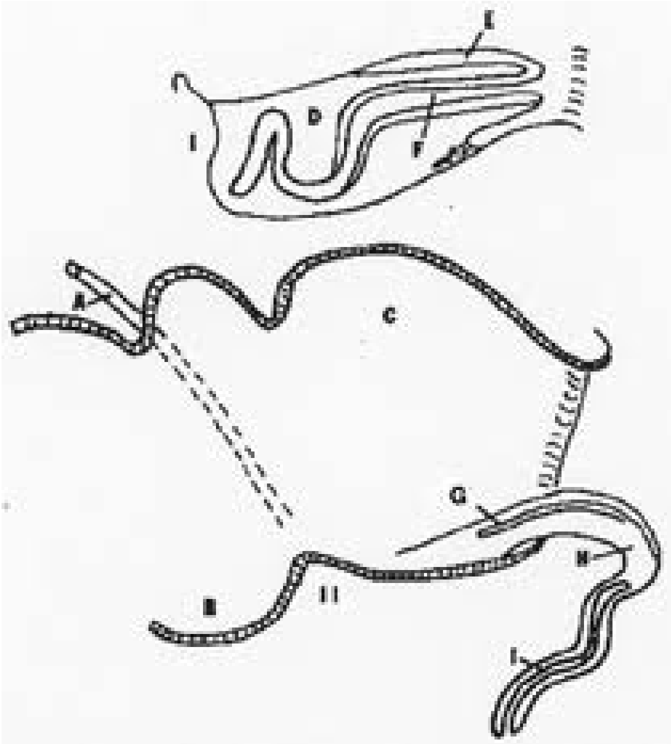


Figure 7.12 - Diagram of left lateral view of a retracted and erect phallus of a male emu or rhea. Note: The top drawing represents the phallus within the Pouch. A vas deferens, B. urodeum, C. proctodeum, D. pocket to contain phallus, E. erectile wall of phallus, F. inverted hollow tube of phallus, G. phallic sulcus, H, erectile tissue, and I. erect phallus with blind hollow tube. (Source : Fowler in Tully & Shane 1996).

The lack of any distinct external sexual dimorphic characteristics makes positive sex determination in cassowaries difficult without cloacal examination (Bentrupperbäumer 1998). Also see section 7.3.1. Ratites of both genders possess a genital prominence projecting from the ventral aspect of the proctodeum (Fowler in: Tully & Shane 1996; Stewart in: Ritchie et al 1994). Palpation of the prominence will reveal the gender of sub adult and adult cassowaries (Figure 7.12).

7.3.9 The Casque

It has been described as bony, and horny, externally comprising a hoof-like material (Richardson 1991) or keratinous skin (Crome & Moore 1988a), or a horn-covered bony growth (Cho *et al*. 1984), similar to the 'tortoise shell' as found in the epidermal scales of the marine turtle (Richardson, 1991). Richardson's (1991) study on the skull of a single male cassowary, found that upon maceration, the external sheath fell away from its core revealing that the horny sheath had a hard outer layer covering, and a thick inner layer.

Immediately beneath the sheath Richardson (1991) found a distinct core of sculpted calcified material which had an external flattened thick layer surrounding an inner dense network of what appeared to be fine trabecular bone. The calcified material of the museum specimen studied was thought to possibly be bone, however, reports that in live specimens and specimens that have recently died, the casque is malleable, suggests otherwise.

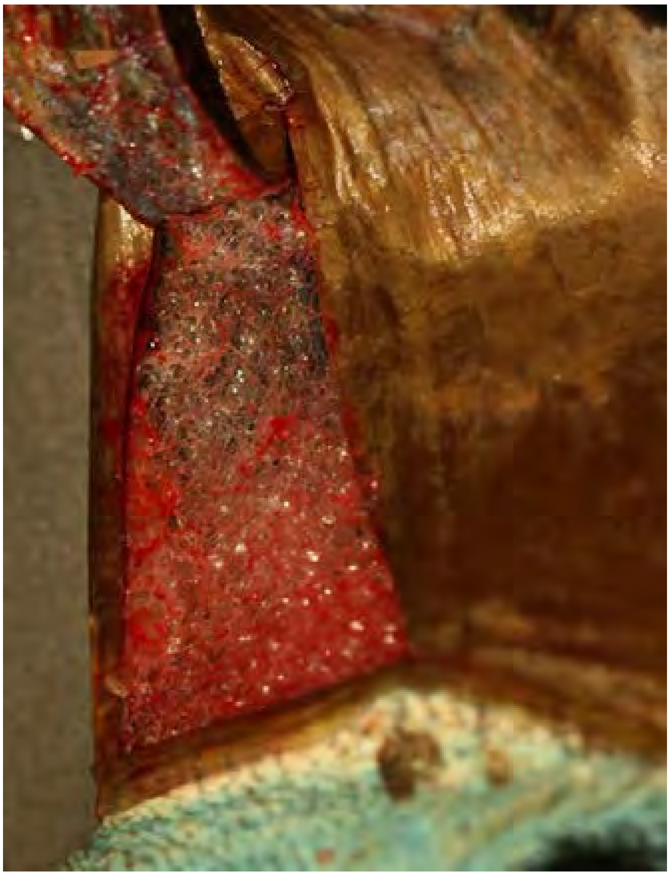


Figure 7.13 - Casque, right lateral aspect. Keratinous outer layers lifted to reveal inner material.

Figure 7.14 - Casque, internal.

The casques of both specimens were closely examined. Lateral palpation revealed high malleability, although rostro-caudal palpation proved far less supple. Initially, a lateral section of the outer layers was completely removed (Figure 7.13). The outer casque was found to contain two layers – the outermost- a thin, keratinous, slightly opaque film which easily fell away from the inner layer. The inner layer was equally thin, although comprised of a material which was more dense and non-translucent. Similarly to what was found by Richardson (1991), a distinct core network of what appeared to be very delicate, tenuous, almost translucent structures, comparable in appearance to trabecular bone (although not identical to trabecular bone) was uncovered (Figure 7.14). This structure lost density towards the crown. The upper reaches of the material were soft, and graduated to a more rigid structure of the same material rostrally and closer to the cranium. The whole network appeared to be very lightly coated with blood. Two apertures were identified entering the cranium from the casque, appearing to be in line with the nares, however injection of dyes did not reveal any direct association. Further examination of the casque and other cephalic structures (i.e. brain, ear bones) through radiography and histological analysis may provide clues as to the operational means and true purpose of the casque.

The function of the casque is unknown, however observations from recent decades of the casques of recently dead specimens and surveillance of wild and captive birds suggests that two hypotheses from the literature are out of date. Cho *et al*. (1984) suggested that the casque was an effective weapon against enemies, however no hard evidence to support this as fact has ever been witnessed, and the structure of the appendage indicates otherwise; and, to part leaf litter and other material from the forest floor when foraging - which has also never been observed.

Some more likely functions include: protection as the bird moves through thick vegetation (Crome & Moore 1988a; Fowler 1991; Kofron 1999), that it possibly serves a secondary sexual function (Crome & Moore 1988; Graham Lauridsen *personal communication*), or that it might play some role in sound reception or acoustic communication (Mack & Jones 2003). When preening some parts of the body (namely the upper back and lateral body regions), the casque contacts the feathers in these areas, suggesting that keratinous flakes may play a minor role analogous to feather dust or uropygial secretions in other birds.

7.3.10 Concluding Remarks

The death of a cassowary, although tragic, provides us with a unique opportunity to collect and build a robust species specific database of anatomical and physiological records.

Ignoring such opportunities thus far in the captive context has meant that very little information about this iconic endangered species is available, putting the captive industry and indeed the management of the species in a poor position to improve their stagnating situation.

Thorough data collection will add to the body of knowledge that can be applied to the species as a whole, as opposed to representing a picture of an individual specimen. It will also eliminate the current need to rely on data obtained from similar species. New data, as shown with other species, will assist with the captive management of, and disease prevention in, other cassowaries.

A post mortem evaluation schedule has been formulated to facilitate consistent and meaningful data collection (Appendix 3).

7.4 FUTURE DIRECTIVES AND AVENUES OF RESEARCH

- Infrasound – casque – neuro-physiological evaluation,
- Smell – olfactory bulb
- Vision – ultraviolet detection.

BEHAVIOUR

While many incidental observations of cassowary behaviour have been documented (Crome 1976; Crome & Moore 1990; Fisher 1968; Hindwood 1963; Frizelle in: White 1913; Kofron 1999; Latch 2007; Lavery *et al*. 1968; Macgillivray 1917; Mack & Jones 2003; Westcott *et al*. 2005; Westcott *et al*. 2008; Worrell *et al*. 1975), systematic analyses of free living populations (aside from Bentrupperbäumer 1998) have not taken place. Behavioural studies of captive birds are also scarce, and those that do exist are largely based on case studies of individuals or pairs. Consequently, much of the information that we have historically accepted as fact, may in fact be subjective.

To confront this, the behaviours of wild and captive birds are offered here. A number of behaviours that have been recorded in captivity and not in the wild have also been included and are open to interpretation as to whether or not they are abnormal behaviours, or whether they have merely not been observed in wild birds. Stereotypic behaviours are also incorporated.

Suggested Readings

- Bentrupperbäumer, Joan (1997) *Reciprocal ecosystem impact and behavioural interactions between cassowaries, Casuarius casuarius, and humans, homo sapiens: exploring the natural-human environment interface and its implications for endangered species recovery in north Queensland, Australia.* PhD thesis, James Cook University.

  Available for download at http://eprints.jcu.edu.au/9389/

8.1 SOCIAL ORGANIZATION

In a wild study site, Bentrupperbäumer (1998) found an average density of 2.5 birds per km² for breeding adults. Direct observation revealed mean female home ranges in this particular study site was 0.86km²; and male home ranges in the same study site were slightly smaller at 0.65km². Home ranges between sexes overlapped extensively (90-100%), and while same sex home ranges did overlap, shared areas were minimal Bentrupperbäumer (1998). Female home-range sizes were on average 31.9% larger than males.

8.2 COMMUNICATION

8.2.1 Vocalizations

Bentrupperbäumer (1998) noted that the use of auditory signals, while not overly frequent, appeared to be an important mechanism for communication between individuals, serving to attract receptive partners, act as agonistic signals directed at neighbours or intruders, and appease and inform offspring. See Appendix 11 for the cassowary vocal repertoire, mentioned throughout this section.

8.3 ACTIVITY AND MAINTENANCE

8.3.1 Preening

Apart from being a standard plumage maintenance activity, preening is also linked with agonistic behaviour, and displacement behaviours, outlined later in the chapter.

8.3.2 Foraging

See Chapter 9.

8.3.3 Bathing

Wild birds appear to enjoy bathing (Macgillivray 1917; Alexander 1926), and given the opportunity, captive birds will bathe throughout the year.

8.3.4 Time budget wild vs captive

In a study on wild birds conducted by Bentrupperbäumer (1998), data was obtained from a number of cassowaries in one study site, revealing activities demonstrated by birds between 0700 and 1800. Roughly 20% was spent travelling, 35% foraging, 35% resting, 7% preening, and the remaining 3% were classified as miscellaneous activities. Bentrupperbäumer (1998) noted that activity patterns varied according to the time of day, and that foraging activities peaked in the morning (0800-0900) and late afternoon (1700-1800), and was the predominant activity throughout the day.

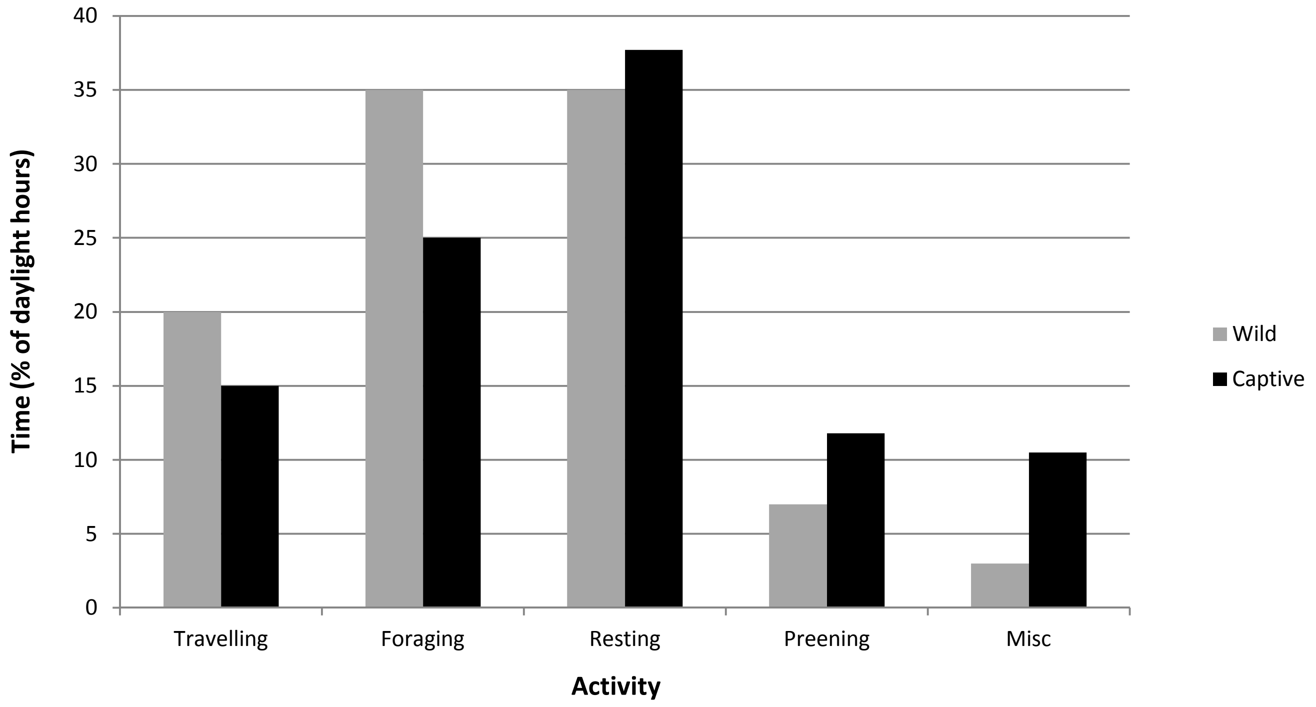


Figure 8.1 - Time budget comparison for wild and captive cassowaries.

Time budgets of 11 captive birds were captured from memory by a number of institutions, and appear to vary widely between individuals and institutions throughout the year. On average, captive birds spend 5% less time travelling, 10% less foraging, 2.5% more time resting, 5% more preening, and 8% more miscellaneous activities than wild birds. In Australia and North America, most institutions observe an increase in activity out of breeding season, with more time spent travelling and foraging. Conversely to this, during the breeding season (respective winters), an increase in resting behaviour is observed, particularly from the female (Kirra Stout *personal communication*, *personal observation*). Cooler climates may also affect activity levels throughout the year.

Figure 8.1 shows a time budget comparison for wild and captive cassowaries. For captive birds, less time spent travelling and foraging tends to suggest that the distances required to travel in order to obtain food are less in captivity, and also that because food is generally offered in bulk, foraging time is reduced.

It is widely accepted that the physical fitness of captive animals is generally lower than that of their wild counterparts, so longer rest periods might be expected.

Bentrupperbäumer (1998) found that in a normal 10 hour day, cassowaries in her study site travelled on average 3.8km.

8.4 SOCIAL BEHAVIOUR

Patterns of organisation and behaviour in cassowaries are complex (Bentrupperbäumer 1998; Marchant & Higgins 1990).

8.4.1 Agonistic (associated with conflict)

Conflict is a fundamental component of a territorial species behavioural repertoire. Agonistic behaviours of wild birds are described, followed by those observed in captive birds. These are interpreted with subjective comments.

In captivity, a typical agonistic display will be initiated by one bird, and may be directed at a conspecific, a human, an animal or other item. Displays usually contain one or a number of behaviours, in a complex sequence.

8.4.1.1 'boom'

The boom vocalization is typically associated with passive agonistic behaviour, either to signify territory, impending attack, or merely presence, and is usually the first behaviour in a typical sequence. A boom does not necessarily indicate an impending physical interaction. More often than not, the boom is followed by 'preening' before the bird resumes its pre-display activity.

8.4.1.2 'throat inflation/deflation' – see 'caution'

In some displays, a bird may inflate and deflate the cranial half of the proximal aspect of the throat. This is typically deemed a reaction to a passive agonistic encounter, and is observed when a perceived threat approaches (as in the case of a human approaching a male with chicks).

8.4.1.3 'Stretch Display'

During the stretch display, birds will extend their head upward, giving the appearance of a much greater threat. Birds generally approach slowly with one eye on the annoyance, switching eyes, and appearing to approach almost sideways keeping the annoyance in their mid-peripheral vision. Rump feathers may or may not be raised in this display. Cheeks may or may not be distended during this display.

8.4.1.4 'Preening'

Short bouts of vigorous preening have been linked to agonistic displays as it usually occurs during an agonistic interaction. It is rarely observed as the initial behaviour displayed in an agonistic reaction, but rather it follows any of the other behaviours displayed. Feathers around the legs, rump and back are most often preened.

8.4.1.5 'Cheek distension'

Cheek distension – is observed during some agonistic interactions and is usually accompanied by the '*stretch display*'. It may be an indicator that a '*charge*' or other physical interaction such as a '*peck*' may be about to take place. Not all '*charges*' begin with cheek distension.

8.4.1.6 'Raised rump feathers/protruding wing feather quills'

Before and during a charge, rump feathers are raised, further exaggerating the size of the bird. Wing feather quills may or may not be protruded during the charge.

8.4.1.7 'Charge'

The charge is a rapid approach by the bird toward an annoyance. Usually all vertebrae are horizontal, including the cervical vertebrae, and the head is forward facing. The charge may or may not be accompanied by a raspy hissing sound, and usually terminates in contacting either an object (i.e. a fence) or the annoyance. Contact is made with the chest, and quite often with the feet.

8.4.1.8 'Bluff'

The bluff is as per the '*charge*' however does not terminate in contact with the annoyance. Rather the bird stalls in an upright position, just shy of the annoyance. This may happen several times if the annoyance is moving.

8.4.1.9 'tentative stepping'

Tentative stepping, whereby a bird may either step back and forth on each foot but not make any ground, is observed when the bird appears unsure of the annoyance. This is usually accompanied by '*throat inflation/deflation*' and often precedes a '*charge*' or '*bluff*'.

8.4.1.10 'Peck'

In an agonistic interaction is usually an abrupt attempt to grasp and release a part of the annoyance. It is generally associated with minor physical interactions with smaller animate objects such as hands, insects etc.

8.4.1.11 Observed sequences

After identifying an annoyance, generally an active interaction display will start with a '*boom'*. This may be followed either by rapid '*preening*', or if the annoyance is within close proximity, the '*stretch display*', which is usually accompanied by '*cheek distension*' and followed by either '*tentative stepping*' and/or '*charge*' with '*raised rump feathers and protruding wing quills*'.

In instances where the annoyance has been a human, a loud, raspy hissing sound accompanies the '*charge*' or '*bluff*', with the bird stopping short of the annoyance while displaying '*throat inflation/deflation*'.

In the case where the annoyance is another bird, generally more passive of the two will '*retreat*'. *See Submission*

In minor active interactions, generally the bird will display '*cheek distension*' and the '*stretch display*', followed by a '*peck*'.

8.4.2 Submission

A number of different postures have been linked with passive or submissive behaviour and are observed in wild (Bentrupperbäumer 1998) and captive (*personal observation*) male and female birds.

Generally, retreating from an aggressor or perceived threat is a standard submissive response to avoid aggressive interaction. The defeated bird will run to escape while grunting (See appendix 11).

In other situations, particularly when in close proximity to an aggressor, adopting a sternally recumbent pose, with the head and neck drawn into the body (in an 'S' shape – where the cranio-dorsal aspect of the neck contacts the thoracic vertebrae [upper back] and the lower mandible contacts the anterior aspect [front] of the lower cervical vertebrae [neck]) as if to further reduce body size, has been observed consistently in captivity.

A subtle lowering of the beak whilst the body is in a sternally recumbent position and the head and neck in a normal roosting position has also been interpreted as a submissive behaviour in wild incubating males (when approached by females) (Bentrupperbäumer 1998), and in captive females during courtship and mating (*personal observation*).

8.4.3 Vigilance/apprehension/perception of threat

In situations where captive birds are anticipating a negative event (such as a manual capture, or simply being within visual or auditory range of a medical procedure being performed on another animal), birds have been observed standing with a stretch display (tail feathers not raised). This is usually followed by a lowering of the head, accompanied by a rumble (see appendix 11). Birds in this situation will generally stand very still in the same position with an eye on the potential aggressor unless presenting the aforementioned vocalization.

If the situation becomes increasingly threatening, the bird may begin to pace uncomfortably along a fence line in an attempt to remove itself from the impending potential danger.

8.5 SEXUAL BEHAVIOUR

See chapter 11.

8.6 OTHER

8.6.1 Curiosity/uncertainty

Curiosity and uncertainty towards animate and inanimate objects has been observed in many captive institutions, and may involve the bird slowly approaching or circling the object with neck extended upward and/or forward accompanied by the occasional withdrawal of the head from the direction of the object. Forward and backward stepping or pivoting slowly back and forth on one foot, are occasional features of this behaviour. These may be followed by gentle pecking, foot stomping on or near the object, or retreat.

Inanimate objects include new items such as dust pans, brushes, sprinkler heads, pole darts, watering cans, rakes (CTZ, HCA). Care should be taken that birds are not given access to items that may cause obstruction or laceration of the gastrointestinal tract.

Animate objects such as skinks and lizards have also been exposed to this behaviour.

8.6.2 Coprophagy

Coprophagy is observed in most captive specimens and may indicate that a bird's appetite has increased. Food amounts should be adjusted accordingly.

8.6.3 Disturbances

Disturbances such as the nearby use of power tools and heavy machinery have been seen to cause discomfort and agitation in cassowaries. Rapid head-shaking, persistent yawning and short-term pacing have been linked with heavy and light machinery use at a number of institutions. All of these behaviours ceased when the machinery was not in use and started again when the work resumed.

8.6.4 Stereotypic behaviours

The concept of abnormal or stereotypic behaviour becomes difficult to define when so little is known about the focal species, however are relatively easy to recognize if you know your bird. Recognising that phenotype is lost through generations in captivity can also make identifying natural behaviour difficult. Stereotypic behaviours are classically identified as repetitive, invariant behaviour patterns with no obvious goal or function.

8.7 INTERACTION

8.7.1 Intersexual interaction

Cassowaries have been described as solitary (Hanford & Mares 1985; Moore 2007), with adult females only accompanying adult males to form short-term pair bonds during the breeding season (Bentrupperbäumer 1998). This has been observed in many captive situations, whereby females will only tolerate brief interactions with a conspecific leading into and during the breeding season. In this situation, females are generally given access to males (or vice versa) intermittently – as brief as courtship and copulation, or, until eggs are laid.

Bentrupperbäumer (1998) concluded that non-breeding contact with conspecifics was normally aggressive, which is confirmed in the majority of captive institutions.

While non-breeding interaction is aggressive in most captive situations, some institutions have found that their birds can be housed together throughout the year without any difficulties. Generally these 'compatible' 'pairs' ('pairs' may be related in some instances) have been raised together and so have a high level of familiarity with one another, however not all birds raised together will form a compatible 'pair'. Consideration should also be placed on the genetic compatibility of birds before a decision is made to raise the birds together.

For birds housed together throughout the year, a slight level of dominance by one bird (male or female) is occasionally observed at feeding times.

8.7.2 Intrasexual interaction

Bentrupperbäumer (1998) concluded that same sex neighbours generally avoid each other since encounters normally manifest some aggressive tendencies.

All female-female interactions observed by Bentrupperbäumer (1998) were overtly aggressive and occurred mainly on home-range boundaries, suggesting territoriality within the species. Interactions between males were very rare and usually involved short, rapid pursuits, and retreat by the other male.

Historically, captive institutions have only housed a male/female pair. Very few institutions have held more than one of either sex, and as a consequence, records of intrasexual interaction in captivity are lacking and poorly understood.

8.7.3 Female/offspring interaction

In nature, Bentrupperbäumer (1998) found that female/offspring interactions were infrequent and always agonistic. Anecdotal reports of wild dam's co-parenting with sires are very rare, but not unheard of.

In captivity, as a means to minimise hatchling and sub-adult mortality, protected contact has been the only interaction observed between dam and offspring. Preferably this management strategy should be maintained.

8.7.4 Male/offspring interaction

See Section 8.7.7, and Section 8.7.8.

8.7.5 Sub-adult interaction

Bentrupperbäumer (1998) established that sub-adults were solitary all of the time.

In captivity, sub-adult interaction is not commonly observed as birds are generally separated before this age. In those birds that have been housed together to sub-adult age, interactions vary from 'playful' to agonistic, and indifferent. Institutions housing multiple sub-adults should place heavy focus on behavioural interactions to ensure that no birds are injured as a result of major agonistic interactions.

8.7.6 Juvenile interaction

8.7.6.1 'Play'

'Playful' behaviours have been observed at numerous institutions whereby chicks, juveniles and sub-adults within the same age range and from the same clutch, will chase and kick each other (*Personal observation*, Mike Taylor, *personal communication*) This behaviour has also been observed in wild cassowaries (Graham Lauridsen *personal communication*; Dan Mead, *personal communication*). In the absence of other cassowaries, subjects (including adults) have been observed kicking and stomping inanimate objects such as natural enclosure furnishings (*Personal observation*, Mike Taylor *personal communication*).

8.7.7 Parental behaviour

8.7.7.1 'Bill clacking'

The sire will stimulate feeding in the chicks by clacking the beak next to a food source, and by picking up pieces of food and mashing them with his beak until the chicks are paying attention.

8.7.7.2 'Brooding'

Parental care of two chicks observed by Bentrupperbäumer (1998) occurred until 323 days after hatching.

8.7.7.3 'Caution'

The sire will demonstrate caution or danger to the chick/s by pecking on top of, or near the head of the chick.

8.7.8 Hatchling behaviour (Captive observations)

Although precocial, hatchlings are entirely dependent on the sire for warmth, protection, and identifying suitable food items. In the first few days after hatching, the family group will not stray far from the nest site.

Once the family group have left the nest site they generally will not return to that exact site but may remain in close proximity.

Hatchlings will rarely wander far from the sire. If visual separation is encountered, hatchlings will emit a high pitched squeal, to which the sire will respond by moving quickly towards the offspring.

Food is identified and macerated by the sire and provisioned to the hatchlings.

8.7.9 Juvenile behaviour

Juveniles begin to wander further from the sire as they grow increasingly confident, and are often seen ground foraging independently of the sire, but still within visual range. They are still dependent on the sire for warmth and protection, and for identifying suitable food items.

8.7.10 Sub-adult behaviour

Sub-adult birds wander further from the sire and are often seen ground foraging independently of the sire, and often out of visual range.

8.8 CHANGES IN BEHAVIOUR

8.8.1 Seasonal (Pre-breeding – courtship may be occurring)

Pre breeding season sees a pronounced decrease in appetite and a gradual slowing of foraging and travelling activities. An increase in frequency of vocalizations by captive females is generally observed during this period.

Females may become more tolerant of conspecifics and humans.

8.8.2 Seasonal (Breeding – when courtship, copulation and incubation is occurring)

The breeding season sees a further decrease in foraging and travelling activities from both sexes, particularly from the male who may be incubating. Captive males tend to display an increase in defensive behaviour while incubating. Decreased motivation is frequently observed during this period with many institutions encountering difficulty in even simple programs such as moving birds from enclosure to enclosure.

Throughout most of the year, females are generally quite defensive/aggressive, however at this time of year, some captive institutions have observed a dramatic change to tolerant/passive behaviour. Some females will allow keepers to easily push the bird into a sitting position, and will also allow palpation of the back, legs and lower neck. Fearful behaviour is also observed, whereby a female will run from personnel at whom she would normally charge and may include some fence pacing. Disturbances (Section 8.6.3), may also cause fearful behaviour

8.8.3 Seasonal (Post-breeding – hatch/no hatch/parenting)

Post breeding season sees a dramatic increase in appetite and prompt increase in foraging, travelling, and other activities from both sexes. Captive males will display active defensive and aggressive behaviour if eggs hatch.

8.8.4 Unseasonal

Unseasonal change in behaviour may be an indicator of illness, injury, disease or other discomfort. Some indicators might include rapid pacing of perimeter fencing, increased vocalizations, panting, limping.

A captive male of wild origin – typically passive bird, rarely showing aggressive behaviour unless incubating eggs or rearing chicks. His good body condition (BCS 4) post-breeding season (circa December-January) was attributed to the fact that he was not required to incubate eggs that season. The bird became aggressive towards keepers approximately three weeks prior to presenting with collapse and extreme respiratory distress. After failed aggressive treatment, the bird was presented to veterinarians for post mortem.

8.8.5 Behavioural indicators of stress

Behaviours that typically indicate possible stress include, but are not limited to: fence pacing, attempting to jump fences, attempting to push through fences, mouth agape, rapid breathing, and increased vocalizations.

8.9 INTERSPECIFIC COMPATIBILITY

A handful of institutions have successfully housed different species with cassowaries. It is important to note however that while one institution may find a particular species compatible, others may not. Results are largely dependent on the demeanour of the cassowary with which the species will be housed.

Table 8.1 - Observed Cassowary/inter-species compatibility.

Taxon Name	Common Name	Institution
	Compatible	
Anas superciliosa	Pacific Black Duck	CTZ, DWGC
Tadorna radjah rufitergum	Radjah Shellduck	CTZ
Megapodius reinwardt	Orange-footed Scrubfowl	CTZ
Thylogale stigmatica	Red-legged Pademelon	CTZ
	Incompatible	
Burhinus grallarius	Bush Stone-curlew	CTZ
Varanus varlus	Lace Monitor	Wild
Dacelo leachii	Blue-winged Kookaburra	CTZ
Dacelo novaeguinea	Laughing Kookaburra	CTZ

8.10 MANIPULATING TIME BUDGETS

Animals in captivity tend to maintain higher body weights and fat contents than in the wild (Kirkwood 1991) due to lack of exercise and poor diet, which can have negative implications for the animals' health and general welfare, and generate negative images about zoos to the public. Furthermore, stereotypic and undesirable behaviours can develop as a result of this lack of normal activity.

As cassowary carers in a captive environment, we have the capacity to positively alter a large number of variables affecting birds in our care. Enriching the way zoo-housed animals are fed is now a widely employed method of improving the welfare of these animals (Young 1997), and if implemented with enough care and planning, can assist in diminishing health problems.

Consideration must be placed on the fact that although increasing the foraging time of captive animals may be beneficial for the psychological well-being of an animal, it may have a detrimental effect on the physical well-being (Young 1997). As such, caution should be exercised so that a neat and appropriate time budget of activity:rest is achieved based on the needs of each individual. It should include contingencies for maintaining desirable or appropriate already conditioned behaviours; and should be in line with the institutions' motive for housing the animal.

Time budgets of individual specimens should be recorded (appendix 5) and analysed so that a budget can be designed that encourages a plan closer to that which is displayed by a wild counterpart.

Traditionally, most animals in zoological institutions are fed once or twice a day out of convenience – a practice which is outdated and no longer appropriate unless the time is used to train or condition an individual; and, as outlined in the paragraphs above, cassowaries do not naturally consume one or two meals a day. Feeding practices can however be manipulated to stimulate species-specific natural behaviour and increase activity levels, as opposed to offering bulk food in one or two sessions.

NUTRITION & FEEDING

In a captive context, nutrition involves feeding the correct balance of nutrients to allow animals to display a healthy range of natural behaviours like foraging and allows biological functions such as growth stimulation, maintenance of life, reproduction and energy production to persist at all relevant stages of life.

Nutrition is a fundamental part of captive management and devising appropriate diets for the great variety of species maintained in captivity presents a major challenge (Kirkwood 1991). It is widely accepted that very little information exists on the nutrient requirements of wild, non-domesticated animals, or wild animals in captivity (Kirkwood 1991, Murphy & King 1982, Houston 1997, Dierenfeld 1997), and while detailed natural history documentation of field biologists and ecologists (Westcott *et al.* 2005, Bentrupperbäumer 1998) endows us with a useful written record of the foods consumed by cassowaries in the wild, such information with no chemical evaluation of dietary constituents, or assessment of utilization, provides only a partial basis for applied feeding programmes (Dierenfeld 1997).

The following is a collation and analysis of current available empirical anatomical, physiological, behavioural and ecological data relative to cassowaries, and information from more extensive testing carried out on similar species, in an effort to judiciously develop a series of rational diets appropriate for the cassowary at different life stages. It is vital however, to understand that there is considerable interspecies variation regarding nutrient requirements. (Macwhirter in: Tully *et al*. 2000)).

9.1 FEEDING BEHAVIOUR

9.1.1 Classification – facultative frugivore

Cassowaries have been described as obligate frugivores (Marchant & Higgins 1990, Romer 1997, Bentrupperbäumer 1998), but do consume a considerable amount of protein at different life stages, and throughout the year. Observations from captive cassowary scats reveal a marked breakdown of animal protein and calcareous materials in faeces, which indicates that studies of the contents of wild cassowary scats may underestimate the amount of actual animal matter consumed. Anecdotal reports of wild birds also indicate that variable portions of animal protein are consumed at different life stages (Graham Lauridsen *personal communication).*

9.1.2 Native diet

See appendix 1.

9.1.3 Foraging behaviour and activity

Cassowaries generally eat fruit or other items from the ground, but are also known to jump in order to reach low growing fruit. Bentrupperbäumer (1998) noted that when fruit was abundant, cassowaries were quite selective, and often rejected partially ripe or over ripe fruits. Such behaviour has also been witnessed in captivity.

Food items are held by the tip of the beak.   A swift backward movement of the head and neck accompanied by the release of the beaks' grip tosses the fruit to the top of the oesophagus. For odd shaped fruits or fruits with any protuberances, cassowaries will swallow air into the oesophagus, perhaps to assist in moving the food item more easily to the proventriculus. By the time the food item reaches the bottom of the neck, it appears as though any air which had accompanied thus far has already been expelled via the mouth.

Bentrupperbäumer (1998) identified that 35% of daylight hours were spent foraging, and further noted that activity patterns varied according to the time of day. Foraging activities peaked in the morning (0800-0900) and late afternoon (1700-1800), and was the predominant activity throughout the day (Bentrupperbäumer 1998).

Similarly, observations of wild birds by Westcott *et al.* (2005) indicated that foraging and movement occur throughout the day, with peaks in the foraging activity taking place in the early morning and late afternoon. The total amount of time spent foraging in an average day was also quantified as 35% (Westcott *et al*. 2005). Bentrupperbäumer (1998) postulated that continuous daily movement associated with foraging may aid digestion.

Also see section 8.7.7.

9.1.4 Preferences

At Cairns Tropical Zoo, adult interest in animal protein and different fruits varies throughout the year, and between sexes.

Information on fruit items selected by wild cassowaries is extensive. Westcott *et al.* (2005) recorded fruits from 238 species of plant in the cassowary diet, including seven species of exotic plants commonly found in rainforests in the Wet Tropics Region. Bentrupperbäumer (1998) also observed inorganic material such as soil and rocks in scats.

Dietary preferences appear to be very broad and indiscriminate as numerous post-mortem results, and scat analysis reveal that almost any soft fleshy fruit will be eaten, along with bird eggs (Bentrupperbäumer 1998), rats, mice (Alexander 1926), frogs, bones, lizards, grass seeds, fungus, and plant material (Graham Lauridsen *personal communication*) including the leaves of various plants, and the flowers of *Syzygium cormiflorum* (Bradford *et al*. 2008). Leaves are also often found in the scats of captive birds (WOCC, SI, HCA) (Sara Hallager *personal communication*, *personal observation*).

Post mortem examinations conducted after Cyclone Larry when native fruits were scarce revealed a wide range of different foods were consumed, confirming Latch & Gayler (n.d.) statement that cassowaries inhabiting areas near human habitation are likely to search gardens for food in times of low fruit abundance in the forest. Food items recovered from the stomach contents included vast quantities of fungus, carrion, meat, cheese, bones, pasta, chilli and tomato (Graham Lauridsen *personal communication*).

Birds at the Garner's Beach Rehabilitation Centre appear to crave protein, and given the chance, will eat it at the exclusion of anything else (Graham Lauridsen *personal communication*). Wild birds in the Mission Beach area are occasionally seen scavenging from road kill sites and reports of cassowaries killing and eating small mammals and reptiles are also common (Graham Lauridsen *personal communication*) in the wild, and in captivity (*personal observation*, Kirra Stout *personal communication*). Bentrupperbäumer (1998) observed a male identifying and supplying high protein food items for his chicks, while failing to consume them himself, suggesting that invertebrates may constitute an essential dietary supplement for chicks.

Interestingly, the dietary preferences of captive cassowaries appear to vary throughout the year, and even differ between individuals (*personal observation*. CTZ, HCA, TCS). At a handful of institutions, a trend towards red/pink fruits (tomato, watermelon) and green fruits (grapes, kiwifruit) is observed in the breeding season (CTZ, HCA, TCS).

Substantial intake of soft red podzolic soil and bare/spent seeds was observed by Bentrupperbäumer (1998) in one year of her study, suggesting the need for mineral supplements and possibly "filler". Macgillivray (1917) also found numerous scats consisting of large stones, and in captivity stones are regular feature. It was speculated at the 2011 CHW that the stones consumed by captive birds may serve as an analogue to the large seeds found in the wild diet, and act as comminuting gastroliths in the ventriculus, given that generally captive diets are comprised of commercially available fruits which lack large seeds. Stones consumed vary in size from 7-25mm in diameter, and are generally smooth- semi-smooth quartz and limestone. Interestingly, in the many post mortems of wild cassowaries conducted by Dr Graham Lauridsen, no stones have been found in the stomach contents of deceased birds (Graham Lauridsen *personal communication*).

9.1.5 Appetite

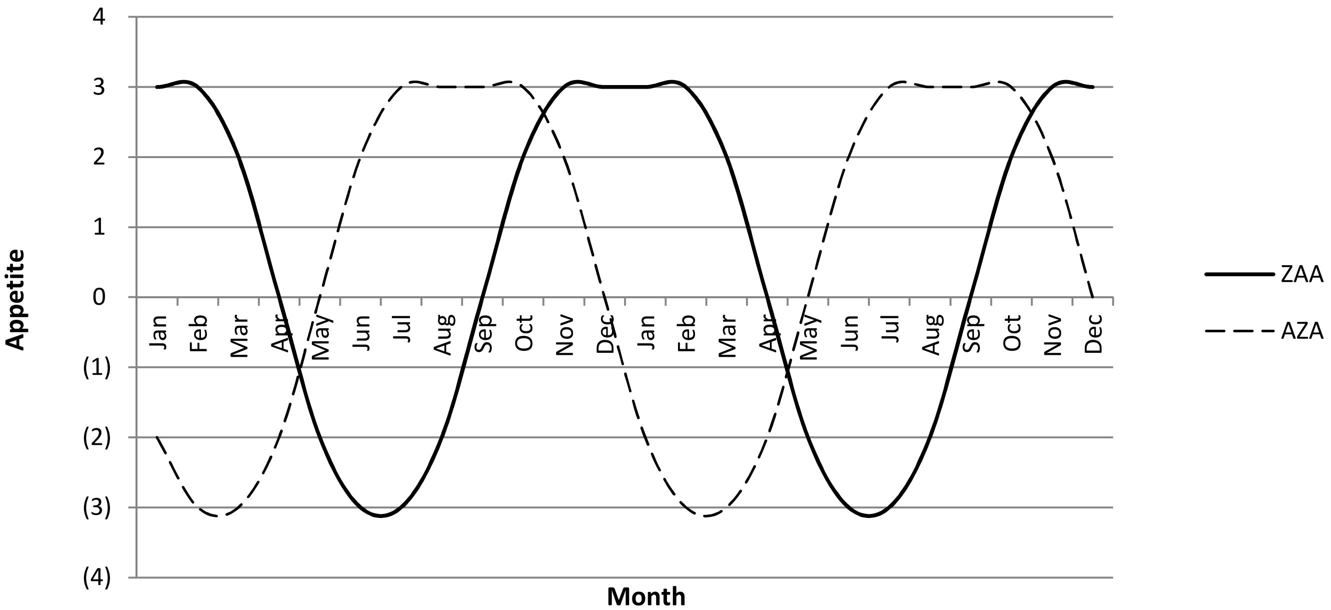


Figure 9.1 - Seasonal appetite of captive cassowaries in ZAA & AZA regions (2 year projection).

Similarly to the emu, seasonal variation in feed intake is consistently observed in captive adult birds (Figure 9.1), with the appetite rising sharply in both males and females as egg production ceases in late winter/early spring before declining sharply as the new breeding season commences in mid-late autumn. It was speculated at the 2011 CHW that this is probably due to the slowing of the metabolism in preparation for the males' period of relative inactivity while incubating the eggs. A decrease in food consumption to <1kg daily is observed in some cases. At this stage, female interest in animal protein increases, but appears sporadic.

Post breeding season coincides with moult, and a significant increase in food consumed is noted – from approximately 1kg daily to up to 15kg daily. At this stage, the male is generally more interested in protein.

The appetite of a healthy, wild born, captive sub-adult (estimated to be 2.5 years old) bird fluctuated weekly leading into the natural breeding season and varied from <3kg to >10kg daily (personal observation). No other reports of diet fluctuation were received from any other institution for this age class.

9.2 DIGESTIVE ANATOMY AND PHYSIOLOGY

The digestive tract of cassowaries is relatively short compared with other ratites (Noble 1991) and hence has a fast passage of ingesta (See Mack & Druliner 2003). As a consequence cassowaries have a high dietary requirement which can reach 10% of their body weight in daily intake (Romer 1997).

Birds have relatively long necks because their beak must serve the function of hands or paws in food gathering, preening, etc (Duke 1997), therefore the oesophagus is also long and is comprised of delicate longitudinal muscles. The oropharynx is also large and allows the birds to consume sizeable fruits whole, without prior manipulation.

Ratites do not have a crop (Tully & Shane 1996), but like all birds, are monogastric and so food that is consumed passes directly from the oesophagus which simply widens to become the proventriculus (glandular stomach). This glandular stomach in ratites achieves the storage function of the crop in other birds (Cooper & Mahroze 2004). In the ostrich, movement of food from the oesophagus to the proventriculus occurs without any distinct demarcation (Smith & Sales 1995 in: Cooper & Mahroze 2004). The proventriculus joins the gizzard.

Information on gastric motility in the cassowary is lacking, but deductions can be made from the appearance of a scat. The cassowary stomach appears to merely massage the skin and peri carp from the seed or the fleshy aril or receptacle from the fruiting body in a relatively gentle process (Bradford & Westcott 2008, Stocker & Irvine 1983). At times the fruit completes the journey through the digestive system apparently unchanged with the flesh still attached and the seed viable (Romer 1997, *personal observation).*

It is worth mentioning again that significant breakdown of protein materials has been observed in the scats of captive birds. The only remains of day old chickens fed to captive birds throughout the year were body parts comprised of keratin, such as feathers, leg scaling and claws.

9.3 NUTRITION

Identification of the nutritional needs of wild birds, and the subsequent clarification of the apparent enigmas of nutrient requirements and supply, is hindered by the overwhelming chore of detailed compositional analysis of naturally occurring foods (Murphy & King 1982). It is further hindered by the fact that components of a true wild cassowary diet are not commercially available, and have little commercial value.

On the other hand, the poultry industry and emerging ratite industry have developed diets relevant to the different stages of growth and use. These are a starter diet, an adult maintenance diet and a breeding hen diet. Some may contend that such specificity for cassowaries is unreasonable as our knowledge of the nutrient requirements of this species is so limited that there is barely enough information to develop a single rational diet. Nevertheless the paragraphs below provide us with some very basic important information, which, when coupled with a number of diets that have either been successful, partially successful or unsuccessful, gives us a baseline with which to work. The following paragraphs highlight general information about avian nutrition, and judiciously suggest diets that represent a formulation compromise which have been used to successfully grow, maintain and breed Cassowaries in captivity (See Appendix 12 and 13).

9.3.1 General information

Cassowary weight and condition fluctuate naturally throughout the year, and most institutions have found that birds are quite good at self-selecting a quantity of food that is appropriate for each season in their annual cycle.

Recording the amount and type of food consumed and food not offered provides a clear picture of the cassowary appetite throughout the year and can also provide direction for diet adjustment if obesity is a concern.

The amount of cellulose and lignin that cassowaries can digest has not been quantified, although the appearance of scats from captive and wild birds suggests that the capacity is low. The fact that cassowaries will eat foods in which nutrients are concentrated such as small vertebrates, insects and mainly fruits, is consistent with a limited capacity to digest fibre.

Variety would be appropriate (with respect to native fruits in the wild diet) if we could offer wild foods in the same proportions they would be sought out in the wild (Bauck 1995), however these are rarely available commercially in Australia, let alone abroad. Therefore institutions must consider feeding an appropriate variety of commercially produced fruit and protein types throughout the year.

Birds are unable to synthesize nine of the 20 amino acid in proteins because of a lack of specific enzymes, and therefore dietary protein must supply sufficient levels of essential amino acids, with enough excess amino acids to supply nitrogen needed to synthesize the nonessential amino acids (Klasing 1998 in: Sales 2006). Manion and Kent (2010) suggest that about 11 cannot be manufactured by the emu, and must therefore be present in their feed. Although obesity does not appear to be a common problem in cassowaries, Sales (2006) suggests that consideration in the captive environment should be given to the fact that excess amino acids are degraded to energy, often resulting in fattening. Fattening appears to be a natural annual cycle for cassowaries and their intake is dictated by appetite which naturally varies throughout the year.

Although a growing number of avian species have been observed feeding on calcium-rich food (e.g.,Dhondt & Hochachka 2001) items during laying, there remains a large number of species for which our knowledge of breeding diet is extremely limited, including cassowaries. Detailed studies of foraging behaviour would demonstrate the range of calcareous material that is exploited by breeding birds (Reynolds & Perrins 2010). The provision of calcium carbonate or decomposed granite in a feeder separate from the main diet may be appropriate. Weekly provision of small stones (1-2cm^3, [quartz]) may assist in the comminuting of food in the gizzard and serve as roughage, and will be readily consumed by the birds. While impaction is not likely, care should be taken to avoid over feeding such items to juvenile birds.

Vitamins and minerals are essential for normal growth, development and health. They must be present in the diet in relatively small amounts.

An adequate supply of water of acceptable quality is essential for the health and well-being of ratites (Tully & Shane 1996).

Native fruiting trees are planted in enclosures at several institutions and supplement a small amount of fruit sporadically throughout the year.

9.3.2 Breeder information

The ultimate goal for breeders is to establish the best possible body condition well before the start of the breeding season.

Breeders should be fed to satiety as their appetite increases at the end of the breeding season, and kept on a varied diet throughout the off season. Any increase in appetite should be met with an increase in food offered. Likewise, a decrease in appetite should be mirrored by a reduction in the amount of food offered, while still maintaining variety.

An increase in appetite/preference for animal protein in either sex should be met by an increase in protein offered. Birds appear to self-limit, and will rarely eat more than six day old chicks or mice, before returning to their fruit meal. The female, while only sporadically, has a greater interest in animal protein (compared with spring and summer) in autumn and winter (during egg production), and will eat as little as 200g of food in total, each day. The male, also only sporadically, has a greater interest in animal protein (compared with summer and winter) in autumn and spring (pre-breeding season and post-incubation).

Vitamins or minerals that are deficient in the emu's diet may not show any ill effects in the breeders, though hatchability may be affected (Spencer 2010).

The production of eggs can make a major nutritional demand on a female bird (Houston 1997), however for larger species, where egg weight is a small proportion of female body mass (ie. the cassowary), the investment in the egg is smaller than that demanded from a small bird whose egg weight is a higher portion of her body mass. Houston (1997) identifies three possible routes from which the resources for egg formation in wild birds could come: increased food intake; the use of body reserves; or, metabolic changes in the female to permit a re-allocation of resources from body maintenance to egg formation. Hence the quality of diet a bird receives before laying can also have a profound influence on breeding success, not only in the immediate period when eggs are being formed, but also mediated via the body condition of the female bird which has been established perhaps over several months before the start of the breeding season (Houston 1997).

Captive female cassowaries seek out additional protein leading into the breeding season while interest in fruit decreases. Concurrent to this, weight loss is also observed suggesting that body reserves are utilized and that metabolic changes are permitting the re-allocation of resources from body maintenance to egg formation. Any attempt to increase the condition of a bird should start well prior to the breeding season. Protein items should be fed *ad-libitum* for at least eight weeks leading into and during the breeding season.

The suggested diets (Appendix 10 and 11) all contain vitamin A, D3, riboflavin, pantothenic acid, biotin, folic acid, vitamin B12, calcium, phosphorous, and the amino acids lysine, methionine, cystine, tryptophan, isoleucine and threonine, as is recommended by the Queensland Department of Primary Industries and Fisheries (Spencer 2010) for poultry and emu production. In the poultry and emu production industries, deficiencies in these nutrients have been implicated in poor hatchability of eggs, malformed embryo's, abnormal development, mortality during incubation, and poor survivability of chicks.

Spencer (2010) suggests that breeder emu's should be fed a well-balanced diet to fully meet the embryo's nutrient requirement, and naturally, this is applicable to the cassowary.

9.3.3 Chick information

The ultimate goal when feeding chicks is to promote healthy growth and prevent the development of skeletal deformities that are regularly observed in growing ratites.

During growth, energy is required both for maintenance functions and also for deposition of new tissue, and the amount by which the total daily requirement exceeds the maintenance requirement depends upon the rate of tissue deposition and the composition of tissue deposited – which vary with stage of growth and between species (Kirkwood 1991).

Juveniles require more protein than adults, particularly in the first and second growth phases and can be offered in a number of forms outlined later in the chapter, however one must bear in mind the potential complications associated with increased protein diets (See Chapter 10, pg x). Excess protein and sulphur-containing amino acids have been implicated in rotational leg disorders in ratites (Gandini *et al*. 1986, Dolensk & Brunning 1978 In: Fowler et. al 1996). A list of complications appears in Chapter 10.

Cassowaries require an appropriate diet with a calcium:phosphorus ratio of approximately 2:1, access to sunlight and graded exercise to allow normal development. A careful review of the calcium content and the calcium:phosphorous ratio of the diet ingested (not the diet provided) should be undertaken.

9.4 SUGGESTED DIETS

9.4.1 Breeder

See appendix 12.

9.4.2 Chick

See appendix 13.

9.5 PRESENTATION OF FOOD

The feeding of all captive animals is more complex than offering a diet with the correct balance of nutrients; the diet should be offered in a manner that is appropriate for the reasons why that animal is kept in captivity (Young 1997). Wherever possible, food should be offered to birds similarly to how they would encounter it in the wild, however this is not always possible due to hygiene, safety of the keepers, or practical husbandry purposes.

A variety of receptacles are used in captivity and most are consistently large, with no protrusions or sharp, hard edges that may harm a bird in any way. These are usually on the ground, or slightly elevated. Integument on and around the head is comprised of soft tissue and are prone to injury. A design utilised by Queensland National Parks and Wildlife to supplement feed cassowaries that were displaced as a result of Cyclone Larry and Cyclone Yasi is shown in Appendix 14. To prevent injury, feeders should ideally not be placed within close proximity to fence lines.

In areas where feral pigeons and other pest species like mynah birds are too competitive for the food, feeding may need to be done in a shelter or other similar enclosed area (Romer, 1997).

The feeding of pair-housed cassowaries in one place may, at different times of year, result in the dominant individual selecting an unbalanced diet from the available food items (*personal observation).*

9.5.1 Feeding enrichment

See Chapter 8 Behaviour for manipulating time budgets.

See Appendix 13 for behavioural enrichment activities.

FUTURE DIRECTIVES AND AVENUES OF RESEARCH

- Qualitative analysis on feeding habits;
- Quantitative analysis on food nutrient composition and utilization across a temporal scale;

- Quantitative and qualitative evaluation of the effects of any manipulated time budgets;
- Nutrient requirements of different age classes/sexes;
- Nutrient composition analysis of wild food items

The nutrient contents of commonly fed items can be found at the USDA National Nutrient Database for Standard Reference

http://www.ars.usda.gov/Services/docs.htm?docid=8964

HEALTH EVALUATION & DISEASE

Parts of this section were reviewed by Veterinarian Anabelle Olsson based on the work originally produced by Dr Katie Reid, Veterinarian at Currumbin Sanctuary in the first manual (Romer, 1997). A special thanks to Veterinarian Graham Lauridsen who also contributed significant work to this section.

Suggested Readings :

Stewart, J. S. *Ratites. In*: Ritchie, B. W., Harrison, G. J., and Harrison, L. R. (1994). Avian Medicine: Principles and Application. Florida. Wingers Publishing Inc. Pages 1284-1326.

Tully, T. M. Jr. and Shane, S. M. (Eds.). (1996). Ratite Management, Medicine, and Surgery. Florida. Krieger Publishing Company.

Westcott, D. & Reid, K. (2002). Use of medetomidine for capture and restraint of cassowaries (Casuarius casuaris). *Australian Veterinary Journal*, 80: 150–153.

Veterinarians dealing with medical and surgical problems of propagation management of ratites should have a basic understanding of ratite anatomy to safely handle these birds and to understand how to collect laboratory samples, administer medications, evaluate radiographs, perform surgery, and distinguish between normal and abnormal tissue at necropsy (Fowler 1991) (See Chapter 7).

10.1 GENERAL

10.1.1 Seasonal fluctuation in body condition

Seasonal changes in body condition are natural in cassowaries (See Appendix 10).

A number of institutions have reported female birds with a slight limp during and post breeding. The condition has also been observed in a number of wild birds. Birds will occasionally adopt a sternally recumbent position with a leg outstretched behind them. Etiology is not known with certainty, however is most likely multifactorial with potential influences including genetics, diet, and reallocation/redirection of body stores to facilitate egg production. While this appears to be fairly common, consultant veterinarians should still be informed and keeping staff should monitor the problem.

10.1.2 Seasonal change in behaviour

Seasonal changes in behaviour are normal for many captive birds and are outlined in Chapter 8.

10.1.3 Behavioural Signs of Disease

It is important to observe the uninterrupted behaviour of any bird prior to engaging in potentially stressful physical handling activities so that an accurate assessment can be made of the bird's health. Having a good understanding of the normal behaviour of the individual will also assist in making the overall assessment. Clinical signs of disease may include lethargy, anorexia, dull eyes, plumage deterioration, unseasonal weight change, unseasonal change in condition score, inappetance, unusual gait or posture, shaking or pulsating of any part of the body in conjunction with other signs, general weakness, swelling on any part of the body, sudden disruption or change in normal egg production, or change in temperament or demeanour.

10.2 DAILY HEALTH CHECK - Visual Observation/General Examination

Due to the difficulty of conducting a physical examination, information must be gathered by history, and observation of the bird. History should include changes in patterns of behaviour, appetite and selection of foodstuffs, reactions to keepers, changes in faecal mass and appearance, any other obvious abnormalities, along with any response or reaction to current medications.

Careful observations should be made of the bird at rest and walking, noting any changes in posture, gait, breathing and any loss of symmetry in the bird. Discharges from eyes, nostrils or cloaca should be noted. Check for any swelling or pasting of droppings at the vent, and for swelling or discharge from the eyes or nostrils. Unseasonal changes in activity level should be considered (*personal observation*), along with any lameness.

Changes in any of the aforementioned may indicate illness injury or disease and should be promptly referred to the consultant veterinarian.

Having evaluated the condition of the bird, an informed decision can then be made on whether the benefits of a detailed physical examination warrant the risks associated with capture and restraint. See Chapter 6.

10.3 ANAESTHESIA

Machin (2005) suggests that pain perception in birds is analogous to that of mammals and thus invasive and painful procedures should always be accompanied by appropriate analgesia and anaesthesia.

10.3.1 Modes of Anaesthesia

Anaesthesia can be induced and maintained with a variety of inhalational and parenteral agents, however the latter may be preferred because they can easily be applied without specialized, expensive equipment (Uzun *et al*. 2006). The choice depends on a combination of factors including age, ease of handling, physical condition of the bird and available facilities and experienced staff. Young birds which can be easily physically restrained can be induced with an inhalational agent via a face mask, whereas larger, more intractable birds or birds in a field situation may require intravenous or intramuscular anaesthetic administration. For lengthy procedures, birds should be intubated and maintained with an inhalational agent.

Injectable agents can be remotely administered into the thigh muscles via blow pipe, dart gun or pole syringe. Various agents can be used, however a non-refined combination of drugs may set off erratic behaviour and/or cause the bird to impact the ground with considerable force (*personal observation*; Mike Taylor *personal communication*).

Benzodiazepines have been used alone or in combination in ratites, and include agents such as diazepam, midazolam and zolazepam (Greene 2002). These drugs are not commonly used as sole agents due to their weak sedative effect, so are more commonly used in combination with cyclohexamines, opioids or α_2-agonists.

Cyclohexamines have been used alone or in combination in ratites (Westcott & Reid 2002) and include drugs such as ketamine and tiletamine. Ketamine used alone, either IM or IV, requires large doses and has been associated with excitable induction and recovery and convulsive behaviour during recovery (Cornick-Seahorn in: Tully &

Shane 1996). Anecdotal reports suggest that ketamine used in isolation produces poor results (Graham Lauridsen *personal communication*).

Ketamine has been used in combination with etorphine to produce reliable sedation with some excitement during induction (Stoskopf *et. al.* 1982). Combination with xylazine resulted in rough recovery (Graham Lauridsen *personal communication*). Acepromazine, diazepam, and midazolam can also be used with ketamine at a suggested dose rate of 1-2mg/kg, however very little published data is available for cassowaries. In species such as flamingo, recovery from ketamine can be unpredictable and is more likely to lead to post-anaesthetic problems (Brown & King 2005). Preferably, if anaesthesia is required after sedation, mask and induction with isoflurane is recommended (Westcott & Reid 2002).

For wild birds, a combination of tiletamine and zolazepam is utilized (Zoletil® 2-8mg/kg IM) for its quick knock down effect and has been used on more than 80 individual cassowaries where physical restraint is either impossible or extremely dangerous (Graham Lauridsen *personal communication*). Birds are generally recumbent within three minutes of administration. Its effects are dose dependant – the more given, the deeper the sedation/anaesthetic effect. At higher doses, birds can remain laterally recumbent for an hour or more allowing many minor surgical procedures with a minimal amount of physical restraint. Vets in North Queensland dealing with wild birds have taken blood, skin biopsies, implanted microchips and attached radio trackers all with Zoletil alone (Graham Lauridsen *personal communication*). Graham Lauridsen (*personal communication*) maintains that the only negative aspect of the use of Zoletil® is that the occasional bird – if not left quiet and undisturbed – will wake up and stagger around, fall into vegetation and struggle, or in rare instances, drop its head to the ground. This should be considered when sedating captive birds such that plans include steps to mitigate injury to the bird while it recovers. Although Zoletil® cannot be reversed, recovery can be smoothed with diazepam.

Potent opioids have been used in ratites and have the advantage of the availability of a reversal agent. Carfentanil has been used alone and in combination with xylazine to induce anaesthesia, however as with the use of etorphine, it produces an initial excitement phase during which it is possible for birds to either injure themselves or develop hyperthermia and subsequent rhabdomyolysis (see Westcott & Reid 2002). Previous trials using ketamine and etorphine required extremely high doses to result in the desired level of sedation indicating that cassowaries are able to metabolise or sequester such drugs extremely rapidly (Stoskopf *et al.* 1982).

Carfentanil, Etorphine and Butorphanol have also been used in cassowaries.

Several α_2-agonists have been used alone or in combination (Westcott & Reid 2002) and include agents such as xylazine and medetomidine.

Xylazine has a significant cardiopulmonary depressant effect but has been reported to produce fair sedation, although stimulation can prevent optimum sedation (Westcott & Reid 2002).

Heavy sedation using medetomidine has been observed at dose rates between 0.3-0.54mg/kg IM, while doses between 0.26-0.31mg/kg IM provided light sedation (Westcott & Reid 2002). Sedation was reversed with atipamezole at a dose of 15-80mg/kg which produced a return to alertness in 40-139 minutes. In captivity, medetomidine in combination with butorphanol, propofol and intubation has been successfully used with good levels of sedation. Full anaesthesia has been achieved using 0.5mg/kg medetomidine IM, followed by 0.05-0.5mg/kg butorphanol IM and then propofol IV to effect (up to 10mg/kg) and intubation for gaseous anaesthesia (Unwin 2004).

Although the use of medetomidine has been published in the literature, it has been found to be of little to no use in practical terms, in the area of wild cassowary handling (Graham Lauridsen *personal communication*). The drug has a long onset of action and personnel dealing with wild unrestrained birds are unable to allow a partially sedated bird to walk into the bush without the certainty of knowing that it is going to lay down (Graham Lauridsen *personal communication*). It has been tried unsuccessfully on a number of occasions and so its use is restricted to chicks or birds that are unable to escape (Graham Lauridsen *personal communication*).

Gaseous anaesthetics such as isoflurane and halothane have been used with success in ratites both as induction agents and for maintenance, however manual restraint is still required if used for induction which may limit their use to chicks and debilitated patients. Currently, Isoflurane is the preferred inhalant gas.

Various other agents such as Acepromazine (0.5-5mg/kg PO) and Azaperone (1-2mg/kg IM; 0.2-0.3mg/kg IV; 1mg/kg PO) have been used with varying degrees of success. See Appendix 17 for a full list of therapeutics.

10.3.2 Monitoring and Recovery

Anaesthetics and sedatives possess some side effects, among which negative cardiovascular and respiratory side effects are of major concern in avian species (Uzun *et al*. 2006). Heart rate increase, abnormal cardiac rhythms and bradycardia, along with significantly depressed respiration (Uzun *et al*. 2006) have been observed in species other than cassowaries.

Regardless of the agents used, cassowaries should be well padded during the anaesthetic period to minimize neuropathy and myopathy. Hessian sacks filled with saw-dust have been used as padding by some institutions.

Thermoregulation is impeded during anaesthesia and body temperature should be carefully monitored to avoid hypothermia or hyperthermia. Normal body temperature is around 40^{o}C. In other species, birds that become hypothermic while under anaesthesia will have prolonged recoveries and fatalities may result.

Administration of warmed fluids (Ringer's or Hartmann's solution) may be required for procedures of more than 30 minutes duration. Where significant blood loss is anticipated, plasma expanders or a blood transfusion may be indicated. (Donor is preferably from the ratite family but does not have to be a cassowary).

Comprehensive records should be completed during the anaesthetic including sequential monitoring of heart rate, respiratory rate, body temperature and any other salient observations (See appendix 8). A complete physical examination including measurements (See Section 10.11) and weight, sexing (Chapter 7 Section 7.8.3.1) and blood collection should be performed whenever possible.

If possible, blood oxygen should be monitored.

Cassowaries should be allowed to recover from anaesthesia to a fully awake state in a sternally recumbent position in a small, dark and quiet environment such as a well-padded transport box before being released.

The bird should be closely monitored until it is responding normally to visual stimulus. Ideally the head should be supported until the bird is able to maintain normal head posture. Assistance should be close by to redirect the bird, should the bird decide to prematurely stand up.

Diazepam has been used to smooth reversals (Graham Lauridsen *personal communication*).

10.3.3 Potential complications

As with other species, complications can arise during anaesthesia. These can be minimized by thorough planning, careful monitoring and adjustment of anaesthetic regime in response to physiological parameters.

Anaesthetic depth in birds is monitored by a constellation of signs including heart rate, respiratory rate and depth, palpebral reflex and corneal reflex. The respiratory rate of 6-12 breaths/minute should remain regular, deep and stable during anaesthesia. Apnoea sometimes occurs during general anaesthesia in ratites and may be caused by hypocapnia associated with excessive ventilation, but is more likely due to extreme depth of anaesthesia. If apnoea occurs, depth of anaesthesia should be immediately reassessed and decreased as indicated. Ventilation with 100% oxygen should be provided at 2-4 breaths/minute and the cardiovascular system should be evaluated because apnoea may indicate impending cardiac arrest (more likely to occur with halothane than isoflurane anaesthesia). Administration of Doxapram (5mg/kg IV) may be beneficial in stimulating respiration. Cardiac arrest is associated with a poor prognosis, and efforts at resuscitation are often unsuccessful in avian species.

Regurgitation may occur during general anaesthesia. The risk of aspiration pneumonia may be minimized by slight elevation of the neck and intubation with an appropriately sized endotracheal tube, both of which will help to prevent passive regurgitation.

The most common post-operative complication is self-trauma during recovery. This can be avoided by confinement to a dark, padded box or physical restraint until coordinated movement has been regained.

Exertional rhabdomyolysis may occur in ratites and the risk increases if induction is rough and prolonged, and if ambient temperature is high. Risks can be minimized by smooth induction, monitoring body temperature and taking appropriate action if body temperature exceeds 41^{o}C.

10.4 VENIPUNCTURE

10.4.1 Subcutaneous

Subcutaneous administration of medications is difficult because the skin adheres to the underlying tissues (Stewart in: Ritchie *et al*. 1994). These can be given in the knee web cranial to the thigh (Blue-McLendon 1992) or if appropriate, intravenously in the medial metatarsal or jugular veins.

10.4.2 Intramuscular

Pectoral musculature of cassowaries is significantly reduced consisting of vestigial supracoracoideus and pectoralis muscles. The iliotibialis, gastrocnemius and fibularis muscles of the thigh are often the preferred site for intramuscular injection. Cassowaries, like other avian species, have a renal portal system which was previously thought to shunt nephrotoxic drugs via the kidneys prior to exerting their effect if administered caudal to the kidneys (Stewart in: Ritchie *et al*. 1994) however this has not been fully elucidated (West *et al.* 2007). The epaxial musculature along either side of the spine offers an easily accessible and safe site for intramuscular injection if a bird's movement is largely restricted.

10.4.3 Intravenous

The two preferred sites for intravenous therapy are the medial metatarsal vein, and the jugular vein. Working at either site is potentially hazardous to the patient and any handlers. If the patient is sedated or immobilized, the medial metatarsal vein presents a convenient site for an indwelling catheter, however is difficult to observe through the leg scaling (see Chapter 7 Figure 7.11). A higher risk of hematoma formation exists with the jugular vein, particularly if the bird is only mildly sedated. With the bird restrained in lateral recumbency the vein can be occluded distally and the jugular can be palpated digitally. If chosen, the catheter should be securely and gently fastened using tissue adhesive and a light bandage. The decision of which site to use should be based upon the severity of the illness, behaviour of the patient, the level of sedation applied to the patient, and the manual expertise available to the consultant veterinarian. Alternatively, birds can be conditioned to voluntarily receive a catheter to the brachial vein (Cindy Pinger *personal communication*).

10.4.4 Other information

Also see section 10.6.1.

10.5 CLINICAL EXAMINATION

Once the bird has been sedated and/or restrained (see Chapter 6), a complete physical examination should be performed which may identify a clinical condition or abnormality in addition to the primary problem and provide a baseline for subsequent examinations.

Wherever possible, accurate weight records should be maintained with weights recorded at least once a month.

The assessment should start at the head, checking eyes, beak, nostrils and mouth. Any asymmetry should be noted. Oral examination should document any intra-oral and/or extra-oral abnormalities, including plaques or cleft palates in young birds. The ear canal should be checked for ectoparasites (Fowler 1991). The neck is examined for swellings or other abnormalities.

The fat and muscles over the sternum, ribs and back should be palpated to determine general body condition of the bird (See Appendix 10). If an increase in weight does not correspond with an increase in body condition score, consider behavioural observations to determine whether or not there is a health problem.

Wings are vestigial but still should be examined. If possible, legs should be flexed and carefully assessed for any damage or abnormalities, paying particular attention to the joints.

The examining veterinarian should check for ascites (distended abdomen), along with any other inflammation, exudates, swelling, masses, or parasites that indicate disease.

A blood sample should be taken and complete blood count and routine chemistry panel run. Feathers should be collected at this stage for DNA analysis (Discuss with Species Co-ordinator). It is also recommended that a microchip be implanted.

10.6 DIAGNOSTIC EVALUATION

10.6.1 Blood Sampling

Blood collection techniques should minimise stress and patient contact time. In the cassowary, the vein of choice by a number of veterinarians is the medial metatarsal vein in either l*e.g.* Due to vestigial wing development, the brachial vein is small (See Chapter 7 Figure 7.9), however can still be used to collect sufficient quantities of blood for a chemistry panel and CBC by conditioning the bird to enter a crate, and desensitizing the wing area to receive a catheter (Cindy Pinger *personal communication*). Blood has also been collected from the brachial vein during standard manual restraint procedures. The jugular veins on both sides of the neck are large in cassowaries and have successfully been used for administration of intra-venous fluids, however use of these veins can lead to very large haematoma formation and if the bird moved suddenly the jugular vein is easily lacerated, resulting in significant and sometimes fatal haemorrhage. The selection of the site for venipuncture should be at the discretion of the consultant veterinarian.

Whenever taking blood samples from cassowaries, pressure at the site for up to two minutes may be required to produce good haemostasis – longer for intravenous puncture sites.

Blood should be collected using a syringe and 23-21 gauge needle. It is safe to collect 5mL per kilogram body weight, so a routine blood sample of 5-10mL can be safely collected from all but the youngest chicks, unless a physical condition contraindicates this. Blood should be gently and promptly transferred to a heparinised syringe or heparinised (green top) collection tube for diagnostic haematology. This should be gently rotated for several minutes to ensure adequate mixing of the anticoagulant. A fresh whole blood smear should be made at the time of collection and air dried. This provides better cell morphology than an anti-coagulated sample. The blood and slide should be refrigerated as soon as possible after collection and transported without undue delay for analysis.

See Appendix 16 for reference ranges obtained from ISIS. An unpublished collaboration between Annabelle Olson and Graham Lauridsen regarding blood parameters of wild birds may assist in establishing normal reference ranges in the near future. Normal clinical pathology has not yet been established for cassowaries in other age classes.

10.6.2 Faecal Evaluation

The presence and quality of faeces should be monitored daily by keepers. A normal scat from a healthy bird, dependant on food items given, will contain undigested seeds, fruit skins and occasionally partially digested fruit pieces, be moist but not watery (unless hot, and unless food items have a particularly high water content), with no visibly separated urate component. Visibly separated urates and/or bright green and dark green to black mucoid diarrhoea generally indicate a sick bird. Dark green faeces with a visibly separated urate component have also been observed in healthy female birds during the breeding season (times of low appetite) and is considered normal (*personal observation*, Mike Taylor *personal communication*), however close monitoring and regular faecal testing may alleviate any further concerns.

To collect a faecal sample, birds should be isolated individually into a clean holding pen so that a sure sample can be collected for each bird.

10.6.3 Radiology

Radiology is an important diagnostic tool and although little literature is available relating specifically to cassowaries, a number of studies highlighting ultrasound as an important tool specific to captive breeding and management, and soft tissue evaluation exist in the literature (Hildebrandt *et al*. 2006, Hildebrandt *et al*. 2000, Hermes *et al*. 2004).

The necessity for animal handling and sedation add invasive components to the application of ultrasonography in non-domestic species (Hildebrandt 2006) through the risk of restraint (physical or chemical) (Hildebrandt *et al*. 2000), however there has been no report of injury or ultrasound-induced discomfort when examinations were performed under the international ultrasound safety guidelines (Hildebrandt 2006).

10.7 SUPPORTIVE CARE

10.7.1 Hand Feeding

Under critical circumstances, hand feeding or close presentation of food should serve as the key approach to stimulate the appetite of an otherwise inappetant bird. An ill bird will generally be inappetant, and may not approach a feeding receptacle for food. As such, it may be required that the personnel are in very close proximity to the bird, without any formal barriers between the bird and personnel. Whatever the reason for handfeeding, this method should be approached with caution and only be carried out by personnel with a working understanding of the individual's behaviour and of species biology.

Initially, personnel may have to gently pry open the beak and place the food item in the back of the oropharynx, being careful to avoid the tracheal entrance. Persistence is the key.

An adult male cassowary was presented to veterinarians with lethargy, inappetance and chronic illthrift. Blood smear examination and biochemistry showed a marked left shift and toxic change in heterophils indicating severe acute inflammation. Aggressive medical therapy included IV fluids, antibiotics, multivitamins, cortisone and anti-inflammatories. Additionally the bird was hand fed without any formal barriers for one month with continued antibiotic and electrolyte treatment. The bird made a full recovery.

10.7.2 Gavage/Tube Feeding

Tube feeding is similar to other avian species. The glottis can be easily visualised and avoided. As in other birds, the oesophagus lies ventral to the glottis. Dependant on the tractability of the patient, no less than three appropriately trained personnel should be involved in the procedure - one to tube, and the remainder to restrain the bird.

A soft polyurethane or silicone orograstric tube with a diameter of 20mm or less for an adult bird should be used for the procedure. The end of insertion should be rounded and smooth, and the aperture for the food entering the proventriculus should be located along the length of the tube towards the end of insertion. The clean tube should be well lubricated with warmed KY Jelly and the food or medication should be loaded into the tube before insertion so that air is not pumped into the proventriculus. Great care must be exercised in gradually guiding the tube to the proventriculus, as the fragile esophagus is comprised of only thin longitudinal muscles.

10.7.3 Fluid Therapy

Fluids are administered to cassowaries in a similar manner to other avian species. Oral or intravenous fluid therapy methods are most common. See Section 10.4.3.

10.7.4 Neonatal Medicine

Supportive care for cassowary chicks is the similar to other avian species. If the chick is being parent-reared, the aim should be to return the chick to the sire as soon as possible. Successful re-introduction to parent birds have been observed after periods weeks (Mike Taylor *personal communication*, Dan Mead *personal communication*). If aggressive therapy is required, a commitment to hand-rearing may be necessary.

10.8 PREVENTATIVE MEDICINE

10.8.1 Quarantine

Biosecurity, together with adequate management and nutrition, plays a critical role in reducing the risk of introducing new pests and diseases to an existing establishment. Adequate quarantine will reduce the likelihood of additional exposure and limit mortality in the event of infection.

As new birds have the potential to contaminate soil and facilities with various pathogens, a suggested minimum quarantine period of 30 days should be applied to any new bird prior to entering a collection. During this period the bird should be found free of evidence of communicable diseases. New birds should be quarantined away from existing birds where possible.

Parasite screening and management should form a part of routine quarantine procedures. See section 10.9 for diseases of concern. These should form the basis for assessment whilst in quarantine.

10.8.2 Routine treatments

In North America, some institutions vaccinate against Eastern Equine Encephalitis, Western Equine Encephalitis, and West Nile Virus (Mike Taylor, *personal communication*).

10.9 DISEASES OF CONCERN

Cassowaries have a long life span, sometimes in excess of 45 years in captivity. Few published records currently exist of diseases in cassowaries and little is known of the impact of disease on wild populations.

With much of the focus of captive cassowary management being directed towards breeding, it is imperative that the birds are in optimal health for a successful outcome. The following section outlines a number of diseases that have been observed in cassowaries and some diseases observed in ratite species that might be expected in cassowaries. Etiology, treatment options and modes of prevention are included where available.

10.9.1 Nutritional

	Hipovitaminosis E
Observed in :	Ostrich
Etiology :	Vitamin E deficiency
Symptoms/ Presentation :	Muscle degeneration, paresis, poor weight gain, high AST and CPK values
Diagnosis :	Clinical examination, diagnostic imaging
Treatment :	Antibiotics, pain relief, nutrition support/fluid therapy
Age predisposition :	Chick
Prognosis :	Good
Management Recommendation:	Increase vitamin E by offering fruits such as kiwifruit, nectarines, papaya, peaches, tomato, cooked carrots and cooked sweet potato, all in moderation

Source: Blue-McLendon 1992, Dierenfeld 1989.

	Hypovitaminosis A
Observed in :	Rhea
Etiology :	Vitamin A deficiency
Symptoms/ Presentation :	Clinical epiphora, oral abscesses, decreased growth
Diagnosis :	Clinical examination
Treatment :	Vitamin A supplementation
Age predisposition :	Any age
Prognosis :	Good
Management Recommendation:	Increase vitamin A by offering fruits such as apricots, rock melon, mango, nectarines, papaya, peaches, cooked carrots and cooked sweet potato, all in moderation

Source: Speer 2006.

	Polyneuritis “Star Gazing”
Observed in :	Ostrich
Etiology :	Thiamine deficiency
Symptoms/ Presentation :	Lethargy, head tremors, decrease in appetite, impaired digestion, weakness, convulsions
Diagnosis :	
Treatment :	Thiamine supplementation
Age predisposition :	Any age
Prognosis :	Good

Source: Speer 2006.

	Osteopyplasia
Observed in :	All ratites
Etiology :	Rapid growth of the tibiotarsal and tarsometatarsal bones. Congenital and environmentally induced. Manganese deficiencies have been associated with slipped tendons in gallinaceous birds, but a deficiency of this mineral has not been associated with porosis in ratites.
Symptoms/ Presentation :	Leg deformity and stunted growth. Rotation of either tibiotarsal or tarsometatarsal bones will produce valgus or varus deformation of the hock joint. May progress to unilateral slipped tendon deformity.
Diagnosis :	Visual examination, diagnostic imaging
Treatment :	Vitamin E and selenium with discretion, exercise
Age predisposition :	Young chicks
Prognosis :	Good if identified early
Management Recommendation:	Deformities are probably multifactorial, with decreased exercise, genetics, and diets of high fat and protein all being involved (Blue-McLendon 1992). Consider increasing vitamin E in regular diet by offering fruits such as kiwifruit, nectarines, papaya, peaches, tomato, cooked carrots and cooked sweet potato, all in moderation. Consider increasing selenium in regular diet by offering fruits such as banana, honeydew, frozen peas and cooked carrot, all in moderation. Moderate fat and protein

Source: Blue-McLendon 1992.

10.9.2 Parasitic

	Ectoparasite
Observed in :	All ratites
Symptoms/ Presentation :	Minor swelling at the site of attachment. Can cause slow growth, unthriftness and reduced egg production.
Diagnosis :	Visual observation
Treatment :	Direct application of 5% carbaryl dust, 2% malathion spray
Age predisposition :	Any age
Prognosis :	Good
Management Recommendation:	Topical treatment with ivermectin quarterly
Other notes :	Hard ticks do not transmit known disease-causing organisms to ratites

Source: Craig & Diamond in Tully & Shane 1996, Proctor 2001.

	Endoparasite
Observed in :	Cassowary, Ostrich, Rhea, Emu
Etiology :	Helminths
Symptoms/ Presentation :	Inappetance, unthriftness,
Diagnosis :	Faecal float, smear
Treatment :	Praziquantel at 7.5mg/kg or Fenbendazole at 15 and 25mg/kg may halt cestode infection. Ivermectin given at one month intervals beginning at one month of age will prevent nematode infestations.
Age predisposition :	Any age
Prognosis :	Good
Management Recommendation:	Routine parasite screening – every three to four months and treatment as required

Source: Craig & Diamond in Tully & Shane 1996.

10.9.3 Bacterial

	Botulism
Observed in :	Cassowary, Ostrich
Etiology :	Ingestion of a toxin produced by *Clostridium botulinum* - either directly from a carcass, from maggots feeding on a carcass or from drinking water containing rotting flesh
Symptoms/ Presentation :	Paresis and paralysis of voluntary muscles. Generally starting with wings (in flighted birds), inner eyelid membrane, followed by neck muscles. Weakness, ataxia
Diagnosis :	Demonstration of toxin in serum, liver homogenates or crop, or GI washings.
Treatment :	Numerous treatments reported, including bacitracin or streptomycin, although none have been uniformly successful. Antitoxin is available, but requires special handling and must be given early in the intoxication. Fluid therapy, shade. Some affected birds may recover without treatment
Age predisposition :	Any age
Prognosis :	Good
Management Recommendation:	Remove any uneaten animal matter from enclosures and water sources, particularly on hot days and warm nights
Post mortem findings :	No characteristic gross lesions

Source: Romer 1997.

	Omphalitis
Observed in :	Cassowary, Emu, Ostrich
Etiology :	Penetration of bacteria through the shell into the yolk sac
Symptoms/ Presentation :	Redness, warmth, swelling, pain, discolouration of yolk sac, jaundice, poor appetite
Diagnosis :	Physical examination, clinical appearance of yolk sack and umbilicus area
Treatment :	Surgical removal of the yolk sac, antibiotic therapy, supportive care, fluid therapy
Age predisposition :	Hatchling ratites
Prognosis :	Depends on severity
Management Recommendation:	If specimen was artificially incubated, Betadine or silver sulfadiazine umbilicus site at hatch
Post mortem findings :	Renal failure, aspiration

Source: Mike Taylor *personal communication*.

	Toxoplasmosis
Observed in :	Cassowary, Rhea
Etiology :	Cats are the definitive host of *Toxoplasma gondii.* Contamination may result from eating contaminated soil or meat products
Symptoms/ Presentation :	Acute collapse, dyspnoea (Orosz et al 1992). Bloody diarrhoea, anorexia, (Craig & Diamond in Tully & Shane 1996)
Diagnosis :	Antibody titer
Treatment :	Antibiotics, 9 day treatment with trimethoprim sulfadiazine (50mg/kg)
Age predisposition :	Any age
Prognosis :	Good
Cautions :	Zoonotic potential. Immuno-compromised persons are most susceptible.

Source: Craig & Diamond in Tully & Shane 1996; Dubey 2002; Dubey et al. 2000; Orosz *et al*. 1992.

	Tuberculosis
Observed in :	Cassowary, Emu, Ostrich
Etiology :	*Mycobacterium avium*
Symptoms/ Presentation :	Progressive weight loss in spite of good appetite, depression, diarrhea, increased thirst, respiratory difficulty, decreased egg production. Systemic illness, chronic ill thrift, atrophy of muscles over sternum (in domestic poultry - difficult to detect in ratites). Muscular wasting, weakness, cachexia. Clinical symptoms include elevated WBC, low RBC
Diagnosis :	Clinical assessment, Intradermal tuberculin testing in an individual bird, PCR, ELISA. Check oropharanx for plaques - generally birds with these plaques test positive for TB
Treatment :	Not usually recommended due to zoonotic potential
Age predisposition :	Any age
Prognosis :	Poor, however successful therapy has been recorded in a bird overseas following very early diagnosis and extensive long-term therapy.
Management Recommendation:	Minimize stress, proper ventilation, prevent malnutrition, quarantine new arrivals
Cautions :	High zoonotic potential. Face mask for post mortem procedures to minimize risk of infection. Immuno-compromised persons are most susceptible. Safety precautions including the use of a face mask during post mortems and normal hygiene practices should be emphasized to minimize the risk of infection
Post mortem findings :	Typical granulomatous nodules throughout liver, spleen, intestine and mesenteric lymph nodes may be present. Large granulomatous masses may occur in or adjacent to organs. Lung infections are not a consistent feature of avian TB in birds. In other species, prolapse of the terminal intestinal tract (Shane & Tully in Tully & Shane 1996)
Other notes :	The prevalence of this disease in wild cassowaries and its role in population dynamics is not known. Most of the recorded cases in the Cairns region have been dispersing age birds. Further research into this and other diseases of wild birds needs to be addressed

Source: Graham Lauridsen *personal communication*, Olsson *unpublished*, Shane & Tully in Tully & Shane 1996, Speer 2006.

	Salmonellosis
Observed in :	All ratites
Etiology :	Salmonella spp.
Symptoms/ Presentation :	No specific clinical signs
Diagnosis :	Cloacal swab, microbiological screening
Treatment :	Antibiotic therapy
Age predisposition :	Any
Prognosis :	Good
Management Recommendation:	Whole-blood S. Pullorum agglutination test
Cautions :	Zoonotic potential
Other notes :	Treatment with antibiotics generally suppresses clinical infection but may lead to an asymptomatic carrier state

Source: Stewart In: Ritchie et al 1994, Tully & Shane 1996b, Thomas *et al*. 2001.

10.9.4 Mycotic

	Aspergillosis
Observed in :	Cassowary, Emu, Ostrich
Etiology :	*Aspergillus fumigates*, *Aspergillus flavus* and *Aspergillus niger* -opportunistic, secondary to poor husbandry, continual damp conditions (as in a prolonged wet season of the tropical region), or other causes of debility such as concurrent injury, illness or antibacterial medication causing respiratory symptoms.
Symptoms/ Presentation :	Clinical signs include inappetance, polydypsia, polyuria, cyanosis, and non specific signs such as weight loss, progressive weakness, green watery diarrhoea, anorexia, dyspnoea and wheezing. Lungs are the internal organs reported to be the most affected
Diagnosis :	Physical examination, endoscopic examination, endoscopic sampling of affected tissue for cytology, culture or biopsy. Air sac wash for cytology and culture. Air sacs are poorly visible in radiographs, and so are likely to be of little use for cassowaries. MRI may be useful in cases where focal granuloma of the brain is suspected
Age predisposition :	Any age
Prognosis :	Often poor due to delayed diagnostics and treatment failure
Management Recommendation:	Hosing and washing of enclosed spaces should be mop or towel dried, rather than dried by evaporation. Daily disinfection with quarternary ammonium agent such as F10 is recommended. Reduce stress and manual restraint. Provide adequate ventilation to reduce humidity. Straw or chaff should never be used as bedding for injured or debilitated birds due to the risk of fungal spores. Smoking in the home environment should be eliminated. Straw or chaff should never be used as bedding for injured or debilitated birds due to the risk of fungal spores. Consideration should be given to prophylactic antifungal medication for any bird recovering from a debilitating injury or on antibacterial medication
Other notes :	Consideration should be given to prophylactic antifungal medication for any bird recovering from a debilitating injury or on antibacterial medication

Source: Atasever & Gümüşsoy 2004, Riddell 1987 in: Reissig et al 2002, Romer 1997.

10.9.5 Viral

	Eastern Equine Encephalitis
Observed in :	Cassowary, Emu
Symptoms/ Presentation :	Lethargy, gurgled breath, self-ostracizing, rapid onset ataxia or prostration, Severe aspiration pneumonia
Diagnosis :	PCR, diagnostic imaging, demonstrated serologic titer, clinical examination
Treatment :	No successful treatment. Equine bi or trivalent vaccination seems to be protective
Age predisposition :	Any
Prognosis :	Poor
Management Recommendation:	Euthanasia. Mosquito abatement
Post mortem findings :	Perivascular lymphohistiocytic inflammation. Bacterial sepsis secondary to aspiration pneumonia not ruled out. Gross lesions: hemorrhagic enteritis, petechial haemorrhages or serosal membranes - no CNS lesions seen. Histopathology: sever necrosis of hepatocytes and intestinal mucosa. Necrotizing vasculitis of spleen and lamina propria of intestine
Other notes :	Based positive PCR and compatible lesions, inflammation likely a systemic manifestation of EEE virus. Mosquitoes are considered a key vector for transmitting this virus

Source: Speer 2006.

Disease :	Western Equine Encephalitis
Observed in :	Emu
Symptoms/ Presentation :	Depression, anorexia, ataxia, paddling of legs, abnormal neck motions, lateral recumbency
Diagnosis :	HI, HA, PCR
Treatment :	Supportive care. Protection against secondary bacterial invaders. Fluids, analgesics, antibiotics
Age predisposition :	Young more susceptible than old
Prognosis :	Very good
Management Recommendation:	Mosquito abatement
Cautions :	Zoonotic potential
Post mortem findings :	Gross lesions: vasculitis, reositis, pericardial fluid

Source: Speer 2006.

	Newcastle's Disease
Observed in :	All ratites
Symptoms/ Presentation :	Limb paralysis, torticollis, tremors, opisthotonus, limp neck, twitching of neck muscles, inability to stand, ataxia, depression, diarrhea, anorexia, coryza, conjunctivitis, rhinitis, sneezing, coughing, dysplea, limb paralysis, pause in egg production with no other outward signs
Diagnosis :	HI, HA, PCR
Treatment :	Nil
Age predisposition :	Any age
Prognosis :	Poor
Management Recommendation:	Euthanasia. Vaccination with modified live eyedrop (LaSota) has produced antibody in Ostrich and Emu
Cautions :	High potential to transfer to other avian species
Post mortem findings :	Gross lesions: enlarged liver, epicardial hemorrhage. Histopathological lesions may not be found
Other notes :	Transmission is generally by humans

Source: Speer 2006.

Avipoxvirus and Paramyxovirus type 1 have both been reported in the cassowary (Stewart 1994).

10.9.6 Non-infectious

Disease :	Capture or Exertional Myopathy
Observed in :	Emu
Etiology :	Exposure to high stress, excess heat, or excitement
Symptoms/ Presentation :	Muscle ischemia secondary to exercise or excitement. Avascularity and lactic acidosis cause muscular lysis, myoflobin release and a nephropathy. Clinical signs include muscle pain and swelling. Severe cases are characterised by stiffness, hyperpnea, collapse, myoglobinemia, and acute renal failure. Serum potassium, phosphorous and muscle enxymes are increased
Diagnosis :	Physical examination
Treatment :	Supportive care such as IV fluids, bicarbonate, body cooling, rest and muscle relaxants (e.g. Diazepam)
Age predisposition :	Any age
Prognosis :	Depends on severity
Management Recommendation:	Limit stressful encounters to cooler temperatures.

10.9.7 Neoplasia

	Tumour
Observed in :	All ratites
Etiology :	Numerous
Symptoms/ Presentation :	Unusual growth/s
Diagnosis :	Biopsy
Treatment :	Surgical amputation
Age predisposition :	Any age
Prognosis :	Depends on severity
Other notes :	in the case of (Ensley et al 1984), gross and microscopic findings were most consistent with a foreign body reaction

Source: Ensley *et al*. 1984.

10.9.8 Developmental

	Yolk-sac Malabsorption
Observed in :	Cassowary, Ostrich
Etiology :	Numerous
Symptoms/ Presentation :	Swollen abdomen, dyspnoea, exercise intolerance, inability to stand or walk, inappetance, weight loss, or failure to grow.
Diagnosis :	Physical examination
Treatment :	Surgical removal of yolk-sac, antibiotics
Age predisposition :	Hatchlings
Prognosis :	Dependant on timing of physical examination
Management Recommendation:	See appendix 18

Source: Kenny & Cambre, 1992.

10.9.9 Skeletal

	Avian Urolithiasis (Gout)
Observed in :	Cassowary
Etiology :	Result of kidney damage from any number of potential causes. Namely infectious disease, nutritional issues, toxic substances.
Symptoms/ Presentation :	Decreased appetite, lethargy, weight loss, abnormal droppings, change in temperament
Diagnosis :	Patient history, diet analysis, diagnostic imaging, blood chemistry panel, biopsy. Demonstration of uric acid crystals in joint fluid.
Treatment :	Ongoing treatment required. Reduce protein and supplement with vitamin A. Experimental diets containing ammonium chloride, ammonium sulphate, DL-methionine, and methionine hydroxyl analog have been used to treat pullets and layers in the poultry industry. Check with your veterinarian if these treatments are approved.
Age predisposition :	Adult birds
Prognosis :	Manageable with ongoing treatment
Management Recommendation:	Adequate nutrition, access to water
Post mortem findings :	One spheroid expansile lesion diagnostic of gout was present in a cassowary upon inspection of museum specimens surveyed by Rothschild & Rühli (2007).
Other notes :	A bird was found to have visceral and/or articular urate deposits

Source: Reece *et al*. 1992, Rothschild & Rühli 2007.

	Renal gout
Observed in :	Cassowary
Symptoms/ Presentation :	Curled toes, wry-neck, lacking appetite, lethargic
Diagnosis :	At necropsy
Treatment :	Supportive care, antibiotics, antifungal medication, fluid therapy - all unsuccessful
Age predisposition :	hatchling
Prognosis :	poor
Management Recommendation:	See appendix 18

Source: Mike Taylor *personal communication*.

	Arthritis
Observed in :	Cassowary
Etiology :	Genetic, developmental
Symptoms/ Presentation :	Lethargy, discomposure, swollen joints, asymmetry while in standing or sitting position.
Diagnosis :	Physical examination, patient history, diagnostic imaging
Treatment :	NSAIDS, Glucosamine
Age predisposition :	Adult birds
Prognosis :	Good. Manageable with ongoing treatment
Management Recommendation:	Adequate nutrition from hatch
Other notes :	A number of related female birds at different institutions have presented similar symptoms

Leg abnormalities

Limb deformities are common in ratite chicks (Speer 2006). In future, it will be particularly important to characterise the type of leg problem being encountered, the environment the animals are in (temperature, light, litter condition and type, and air movement), genetics, health status of breeder birds, and nutrient content of diets (Speer 2006).

	Leg and feet deformities
Observed in :	All ratites
Etiology :	Multifactorial. Environment, genetics, health status of breeders, nutrient content of diets, lack of exercise
Symptoms/ Presentation :	Twisted or bowed bones of the legs and feet, swollen hock joints, slipped tendons, progressing external rotation of the tibiotarsus and/or tarsometatarsus, tibial dyschondroplasia, perosis, chondrodystrophy, rickets, retained cartilage cores and osteochondrosis dissicans
Diagnosis :	Physical examination, diagnostic imaging
Treatment :	Dependant on symptoms, but may include derotational osteotomy, stack pinning with hemicerclage wires, K-E devices and plates. Periosteal stripping.
Age predisposition :	Chicks
Prognosis :	Poor
Management Recommendation:	Thorough assessment of specific deformity as occurs. Review management strategies, genetics, environment, health status of breeders, nutrient content of diets, exercise regime
Other notes :	SEE Chapter X – nutrition and feeding

Source: Speer 2006.

10.9.10 Trauma

	Fracture
Observed in :	All ratites
Etiology :	Trauma
Diagnosis :	Radiology
Treatment :	Analgesics and splint for leg injuries. Injured birds should be treated in situ by erecting a temporary enclosure around the bird and providing food and water until the bird is sufficiently recovered to fend for itself. Due to the anatomical neck structure, cases of cervical vertebral fractures often present partial or complete paralysis so treatment is not recommended
Age predisposition :	Any age
Prognosis :	Often poor in older birds due to injuries or subsequent stress of treatment. Good in younger birds
Management Recommendation:	Fractures have been observed following fighting with other birds. Contact time between birds should be monitored closely and birds separated at the first sign of serious physical aggression

Source: Graham Lauridsen *personal communication*; Bennett and Kuzma (1992).

10.9.11 Reproductive tract

Disease :	Prolapse
Observed in :	All ratites
Etiology :	Trauma of urogenital organ/s
Symptoms/ Presentation :	Internal organ protruding from cloaca
Diagnosis :	Physical examination
Treatment :	Clean prolapsed or damaged organ and replace inside cloaca. Surgical amputation has occasionally been required.
Age predisposition :	Any age
Prognosis :	Depends on severity

Source: Hicks-Alldredge in: Tully & Shane 1996.

	Salplingitis - Infection of upper reproductive tract
Observed in :	Cassowary
Etiology :	Infectious agent most often isolated is *E. Coli*. Other agents include *Mycoplasma gallisepticum*, *Salmonella* spp., *Streptococcus* spp., and *Pasteurella multocida*. Infection may result from muscular fatigue of the oviduct during egg production, allowing an ascending bacterial infection from the cloaca
Symptoms/ Presentation :	Rough shelled eggs, but more advanced or extensive infection will induce depression, lethargy, anorexia, green urates or failure to lay eggs, cloacal discharge. Physical examination reveals a doughy abdomen, and blood tests may show evidence of acute or chronic inflammation/infection. Clinical examination my reveal non-functional oviduct and atrophied ovaries
Diagnosis :	Physical examination, patient history, diagnostic imaging, blood chemistry panel
Treatment :	Broad spectrum antibiotic therapy (enrofloxacin)
Age predisposition :	Adult
Prognosis :	Good
Management Recommendation:	Monitor closely during and after breeding/laying season
Other notes :	Commonly seen at the end of egg laying cycle. Gross examination may be difficult to differentiate from impacted oviduct

Source: Hicks-Alldredge in: Tully & Shane 1996.

	Egg binding
Observed in :	All ratites
Etiology :	Cold weather, age, malnutrition, poor condition of mucous membranes in the vent area, and lack of exercise
Symptoms/ Presentation :	Often no clinical signs exhibited. History of continued reproductive activity without lay, straining, vaginal 97rolapsed, or no outward signs at all
Diagnosis :	Patient history, gross examination, diagnostic imaging
Treatment :	Increase ambient temperature of the bird and administration of calcium and oxytocins
Age predisposition :	Adult
Prognosis :	Good
Management Recommendation:	Exercise and enrichment regime

Source: Hicks-Alldredge in Tully & Shane 1996.

10.9.12 Toxicity

	Toxicity
Observed in :	Cassowary
Etiology :	Consumption of or exposure to toxic substances
Symptoms/ Presentation :	Severe diarrhoea, wobbling, anorexia and polydypsia
Diagnosis :	Gross examination
Treatment :	Aggressive fluid therapy
Age predisposition :	Any age
Prognosis :	Depends on severity
Management Recommendation:	Ensure known non-toxic items are not fed
Post mortem findings :	Prolapse of the penis, severe enteritis, and swelling of the kidneys with sub-capsular heavy deposits of urates. Leaves collected from the gizzard of one bird were identified as coast live oak (*Quercus agrifolia*) and diagnosis was made based on the renal lesions and the finding of a high content of tannins in the liver and gastrointestinal tract

Source: Kinde 1988.

	Selenium toxicity
Observed in :	Ratites
Etiology :	Empirical dosage with parenteral Vitamin E/Selenium compound
Symptoms/ Presentation :	Acute death with pulmonary edema and congestion
Treatment :	Nil
Age predisposition :	Any age
Prognosis :	Varies
Management Recommendation:	Judicious administration of parenteral Vitamin E/Selenium compound
Post mortem findings :	Liver selenium ranged from 6.97ppm - 9.8ppm

Source: Speer 2006.

10.9.13 Other

	Pododermatitis (Bumblefoot)
Observed in :	All ratites
Etiology :	Numerous
Symptoms/ Presentation :	Swelling of foot pads, difficulty standing, assymetry
Diagnosis :	Gross examination
Treatment :	Surgical or non-surgical, depending on severity
Age predisposition :	Any age
Prognosis :	Dependant on severity
Management Recommendation:	Ensure that substrate in small enclosures are cleaned or replaced regularly. Provide varied substrates

Source: Stewart in: Ritchie *et. al* 1994.

	Feather Loss
Observed in :	Cassowary
Etiology :	Moult? Unknown, but appears to be self limiting. Possibly related to specific nutritional requirements at that particular time of year. May be associated with internal or external parasites
Diagnosis :	Gross examination
Treatment :	Some birds have responded to Ivermectin
Age predisposition :	Adult
Prognosis :	Good
Management Recommendation:	Monitor for seasonal occurrence
Other notes :	Appears to be a seasonal occurrence in many birds, varying in intensity

	Hyperthyroidism
Observed in :	Cassowary
Symptoms/ Presentation :	Chronic feather loss - underlying skin over whole body almost completely exposed
Diagnosis :	Blood chemistry panel, biopsy, gross examination, clinical examination
Treatment :	Nil
Age predisposition :	Unknown
Prognosis :	Unknown
Other notes :	

Source: Graham Lauridsen personal communication.

10.10 POST MORTEM EXAMINATION

Due to inherent difficulties in conducting routine clinical examinations of cassowaries, it is most important to utilise the opportunity to conduct a thorough post mortem examination as a matter of priority on any bird that dies. Little is published of the gross and clinical anatomy or physiology of cassowaries and minimal literature exists pertaining specifically to the diseases of cassowaries so the result of a detailed post mortem will add to the body of knowledge and assist in the management and disease prevention in other cassowaries.

A standardised post-mortem form assists with the development of a thorough technique (See Appendix 3).

Strict hygienic precautions should always be followed when conducting a post mortem examination on a cassowary because of the possible transfer of pathogenic organisms, or poisons. Safety precautions including the use of a face mask and surgical gloves during post mortems and normal hygiene practices should be emphasised to minimise the risk of infection.

The examination should begin with a review of the patient history and any medical records. Any significant medical history should be attached to the post mortem evaluation form. If no records exist, a unique accession number should be assigned. The identity of the bird should be verified and the body weight measured and recorded.

If the bird is still alive and awaiting euthanasia, blood should be collected for a full chemistry panel, EDTA for haematology, plasma for biochemistry and serum for serology. Purple and green heparinised tubes should be used for anti-coagulated samples.

The examining veterinarian should observe the overall condition of the head, viscera, and carcass looking for inflammation, exudates, swelling, masses, or parasites that indicate disease. Following external examination of the carcass the feathers are dampened with a disinfectant to prevent aerosol spread of feather debris and potential pathogens.

The coelomic (thoraco-abdominal) cavity is opened (ideally without disturbing the viscera) by incising along the abdominal midline and then cutting through the ribs cranially. Bone cutters can be used to cut through the coracoids-scapula at the cranial-most end. The sternum can then be reflected over to one side. The organs first are examined *in situ*, taking note of the position and appearance of organs and lesions.

The heart should be observed and palpated, followed by the lungs on all external surfaces and brachiated entrances. The abdominal and thoracic air sacs should be observed. Lesions should be noted, and sampled if visual diagnosis is not possible. The digestive system should be inspected, including the oesophagus, and the condition of musculature surrounding the lumen of the proventriculus and ventriculus. Any impactions and/or undigested material should be noted.

All other visceral organs, along with the neck, trachea, head, eyes and sinus openings, and all internal surfaces should be observed. The liver and spleen should be observed and palpated, noting any lesions. The kidneys should be observed with the carcass, and palpated after removal to an inspection tray. Any lesions should be noted.

Routine microbiological samples from the liver, lung, mesenteric lymph nodes and heart blood should be collected aseptically at this stage. All remaining organs are then removed and examined in more detail. The sex of the bird should be confirmed and recorded. If no gross lesions are detected it is appropriate to take samples of all major organs for histological examination. Palpation of suspect lesions, and where necessary, incision to detect disease conditions and/or pathological changes. Care should be taken when handling organ sections to avoid compression artefact of the tissues. Slices of tissue should be cut with a sharp blade and gently transferred to the formalin pot. Air sac tissues should be placed on a small piece of paper before fixation to facilitate identification of the tissue for processing. Sections of the intestines should be opened to ensure proper fixation of the mucosa. The amount of formalin required for proper fixation is equal to ten times the volume of the sample. Proper labelling of the formalin pots is essential to assist the pathologist in identification of the tissues. Parasites are best preserved in 70% ethanol. Tissues retained should be recorded in the Post Mortem Evaluation form (Appendix 3).

All routine, physical, blood and post mortem examination findings should be forwarded to the species co-ordinator for analysis and addition to a clinical database for cassowaries.

10.11 THERAPEUTICS

Pharmacokinetic studies have not been conducted on Cassowaries, however much is gained from extrapolation of information published on other commonly farmed ratite species. The most commonly used veterinary drugs are not registered for use in birds but can be used judiciously if required. Some useful therapeutics in cassowaries include but are not limited to those listed in Appendix 17. Consult an experienced veterinarian for further advice on therapeutics.

See appendix 17 for a schedule of drugs used for treatment in cassowaries.

Fenbendazole (Panacur), a commonly used antihelminthic, has been found to cause bone marrow suppression in other avian species (Howard *et al*. 1999) and so should be used with caution in cassowaries.

FUTURE DIRECTIVES AND AVENUES OF RESEARCH

- Establish clinical database of health concerns, treatment, management and etiology.
- Optimise post-mortem examination procedures to compile a species-specific clinical database.
- Consistently report clinical findings to add to species-specific clinical database.
- Establish normal serology and SBC ranges for differing age classes and sexes.

INTRODUCTIONS

11.1 IMPORTANT CONSIDERATIONS

The first phase in any cassowary introduction should be the development of an animal management strategy. The strategy should include possible facility adjustments, alternative courses of action, staff involvement and intervention equipment required during introduction procedures.

11.1.1 Safety

As described in Chapter 6, section 6.1.

11.1.2 Facilities

It is important that a thorough evaluation of the facility is conducted prior to attempting an introduction to determine whether any modifications are required and hence whether a safe introduction can be attempted.

A number of institutions holding cassowaries have a single large exhibit with an adjoining enclosure or holding pen connected by a single access gate. As with introductions for other potentially dangerous species, single enclosures should not be used. Facilities such as this limit the opportunity to safely introduce specimens; however minor structural adjustments may assist in facilitating a successful introduction.

For the configuration of 1.1.0 birds, two adjacent enclosures with a holding enclosure linked to both is ideal. The main exhibits should be linked by gates at opposite ends of a shared fence line.

For the configuration of 2.1.0 birds or 1.2.0 birds, three adjacent enclosures with a holding enclosure linked to all three is ideal. The three main exhibits should be linked by gates at opposite ends of shared fence lines. From a species management perspective, this configuration is preferable as it allows birds to choose a mate, which appears to be an important factor for cassowaries.

11.1.3 Quarantine

As described in Chapter 8, Section 8.1.

11.1.4 Personnel, equipment, location

Personnel involved in monitoring and conducting introduction procedures should have a sound working knowledge of cassowary behaviour, and be appropriately trained to respond safely to any incidents.

11.1.5 Timing of introduction

Timing of introductions is crucial and encompasses a number of different aspects.

11.1.5.1 Pace

ASMP studbook records show that six deaths have occurred as a result of injuries sustained from an exhibit mate. Although this is a small figure, it does have a significant impact on the performance of any breeding program with an already limited pool of breeding candidates. The pace of introductions should be dictated by the behaviour of the birds and should not be rushed to meet breeding recommendation deadlines. While successful results might occasionally be achieved in less than six months, more often two-three years is observed.

11.1.5.2 Time of day

Physical introduction procedures should take place in the cooler parts of the day.

11.1.5.3 Season

It is recommended that introductions be dictated by the physiological processes within the birds in response to seasonal changes in the environment. Auditory and visual introductions geared towards breeding should commence prior to the breeding season for the best chance at success.

For introductions of hatchlings to sires, whether surrogate or natural, ideally the sire will have existing offspring of a similar age. For experienced sires, the likelihood of successfully introducing hatchlings is expected to increase.

Introductions of young sub-adults to sub-adults can occur at any time of year. For older sub-adults, it is probably best to attempt introductions around the breeding season.

11.2 INTRODUCTION COMPONENTS

Introductions can be divided into four key components: acclimatization, auditory, visual and physical. While all types of introduction will have auditory and visual components, not all will necessarily include a physical introduction.

11.2.1 Acclimatization

Before any introductions are attempted, all birds involved should be familiar with their surroundings and be allowed ample time to settle into their respective enclosures. Birds' appetites should be as expected for the time of year and normal behaviour …well before the onset of the breeding season.

A record should be kept of the amount and types of food consumed, and the demeanour and behaviour of each individual.

11.2.2 Auditory

In nature, low frequency sounds attenuate less in dense forests, and vocalizations from conspecifics are generally the first communication that birds will have with one another.

In captivity, auditory introduction will be the first contact between the individuals. Close observation and records should be kept outlining any behavioural responses of individuals to vocalizations (appendix 11) made by the conspecifics.

11.2.3 Visual

Given the open nature of most cassowary enclosures it is difficult to audibly separate individuals, so every effort should be made to completely visually separate the birds while they are settling in to their respective enclosures.

11.2.4 Physical

Rushing into a physical introduction could prove fatal, so personnel should not push the situation if birds are not comfortable. Close monitoring is paramount at this stage. Suitably qualified personnel should be on hand to assist if the introduction is not going smoothly. A plan to separate the birds should be discussed, including contingencies and escape routes for personnel. Any equipment necessary to separate the birds should be at the disposal of on-site keepers.

11.3 INTRODUCTION SCENARIOS

Introductions for cassowaries are generally quite simple – they either work, or are confronted with consistent difficulties. The following sections highlight components that are relevant to the different introduction scenarios of concern, along with when to attempt introductions, what behaviours should be expected, and what signs are good indicators of compatibility. In this context, compatibility refers to seasonal tolerance of the male by a female or vice-versa, for the short-term purpose of breeding only.

*11.3.1 ***ALL SCENARIOS involving adults, sub-adults*

In all scenarios, acclimatization (section 11.2.1) and auditory access (section 11.2.2) should be the first steps in the introduction procedure.

*11.3.2 ***PAIR FORMATION*

For the formation of a breeding pair for the breeding season only.

11.3.2.1 Visual access

Partial visual access should be allowed through two locked access gates for a few short intervals throughout the day. The remaining fence line should be covered. The idea being that the birds will associate these areas as connections to the adjoining respective enclosure. Close observation and records should be kept outlining any behavioural responses of individuals to body language of the conspecifics.

Incrementally, full visual access should be allowed. Initially, feeding should not occur along shared fence lines. By the breeding season, birds will ideally be feeding comfortably along shared fence lines.

11.3.2.1.1 Expected behaviours

Being a territorial species, varying degrees of aggressive behaviour can be expected with both visual and physical introductions. Dependant on the individuals, conflict may be limited to a threat display by one bird and submission by the other, without any physical contact. Other occasions may warrant immediate separation to limit injuries. Agonistic behaviours are listed in section 9.4.1 of this chapter. Attempts should not be made to physically introduce birds if any of the agonistic behaviours are observed during the breeding season.

11.3.2.1.2 Indications of compatibility

Compatibility in this context refers to seasonal tolerance of the male by a female or vice-versa, for the short-term purpose of breeding only. Most institutions observe year-round aggression in birds and should be held separately unless there are clear indications from both birds that they are receptive and are showing the behaviours mentioned below.

The most reliable indication of compatibility is tolerance of conspecifics within close proximity, most prominently during feeding time, most likely during the winter and spring months in all regions. Sitting along shared fence lines, and attempts at preening through the fence and gentle pecking are also recognized as signs that the birds are compatible.

The normal sitting/resting position (with beak in a horizontal position) differs from the more tolerant or passive sitting position where the beak is pointed at the ground. The female may be leaning forward somewhat whilst in her seated position, giving the appearance that her rump is slightly raised. 'Submission' described in 9.4.2 (this chapter) can also be an indication of receptiveness, so long as conspecifics are not displaying any agonistic behaviour.

Additional behaviours indicating compatibility are listed in Chapter 10 Reproduction, sections 10.5 and 10.6.

Although unusual, some pairs have demonstrated year-round tolerance of one another with no outward signs of aggression. These birds can be housed together full-time. For those who consistently show signs of incompatibility, a revision of pairing and recommendations should be considered by the species coordinator.

11.3.2.2 Physical access

Physical introductions should be primarily dictated by a consistent lack of agonistic behaviour from both birds, in conjunction with consistent presentation of behaviours that indicate compatibility.

Depending on the behaviour observed in both birds, the next step is to allow physical access. Gates should be opened slowly and simultaneously allowing animals every opportunity to escape from one another. The birds may not enter the adjoining enclosures immediately.

In some cases, individuals may begin to display aggressive behaviour after copulation has occurred. In this case, birds should only be allowed temporarily access to one another until copulation has occurred. In any case, birds should be closely monitored by keeping staff so that any agonistic interactions can be interrupted, or so that the pair can be separated.

*11.3.3 ***SUB-ADULT TO SUB-ADULT*

11.3.3.1 Visual access

Partial visual access should be allowed through two locked access gates for a few short intervals throughout the day. The remaining fence line should be covered. The idea being that the birds will associate these areas as connections to the adjoining respective enclosure. Close observation and records should be kept outlining any behavioural responses of individuals to body language of the conspecifics.

Incrementally, full visual access should be allowed. Feeding can occur along shared fence lines.

11.3.3.1.1 Expected behaviours

Being a territorial species, varying degrees of aggressive behaviour can be expected with both visual and physical introductions. Dependant on the individuals, conflict may be limited to a threat display by one bird and submission by the other, without any physical contact. Other occasions may warrant close observation in the case that separation is required. 'Play' is often observed between sibling sub-adults (see section 9.7.6), however this should not be confused with agonistic behaviour whereby one bird has submitted to the other, or is continually being chased. Agonistic behaviours are listed in section 9.4.1 of this chapter. Incompatibility may be highlighted by constant chasing along shared fence lines, running along fence lines or hiding and inappetance.

11.3.3.1.2 Indications of compatibility

Compatibility in this context refers to seasonal tolerance of the male by a female or vice-versa, for the short-term purpose of breeding only. Most institutions observe year-round aggression in birds and should be held separately unless there are clear indications from both birds that they are receptive and are showing the behaviours mentioned below.

The most reliable indication of compatibility is tolerance of conspecifics within close proximity, most prominently during feeding time, most likely during the winter and spring months in all regions. Sitting along shared fence lines, and attempts at preening through the fence and gentle pecking are also recognized as signs that the birds are compatible.

Although unusual, some pairs have demonstrated year-round tolerance of one another with no outward signs of aggression. These birds can be housed together full-time. For those who consistently show signs of incompatibility, a revision of pairing and recommendations should be considered by the species coordinator.

11.3.3.2Physical access

Physical introductions should be primarily dictated by a consistent lack of agonistic behaviour from both birds, in conjunction with consistent presentation of behaviours that indicate compatibility.

Depending on the behaviour observed in both birds, the next step is to allow physical access. Gates should be opened simultaneously allowing animals every opportunity to escape from one another. The birds may not enter the adjoining enclosures immediately.

In some cases, individuals may begin to display agonistic behaviour. In this case, birds should be observed for a period of time and separated if agonistic behaviours do not cease.

*11.3.4 ***HATCHLING TO SIRE – including surrogate species sire*

11.3.4.1 Visual access

In most cases, this will be a reintroduction of a hatchling to its natural parent. In this instance, the need for acclimatization is unnecessary; however auditory access may play a part in the behaviours expected of the sire. Removal of a hatchling from a sire for treatment should be minimised to increase the likelihood of acceptance upon reintroduction.

11.3.4.1.1 Expected behaviours

Being a defensive species, varying degrees of aggressive behaviour can be expected towards personnel conducting the introduction. The sire may respond to distress calls by the hatchling by displaying ‘vigilance’ (Chapter 9, section 9.4.3). Additionally the display may include a number of agonistic behaviours towards personnel, listed in Chapter 9 section 9.4.1). The sire may attempt to ‘bill clack’ (Chapter 9, section 9.7.7) near the chick. Stomping at or near the chick is a sign of incompatibility. Dependant on the amount of time the hatchling has been away from the sire, the chick may either attempt to run towards, or away from the sire/siblings.

For this type of introduction to surrogate species, the likelihood of successful introduction is increased if the surrogate sire has existing offspring of a similar age.

11.3.4.1.2 Indications of compatibility

Bill clacking or gentle attempts at preening near the chick is a good sign that the male is attempting to caution to the chick that danger (i.e. a human) is imminent – a positive sign that he is willing to accept the chick.

11.3.4.2 Physical access

Physical introductions should be primarily dictated by a consistent lack of agonistic behaviour from the sire towards the chick, in conjunction with consistent presentation of behaviours that indicate compatibility.

Depending on the behaviour observed in both birds, the next step is to allow physical access. Close monitoring by several staff should be paramount at this stage.

A hatchling should be accompanied by personnel in a holding exhibit adjacent to the sire's enclosure. Both should be monitored. Hatchlings should be removed at the first sign of agonistic behaviour from the sire.

11.4 NON-RECOMMENDED SCENARIOS

11.4.1 Intra-sexual

Chapter 9, section 9.7.2 highlights intra-sexual interactions in wild birds. Based on Bentrupperbäumer's (1998) work as the only systematic observations of intra-sexual interaction amongst cassowaries, this type of introduction is not recommended.

11.4.2 Hatchling to Dam

Chapter 9, section 9.7.3 highlights offspring/dam interactions in wild birds. Bentrupperbäumer's (1998) work as the only systematic observations of offspring/dam interactions amongst cassowaries, this type of introduction is not recommended.

11.5 OTHER CONSIDERATIONS

11.5.1 Housing offspring when independent of sire

Consideration should be given to housing availability such that offspring can be housed safely away from the sire as soon as he begins to chase them away.

REPRODUCTION & BREEDING MANAGEMENT

Captive breeding of wild animals has become an integral part of conservation programmes which aim to preserve wild populations and habitats (Schulze 1998) however much debate exists regarding the role of the captive industry in cassowary conservation. At present, there is a general consensus from most stakeholders involved in cassowary conservation that captive breeding adjunct to *in-situ* cassowary conservation measures is unnecessary at this stage and that the existing ASMP Regional Southern Cassowary population is unlikely to be considered for release purposes. The primary roles of the population management program are to ensure the persistence of sustainable, genetically healthy, captive populations that can support the development and documentation of husbandry techniques for the species, assist with scientific research in a semi-controlled setting and support the illustration of biodiversity through public education.

In contrast to Emus, Ostrich and Rheas, Cassowaries are difficult to breed in captivity (Göritz *et al*. 1997) and despite numerous successes and prolific breeding by the occasional pair in the middle of last century, current reproductive successes are poor, and this is reflected by the relative quiescence of cassowary studbooks worldwide. In the last 50 years, only 15 pairs in the Australasia region have been successful in breeding. Institutions participating in other regional programs are also experiencing difficulty in consistently reproducing from their birds.

Proper management and successful propagation of captive birds require comprehensive knowledge of avian reproductive anatomy and physiology (Gee in: Gibbons *et al*. 1995), social structure, and breeding requirements, if the species is to reproduce successfully in captivity.

In captivity, potential mates are chosen by population managers on the basis of genetic and demographic considerations in order to maintain maximum genetic diversity, and to avoid inbreeding, while little thought is given to exactly how we will achieve reliable and consistent breeding. Additionally, little attention has been given to aligning the lives of captive birds with their natural history, and considerable research is still required in relation to nutrition, egg fertilization, egg incubation, embryo mortality, hatchling mortality, reproductive anatomy, reproductive fitness, and the underlying behavioural and autonomous physiology of reproductive processes, which are likely to be of particular importance to the success of this program.

Population managers might dream of being able to identify what traits affect mate choice in the wild, however assessing an individual’s phenotypic and genotypic attributes is difficult and in reality managers will have to be satisfied with an assessment of the health and nutritional status of captive animals (Curio In: Caro 1998).

Given the paucity of facts, it is difficult to pinpoint what might be affecting the reproductive success of captive birds and therefore impractical to recommend how these issues might be addressed, however we speculate that circumventing such details has led us to our current standing, and believe that a number of factors are contributors.

In order for this program to be successful, we must find ways to access additional space where both intensive management and development of new management techniques can take place, and learn how to test and evaluate a captive situation so that breeding is predictable, not lucky (Sheppard in: Gibbons *et al*. 1995).

The following is a compilation of background knowledge and information regarding cassowary reproduction with suggestions for improving reproductive success.

Suggested Readings:

Elphick, C. S., Reed, J. M., and Delehanty, D. J. (2007). Applications of Reproductive Biology to Bird Conservation and Population Management, In: Reproductive Biology and Phylogeny of Aves (Birds). B. G. M. Jamieson (ed). Science Publishers, Enfield, New Hampshire.

12.1 MATING SYSTEM

Cassowaries have been witnessed exhibiting simultaneous polyandry (Crome & Moore 1988b, Moore 2007), and simultaneous polygyny (Bentrupperbäumer 1998, Moore 2007). In some situations, successive (also known as serial or sequential) polyandry may occur.

Generally, wild and captive Cassowaries display strict male-only care.

Anecdotal evidence has brought to light three wild situations in which the dam was observed co-caring for chicks with the sire (Liz Gallie *personal communication*; Jax Bergersen *personal communication;* Allen Sheather *personal communication*). In one case, upon death of the sire and two of the three chicks, the dam assumed full parental duties of the remaining chick and raised it to independence. Such sporadic cases appear to be anomalies, and captive carers should not prematurely assume that captive females will tolerate offspring.

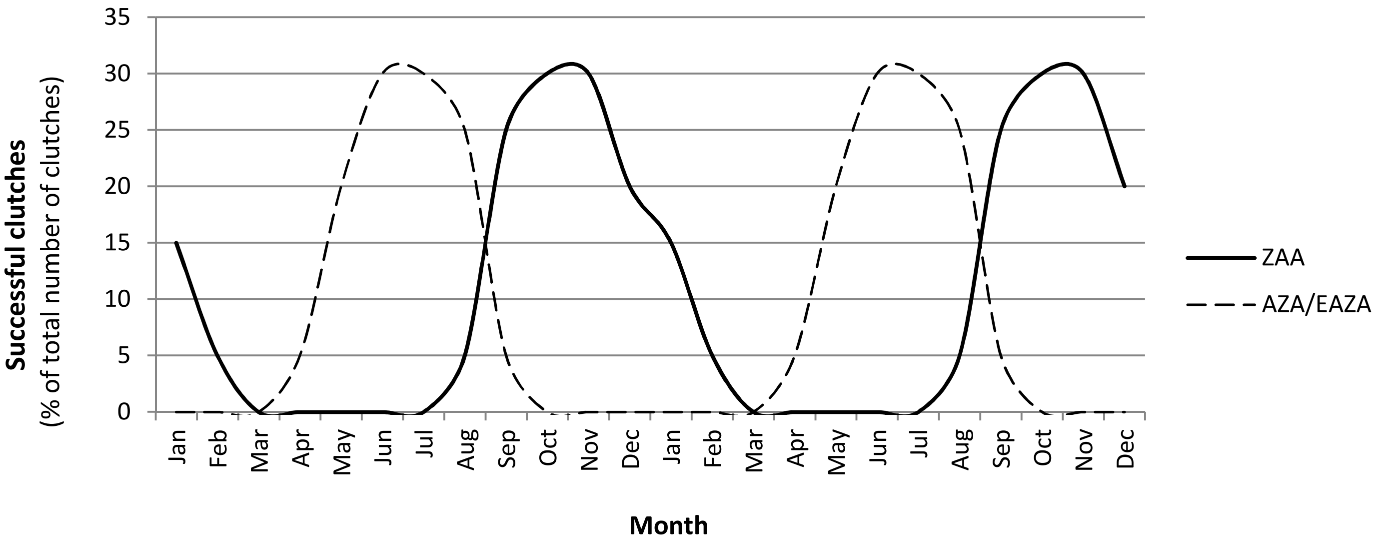


Figure 12.1 - Regional breeding season curve (24 months), smoothed data.

In polygamous systems one individual forms pair-bonds and copulates with more than one individual of the opposite sex during a single breeding season (Jenni 1974). In this system, the relationships between the various individuals may be simultaneous or they may be arranged sequentially in a series of relationships that resemble monogamous bonding (Jenni 1974).

Polyandry, a form of polygamy which is regularly observed in other species of ratite, is also displayed by Cassowaries. In polyandrous systems, a female forms pair-bonds simultaneously or sequentially with more than one male, and males assume most or all of the parental duties (Graul *et al*. 1977). In Cassowaries, at different times, each male interacts with the female as if the bond were monogamous. The males perform all post-ovipositional reproductive behaviour, freeing the female to interact with another (male) and produce a clutch for him (Jenni 1974). Females in the wild may take more than one mate, with up to three being seen (Crome & Moore 1988b).

Furthermore, polygyny, another form of polygamy, whereby a male will bond with two or more females simultaneously during a breeding season (Moore 2007) is also displayed by Cassowaries (Bentrupperbäumer 1998).

12.2 SEASON

For survival and reproductive success, appropriate timing of reproduction is crucial (Mans & Taylor, 2008) and from a management perspective, understanding the timing of regression and recrudescence is important because it determines when reproduction is possible and certain reproductive behaviours are most likely to occur (Elphick *et al*. 1997).

Bentrupperbäumer (1998) defined the breeding season as the period between the first sign of pair-formation and the hatching of chicks, consisting of two primary stages: courtship/laying and incubation.

Although Cassowaries may breed at any time of year when environmental conditions are favourable (Moore 2007), the breeding season in the wild appears to be from May to November, with the main season taking place between June and November (Moore 2007), coinciding with maximum abundance of fruit in the forest (Crome 1976, Crome & Moore 1988b) and with the fruiting of Laurels which are high in fat and protein (Romer 1997). The majority of new chicks in the wild appear in September (Moore 2007).

Figure 12.1 shows that breeding in captivity has been observed throughout the year (Hall 2012, LaGreco 2010, Lammers 2010), but it appears to generally coincide with winter/spring in the ZAA, AZA and EAZA regions, which is consistent with observations of wild birds.

12.3 REPRODUCTIVE CONDITION

12.3.1 Body condition scoring

See Appendix 10.

12.3.2 Assessment of reproductive condition

Very few studies (with the exception of Göritz *et al*. 1997) have been conducted on Cassowaries to assess the condition of the reproductive organs of individual's pre, during and/or post breeding, and hence assessing suitability for inclusion in a breeding program. Hildebrandt *et al*. (2000) suggest that the development of reliable methods for visualizing the reproductive tract and monitoring the cycle of exotic species is needed to optimize breeding management in captivity.

Physiological factors including the status of the endocrine system and real time surveillance of the reproductive tract via ultrasonography in both male and female birds (both across a temporal scale) may assist in revealing the true capacity for or the likelihood of a bird to reproduce and when it is likely to do so.

A number of approaches that have been used to accurately produce a working knowledge of the reproductive systems of other species are outlined in the following paragraphs.

Ultrasonography is an ideal tool to study reproductive biology in both captive and wild populations (Hildebrandt *et al*. 2000). A number of studies highlighting ultrasound as an important tool specific to captive breeding and management, and soft tissue evaluation exist in the literature (Hildebrandt *et al*. 2006, Hildebrandt et al 2000, Hermes *et al*. 2004, Hildebrandt *et al*. 1995), largely applicable to elephants and rhinoceroses, although a handful of references exist for ratites also (Wagner & Kirberger 2001, Göritz *et al*. 1997).

Göritz *et al*. (1997) conducted a study focussed on trans-intestinal sonography (TIS) in five captive cassowaries to assess and categorise birds in terms of breeding potential. They state that TIS makes the visual depiction and differentiation of the male and female sexual apparatus possible, assisting in the sexing of birds, and facilitates an individual assessment of health status and reproductive activity of the gonads (Göritz *et al*. 1997). Size and internal structure of the testis, number and size of follicles and appearance of the oviduct, are valuable parameters to assess the breeding potential of individuals (Göritz *et al*. 1997).

The necessity for animal handling and sedation add invasive components to the application of ultrasonography in non-domestic species (Hildebrandt 2006) through the risk of restraint (physical or chemical) (Hildebrandt *et al*. 2000), however there has been no report of injury or ultrasound-induced discomfort when examinations were performed under the international ultrasound safety guidelines (Hildebrandt 2006).

Further studies in these areas may positively contribute to the assessment of reproductive condition in Cassowaries across institutions willing to trial such applications, which may in turn benefit breeding programs and the long-term management and outcomes for the species.

12.4 FECUNDITY

Breeding ages in Cassowaries appear to cover a wide span (Romer 1997). In the Australasia region, the youngest captive mature male known to breed was a three and a half year old at Currumbin Sanctuary who fertilized a clutch, however most breeding activity appears to start around four years (Romer 1997). Fisher (1968) pointed out that birds which arrived at Edinburgh Zoo in April 1963 still in their brown plumage, bred in 1965, roughly coinciding with Romer's (1997) comment. Worrell *et al*. (1974) mention the breeding of Cassowaries at the Australian Reptile Park, and although the paper states that two of the three birds were between 5-6 years old and the other was 18 months old, which birds actually bred, is not specified. Analysis of the ASMP and USA studbooks shows that successful breeding events peak between 10 and 15 years of age however sample sizes are small.

One breeding male first mated when 31 years old at Denver Zoo (Whitehead & Masson in: Romer 1997). A number of reports of wild females under long-term observation in the Mission Beach area suggest that birds are capable of reproducing into their forties (Liz Gallie *personal communication*) and this is further mirrored by a handful of successful breeding events in the ASMP Regional population, which, to date have been considered anomalies.

On the ASMP Regional studbook, sample sizes are small (n = <40) for all age classes above seven years in males and ten years in females. Of the 15 males that have bred, 11 are of known age; and from 15 females that have bred, 14 are of known age. Such small sample sizes make it impossible to identify any trends in age-specific fecundity, and data presented in Mx graphs must be treated with a great deal of caution. Analysis of model data through PM2000 appears to suggest that male fecundity peaks at 28 years; however this reflects data from just two males who survived to this age and bred. Likewise, model data of female fecundity suggests a peak at age 23 although this reflects records from only three females and it is impossible to interpret any general trends in species fecundity from such small data (See Appendix 2).

At this stage, what we can identify from the data is that males have been recorded breeding from age three to 37, and females from age two to 40. Given the meagreness of data, particularly for those over 20 years old (n = <20 for males and females), these data are not likely to represent the true reproductive limits of this species in captivity. Anecdotal evidence from wild birds indicates that Southern Cassowaries are capable of reproducing into their forties.

Although older birds will not be excluded from analysis (unless health causes their exclusion); older birds in the ASMP Regional population will be paired with other old birds where possible, so that younger, presumably fitter birds of data-proven breeding age can be paired together.

Bentrupperbäumer (1998) indicated that approximately 80% of wild male cassowaries breed only once every 3 years, and approximately 20% breeding twice within the same timeframe. She also noted that females were observed mating in two out of three years. In captivity, birds are capable of reproducing annually if chicks are removed at an early age, however population managers should base such recommendations on the condition of the birds at the onset of breeding.

12.5 COURTSHIP

At the time of writing, the author was only aware of a handful of published observations on sexual interaction in wild cassowaries e.g. Crome 1976; Marchant & Higgins 1990; and Bentrupperbäumer

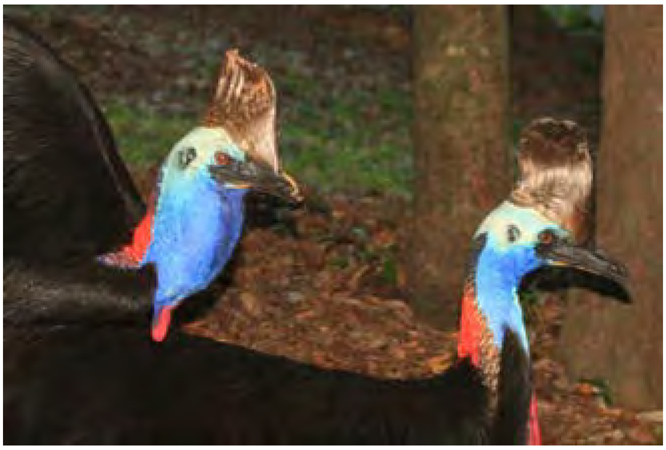
Figure 12.2 - Females' usual resting position.

Figure 12.3 - Female's copulatory position.

1998). Marchant & Higgins (1990) and Crome (1976) suggest that courtship in the Cassowary is initiated by the male, while Bentrupperbäumer (1998) observed that females initiated the majority of sessions. Initially, the female chases the male away but later allows him to come closer and closer until eventually they form a pair and feed together (Crome 1976). This also appears to be the case in some captive birds; that is, the female is generally more tolerant of the male leading up to and during the breeding season (*personal observation*, Romer 1997). Wild birds appear to maintain a solitary existence before and after each courtship session (Bentrupperbäumer 1998).

In the captive breeding season, mating has been observed throughout all daylight hours.

Females will passively occupy a space near the male at this time of year. A subtle difference between the females' usual resting state (Figure 12.2) and her copulation position (Figure 12.3) is the position of her beak pointing distally in the latter. If the attention of her potential mate is not focused on her, she will look around whilst in the pre-copulatory position. Once the attention is directed back at her, she will look forward and again point her beak towards the ground and sit very still.



Left: Figure 12.4 - Male throat swelling during courtship.

Right: Figure 12.5 - Male stroking rump of female during courtship.

In pre-copulatory display, the male is seen 'dancing' in a circle around the female, his throat swelling and deflating (Figure 12.4), which agrees with Crome's (1976) observation. Crome (1976) however, observed the male's throat trembling and emitting a low rumbling 'boo-boo-boo', and was not told of any feathers raised in the display. Captive males have been observed stroking the rump of the female with their claws (Figure 12.5) as they pause standing at her rear (some institutions have interpreted this as simply trying to get in the right position to mount), while leaning forward to gently clap his beak on the skin at the back of her neck (Figure 12.6), and preening feathers from the base of her neck all the way to her rump (*personal observation*, Mike Taylor *personal communication*). During the display, the male has been observed picking up a single leaf and placing it on his own upper back, and also eating leaves (*personal observation*; Bentrupperbäumer 1998) (which has also been observed during the pre-incubation period (Bentrupperbäumer 1998) and during incubation (Bentrupperbäumer 1998; *personal observation*). The entire courtship display lasts for between 2-15 minutes before the male mounts the female (*personal observation*). Interruptions during this stage of the copulatory process have subsequently discouraged couplation (*personal observation*). Zoo animals that are continually disturbed by visitors or that have a constant view of predators may not breed (Curio In: Caro 1998) so extreme care should be taken to minimise interruptions while birds are attempting copulation in order to maximise the likelihood of success.

This behaviour has also been observed on several occasions where the roles are reversed, i.e. the female dances around the male, who is sitting passively on the ground (*Personal observation*, Jodie Hughes *personal communication*). Likewise, a handful of cassowaries have been observed performing the pre-copulatory and


Left: Figure 12.6 - Male preening neck of female during courtship.

Right: Figure 12.7 - Male in horizontal squatting position behind female, pre-intromission.

copulatory behaviours with inanimate objects such as rocks and logs (Nashville, Jodie Hughes *personal communication*).

Leading into and throughout the breeding season, females are generally more vocal than usual. By and large, females are more vocal than males, regardless of the season.

12.6 COPULATION

Figure 12.8 – Intromission.

Copulation has been observed regularly in numerous institutions holding this species, and observations of wild birds were recorded and presented to the scientific community by Crome (1976). Crome (1976) stated that after a pre-copulatory display, the male led the female a short distance, whereby the female went into a semi-squatting position and the male mounted. In captivity, the male has not been seen leading the female from the pre-copulatory dance arena to copulate (*personal observation*). During copulation, the greater mass of the male moves from a horizontal squatting position behind the female (Figure 12.7) to a near vertical one upon intromission (Figure 12.8).

Copulation has been observed for up to a month leading into the breeding season, and between the laying of each egg (*personal observation*, Whitehead & Mason in: Romer 1997), reiterating Fisher's (1968) comment that mating occurs between laying, a fact which staff at Edinburgh Zoo (and presumably a number of other institutions) had previously been led to doubt. Crome & Moore (1988) states that copulation is brief, however, (depending on your definition of brief) the pre-copulation and copulation event has been recorded to last up to 30 minutes (*personal observation*).

On occasion, captive and wild females have been observed abruptly jumping to her feet while the male is still mounted, throwing the male off and charging after him (e.g. Bentrupperbäumer 1998; *personal observation*).

12.7 NEST BUILDING

Bentrupperbäumer (1998) stated that females do not appear to discriminate where on the forest floor they lay their eggs, however one feature that appeared common to all nests in her study was the closed structure of either the immediate or at least proximal understorey - comprised of Lawyer vine thickets, dense regrowth, rall tufts of grass, and vine thickets. Similarly, cassowary nests have been found at the base of a large clump of lawyer-vines (*Calamus moti,* Bail.) (Frizelle in: White 1913), or in a sheltered position such as between buttresses or beside a log (Romer 1997).

Macgillivray (1917) recorded that a nest consisted of a layer of grass and leaves three feet in diameter and two inches in thickness, however such material may merely be gathered by the male from his immediate surrounds throughout the incubation period, as has been observed in captivity (Figure 12.9) rather than a nest built pre-oviposition (Bentrupperbäumer 1998).

12.8 THE EGG

Tully & Shane (1996) provide a summary of Ostrich (*Struthio camelus*) and Emu (*Dromaius novaehollandiae*) egg formation in 'Ratite Management, Medicine and Surgery', however research on Cassowary egg formation is lacking. It should be noted that significant differences in egg formation exist between other ratite species so information from those species should not be broadly generalised to Cassowaries.

The avian eggshell is considered as a mediating boundary that operates along with the nest microenvironment and the behaviour of the brooding parent(s) to isolate the embryo from the external environment (Board & Scott 1980). Board & Scott (1980) also state that particular importance is attached to shell modifications that could assure that the pores are not flooded or blocked with debris. Additional to this, utmost care is taken by the male to ensure the safety of his eggs.

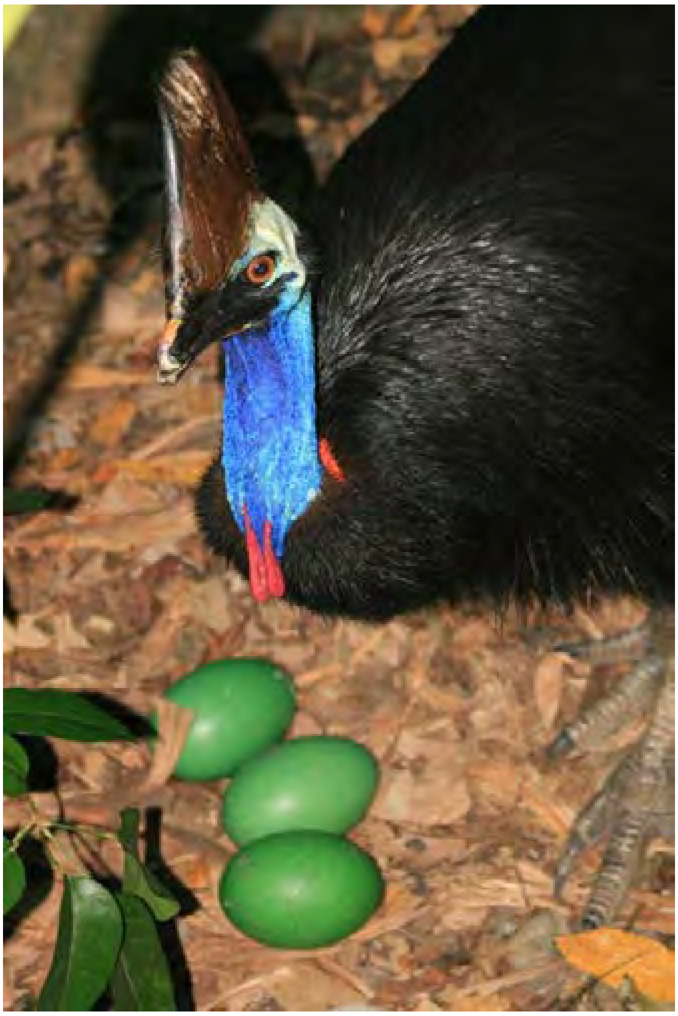


Figure 12.9 - Male cassowary with nest and eggs.

The Cassowary egg has been described as elliptical, glossy, coarse or finely granulated, light pea-green, being a blend of green granulations and greenish-white interstices (Marchant & Higgins 1990); and pale dull brown/green to bright apple green with variation in texture from distinctly granulated surfaces to fine granulation (Bentrupperbäumer 1998). The eggshell of the Cassowary contains reticulate branched and unbranched pores (Board & Scott 1980).

Table 12.1 - Cassowary egg dimensions.

n	mean length (mm)	mean width (mm)	Weight (g)
5	135.2 ± 2.8	95.2 ± 2	-
9	141.2 ± 9	100.4 ± 5	-
6	135.5 ± 8	95.1 ± 4	650
1	152.0	102.0	-
21	**138.7**	**97.7**	**650**

Source: Hindwood 1962, CTZ, Romer 1997, Campbell & Barnard 1917.

In White's (1913) notes on the Cassowary, he reports that 'Birds often seen, but eggs impossible to find', going on to say that the aborigines even appeared able to secure only odd eggs. To this day, the nesting habits of wild birds are poorly known, and poorly spoken for in critically assessed scientific literature. Marchant & Higgins (1990) are doubtful if as many as 30 nests have been found in Australia by Europeans, and that very few records have been obtained since 1920, with the exception of Hindwood (1962).

Institutions holding Cassowaries suggest that the interval between laying is from 3-7 days. Hindwood (1962) assumed that eggs were laid at 4 day intervals.

The only critically assessed information existing on the number of eggs laid in a clutch is from Moore (2007) and Hindwood (1962). Information collected from institutions holding Cassowaries indicate that up to 13 have been laid in a single clutch, but three to six is far more common (*personal observation*, Romer 1997).

12.8.1 Egg Breakage

Disappearance of eggs and egg breakage by cassowaries is a common occurrence in captive institutions around the world. In cases where pairs are housed together year-round, the female has been responsible for egg breakage, and have been observed eating the contents and the shell, however some males are also known to break and eat eggs. Increasing available calcium in the diet by providing boiled eggs (halved), with the shell included, may decrease the probability that this occurs. Clumsiness by the male may also cause breakage and should be monitored. Appropriate selection of nest site by personnel working with cassowaries may lower the number of cracked eggs (see section 11.11.1.4).

Broken or cracked eggs should be removed from the nest site.

12.9 INCUBATION AND HATCHING

Bentrupperbäumer (1998) noted that one male in her study site did not start to fully incubate until 10-13 days later when a third egg was laid, which has also been observed in captivity (*personal observation*). In captivity, the male has been observed walking around the eggs, turning the eggs, and occasionally incubating for short periods, which was also observed in Bentrupperbäumer's (1998) study.

Incubation is performed by the male only (Marchant & Higgins 1990), is continuous (Bentrupperbäumer 1998) apart from a few attempts to remove intruders and turn eggs (*personal observation*), and does not begin before a full clutch is laid (Bentrupperbäumer 1998; *personal observation*).

Brief visits by females to the nest sites of incubating males were observed by Bentrupperbäumer (1998) to be non-aggressive, with males merely presenting a submissive posture by dropping the beak forward.

Incubation periods for naturally incubated eggs seem relatively steady in captivity, ranging from 47-56 days Cairns Tropical Zoo and 51 days at Dreamworld (Michele Barnes *personal communication*) Romer (1997) states that up to 57 days have been recorded and smaller eggs tend to hatch sooner than the large eggs.

Artificially incubated eggs at White Oak Conservation Centre in the U.S. observe an average incubation period of 41 days. (Mike Taylor *personal communication*), however this is a significantly shorter timeframe than what has been observed when eggs are incubated naturally.

If a male is still incubating 65 days after the last egg is laid, consideration should be made for a decision to remove the eggs for egg necropsy or post mortem evaluation (See Appendix 6 & 3).

At Cairns Tropical Zoo, the male has not been observed assisting the chick in any way during hatching, which is mirrored by Bentrupperbäumer's (1998) statement. In fact, the male (at CTZ) even left the nest occasionally to escort the already hatched chick.

12.10 BREEDING MANAGEMENT

12.10.1 Stages for intervention

Elphick *et al*. (2007) identified a number of reproductive stages that present opportunities for management intervention in a captive setting which may also be applied to cassowaries. These include reproductive readiness, breeding site selection, mate selection (e.g. pair bonds), offspring production (nest building, egg production, clutch size), and parental care (incubation, provisioning, brooding). This section highlights opportunities for management intervention, and discusses manipulation of biological filters.

12.10.1.1 Reproductive readiness

In captivity, options for manipulating the reproductive system are more numerous than in the wild, and can range from directly altering the bird's physical and social environment to changing its physiological state (Elphick *et al*. 1997).

Because normal maintenance activities are so costly, successful reproduction can occur only when birds can acquire sufficient energy, nutrients and minerals in excess of their high basic requirements (Elphick *et al*. 1997), which will allow them to produce large eggs and invest further energy during incubation and raising of the chicks. Breeding is seasonal, and appears to be timed to take advantage of abundant food resources.

The nutritional status of parent birds plays a significant role not only in preparing their own bodies for reproduction and the breeding season, but is also crucial to the transfer to the egg of an adequate, balanced supply of nutrients required for normal development of the embryo (Wilson 1997). Adequate breeder nutrition is also vital for ensuring fertility, and ensuring good survival rates of hatched chicks (Cooper *et al*. 2005, Brand *et al*. 2002). Again, some direction may be taken from the poultry industry, but it is vital to understand that there is considerable interspecies variation regarding nutrient requirements (Wilson 1997) (See Chapter 9).

For further details about cassowary body condition and scoring, see Appendix 10.

In a captive context, it is imperative that birds are in peak condition with access to sufficient nutrients, minerals and energy to satisfy the high demands of egg laying and incubation. Maintaining a good diet while the appetite is up, translates directly into improved body condition in other species (Heitmeyer & Fredrickson 1990). The appetite of captive cassowaries is generally a good indicator of when to increase and decrease food amounts offered. See Chapter 9.

Another way of altering the conditions in which birds live, is to change the social environment (Elphick *et al*. 1997). For cassowaries, which appear to be mostly solitary apart from during the breeding season, changing the social environment may prove to be rather difficult given the many limitations such as available space and other resources in captivity.

According to ZAA studbook data, (data analysis limited to pairs that have successfully hatched more than 5 clutches) birds, were at the same institution for at least two years before successful reproduction. We speculate that the birds require some level of familiarity either visually and/or verbally with one another, before mating and reproductive success will occur. It may be possible to stimulate healthy competition through simulating conspecific interaction by playing recorded vocalizations to a bird/s at one institution from prospective suitor/s from another institution prior to transferring any animal. The aim would be to convince the existing bird/s that another bird is in the area in the hope that this would accelerate familiarization between birds and ultimately facilitate copulation and reproduction. For future pairings, population managers and institutions should consider playing recordings of different calls from prospective mates for a period of up to two years before transferring the animal to condition or bond existing birds to the presence of new birds.

Early familiarization between chicks is also a proven method for producing a successful pair Romer (1997).

Potential options to manipulate the reproductive system might also include changing photoperiod (Farner & Wingfield 1980) (assuming that the pineal gland in cassowaries plays a part in cuing reproductive timing as it does in other species) or to use endocrine therapy to bring birds into breeding condition, however such therapy is likely to be quite invasive and costly to implement, and realistically can be applied only to a relatively small number of individuals Elphick *et al*. (1997).

12.10.1.2 Breeding site selection

Elphick *et al*. (1997) describes the breeding site as a place that is used for attracting mates, providing foraging habitat, nesting, and raising young, implying habitat at the broader landscape scale. The selection of breeding sites (or enclosure sites) appropriate for cassowary within an institution is generally constrained by availability of space and environmental conditions however enhancing available space to create a habitat that will provide favourable environmental conditions may potentially increase breeding opportunities.

12.10.1.3 Mate selection (pair bonds, breeding system) also a constraint

In nature, the home range of a single female may loosely encompass that of several males (e.g. 2.1.0, 3.1.0, 4.1.0), however this observed social system has not been replicated in the captive setting, where traditionally one female is paired with one male. This unit (constrained by standard 2-enclosure system in most institutions) is seldom encountered in the wild and has proven to be largely unsuccessful in captivity by limiting potential mate options to a single bird. Furthermore, birds housed at institutions have generally been kept as ‘pairs’ despite a number of years running without any signs of successfully reproducing.

Providing a captive female with more than one male may encourage reproductively beneficial competition (and, optimistically, copulation and reproductive success for at least for one of the males), by giving the female options with whom to breed as opposed to offering her one male in perhaps sub-optimal condition.

A number of institutions in the ZAA region are currently trialling a method whereby one female is given the opportunity to interact with two males simultaneously, but on an individual basis, in the hope that one of the males will meet her requirements and the ‘pair’ will go on successfully reproduce. The remaining (unsuccessful) bird is then available for a new pairing recommendation at a different establishment. Likewise, as males occasionally pair with more than one female in a given season, a scenario where one male is given the opportunity to interact with two females simultaneously, on an individual basis is also being trialled. Again, the remaining (unsuccessful) bird is made available for a new pairing recommendation at a different establishment. Despite the infancy of such trials, preliminary results look like progressing towards the establishment of successful pairings.

The lack of spaces in existing participating institutions limits such trials to larger establishments with the capacity to redevelop existing enclosures, or new establishments with the capacity to build the recommended enclosure configuration of three adjacent exhibits with a shared holding pen. It is recommended that institutions assess existing enclosure dimensions and configurations to determine whether or not any minor adjustments might allow for mate-choice trials to occur. See Chapter 6.

Mate quality or fitness appears to be an important factor in determining the likelihood of birds to find a suitor and to reproduce. Cues used to assess mate quality differ among species but often are associated with body size, body condition (e.g., stored fat), singing rate, or traits displayed in the plumage or skin (Elphick *et al*. 1997). In the wild, it is assumed that the female can choose which of 'her males' she will mate – likely to be dependent on each of the males' condition at any given time during the breeding season, picking the male in best condition at the time to ensure greater chance for offspring to be successfully reared and recruited into the breeding population. She may mate with one or all of her males in a given season.

For male cassowaries, anecdotal evidence suggests that optimal physical condition is a determinant factor influencing whether or not breeding will be attempted in a given year. As males eat very little while incubating, it is imperative that their epaxial fat stores are significantly developed well prior to the breeding season and incubation period, to see them through the season. See Appendix 10.

As captive managers we have the capacity to interfere with mating decisions, either by limiting which individuals are able to breed together, improving body condition of individuals, or by simultaneously offering auxiliary suitor options and hence increasing the probability of pair formation; however, we are confined by species fecundity, the goal to maintain genetic diversity, and to keep inbreeding coefficients below an agreed threshold.

If successful copulation, oviposition or hatching does not occur in light of this combination of strategies after three years (particularly for birds in the 1.1.0 configuration) the pairing should be re-evaluated at the population manager level. It is recommended that the reproductive condition and fitness of both birds be assessed. See Section 11.3.2.

12.10.1.4 Offspring production (nest building, egg production, clutch size)

Once a breeding site and mate have been selected, birds must build nests and produce eggs (Elphick *et al*. 1997).

Male cassowaries will generally choose a nest site that is reasonably well-protected and well-shaded, however sites chosen by females are usually awkward, problematic, and quite often nowhere near the site that has been carefully selected by the male i.e., next to paths, on the sides of hills (Romer 1997, *personal observation*). Dummy eggs (plaster-filled emu eggs, painted a light shade of green) have been effectively utilized to change the nest site position at Cairns Tropical Zoo on a number of occasions and at Frankfurt Zoo on one occasion. Placing leaves, shredded palm fronds, sphagnum moss and soft bark nearby the male while nesting may encourage him to create a nest; however consideration should be made when choosing nesting materials, as hatchlings and juveniles tend to show a great interest in small items resembling food. Fisher (1968) recorded that a pair in Edinburgh nested in a hut, and Romer (1997) suggests that the provision of a hut or shelter will often encourage the pair to nest within it, which can be of use for management purposes.

Egg production in cassowaries is similar to other ratites – many eggs are produced each season, with up to 28 observed in captivity (however not all were fertile (Romer 1997)), with an average clutch size of 4. Generally, the more laid, the lower the fertility (Romer 1997). Clutch size can be manipulated by removing eggs as they are produced, and holding eggs until the desired number of eggs is produced (21-24 regularly by a female at Cairns Tropical Zoo). If eggs are to be naturally incubated, no more than 6 eggs should be offered to the male such that he is able to provide sufficient warmth to all of the eggs.

An egg necropsy form has been developed to attempt to standardize assessment of known failed eggs (See Appendix 6), which, based on information from the poultry industries, may allude to the cause of failure.

While artificial insemination has been trialled on other ratites (*E.g.* Malecki *et al*. 2008), it has not been attempted with cassowaries, and remains a potential target for the future.

12.10.1.4.1 Techniques to limit egg production

Chronic egg laying has been observed within the breeding season in cassowaries, and has been implicated in dystocia, egg binding, prolapse, salplingitis and oviduct impaction, which may reflect abnormalities in the neuroendocrine system (Mans & Taylor 2008). As egg laying is ultimately controlled hormonally, without knowledge of species specific endocrinology, it is difficult to interrupt without causing side effects.

A number of techniques to control egg production have been trialled across regions, however all have been met with limited success.

At Cairns Tropical Zoo, two techniques to stop egg production have been trialled, neither producing the desired result.

Early on in a season (August), the pair was allowed to produce a clutch, which were subsequently blown and plaster filled. The dummy eggs were offered to the male, and the female separated from the display exhibit. In the first two weeks of separation, the female produced another two eggs. The male incubated the plaster-filled eggs to term and a several weeks later abandoned the site. Re-introduction of the female after the season had ended (December) went smoothly, and only minor dominance was observed. Within two weeks the pair were re-mating and before long more eggs were produced (January), all of which were removed. The separation presented a mere interruption to the season.

On a number of separate occasions, eggs have been removed as they were laid, however as in other species, this promoted egg production rather than limited it.

As with other avian species, a stressful event, whether the mechanism is environmental, physical, physiological, psychological or a combination of these, can all successfully interrupt a laying period. However, this method may come under some scrutiny with regard to potential welfare issues, due to the necessity to expose the bird/s to a stressful event.

Separation of a pair is the most straightforward means of preventing mating and egg laying.

12.10.1.5 Parental care (incubation, provisioning, brooding)

For species with precocial young that can get around on their own and find their own food, parents still provide considerable protection by brooding, by warning against and distracting predators, and by guiding the young to safe areas (Elphick *et al*. 1997). It is not known whether there is any transmission of complex behavioural information among parents to offspring, but regardless, it is critical that foster chicks be raised appropriately.

Parental-care by a cassowary is obviously most appropriate, however in some cases, surrogate care may be required.

Surrogate care by other species such as emu's, may allow further manipulation of the number of eggs produced. It may be fitting to employ an emu during the incubation period if required, but care should be exercised if they are to be used to raise young. See Chapter 14.

12.10.2 Monitoring

It is imperative that the success or failure of any intervention be well documented in the short and long term so that assessment can be made to deem particular approaches either appropriate or unsuitable for captive cassowary breeding management.

12.11 BIOLOGICAL FILTERS AS CONTRAINTS TO MANAGEMENT OPTIONS

Elphick *et al*. (1997) also identified various biological filters such as behaviour, reproductive endocrinology, nutrition and environmental conditions which can constrain management options. Being aware of such constraints, and developing a working knowledge of the species behaviour will assist us in making better informed management decisions.

12.11.1 Behaviour

Just as being able to secure and defend a feeding range tends to define the Cassowary female's role in the wild, we find anecdotally a gender bias towards higher rates of aggression among females in the captive environment. What we need to understand is that these behaviours are generally not very flexible, and females will normally only tolerate males during the breeding season. Some institutions have experienced no aggression, while others have found that the pair must remain separated throughout the year. Other pairs appear to be wholly accepting, and even if separated, no problems are met on re-introduction at any time of year.

It appears that female behaviour is the primary factor determining the success or failure of an introduction. Recognition of the subtle differences between reproductive and non-reproductive behaviours will increase the probability of a successful reproductive event.

Timing of introductions appears to be particularly important and should be based on close observations of behaviour of both birds. Thorough understanding and accurate interpretation of pre-breeding/breeding behaviours are crucial to facilitating a successful introduction. Behaviours that indicate tolerance include, but are not limited to those listed in "pre-copulation" and "copulation" (See Chapter 8 & 11).

12.11.2 Reproductive endocrinology

Malecki *et al*. (1998) highlighted endocrine analyses as an important tool specific to captive breeding and management and in the monitoring of hormone levels throughout the year.

Endocrine analyses, particularly non-invasive urine and faecal assays, can provide valuable complementary support for ultrasonographic findings (Hildebrandt *et al*. 2000). Currently the lack of such information constrains our ability to back our behavioural observations with physiological data, hence affecting our ability to correctly judge the most appropriate timing for introductions.

Graham Lauridsen (*personal communication*) identified seasonal changes in testicular morphology of male cassowaries, suggesting that LH, testosterone and prolactin are active at different levels throughout the year, which may affect his capacity to breed throughout the year.

12.11.3 Nutrition

Nutrition has the potential to affect reproduction in every species. Poor nutrition may suppress a bird's ability to resist disease, prolong recovery from illness or decrease reproductive performance (Macwhirter in: Tully *et al*. 2000).

The nutritional status of parent birds plays a significant role not only in preparing their own bodies for reproduction and the breeding season, but is also crucial to the transfer to the egg of an adequate, balanced supply of nutrients required for normal development of the embryo (Wilson 1997).

Our current knowledge of the nutritional requirements of cassowaries is limited, aside from a smattering of anecdotal reports of diets that have successfully grown, maintained and bred birds in captivity - with no methodical studies yet conducted. Detailed studies of natural diet and foraging behaviour of wild birds is possible, however identification of the nutritional needs of wild birds, and the subsequent clarification of the apparent enigmas of nutrient requirements and supply, is hindered by the overwhelming chore of detailed compositional analysis of naturally occurring foods (Murphy & King 1982), most of which are not available commercially for testing. Furthermore, the number of individuals for each age class in even large institutions is limited, and hinders detailed analysis of the nutritional requirements of those classes.

Some direction may be taken from the poultry industry, but it is vital to understand that there is considerable interspecies variation regarding nutrient requirements (Wilson 1997). See Chapter 9 & 13.

12.11.4 Environmental conditions

Control of physical environmental conditions affecting cassowaries is particularly challenging in a captive setting, given the open nature of the majority of cassowary enclosures. Cassowaries are however proven breeders under conditions that lack any resemblance to their native environment. Despite this apparent adaptability, conditions should be replicated as closely as possible to the natural environment.

Generally, removal of stress can promote breeding in captivity (Curio In: Caro 1998), such as removing predators from visual and/or auditory range.

12.12 CHICK MANAGMENT

12.12.1 Age at removal from parent

In nature, the sire will begin to chase offspring away anywhere between 9-18 months of age. In captivity, offspring should be removed from the sire when the chasing behaviour is observed in the sire, or if any significant aggression is noted from the sire towards the chicks.

Future Directives and Avenues of Research

- Mate-choice and pair formation
- Trigger diets

ARTIFICIAL INCUBATION

Successful captive propagation technology for birds requires expertise in both aviculture and avian science (Kuehler & Good 1990), and necessitates familiarity with incubation temperatures, humidity, airflow, hygiene and optimal egg turning regime for the species of interest, as a growing number of studies in the commercial ratite industry are showing us that failure to incubate under optimum conditions can result in poor hatchability, weak chicks (Brown *et al*. 1996) and poor success after hatching (Cooper 2001, Jeffrey *et al*. 2007).

Very little critically assessed literature exists relating specifically to the artificial incubation of cassowary eggs, however a number of techniques that are generalized to ratite eggs are listed, and use of such information should be at the discretion of the institution. Parameters that have been trialled on cassowary eggs where successful and unsuccessful hatches have occurred are included here as a starting point. If artificial incubation is attempted, each of these variables should be manipulated individually so that we can identify what is working and what isn't. Data from the ratite industry are offered here for comparison and may assist in establishing optimal conditions for the incubation of cassowary eggs. By assessing failed hatches, we are given the opportunity to collect such data and potentially improve reproductive output for this species in captivity.

Suggested Readings

- Cooper, R. G. (2001). Handling, Incubation, and Hatchability of Ostrich (*Strutio camelus var. Domesticus*) Eggs: A Review. *Journal of Applied Poultry Research*, 3: 262-273.

  Available at:

  http://japr.fass.org/content/10/3/262.full.pdf+html

- Jeffrey, J. S., Martin, G. P., Fanguy, R. C. (2007). The Incubation of Ratite Eggs. [Online]

  Available at:
  http://www.thepoultrysite.com/articles/812/the-incubation-of-ratite-eggs

13.1 JUSTIFICATION

Artificial incubation should only be attempted if natural incubation of the eggs cannot occur. If artificial incubation must occur, every attempt should be made to ensure that the sire maintains appropriate incubating behaviours (ie - given dummy eggs) until the real eggs hatch and are returned to the sire. The replacement of whole clutches of eggs with young is usually applied to birds that have been incubating non-viable eggs or whose eggs are needed for other purposes (Jones in: Sutherland et al 2004). The young do better if they are several days old and hence stronger and easier to feed than newly hatched chicks (Jones in: Sutherland et al 2004).

Reasons for removal may include:

- History of low humidity deformations from natural incubation;
- History of destruction of eggs or chicks by sire or dam, or disappearance of eggs; or
- Death, illness or poor condition of sire.

Romer (1997) indicated that the more eggs that are pulled for artificial incubation, the greater the rate of infertile eggs.

In the event that natural incubation cannot occur, the following provides a number of guidelines for the artificial incubation of ratite eggs.

13.2 SYSTEMATIC ANALYSIS OF ARTIFICIAL INCUBATION PROCEDURES

It is imperative that we use every opportunity to conduct thorough systematic research, which might help to establish optimal parameters for the artificial incubation of cassowaries down the track. While some data has been collected, sample sizes have been too small to draw any solid conclusions and consequently, no strict parameters have been established.

A standardized Artificial Incubation Form (Appendix 7) has been designed to assist with accurate and meaningful data collection that will aid institution and population managers in identifying possible causes for poor hatchability.

13.3 HYGIENE AND SANITATION

Contamination is often a significant source of loss of ratite eggs, therefore preventative measures should be diligently practiced (Wilson 1997). Post-hatch, it is recommended that betadine is applied to the umbilicus to help prevent egg sac peritonitis.

13.3.1 Personal hygiene

Egg handlers should wash their hands in a warm soapy or iodine solution and ensure that hands are completely dried prior to handling eggs at every stage during the incubation process.

13.3.2 Egg sanitization prior to storage/synchronization

Dirty eggs have the potential to carry disease, and should be kept as clean as possible. Stewart (in Tully & Shane 1996) outlines that current practice for the hand cleaning of ostrich eggs involves dry removal of dust and dirt followed by the application of a disinfectant mist (Stewart in: Tully & Shane 1996). Results from egg cleaning for artificial incubation in the zoological industry suggest that dry removal of dust and dirt (very lightly sanding eggs to remove the dirt only – not to the point of removal of any shell) is sufficient and that disinfectant is not necessary.

If disinfectants are used and the temperature of the antiseptic solution is lower than the temperature of the egg, a reduction in the volume of the egg contents occurs, causing a negative pressure and vacuum, which results in an increase in the movement of bacteria through the shell pores and contamination of the internal contents of the egg and subsequent infection of the embryo (Cooper 2001). The disinfectant itself can also be drawn in to the egg in this manner, potentially affecting hatchability. Soaking eggs in cold water also encourages bacterial penetration through the egg shell (Spencer 2010). Eggs should never be soaked in any liquid, or dipped in any liquid of high viscosity as this will further affect water loss, shell porosity and hatchability.

Cassowary eggs have been treated with gentamicin and betadine immersion prior to storage (Mike Taylor *personal communication*) however preliminary data analysis shows that hatchability is compromised. Stewart (in

Tully & Shane 1996) suggests that such sanitization of the shell of internally contaminated eggs is of little value and may even lower hatchability.

13.3.3 Storage room and incubator hygiene

All surfaces in the storage room should be appropriately sanitized and airflow should be constant but without drafts.

Spencer (2010) recommends fumigating eggs and incubators with formaldehyde gas, however this is not endorsed by the author nor the reviewers due to the occupational health and safety risk to humans and the potential harm it may cause to eggs. A thorough wipe down of all surfaces in the incubator with a disinfectant (such as Roccal-D, F10 or bleach) should be sufficient. Removable incubator parts that easily come out should be soaked or spray with disinfectant using the manufacturer's instructions.

13.4 INCUBATOR

13.4.1 Type

The range of incubators available for the incubation of ratite eggs is expanding with the growth of the commercial ratite industry.

Humidaire Co. (Berry Hill Ltd.), Mod. 50: Drum-type, Auto, Solid state; and Multiplo Electric Incubator, fan forced, Manual incubators have both been successful in their use with cassowary eggs.

Chicken egg incubators have also been successfully used (Brad Gabriel *personal communication*).

13.5 INCUBATION PHASES

13.5.1 Monitoring and egg collection

Keeping staff should monitor the dam during the season to ensure that eggs are collected as close as possible to the time of oviposition. 15 minutes is ideal as it will allow sufficient time for the cuticle to dry. Quick collection prevents damage of the embryo in hot [or cold] temperatures, microbial spoilage, and loss from theft or predation (Cooper 2001). Eggs left in the nest for several days are subject to extremes of environmental temperature, particularly when exposed to direct sunlight, resulting in a high incidence of early embryonic mortality due to pre-incubation (Stewart in: Tully & Shane 1996).

Once collected, eggs should be wiped with a clean dry cloth and if necessary, further cleaned using methods listed in 13.2.2.

13.5.2 Egg storage/synchronization

The need to synchronize hatching is critical in [wild] cassowaries, as young must be capable of leaving the nest at the same time (Bentrupperbäumer 1998) and although such precision may not be absolutely necessary in captivity, it can facilitate uncomplicated artificial raising if this is the chosen rearing method.

21.1 C is physiological zero for avian embryos, so at temperatures higher than that development initiates but at different rates in different tissues, which dramatically reduces hatchability.

Eggs should be allowed to return to room temperature before setting in the incubator.

Table 13.1 - Storage period parameters for Cassowary, Emu and Ostrich.

	General	Cassowary	Emu	Ostrich
Storage duration	At least 7 days	Up to 7 days	-	Up to 19 days at 15.51 - 15.56 C without affecting hatchability. Up to 7 days.
Egg treatment prior to storage	Best not to wash. IF washing necessary, use warm water (43.3 - 48.8 C) and approved hatching egg sanitizers.	Left on a table in a well ventilated area before setting in incubator.	Disinfect using a recognized egg-sanitation process, fumigant or egg washing product	Dry removal of dust followed by application of disinfectant mist
Position	Vertical with air cell at top	Horizontal (personal observation)	-	Air cell upwards
Turning	-	-	-	Not required if stored for one week or less. Once daily for longer storage periods
Airflow	-	Well ventilated	-	-
Temperature	13.33 - 15.55 C. 12.77 - 18.33 C	-	10 - 16 C for up to ten days	Below 29.45°C, or between 12.78°C - 18.33°C for up to 7 days
Relative humidity	75%. High	-	-	75%

Source: Hermes 1996, Jeffrey et al. 2007, Kent & Bewg 2010, personal observation, Romer 1997, Stewart in: Tully & Shane 1996.

13.5.3 Incubation

Incubation generally lasts between 40-57 days, depending on egg size, shape, incubator temperature, humidity. High temperatures will cause rapid development and small chicks, or even death of the embryo at an early stage.

13.5.3.1 Position and turning

Eggs should be well spaced to reduce hot and cold spots in the incubator. Opaque shelled eggs, such as cassowary eggs, in which the air cell cannot be definitively found by means of candling, should be placed on their sides (Jeffrey *et al*. 2007) and turned on their long axis. This means that if the pointed ends of an egg were north and south the egg would turn from side to side (east to west) along the equator (Jeffrey *et al*. 2007) Eggs should be turned at least seven times a day, in the opposite direction each time. Turning should occur throughout the day and through the night if using automatic turners. If turning eggs manually, turning throughout the night is unnecessary. Turning eggs in the same direction each time interferes with the centring of the chalazae (Spencer 2010), which has caused high mortality in chicken eggs. It will also cause malformation of the chorioallantois membrane and other structures within the egg (Jeffrey *et al*. 2007).

13.5.3.2 Temperature

Temperature is a critical factor in incubation and should be measured by multiple good quality thermometers at the same level that the eggs are located in the incubator (Romer 1997).

Table 13.2 - Incubation period parameters for Cassowary, Emu and Ostrich.

	General	Cassowary	Emu	Ostrich
Egg treatment prior to incub.	Allow eggs to rest and cool for at least a day before setting	-	Allow to come to room temperature for 12-18 hours before setting in incubator	Kept for 12 hours at room temperature, then washed, disinfected and dried
Position	Vertical with air cell at top; Air cell at top	Horizontal unless air cell can be definitively found	Horizontal unless air cell can be definitively found	Vertical with air cell at top
Turning	At least through a 90° angle, along long axis if positioned on side with a varied direction of turn; Automatic incubators turn up to 24 times in 24 hours, or an odd number of times (minimum 5) if turning by hand; At least 3-5 times daily and up to 12 times	Three times daily, 180° each time, alternating clockwise then anti-clockwise	Odd number of times, minimum 3 times daily;	-
Airflow	21% oxygen, 0.05 - 0.1% carbon dioxide for ratite eggs incubated at less than 3000ft. altitude	-	Important that fresh air is allowed into incubator each day	-
Temperature	36.38 - 37.22 C 35.94 - 36.5 C 35.83 C	Currumbin Sanctuary: 35.5 - 36.7 C (Dry); 27.2 - 30.6 C (wet) ; Melbourne Zoo: 36.5 C (Dry); 31.1 - 31.7 C (Wet) Denver Zoo: 36.1 C (dry); 30.6 C (wet)	35.25 - 35.5 C (dry bulb); 26 - 27 C (wet bulb)	-
Humidity	-	Denver Zoo: 68%	45 - 50% 25 - 40 % 35 - 55 %	15 - 20 % 10 - 40 %
Moisture loss	12 - 16 % 10 - 18 %	12 - 15%, but hatches have occurred from 12 - 20 % loss;	-	12 - 17 % at 38 days

	Currumbin Sanctuary hatched a chick with an 11 % loss ; 13 %	

Source: Birchard *et al.* 1982, Hermes 1996, Jeffrey *et al*. 2007, Kent & Bewg 2010, Namh 2001, Romer 1997, Stewart in: Tully & Shane 1996, Wilson 2007.

13.5.3.3 Humidity

Cassowaries naturally occur in areas of high humidity and their eggs may be particularly susceptible to embryo desiccation following excessive water loss (Romer 1997).

Humidity (%RH) must be adjusted to accommodate the required moisture loss from the egg during incubation (Jeffrey *et al*. 2007). Most commercial ratite eggs will perform well when a moisture loss of 12-16% is achieved. If eggs are losing too much water, humidity can be increased to compensate. Likewise if eggs are not losing enough weight, humidity can be decreased.

Relative humidity can be measured using a dial hygrometer (Romer 1997) or a wet bulb. An internet search will show wet bulb measurements in comparison to %RH based on temperature.

13.5.3.4 Desired % weight loss

12-15% weight loss is the generally desired range for most eggs. Rundel finds that 12-15% is most successful but successful hatches have occurred from 12-20%. Currumbin Sanctuary hatched a chick with an 11% weight loss (Romer 1997).

13.5.4 Pip to hatch

The normal pip to hatch interval is between one and 24 hours.

13.5.4.1 Position and turning

The need for frequent turning is greatest in the early stages of incubation and is not necessary after the egg has pipped internally. Turning of eggs should stop three to four days before the expected hatch.

13.5.4.2 Temperature and Humidity

No consensus exists for the hatching temperature or humidity of ratite eggs, dropping the temperature by .5 a degree and increasing humidity is good practice. If weight loss is not within a suitable range, humidity can either be increased or decreased until external pip to try and correct it as much as possible. Once external pipping has commenced, humidity should be increased regardless to prevent drying of membranes.

Table 13.3 - Pip to hatch period parameters for Cassowary, Emu and Ostrich.

	General	Cassowary	Emu	Ostrich
Turning	Unnecessary	Unnecessary	Unnecessary	Unnecessary
Temperature	1°F lower than that of incubator	Ten days before hatching, decrease from dry bulb reading of 36.5 to 36.2 C		Same as incubation period
Relative humidity	70 - 75 %; Increase RH 5 - 10%	Ten days before hatching, increase to wet bulb reading of 31.7 - 31.8 C	28 - 29 C (wet bulb); 60 %	40 %; Same as incubation period

Source: Hermes 1996, Jeffrey et al. 2007, Kent & Bewg 2010, Romer 1997, Stewart in: Tully & Shane 1996, Wilson 2007.

Temperatures above optimum shorten incubation time (Wilson 2007) while temperatures below can lengthen incubation time.

13.6 ASSISTED HATCH

Assisted hatch may be necessary in some cases. Rundel (in: Romer 1997) observed malpositioned chicks in 20% of fertile eggs, which may be attributed to eggs being incubated in a horizontal position, as was highlighted by Stewart (in Tully & Shane 1996) in ostrich eggs.

If pipping is delayed, a small hole can be made over the air cell, and then the egg should be allowed to rest - do not break the membrane. For any eggs that have not completed the hatching process by the following day, the membrane can be pricked with a dull probe and followed by gradually removing the shell. The location of the head can be found by x-ray, infrared imaging or by flicking the shell with a fingernail while holding the egg to the ear to listen for the location of the call.

13.7 EGG NECROPSY

It is important that all unhatched eggs are examined. While examination may not always be diagnostic - as many problems are management related - egg post-mortem is the most likely way of identifying infectious diseases, nutritional deficiencies and toxins (Nicholls *et al*. 2008 in Bailey). Literature concerning commercial poultry may assist in determining the cause of early and/or late embryonic deaths.

A detailed necropsy will add to the body of knowledge relating to cassowary reproduction and assist in assessment and management.

A standardised Egg Necropsy Form assists with the development of a thorough technique (See Appendix 6).

The examination should begin with a review of the egg incubation history. Any additional history including known developmental progress and status of clutch mates should be entered into the Egg Necropsy Form. A unique accession number should be assigned to the egg. The condition of the egg and storage since death should be recorded, along with the egg weight and measurements.

The examining veterinarian should observe the egg contents *in-situ* prior to removing contents/embryo for post mortem examination. The position and appearance of the embryo/appendages should be noted, along with egg shell quality, integrity of membranes, presence of oedema, haemorrhages, deformities and degree of yolk sac retraction, if relevant.

If no embryo has formed, this should be recorded. If an embryo has formed, a full post mortem should be performed using the Post Mortem Evaluation Form (See Appendix 3).

ARTIFICIAL REARING

Inappropriate rearing methods have been implicated in inadequate social development and poor reproductive success of many species in captivity.

Studies on the effect of rearing method on social behaviour of artificially reared birds are revealing that sociality is an important factor in the development of effective behavioural preparation of individuals for release (e.g. Wallace 1994; Scott & Carpenter 1987; Utt *et al*. 2008; Meretsky *et al*. 2001; Horwich 1989; Kreger *et al*. 2004; Harvey *et al*. 2002; and Navarro & Martella in: Glatz *et al*. 2011) and likewise, the same could be said for captive individuals participating in managed breeding programs.

Suggested Readings

- Immelmann, K. (1975). Ecological Significance of Imprinting and Early Learning. *Annual Review of Ecology and Systematics*, 6: 15-37.
- Lickliter, R., Dyer, A. B., McBride, T. (1993). Perceptual consequences of early social experience in precocial birds. Behavioural Processes, 30: 185-200.
- Valutis, L. L., & Marzluff, J. M. (1999). The Appropriateness of Puppet-Rearing Birds for Conservation Biology, 13: 584-591.

14.1 JUSTIFICATION FOR ARTIFICIAL REARING

Artificial rearing should only be attempted if natural rearing of the chicks cannot occur.

Reasons for removal may include:

- History of low humidity deformations from natural incubation;
- History of destruction of eggs or chicks by sire or dam, or disappearance of eggs;
- History of illness of chicks hatched naturally in the enclosure; or
- Death, illness or poor condition of sire.

14.2 EARLY EXPERIENCE AND SOCIAL BEHAVIOUR IN PRECOCIAL BIRDS

Immelmann (1975) postulated that early experience exerts a crucial and permanent influence in a variety of phenomena, such as the development of normal copulatory behaviour, the development of contact behaviour, the organization of maternal behaviour, the degree of socialization and aggressive behaviour, and the establishment of diurnal rhythms. Lickliter *et al*. (1993) further determined that early social experience with conspecifics is essential for the normal development of early species-typical perceptual and social preferences.

Besides its importance for infant-mother relations, Immelmann (1975) hypothesized that the influence of early experience may be equally important with respect to certain aspects of adult behavior, especially with regard to the determination of sexual preferences, but also to several other aspects of social and other behavior.

14.2.1 Interaction in nature

Under species-typical circumstances, the precocial hatchling would receive an array of visual, auditory, and social stimulation from its surroundings, especially its mother [or father, in this case] and siblings, in the period following hatching (Lickliter *et al*. 1993).

14.2.1.1 Parental interaction in nature

Although cassowary young are precocial, they are wholly dependent on the male until they can forage on their own (Bentrupperbäumer 1998). A high level of interaction is observed in the typical family system and chicks can stay with the sire for up to 18 months. In a small handful of instances, the dam is also plays a role in the raising of chicks.

14.2.1.2 Sibling interaction in nature

In nature, a clutch of cassowary eggs is usually comprised of more than one egg, and any chicks that hatch are raised together for up to 18 months but more commonly to nine months. The role of conspecifics (other than the mother) in the achievement of species-typical behaviour has tended to be overlooked or under-characterised in much of the animal behaviour literature (Lickliter *et al*. 1993). Studies that have considered this role, referring to siblings, (e.g. Lickliter & Gottlieb 1986) found that social rearing with siblings results in a visual preference for the group of siblings over the familiar maternal hen.

In some instances, it may be necessary for a non-cassowary parent such as a human to intervene, or replace the natural parent, however we must recognise that the typical circumstances of development for most avian and mammalian species reliably includes conspecifics, especially parents and siblings (Lickliter *et al*. 1993). As the literature suggests, by removing the natural parent or any siblings, or by altering the equation, as the literature suggests, opportunities for the offspring to learn the central social behaviours that it requires to be able to appropriately interact with conspecifics in the future are compromised.

14.2.1.3 Why should we maintain natural social behaviours?

Maintenance of natural behaviours has wide ranging implications in both birds that are bred for release to the wild, and for birds that are managed as a part of a captive breeding program (whose immediate destiny is to remain in captivity).

Birds for release require all of the skills to be able to prosper in a natural environment – including, amongst others, the ability to recognise predators, and interact with conspecifics. In many cases, as a result of a predictable, often unchanging environment, captive individuals may lose the range of behaviours that enable response to a variable and unpredictable environment (McPhee 2003). Conversely, captive environments can be hyper-stimulating, and behavioural "inaccuracy" or adaptation to such environments is undoubtedly promoted and passed on through any generations that are produced.

Birds participating in captive breeding programs (with no intention of release to the natural environment), may not require the ability to recognise predators, but still require the skills to be able to interact with conspecifics and hence effectively contribute to their respective breeding program. Failure to maintain such behaviours could prove catastrophic for the long-term sustainability of captive cassowary populations, therefore it is imperative that birds are sexually imprinted to the correct species. Understanding the mechanisms by which imprinting occurs (e.g. Bolhuis 1991) can be extremely helpful in designing effective husbandry techniques (Elphick *et al.* 1997).

14.3 IMPRINTING

Newly hatched precocial birds can be imprinted on a wide array of objects in the absence of a natural parent, indicating that early parental recognition is largely acquired (Horwich 1989).

It is widely accepted that close association with humans may produce imprinted birds that are accustomed to humans (Sheppard In: Gibbons *et al*. 1995) while additional work has shown that imprinting resulting from hand-rearing, foster parenting or surrogate parenting often produces animals that are incompetent breeders (Curio In: Caro 1998, Myers *et al*. 1988). Such work is supported in the case of the cassowary as although a number of birds that have been removed from parents and raised together from a young age have gone on to successfully reproduce (Romer 1997), some hand reared specimens are yet to reproduce, suggesting that complex social behavioural information is either passed from parent to offspring and/or learned through interaction with siblings. As the species' reproductive performance in captivity is already limited, it is imperative that steps are taken to ensure that sexual imprinting of birds by humans is minimised.

Two classical cases of imprinting are highlighted by Immelmann (1975). They are 'filial imprinting' or imprinting of the following reaction/behaviour of precocial birds; and, 'sexual imprinting' or the imprinting of sexual preference.

14.3.1 Filial imprinting

Filial imprinting is most often characterized as a phenomenon that results from an interaction between two dissociable processes: the emergence of a predisposition to approach and prefer (i.e., show social behaviour toward) certain classes of stimuli over others, in response to a nonspecific experiential factors, and a learning process that is particular to the requirements of socially living precocial neonates (Lickliter & Harshaw in: Hood *et al*. 2010). Put simply, it is a learning process involved in the formation, in young, usually precocial birds of an attachment to, and a preference for the parent, siblings or parent-surrogate (Bolhuis 1991, Bolhuis 1999, Bolhuis 2010).

Not surprisingly, young chicks of many species have shown that in the absence of a same-species parent or sibling, chicks will develop a preference at a very young age to follow an inter-species parent or other parent-surrogate such as a human, puppet, costume or object. Bolhuis (1991) suggests that the social behaviour of the young animal becomes limited to a particular object or class of objects.

Lickliter & Gottlieb (1986) found that social rearing with siblings results in a visual preference for the group of siblings over the familiar maternal hen. Such a preference may facilitate the development of accurate social behaviour in chicks raised with conspecific siblings, and reduce the concern for imprinting on a non-cassowary 'parent'. Notably however, filial attachment does not necessarily, in all cases, imply that offspring will develop sexual attachment to a subject that resembles the parent, or parent-surrogate.

Filial attachment may be of less consequence to a managed program if the chick is raised with a conspecific, however may be of great consequence if birds were to be considered for release.

14.3.2 Sexual imprinting

Vidal (1980) argued that development of a sexual preference was not a direct consequence of the direct filial attachment. Sexual imprinting is involved in the formation of mating preferences that are expressed later in life (Bolhuis 2010) and is based on resemblance to a parent. Several species of bird were found by Bateson (1964) to direct their first sexual responses towards objects already familiar to them, and to have preferences that were at least partially affected by experience occurring before sexual behaviour had matured. Similarly, Fox (1969) surmised that animals may become over-attached to the parent-surrogates, and direct their later sexual activities or social preferences towards their parent-surrogates, or beings resembling parent-surrogates, as well as showing varying degrees of social incompatibility with their own species. Therefore sexual imprinting is likely to be of greater consequence to managed breeding programs for species whose destiny is to remain in captivity.

14.3.2.1 Sexually imprinting the correct species

Correct sexual imprinting is critical to a successful managed breeding program as cross-fostering or inter-species rearing has resulted in imprinting problems preventing certain precocial species from breeding with their own species (Horwich in: Ellis *et al*. 1996).

Additionally, some institutions have found that individually hand-reared birds show sexual attraction towards humans (through presentation of reproductive behaviours) and not towards conspecifics. Clearly, sexual attachment to a human by a cassowary is not conducive to progressive cassowary reproductive management in captivity and hence caution must be exercised to ensure that sexual attachment does not occur between parent-surrogates (humans or other species) and cassowaries.

The following section aims to clarify the fundamental artificial rearing models for precocial birds, emphasizing where sexual imprinting is expected to occur, and the probability that birds will acquire adequate social behavioural attributes allowing them to reproduce successfully under the current ASMP managed program.

14.4 REARING MODEL ELEMENTS AND ELEMENT TYPES

Models for artificially rearing cassowaries in a captive environment are numerous and complex and the literature may use slightly different terminology. Each model either contains, or does not contain four key artificial rearing elements (i.e. parental, conspecific sibling, inter-species nest-mate, and human). Each key element is broken down further into different types:

14.4.1 PARENTAL ELEMENT

Defined as the element which nurtures the chick. Can be further broken down into different types of parent:

a) ***Intra-species parent***

In this setting the parent is a foster parent belonging to the same species. For example, a biological parent, or cassowary at another institution will fill the parent role.

b) ***Inter-species parent***

In this setting the parent is a foster parent belonging to a species other than a cassowary. For example, an emu or a chicken will fill the parent role.

c) ***Costume parent***

In this setting the parent is a human dressed to resemble an intra-species parent, for example, a human wearing a cassowary costume or puppet.

d) ***Hand/human parent***

In this setting the parent is a human. The chick has full visual, auditory and tactile access to the parent.

e) ***No parent***

In this setting the parent is a human, however the chick has limited or no visual, auditory and tactile access to the parent.

14.4.2 CONSPECIFIC SIBLING ELEMENT

Defined as a sibling of the same species. Can be further broken down into two settings:

a) ***Reared with a conspecific sibling***

In this setting the chick is raised with one or more siblings of the same species, ideally of similar age (hatched in the same season) however not necessarily sharing the same parent/s. Lickliter & Gottlieb (1986) found that social rearing with siblings results in a visual preference for the group of siblings over the familiar maternal hen.

A study on corvids revealed that a puppet was not essential for correct sexual imprinting if subjects were raised in conspecific groups (Valutis & Marzluff 1999).

b) ***Reared without a conspecific sibling***

In this setting the chick is raised without siblings of the same species.

14.4.3 INTER-SPECIES NEST-MATE ELEMENT

Defined as a nest-mate/s of a different species. Lickliter & Gottlieb (1986) found that social rearing with siblings results in a visual preference for the group of siblings over the familiar maternal hen. Can be further broken down into two settings:

a) ***Reared with an inter-species nest-mate***

In this setting the chick is raised with one or more nest-mates of a different species, ideally of similar age (hatched in the same season).

b) ***Reared without an inter-species nest-mate***

In this setting the chick is raised without nest-mates of a different species.

For the purposes of simplifying the rearing models, the inter-species nest-mate element is not included herein. It is expected that the presence of an inter-species nest-mate will increase the likelihood of the chick sexually imprinting on the inter-species.

14.4.4 HUMAN ELEMENT

In captivity, every scenario will have a human element, additional to any parental element, conspecific element and inter-species element.

Reducing human contact and rearing young with conspecifics, can produce a bird which is comfortable in captivity, yet responds normally to other birds for reproduction (Cade & Fyfe 1977 in: Temple).

The human element is also excluded from this discussion henceforth as it is well established that the presence of humans that are not acting in a parental element capacity (i.e. personnel servicing the species for reasons other than parenting) generally produce birds that are comfortable in captivity and generally not sexually imprinted to humans (dependant on the level of human interaction).

14.5 ARTIFICIAL REARING MODELS AND EXPECTED CONSEQUENCES OF MODEL CHOICE

Considering the exclusions listed above, we are left with five fundamental rearing models, each with two scenarios – with conspecific siblings or without conspecific siblings.

14.5.1 Intra-species Parent Model

Use of the intra-species parent model is dependent on the absence of a biological parent and the availability and receptiveness of a conspecific parent at another institution.

Resource investment by an institution for intra-species rearing of cassowary chicks is the same as in a natural scenario, whereby the natural parent would raise the offspring.

i) Expected consequences for cassowary chick reared by conspecific parent with conspecific sibling:

Assuming the level of interaction between the chick and humans is minimal, it is expected that the rearing of a chick by a conspecific parent (foster) will increase the likelihood of filial and sexual imprinting on cassowaries and reduce the likelihood of filial and sexual imprinting on non-cassowaries. The presence of conspecific sibling/s is expected to further increase the likelihood of filial and sexual imprinting on cassowaries, reduce the likelihood of filial and sexual imprinting on non-cassowaries, and reduce parental dependency.

ii) Expected consequences for cassowary chick reared by conspecific parent only (without conspecific sibling):

Assuming the level of interaction between the chick and humans is minimal, it is expected that the rearing of a chick by a conspecific parent (foster) will increase the likelihood of filial and sexual imprinting on cassowaries and reduce the likelihood of filial and sexual imprinting on non-cassowaries. The absence of a conspecific sibling is expected to reduce the likelihood of filial and sexual imprinting on cassowaries, and increase parental dependency by the chick.

14.5.2 Inter-species Parent Model

Use of the inter-species parent model is dependent on the absence of a biological parent or intra-species parent, and the availability and receptiveness of an inter-species parent.

Investment by the institution for inter-species rearing of cassowary chicks is the same as in a natural scenario, whereby the natural parent would raise the offspring.

iii) Expected consequences for cassowary chick reared by inter-species parent with conspecific sibling/s:

It is expected that the rearing of a chick by an inter-species parent (foster) will increase the likelihood of filial and sexual imprinting on the foster parent species. The presence of a conspecific sibling is expected to increase the likelihood of filial and sexual imprinting on cassowaries, reduce the likelihood of filial and sexual imprinting on non-cassowaries, and reduce parental dependency.

iv) Expected consequences for cassowary chick reared by inter-species parent only (without conspecific sibling):

It is expected that the rearing of a chick by an inter-species parent (foster) will increase the likelihood of filial and sexual imprinting on the foster parent species. The absence of a conspecific sibling is expected to reduce the likelihood of filial and sexual imprinting on cassowaries, and increase dependency on the foster parent by the chick. The presence of an inter-species sibling is expected to increase the likelihood of filial and sexual imprinting on the foster species.

14.5.3 (Cassowary) Costume Parent Model

The costume parent model can be used in the absence of a natural parent or intra-species parent, or inter-species parent. Also dependent on whether adequate resources are available to commit.

Investment by the institution is higher in this case than in a natural situation because of the additional resources required to raise the chick.

v) *Expected consequences for cassowary chick reared by costumed personnel with conspecific sibling:*

It is expected that the rearing of a chick by a costumed human will increase the likelihood of filial and sexual imprinting on objects or species resembling the costume. The presence of a conspecific sibling is expected to increase the likelihood of filial and sexual imprinting on cassowaries, reduce the likelihood of filial and sexual imprinting on non-cassowaries. Dependency on costumed human is slightly reduced because of conspecific sibling component.

vi) Expected consequences for cassowary chick reared by costumed personnel only (without conspecific sibling):

It is expected that the rearing of a chick by a costumed human will increase the likelihood of filial and sexual imprinting on objects or species resembling the costume. The absence of a conspecific sibling is expected to reduce the likelihood of filial and sexual imprinting on cassowaries, and increase dependency on the costumed human by the chick.

14.5.4 Hand Rearing (Human Parent) Model

The hand rearing model can be used in the absence of a natural parent, or intra-species parent, or inter-species parent. Also dependent on whether adequate resources are available to commit.

Investment by the institution is higher in this case than in a natural situation because of the additional resources required to raise the chick.

vii) Expected consequences for cassowary chick reared by hand with conspecific sibling:

It is expected that the rearing of a chick by a human will increase the likelihood of filial and sexual imprinting on humans. The presence of a conspecific sibling is expected to increase the likelihood of filial and sexual imprinting on cassowaries, slightly reduce the likelihood of filial and sexual imprinting on humans only. Dependency on human is slightly reduced because of conspecific sibling component.

viii) Expected consequences for cassowary chick reared by hand only (without conspecific sibling):

It is expected that the rearing of a chick by a human will increase the likelihood of filial and sexual imprinting on humans. The absence of a conspecific sibling is expected to reduce the likelihood of filial and sexual imprinting on cassowaries, increase the likelihood of sexual imprinting on humans and increase dependency on humans by the chick.

14.5.5 Isolation Rearing (No Parent) Model

Use of the isolation rearing model is dependent on the absence of a natural parent, or intra-species parent, or inter-species parent. Also dependent on whether adequate resources are available to commit.

Investment by the institution is higher in this case than in a natural situation because of the additional resources required to raise the chick.

ix) Expected consequences for cassowary chick reared in isolation with conspecific sibling:

It is expected that the rearing of a chick in isolation with a conspecific will increase the likelihood of filial and sexual imprinting on cassowaries.

x) Expected consequences for cassowary chick reared in isolation (no conspecific sibling):

The consequences of isolation rearing a cassowary chick without a conspecific parent, foster parent or conspecific sibling on filial and sexual imprinting are unknown.

14.6 REARING MODEL PREFERENCES AND JUSTIFICATION

Table 14.1 places rearing models in order of preference to achieve the highest likely potential for correct sexual imprinting, accurate social behaviour, and assumed reproductive success. Preferences should be taken into account when deciding whether or not to artificially rear a cassowary chick.

Table 14.1 – Artificial rearing model preference and justification

Preference	Model	Justification
1	Intra-species, with conspecific sibling	If the chicks are raised with siblings and/or an intra-species parent, they will sexually imprint on a conspecific, as they would in a natural situation. ***Preferentially higher because of high level of interaction with conspecifics.***
2	Intra-species, without conspecific sibling	
3	Inter-species, with conspecific sibling	
4	Costume, with conspecific sibling	
5	Hand, with conspecific sibling	
6	Isolation, with conspecific sibling	If the chicks are raised by concealed humans, but are housed with a sibling, the chances of sexually imprinting on a conspecific are greater than for chicks raised without a conspecific. ***Preferentially higher because of high level of interaction with conspecific/s. Preference may be lowered because of lack of parental element.***
7	Costume, without conspecific sibling	If the chick is raised by a costume that represents a conspecific parent, there is a greater chance that the chick will sexually imprint on a conspecific, as it would in a natural situation. ***Preferentially higher because of interaction with puppet which ideally, represents a conspecific***
8	Inter-species, without conspecific sibling	If the chick is raised by an interspecies parent without siblings the chick will sexually imprint on the inter-species parent (and/or any inter-species siblings). If the chick is raised by humans, chick will sexually imprint on humans. ***Preferentially lower because of high level of interaction with different species, and lack of interaction with conspecifics.***
9	Hand without conspecific sibling	
10	Isolation, without conspecific sibling	If the chick is raised by concealed humans, but is housed alone, the subject on whom the chick will imprint is unknown. ***Preferentially lower because of parental element and lack of other key elements.***

14.7 REARING DETAILS FOR HAND REARING / ISOLATION REARING / COSTUME REARING

14.7.1 Brooder type/design

It is important that chicks are brooded at the correct temperature in a draught-free suitably sized area (Spencer 2010). Localised heat type brooders are most commonly used for cassowaries. For small clutches, boxes measuring 2m x 1m x 0.8m high have been used by Currumbin Sanctuary, Taronga Zoo, Fleay's Wildlife Park and Rundel, all with four solid sides and an overhead light (Romer 1997). It is recommended that two bulbs be installed; both with adjustable height such that some warmth is still provided in the event that one bulb should fail. It is also advised that both bulbs be placed at one end to create a temperature gradient. Rundel uses a 100 watt bulb and a heating pad at one end (Romer 1997). Chicks are often seen sitting underneath the sire, and as they grow older, will continue to hide under his plumage. Hanging clean mop heads in the brooder box or enclosure may provide the chick with the illusion that a sire is caring for them; however this system may not provide sufficient heat to chicks in colder climates.

Brooder substrates should be inedible, provide good traction and be easily cleaned (Speer 2006). Non-slip substrates such as artificial grass or indoor/outdoor carpet are suitable. Soft sand is not recommended.

Good ventilation is essential.

14.7.2 Brooder temperatures

The best guide to the correct temperature is the chicks´ thermal comfort behaviour (Spencer 2010). Close huddling to the heat source indicates that the chick is cold, while dispersion from the heat source and panting indicates that heat is excessive. A temperature data logger placed at chick height will provide valuable information on temperature fluctuations to assist your management (Spencer 2010). Chicks should be maintained at decreasing temperatures with age (Speer 2006). The following table provides a guide to the temperatures required by ratite chicks at different ages during brooding.

Table 14.2 - Guide to the temperatures required by ratite chicks at different ages during brooding.

Age (days)	Temperature at chick level (°C)
1-7	30+
7-14	28
14-21	26
21-28	24

Source: Kent & Trappett 2010.

14.7.3 Diet

See Appendix 13.

Chapter 6, Section 6.6.3 discusses nutritional requirements of growing ratites. Tapping a food bowl with a puppet beak or pen may stimulate feeding in hatchlings.

Farmed ratite chicks often die because they are unable to find water (Spencer 2010) so water should be offered *ad-libitium*. Multiple watering bowls containing cool, clean water should be available at all times. Spencer (2010) suggests that attention can be drawn to watering bowls by placing shiny or colourful items in the bowls, ensuring that they are securely fastened to prevent swallowing hazard. The water bowl should be no deeper than half the length of the tarsometatarsus to limit possible drowning and to facilitate easy escape.

14.7.4 Specific requirements

Rearing models outlined earlier in the chapter highlight the importance of conspecific sibling company to chicks and the impact that having no such company may have on appropriate imprinting. See section 12.4. The use of a mirror in the brooder may reduce the likelihood of imprinting on humans and increase the likelihood of imprinting to their own species. Careful thought should be given to protecting the mirror though, as cassowary chicks are known to run and kick at each other from an early age.

14.7.5 Hygiene

It is important to maintain enclosure hygiene and provide food on clean plates (Romer 1997). Brooders should be cleaned daily to remove faecal matter and food waste.

14.7.6 Exercise regime

Cassowaries are precocial, and while they require warmth from the male, they are able to leave the nest within hours of hatching. An exercise regime should be implemented with a gradual increase in duration up to 4 weeks of age, after which the chick should need little encouragement to move about on its own. Frequent short breaks in exercise will replicate scenarios in the wild where family groups stop to forage and rest.

Use of a costume by personnel charged with exercising chicks should be seriously considered to limit the likelihood of imprinting on humans.

14.7.7 Weaning

Bentrupperbäumer (1998) observed a wild sire masticating fruit for its chicks. By ten days old the chicks had clearly connected the sound of mastication with the provision of food and by four months, chicks were foraging almost entirely on their own (Bentrupperbäumer 1998). Being a precocial species, weaning can be achieved within a few days of hatching if food items are small enough to be swallowed whole and do not require mastication.

14.7.8 Growth

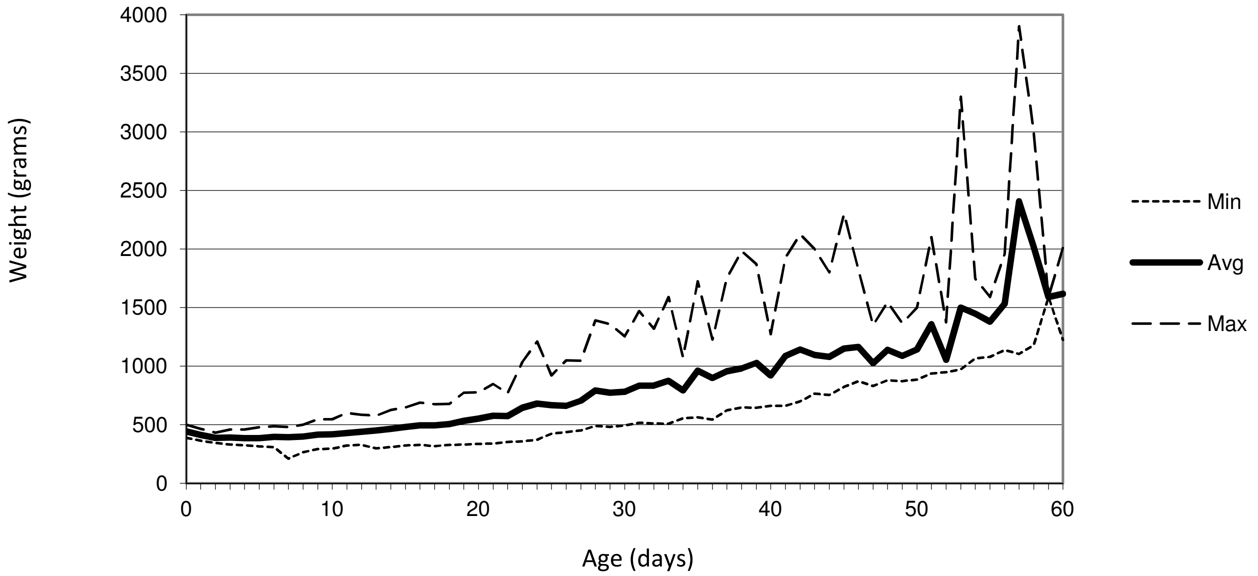


Figure 14.1 - Southern Cassowary Chick Growth Curve (n = 26). Source: *Nicole LaGreco.*

A slight decline in weight is observed in cassowary chicks in the first few days after hatching while the yolk sac is absorbed. Time may vary between two to six days before a chick is comfortably feeding and weight gain commences.

Appendix 1 - Cassowary food plant species

Scientific name	Common name	Fruiting months
Abrophullum ornans	Native Hydrangea	Any month
Aceratium doggrellii		
Aceratium meglospermum	Creek Aceratium	October-February
Acmena divaricata	Smaller Cassowary Satinash	January-November
Acmena graveolens	Cassowary Satinash	April-November
Acmena resa	Red Eungella Satinash	Feb-Nov
Acmensperma claviflorum	Grey Satinash	Sep-Jan
Acronychia aberrans	Acid Berry	Apr-Nov
Acronychia acidula	Lemon Aspen	Apr-Sep
Acronychia acronychioides	White Aspen	Jun-Dec
Acronychia vestita	Fuzzy Lemon Aspen	Apr-Nov
Aglaia australiensis	Brown Ripples	Sep-Feb
Aglaia meridionalis	Rusty Almond	Nov-Feb
Aglaia sapindina	Smooth Fruited Aglaia	Nov-Apr
Alphitonia petriei	Pink Ash	Jan-Jul
Alphitonia whitei	Red Almond	Jan-May
Alpinia arctiflora	Pleated Ginger	Feb-Aug
Alpinea caerulea	Native Ginger	Any month
Alpinia modesta	Stalkless Ginger	Feb-Apr
Alyxia orophila		
Alyxia spicata	Chain Fruit	Any month
Amoora ferruginea		
Amylotheca dictyphleba	Miseltoe	Any month
Antidesma erostre	Wild Current	Jan-Nov
Antirhea tenuiflora	Crimson Berry	Jun-Apr
Apodytes bracchystylis	Buff Alder	Nov-Feb
Archontophoenix alexandrae	Alexandra Palm	Any month
Ardisia brevipedata	Rambling Spearflower	Any month
Ardisia pachyrrhachis	Mountain Ardisia	Sep-Mar
Barringtonia calyptrata	Cassowary Pine	Dec-Jan
Beilschmiedia brancroftii	Yellow Walnut	Aug-Mar
Beilschmiedia oligandra		
Beilschmiedia tooram	Tooram Walnut	Aug-Dec, May
Calamus australis	Wait-awhile	Nov-Apr
Calamus caryotoides	Fish-tail Lawyer Cane	Mar-Nov
Calamus moti	Lawyer Cane	Apr-Aug
Calamus radicalis	Vicious Hairy Mary	Feb-Apr
Cananga odorata	Macassar Oil Tree	Mar-Nov
Canarium muelleri	Scrub Turpentine	Seo-Nov
Canarium vitiense	Canarium	Oct-Dec
Canarvonia		
Canthium coprosmoides		
Carnarvonia araliifolia	Red Oak	Jul-Mar
Castanospora alphandii	Brown Tamarind	Oct-Mar
Castanospermum australe		
Cayratia clematidea	Slender Grape	Jan-Aug
Cerbera floribunda	Cassowary Plum	Jan-Oct
Chionathus axillaris	Mimply Olive	Sep-Mar
Chionanthus ramiflora	Native Olive	Jul-Feb
Chrysophyllum		
Cinnamomum laubatii	Pepperwood	Jul-Nov

Appendix 1 - Cassowary food plant species

Cissus antarctica		
Cissus penninervus	Grape	Jan-Apr
Citronella smythii	Northern Silky Beech	Feb-Mar
Cordyline cannifolia	Palm-lily	Jan-Jun
Corynocarpus cribbianus	Cribwood	Aug-May
Cryptocarya corrugata	Corduroy Laurel	Jun-Jan
Cryptocarya glabella		
Cryptocarya hypoglauca		
Cryptocarya hypospodia	Northern Laurel	Sep-Dec
Cryptocarya mackinnoniana		
Cryptocarya murrayi	Murray's Laurel	Aug-Nov
Cryptocarya oblata	Tarzali Silkwood	Mar-Dec
Cryptocarya pleurosperma	Poison Laurel	Sep-Mar
Cryptocarya rigida		
Cyclophyllum coproxmoides	Coast Canthium	Aug-May
Davidsonia puriens	Davidson's Plum	Any month
Diospyros hebecarpa	Scrub Ebony	Mar-Dec
Diplocyclos palmatus	Striped Cucumber	Sep-May
Diploglottis bracteata	Boonjee Tamarind	Dec-Jan
Diploglottis dipphyllstegia	Northern Tamarind	Sep-Oct
Diploglottis pedleyi	Pedley's Tamarind	May-Sep
Dysoxylum sp		
Dysoxylum klanderi		
Dysoxylum papuanum		
Dysoxylum pettigrewianum	Spurwood	Oct-Mar
Elaeocarpus angustifolium		
Elaeocarpus arnhemicus	Bony Quandong	Sep-Jan
Elaeocarpus bancroftii	Ebony Heart	Any month
Elaeocarpus culminicola	Michael's Quandong	Nov-Apr
Elaeocarpus eumundi	Eumundi QUandong	Mar-Jan
Elaeocarpus foveolatus	Northern Quandong	Jul-Jan
Elaeocarpus grandis	Blue Quandong	Any month
Elaeocarpus largiflorens		
Elaeocarpus stellaris	Quandong	Aug-Jan
Endiandra acuminata	Brown Walnut	Nov-Jan
Endiandra bessaphila	Gully Walnut	Sep-Dec
Endiandra compressa	Queensland Greenheart	Mar-Nov
Endiandra cowleyana	Rose Walnut	Mar-Dec
Endiandra hypotephra	Blue Walnut	Sep-Nov
Endiandra impressicostata	Steelbutt	Sep-Dec
Endiandra insignis	Hairy Walnut	Oct-Jul
Endiandra leptodendron		Sep-Dec
Endiandra longipedicellata	Buff Walnut	Oct-Jan
Endiandra montana	Brown Walnut	Apr-Dec
Endiandra pubens		
Endiandra sankeyana	Sankey's Walnut	May-Nov
Endiandra tooram		
Erythroxylum ecarinatum	Brown Plum	Dec-apr, Sep
Eugenia reinwardtiana	Beach Cherry	Any month
Faradaya splendida	Potato Vine	Aug-Apr
Ficus congesta	Cluster Fig	Any month
Ficus crassipes		

Appendix 1 - Cassowary food plant species

Ficus copiosa	Plentiful Fig	Jan-Nov
Ficus hispida	Hairy Fig	Any month
Ficus oblique var petiolaris	Small-leaved Fig	Any month
Ficus pleurocarpa		
Ficus variegata	Variegated Fig	Any month
Ficus virens		
Ficus watkinsiana	Watkin's Fig	Jul-Apr
Fontainea picrosperma		
Freycinetia (flowers)		
Galbulimima belgraveana		
Ganophyllum falcatum	Daintree Hickory	Dec-Feb
Gmelina dalrymplean	White Beech	Jan-Jul
Gmelina fasciculiflora	Northern White Beech	Aug-May
Gomphandra australiana	Buff Beech	Oct-Feb
Guettardela tenuiflora		
Halfordia scleroxyla		
Hornstedia scottiana	Native Cardamon	Jan-Mar
Hydriastele wendlandiana	Wendland's Palm	Aug-Feb
Hypserpa laurina		Aug-Apr
Irvingbaileya australis	Wax Berry	Any month
Licuala ramsayi	Fan Palm	Nov-Feb
Linospadix minor	Jak-arungle	Any month
Linospadix minorcarya	Walking-stick Palm	Aug-May
Litsea leefeana	Brown Bollywood	Aug-Dec
Litsea reticulata		
Macaranga mallotoides	Brown Macaranga	Nov-Feb
Macaranga tanarius	Blush Macaranga	Sep-Feb
Mackinlaya macrosciaia	Blue Umbrella	May-Nov
Macrozamia denisonni		
Mangifera indica	Mango	Dec-Jan
Melodinus australis	Bellbird Vine	Dec-Apr
Melodorum leichardtii	Zigzag Vine	Any month
Mitrephora froggattii		
Morinda citriflora	Cheese Fruit	Mar-Dec
Musa		
Myristica insipida	Native Nutmeg	Jan-Feb
Myristica muelleri		
Nauclea orientalis	Leichardt Tree	Dec-Jul
Neolitsea dealbata	Grey Bollywood	Mar-Jul
Niemeyera prunifera	Plum Boxwood	Feb-Sep
?omolanthus novoguineensis	Bleeding Heart	Nov-Feb
Normanbya normanbyi		
Otanthera		
Pachygone longifolia		Nov-Jun
Palaquium galactoxylon	Cairns Pencil Cedar	Nov-Jan
Pandanus lauterbachii	Lauterbach's Pandan	May-Jul
Pandanus monticola	Screw Palm	Mar-Sep
Pandanus solmslaubachii	Swamp Pandan	July-Nov
Parinari nonda		
Peripentadenia mearsii		
Phaleria clerodendron	Scented Daphine	Dec-Jul
Physalis minima	Gooseberry	Feb-Dec

Appendix 1 - Cassowary food plant species

Phytolacca octandra		
Planchonella chartacea		
Planchonella obovoidea		
Piper novaehollandiae		Mar-Dec
Pittosporum rubignosum	Hairy Red Pittosporum	Any month
Planchonella obovoidea		
Pleigynium timorense	Burdekin Plum	Apr-Oct
Podcarpus dispermus	Brown Pine	Jul-Mar
Podocarpus grayii	Brown Pine	Oct-Jan
Polyalthia michaelii	China Pine	Any month
Polyscias australiana	Ivory Basswood	Jul-Apr
Polyscias elegans	Celery Wood	May-Nov
Pothos longipes	Candle Vine	Oct-Apr
Pouteria chartacea	Dungulla	Jul-Dec
Poutera myrsinodendron	Black Ash	May-Nov
Pruminopitys amara		
Prunus turnerana	Almond Bark	Sep-Jan
Psidium guajava		
Psychotria dallachiana		Apr-Sep
Ptychosperma elegans	Solitaire Palm	Apr-Nov, Jan
Raphidophora		
Rauwenhoffia leichardtii		
Rhodamnia sessiliflora	Iron Malletwood	Dec-Jun
Rhondomyrtus trineural	Malletwood	Any month
Rhysotoechia robertsonii	Robert's Tuckeroo	Nov-Jan
Rubus alceifolius	Giant Bramble	Feb-Aug
Rubus rosaefolius		
Rubus probus	Raspberry	Apr-Dec
Sarcotoechia protracta		Nov-May
Scavola taccada	Sea Lettuce Tree	Jan-Oct
Scolopia braunii	Brown Birch	Dec-Apr
Semecarpus australiensis	Tar Tree	Nov-Feb
Siphonodon membranaceus	Ivorywood	Any month
Smilax australis	Barbed-wire Vine	Any month
Solanum dallachii	Nightshade	Aug-Dec, Mar-May
Solanum mauritianum	Wild Tobacco	Any month
Solanum torvum	Devil's Fig	Any month
Strychnos minor	Snakewood	Apr-Nov
Syzygium alliligneum	Onionwood	May-Oct
Syzygium angophoroides	Swamp Satinash	Sep-Feb
Syzygium cormiflorum	Bumpy Satinash	Sep-Jun
Syzygium forte	White Apple	Nov-Apr
Syzygium johnsonii	Rose Satinash	Jul-Nov
Syzygium kuranda	Kuranda Satinash	Jun-Mar
Syzygium luehmannii	Cherry Satinash	Nov-Mar
Syzygium sayeri	Pink Satinash	Nov-Apr
Syzygium teirneyanum	Bamaga Satinash	Jan-May
Terminalia arenicola	Brown Damson	Any month
Terminalia catappa	Tropical Almond	Feb-Apr
Terminalia muelleri		
Terminalia sericocarpa	Damson	Nov-May
Tetrasynandra laxiflora	Tetra Beech	Sep-Dec

Appendix 1 - Cassowary food plant species

Trema orientalis	Rought Trema	Jan-Mar
Trichosanthes pentaphylla	Red Gourd	Feb-Jun
Toona australis		
Xanthophyllum octandrum	Macintyre's Boxwood	Any month
Ximenia americana	Yellow Plum	Oct-Jan, May
OTHER PLANTS		
Freycinetia sp		

Source: Bentrupperbäumer 1998, Campbell & Barnard 1917, Crome 1976, Crome & Moore 1988, MacGillivray 1917, Sharland 1970, Stephens 1981, Stocker & Irvine 1983, Westcott *et al.* 2005, White 1913.

Appendix 2 - ASMP population review

Demographic and Genetic Review of the Australasia Regional Southern Cassowary Studbook.

A follow-up to:

Wilken, J. (1997). Demographic and Genetic Review of the Captive Population. Pp. Appendix. in: Cassowary Husbandry Manual. L. Romer, ed. Currumbin Sanctuary.

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Introduction

Studbook data for the Australasia Region captive population *Casuarius casuarius johnsonii* was compiled by Liz Romer as part of the Australasian Species Management Program and is currently maintained by Clancy Hall, Currumbin Sanctuary. The population is managed by James Biggs, Cairns Tropical Zoo.

Studbook data was compiled and analysed using SPARKS 1.54 software (ISIS 2004). Further analyses were performed using PM2000 1.213 pedigree and demographic analysis program (Pollack, Lacy & Ballou 2005).

The ASMP managed population of *Casuarius casuarius johnsonii* consists of 48 birds (20 males, 24 females and 4 unsexed birds). The captive population is either descended from, or includes, 30 wild-caught birds. 16 of these animals have bred in captivity and have living descendants in the current population and have living descendants in the managed population.

1 DEMOGRAPHIC ANALYSES

1.1 Census

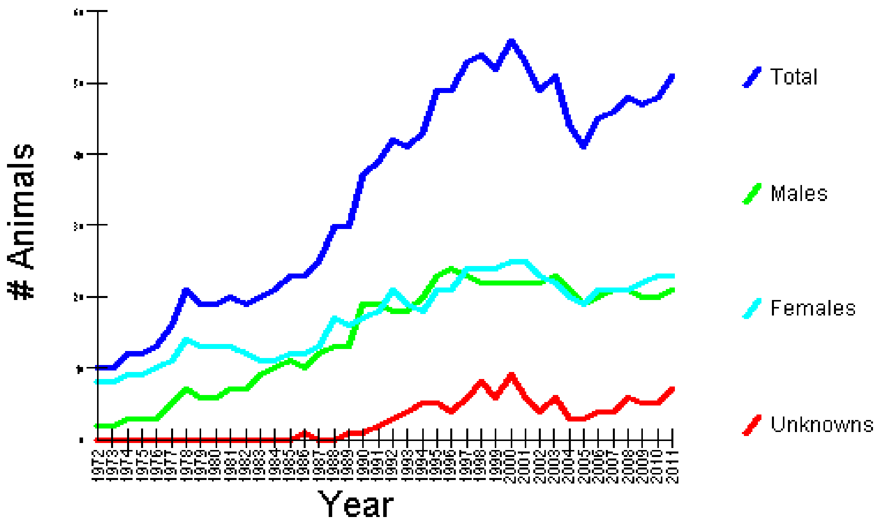

Figure 1 - Annual census of the Southern Cassowary in the Australasia Region

Appendix 2 - ASMP population review

An annual census of the Australasia Regional population (Figure 1) indicates a history of sustained growth from establishment until 2000 through recruitment of wild birds and prolific breeding of a small representation of the founder base. We see a decrease in the population post-2000, followed by an increase from 2005 to a total population of 48. Increases post-2005 are due to a small handful of successful hatches, recruitment of two wild-caught founders and non-recommended recruitment from outside of the program.

1.2 Age structure and sex ratio

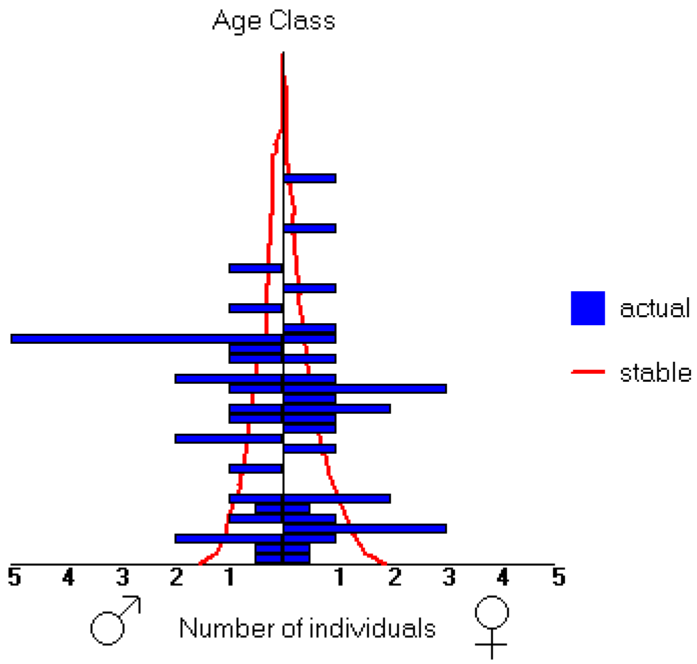

Figure 2 - Age pyramid for the living population of Southern Cassowary based on records from the ASMP studbook

The current living captive population (Figure 2) shows a slight skew in the sex ratio towards females, and a very broadly spread age distribution. The population is comprised of a small handful of juvenile birds, considerable numbers within reproductive age, and a small handful of older birds (assumed to be senescent at 27 years old until revision of Risk Mx interpretation in 2012). This indicates a relatively low level of recruitment of birds into the adult population, and that the reproductive potential of the entire captive population is slowly diminishing.

Appendix 2 - ASMP population review

1.3 Age-specific survivorship

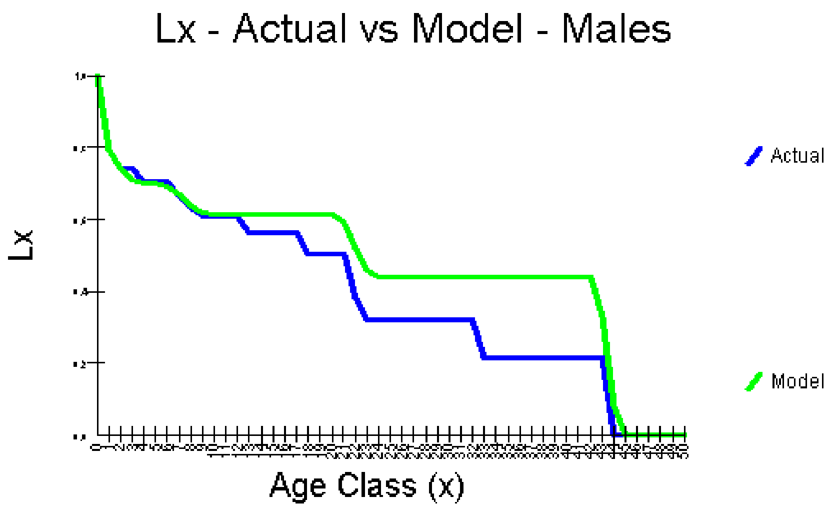

Figure 3 - Survivorship in the captive population of male Southern Cassowary based on records from the ASMP studbook

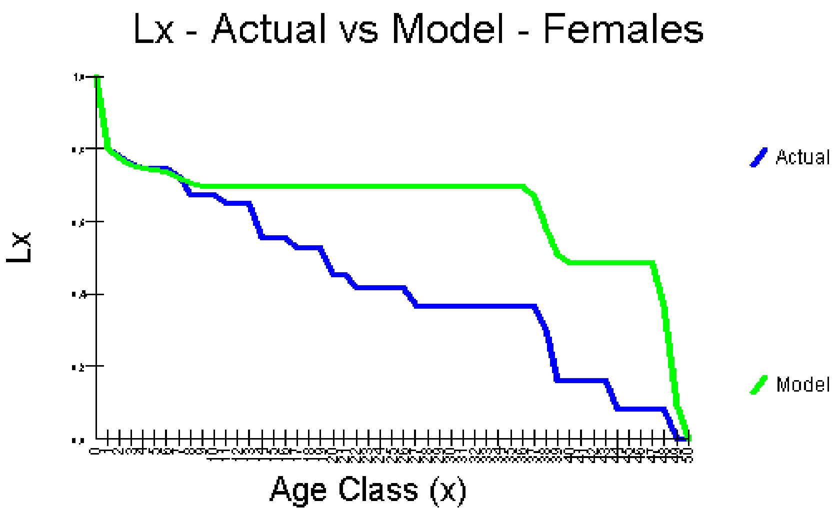

Figure 4 - Survivorship in the captive population of female Southern Cassowary based on records from the ASMP studbook

A number of factors limit the usefulness of a detailed age-specific survivorship analysis (Figure 3 & 4) in the current captive population; these are: i) the ASMP studbook itself is quite young (oldest record is of two birds believed to have hatched in 1948); ii) sample sizes for both sexes above the age of 20 are small (n = <20 for males and females); and nine of 16 original founders (F0) are still alive.

At this stage, the captive population appears to show an intermediary between Type II and Type III survivorship curves, whereby greatest mortality is experienced in the lowest age classes with relatively constant mortality to the highest age classes. The oldest animal recorded on the studbook was a female that survived to the age of 49. The fact that a number of the original F0 birds are still alive indicates that the species is long-lived. In recent years, hatchling and juvenile mortality has decreased.

Appendix 2 - ASMP population review

1.4 Age-specific fecundity

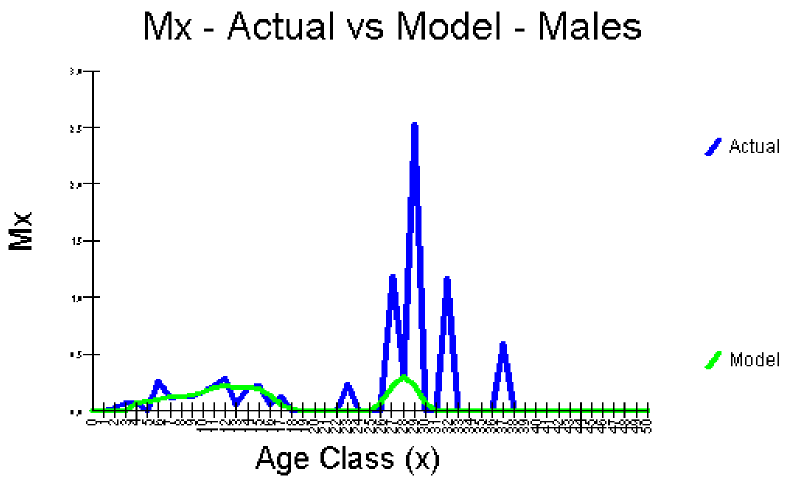

Figure 5 - Age-specific fecundity in the captive population of male Southern Cassowary based on records from the ASMP studbook

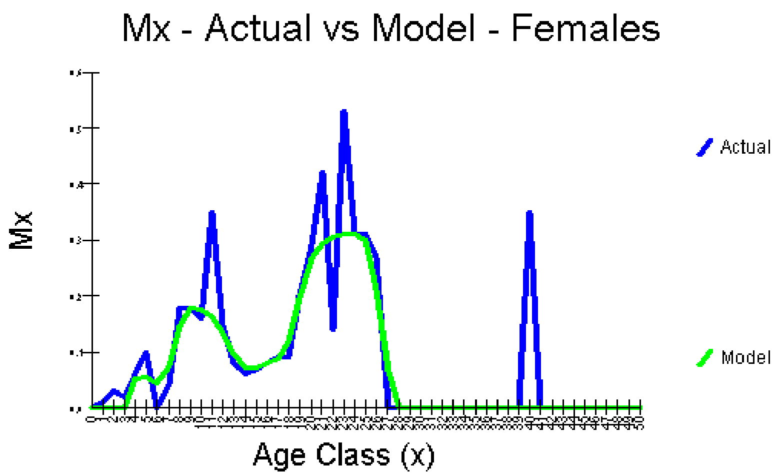

Figure 6 - Age-specific fecundity in the captive population of female Southern Cassowary based on records from the ASMP studbook

Sample sizes are small (n = <40) for all age classes above seven years in males and ten years in females. Of the 15 males that have bred only 11 are of known age, and from 15 females that have bred only 14 are of known age. Such small sample sizes means that it is impossible to identify any trends in age-specific fecundity, and data presented in Mx graphs must be treated with a great deal of caution. Analysis of model data through PM2000 appears to suggest that male fecundity peaks at 28 years; however this reflects data from just two males who survived to this age and bred. Likewise, model data of female fecundity suggests a peak at age 23 although this reflects records from only three females and it is impossible to interpret any general trends in species fecundity from such small data.

At this stage, what we can identify from the data is that males have been recorded breeding from age three to 37 (Figure 5), and females from age two to 40 (Figure 6). Given the meagreness of data, particularly for those over 20 years old (n = <20 for males and females), these data are not likely to represent the true reproductive limits of this species in captivity. Anecdotal evidence from wild birds indicates that Southern Cassowaries are capable of reproducing into their forties.

2 GENETIC ANALYSES

2.1 Inbreeding

Inbreeding is the mating between animals that are related by descent from a common ancestor, subsequent to a defined baseline generation (Lacy 1995). Finite populations lose genetic variation as a consequence of genetic drift and at the same time become inbred (Reed & Frankham 2003).

Opportunities for mating in small populations such as the current ASMP population of Southern Cassowary are restricted, so inappropriate inbreeding may be fostered if the population is not stringently managed. The main genetic consequence of inbreeding, is homozygosis (Charlesworth & Charlesworth 1987) and although rigorous experimental controls are usually lacking, it is clear that many captive populations are suffering increased infant mortality as a result of inbreeding (Lacy *et al*. 1993). Other problems include the loss of genetic diversity through founder effect and genetic drift, the physical expression of deleterious recessives, the interaction between demographic and genetic effects, and inadvertent selection for domestication (Ralls & Ballou 1986).

The inbreeding coefficient (F) is a measure of how inbred an individual is (or the loss of heterozygosity in an individual), and is applicable to birds that are descendants within a population only. It is related to the amount of genetic variation present, in the absence of mutation and selection (Reed & Frankham 2003) and identifies the probability that the individual has reduced genetic variability at any one locus, as a result of inheriting identical genetic material (alleles) from each of its parents (Wilken 1997 in: Romer).

Lacking data to indicate otherwise, it must be assumed for genetic analysis that the wild-caught animals used to initiate a captive population are all unrelated, and thus, the first-generation captive-born animals are, by necessity, considered to be noninbred (Lacy *et al*. 1993) and unrelated to each other (Lacy 1995), that is, they have an inbreeding coefficient of F = 0.000. Inbreeding coefficients were calculated for all descendants in the ASMP studbook through SPARKS pedigree analyses. The living population includes no known inbred birds (population mean F = 0.000), however the parentage of a handful of individuals in the descendant population (n = 8) is unknown. Historically the studbook has included only two explicit records of inbreeding: two offspring (SB 35 & SB 175) produced from a full-sibling (SB 17 & SB 14) mating (F = 0.25), both of which survived fewer than 12 months.

The lack of known inbreeding to date primarily reflects the few generations that the captive population represents; however as the number of generations in captivity increase, the potential for inbreeding will be greater (Wilken 1997 in: Romer).

Appendix 2 - ASMP population review

2.2 Gene diversity retained in the captive population

Genetic diversity (GD) is one of the three forms of biodiversity recognized by the World Conservation Union (IUCN) as deserving conservation based on two arguments: the necessity of genetic diversity for evolution to occur, and the expected relationship between heterozygosity and population fitness (Reed & Frankham 2003).

Generally, the goals of captive breeding programs are to assure the long-term sustainability of captive populations by preserving genetic diversity (Ralls & Ballou 1986), and to avoid the detrimental effects of inbreeding depression (Hedrick 1994). This strategy allows the population to maintain genetic flexibility, and hence enabling it to adapt to new environments, and preserves future management options (Ralls & Ballou 1986).

The current captive population is either descended from, or includes, 30 wild-caught birds. Sampling theory suggests that the proportion of gene diversity sampled from a wild population can be calculated as follows:

$$\mathrm{GD}_0 = 1 - \frac{1}{2N}$$

where N represents the number of wild caught founders.

A population whose history has included 30 founders is therefore predicted to represent a sample of approximately 98.3% of gene diversity expected in the wild. The amount of gene diversity retained in the descendants of these founders is estimated to be 91.79% of that expected in the wild population (as calculated using PM2000). Therefore there has been a loss of 6.09% of gene diversity in the descendants since the founding generation.

Lacy (1987) suggests that population managers should be concerned with the variation depleting effects of genetic drift and highlights that these can be countered by the introduction of very occasional immigrants, or less effectively, by division of the managed population into smaller breeding groups that interchange enough migrants to prevent unacceptably deleterious inbreeding within each subpopulation (Lacy 1987). Since 2002, the ASMP managed population has recruited four new wild-caught founders, however these are yet to contribute to the descendant population.

Appendix 2 - ASMP population review

2.3 Founder base and representation

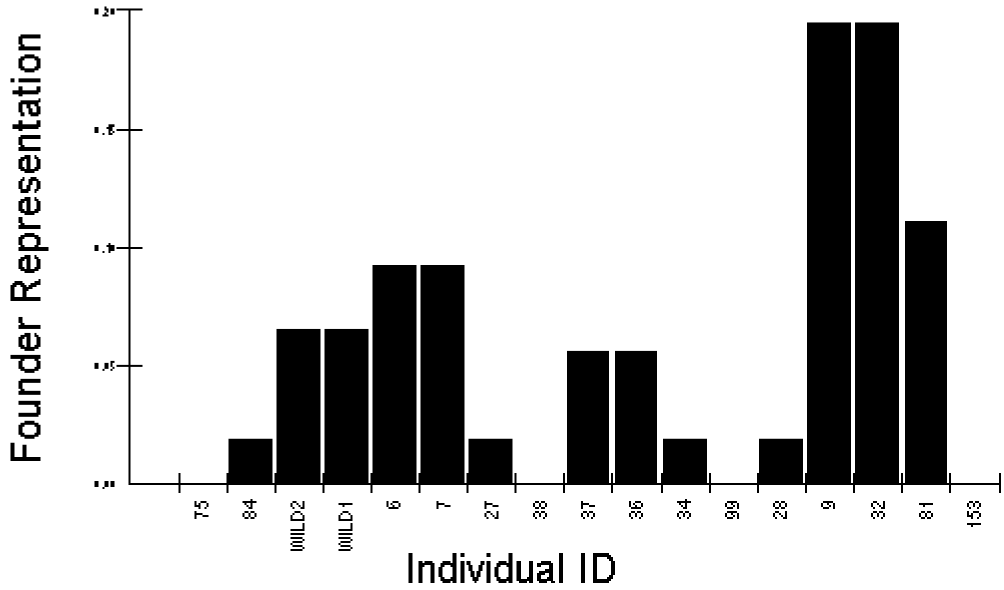

Figure 7 - Founder representation in the captive population of male Southern Cassowary based on records from the ASMP studbook

Scientists associated with the zoo community developed general recommendations for maintaining genetic diversity, such as maximizing effective population size and equalizing the genetic contributions of the founding individuals to the living population (Flesness 1977 and Foose 1983 in: Ralls & Ballou 1996). Unequal genetic contributions by founders decrease the founder equivalents, portend greater inbreeding in future generations than would be necessary, and reflect a greater loss of the genetic diversity initially present in the founders (Lacy 1989).

The descendant population of *Casuarius c. johnsonii* are the products of a strikingly skewed spread of founding birds. SB 9 and SB 32, as a result of prolific breeding, have contributed some 60% of the genetic constitution of the entire descendant ASMP managed population. It is predicted that this will result in a loss of alleles due to drift, an increase in the inbreeding level and strong selection for the captive environment (Ralls & Ballou 1986). Additionally, of the 30 wild-caught birds, seven died without contributing to the descendant population, and the remaining ten are yet to contribute, presenting possible further loss of unique alleles. One of the ten exists outside of the ASMP managed population and is not expected to contribute.

Unsurprisingly, prioritizing pairings that involve animals from under-represented founder lines can increase the frequency of rare founder alleles, and thereby increase gene diversity within the population (Wilken 1997 in: Romer).

Appendix 2 - ASMP population review

2.4 Mean Kinship

Mean Kinship (MK) is the average relatedness between an individual and all other individuals in the living descendent population (Wilken & Lees 1998) including itself, if it is not a founder (Lacy 1995). MK can be used to indicate the relative genetic importance of animals in the population (Ballou & Lacy 1995), and minimizing kinship has been predicted to maximize the retention of gene diversity in pedigreed populations with unequal founder representation (Montgomery *et al*. 1997). Simulations have shown that a program of breeding animals based on choosing those with lowest MK is a better strategy for maximizing long-term preservation of gene diversity and allelic diversity, and avoiding future inbreeding, than is minimizing immediate inbreeding, equalizing founder contributions, or breeding animals most likely to contain unique alleles (Ballou and Lacy, 1995).

Males						Females				
SB #	MK	% known	Age	Location		SB #	MK	% known	Age	Location
153	0.000	100.0	6	COOMERA		160	0.000	100.0	3	BILLABONG
99	0.000	100.0	18	FLEAYFAUN		75	0.000	100.0	0	CURRUMBIN
38	0.000	100.0	25	BEERWAH		88	0.020	100.0	17	ADELAIDE
84	0.010	100.0	0	COOMERA		40	0.040	100.0	23	BEERWAH
27	0.010	100.0	29	BILLABONG		33	0.050	100.0	27	CUDLEE PK
50	0.038	100.0	22	PERTH		31	0.050	100.0	0	CUDLEE PK
49	0.040	100.0	22	CURRUMBIN		18	0.050	100.0	33	MELBOURNE
42	0.040	100.0	22	BEERWAH		43	0.063	100.0	22	PERTH
103	0.063	100.0	15	ROCKHAMP		136	0.070	100.0	11	BEERWAH
45	0.063	100.0	22	MELBOURNE		152	0.113	100.0	6	GOSFORD
147	0.113	100.0	9	GOSFORD		151	0.113	100.0	6	SYDNEY
145	0.113	100.0	12	PERTH		124	0.115	100.0	14	ROCKHAMP
125	0.115	100.0	14	SYDNEY AQ		109	0.115	100.0	15	COOMERA
89	0.115	100.0	17	BEERWAH		100	0.115	100.0	16	LP KOALA
157	0.500	0.0	12	CUDLEE PK		92	0.115	100.0	17	FLEAYFAUN
156	0.500	0.0	U5	KALLANGUR		135	0.123	100.0	13	CUDLEE PK
						164	0.133	50.0	3	CUDLEE PK
						163	0.133	50.0	3	MELBOURNE
						91	0.145	100.0	17	PALMGROVE
						156	0.500	0.0	U5	KALLANGUR

Table 1 - MK of animals in the captive population of Southern Cassowary based on records from the ASMP studbook

MK values were calculated for the ASMP managed population using PM2000 software (Table 1). The current descendant population has an average MK of 0.064. Birds in Table 1 with lower than average MK values are those that are descended from under-represented founder lineages.

Breeding the animals with lowest MK will necessarily maximize GD in the next generation, as it ensures that the founder alleles with lowest frequency are preferentially propagated (Ballou & Lacy 1995). While this may sound straightforward, the major concern for the ASMP studbook is the lack of breeding success from any birds, which is mirrored by the studbooks of our European and North American counterparts.

Appendix 2 - ASMP population review

References

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Appendix 3 - Post mortem examination form

Species :	....	Date of death :	....
Studbook No. & sex :	....	Date of submission :	....
Verified by :		Institution :	

CIRCUMSTANCES OF DEATH:

	□ Euthanasia	□ Natural	□ Other
If euthanized, blood collected pre-euthanasia?		□ Yes	□ No

ABSTRACT OF PATIENT HISTORY & MEDICAL RECORDS:

CONDITION OF CARCASS:

	State of preservation :	□ Good	□ Fair
		□ Poor	□ Marked autolysis
	Storage since death :	□ Refrigerator	□ Frozen
		□ Ambient temp.	□ Fixed

GROSS EXTERNAL EXAMINATION:

Bodyweight :	....	Condition score (spine)	□ 5 □ 4 □ 3 □ 2 □ 1
Tibiotarsus length :	....	Tarsometatarsus length :	....
Wattle length :	....	Wattle width	....
Casque height :	....	Casque length :	....
Casque width :	....		

Including state of moult, ectoparasites, skin condition, lesions etc.

GROSS NECROPSY ON OPENING THE BODY: *including position and appearance of organs, lesions etc.*

ALIMENTARY SYSTEM

MUSCULOSKELETAL

CARDIOVASCULAR

RESPIRATORY

this section can be expanded if necessary

URINARY

Appendix 3 - Post mortem examination form

REPRODUCTIVE

LYMPHOID

NERVOUS

SAMPLES TAKEN:

....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)
....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)
....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)
....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)
....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)
....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)
....	Bact	Paras	Hist	DNA	Cytology	Other (e.g. Serology)

LABORATORY FINDINGS:

PRELIMINARY REPORT: *based on gross findings and immediate laboratory results, e.g. cytology*

FINAL REPORT: *based on all available information*

FATE OF CARCASS/TISSUES:

- □ Destroyed
- □ Frozen
- □ Sent elsewhere
- □ Fixed in formalin
- □ Preserved by other means
- □ Retained for reference

PM EXAMINATION PERFORMED BY:

Name : .... Date/time : ....

Reported by : .... Report date : ....

Program Outline: Southern Cassowary

General information

Taxon		*Casuarius casuarius johnsonii*
Common name		Southern Cassowary
IUCN status		*Endangered*
TAG		*Australian Non-passerine*
Captive management unit:		*subspecies*
Program Coordinator:		*Chris Hibbard*
Contact details:	*Email:*	chibbard@zoo.nsw.gov.au
	Fax:	*02.9978.4613*
	Phone:	*02.9978.4610*
Last updated:		*October 2001*

Aims of captive management

The captive program aims to ensure the persistence of a captive population in ARAZPA institutions that:

- Can support the development and documentation of husbandry techniques for the species
- Supports the illustration of biodiversity

Rationale

The species is considered to be a 'flagship' species for the interpretation of Queensland's tropical rainforest habitat. The founder base for the captive population is small and the ability to freely acquire wild origin founders is limited. As the species is large, solitary, long lived and demands reasonable space to accommodate appropriate management of the captive population is required to ensure all available spaces are appropriately used in support of the genetic and demographic health of the population.

Rationale for Captive Management Unit

The population has historically been split between northern and southern provenance and then again within the southern provenance between highland and lowland populations. In discussion with personnel at Queensland National Parks and Wildlife, it is considered unlikely that specimens bred in captivity from the current stocks would ever be considered for release purposes. As the primary threat process is considered loss of habitat, the breeding of Cassowary in captivity for release purposes is unlikely to be an appropriate conservation measure unless the population goes into catastrophic decline. It is most likely that if captive breeding for release were to be considered that a specific group of wild origin founders would be recruited for this purpose.

The primary role of this program is one of public education, conservation awareness and development of husbandry techniques. On this basis there seems little point in dividing the population beyond subspecies level.

Program goals

Population management:	retain 90% GD over50 years. Stared genetic targets applied due to limited abilityto freely acquire wild origin founders, plus the difficulty of transporting this species across Australia
Husbandry:	Achieve reliable breeding, reduce juvenile mortality rates. Review and update Husbandry Manual every two years.

Program type

Current: No Regional Program
Proposed: Population Management Program

Population management level

Current: 3
Proposed: 1a

Target population size

Target numbers to be determined
Immigration required to be determined

Work plan

To be developed	Responsibility		Due date	Date completed
	Name	Institution		
Regional studbook	Chris Hibbard	Taronga Zoo	Completed	Updated as at 30/03/2002
Management unit diagnosis	Paul Andrew	Taronga Zoo	Dec 2001	Dec 2001
Population management plan	Chris Hibbard	Taronga Zoo	Dec 2001	
Husbandry Manual - (review of completed document)	Chris Hibbard	Taronga Zoo	Nov 2002	
Annual Report and Recommendations	Chris Hibbard	Taronga Zoo	April (annually)	15th April 2002

Endorsements

Plan to be endorsed by the following organisation:	**Endorsement received (date)**
Australian Non-passerine TAG	2002
ASMP Committee	2002
ASMP Participating institutions:	
Adelaide Zoo	2002
Australia Zoo	2002
Dreamworld	2002
Crocodylus Park	2002
Currumbin Sanctuary	2002
Australian Reptile Park	2002
Lone Pine Koala Sanctuary	2002
Melbourne Zoo	2002
Perth Zoo	2002
Rockhampton Botanic Gardens Zoo	2002
Gorge Wildlife Park	2002
Taronga Zoo	2002

Appendix 5 - Routine data collection form

Taxon name: *Casuarius casuarius johnsonii*
Common name: SOUTHERN CASSOWARY

Age :

Date :

Enclosure :

Sex :

Rearing type :

House name :

Birth type :

Regional studbook # :

Birth location :

Sire studbook # :

Birth date :

Dam studbook # :

Acquired :

Source :

Region : □ AZA □ EAZA □ ZAA □ Other

Month : J F M A M J J A S O N D

Sex : M F U **Weight :** **BCS :** 1 2 3 4 5

Temperament towards conspecifics : mostly aggressive mostly indifferent mostly passive

Temperament towards humans : mostly aggressive mostly indifferent mostly passive

Time budget Travelling % Foraging % Resting % Preening %

(daylight hours) : Misc. % **Food consumption :** Hi Mid Lo

Preferred food ______________________________

items : ______________________________

Samples : □ Blood □ Faecal □ Other

Data collector : ______________________________

Appendix 6 - Egg necropsy form

Fig. X - Flow chart for examination of Cassowary egg post-mortem

Repeated candling: confident embryo is terminated; or

Incubation period complete: no hatch

Egg/s submitted for examination

Check history and age of egg/s

Note external shell characteristics, weigh, measure

Clean shell with ethanol

Open egg - photograph & examine in-situ

Infertile

Place in petri dish - photograph & examine, samples taken as necessary

Fertile
(If a well developed embryo is present, take note of the position of the appendages and head in relation to the general position of the chick)

Place in petri dish - photograph & examine (measure crown to rump length), samples taken for histology, bacteriology, etc

If size permits, a full post mortem examination performed on chick

Contents fixed/frozen as necessary

Submit laboratory samples and include results in Egg Necropsy Form

Appendix 6 - Egg necropsy form

Region :	AZA EAZA ZAA	Year :	....
Species :	....	Egg accession # :	....
Incubation type :	Parent Artif Both	Treatment :	Cold Amb Nil
Lay date :	....	Date pulled for artificial inc.:	....
Set date :	....	Expected hatch date :	....
Clutch information : Egg #	....	Of : Total egg #	....
Sire SBK # :	....	Sire Age :	....
Dam SBK # :	....	Dam Age:	....

Previous reproductive failure of Sire : □ Yes □ No If yes, year : ....
Previous reproductive failure of Dam : □ Yes □ No If yes, year : ....

ADDITIONAL HISTORY: candling notes, developmental progress, status of clutch mates, etc.

GROSS EXTERNAL EXAMINATION:

Egg weight : ....
Measure long axis : *cm* ....
Measure short axis : *cm* ....

CONDITION OF CARCASS:

State of preservation : □ Good □ Fair □ Poor □ Marked autolysis
Storage since death : □ Refrigerator □ Frozen □ Ambient temp. □ Fixed

---

MACROSCOPIC EVALUATION OF CONTENTS ON OPENING THE EGG - IN-SITU: *including position and appearance of embryo/appendages, egg shell quality, integrity of membranes, presence of edema, haemorrhages, deformities, degree of yolk sac retraction etc. If relevant.*

□ Photograph attached

MACROSCOPIC EVALUATION OF CONTENTS ON OPENING THE EGG - EX-SITU (PETRI DISH): *other findings*

□ Photograph attached

SAMPLES TAKEN:

.... Bact Paras Hist DNA Cytology Other (e.g. Serology)
.... Bact Paras Hist DNA Cytology Other (e.g. Serology)

LABORATORY FINDINGS:

PRELIMINARY REPORT: *based on gross findings and immediate laboratory results, e.g. cytology*

FINAL REPORT: *based on all available information*

FATE OF CARCASS/TISSUES:

□ Destroyed □ Fixed in formalin
□ Frozen □ Preserved by other means
□ Sent elsewhere □ Retained for reference

PM EXAMINATION PERFORMED BY:

Name : .... Date/time : ....
Reported by : .... Report date : ....

Appendix 7 - Artificial incubation form

Region :	AZA EAZA ZAA	Year :	....
Species :	....	Egg accession # :	....
		Treatment :	Cold Amb Nil
Lay date :	....	Date pulled for artificial inc.:	....
Set date :	....	Expected hatch date :	....
Clutch information : Egg #	....	Of : Clutch #	....
Incubator : Number/model	....	Incubator temperature :	....
Incubator humidity :	....	Turning frequency :	....
% wt loss during incub'n :	....		
Sire SBK # :	....	Sire Age :	....
Dam SBK # :	....	Dam Age:	....

DAY	DATE	WT	COMMENTS
1	d/m	g	
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			this section
15			can be expanded
16			if necessary
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			

DAY	DATE	WT	COMMENTS
33	d/m	g	
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			this section
47			can be expanded
48			if necessary
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			
61			
62			
63			
64			
65			

Disposition of egg : (circle) Unknown Infertile Fertile **Process required**

Early term death	>	Egg necropsy
Mid term death	>	Egg necropsy
Late term death	>	Egg necropsy + P.M.
Hatched	>	Date:

If death is encountered, please attach this form to egg necropsy form

Appendix 8 - ISIS anaesthetic record form

SPECIES:

SEX: DOB / AGE: ARKS NO:

ID: OTHER:

Date of anaesthesia: _ _/_ _/_ _

Health status: 1. Normal. 2. Abnormal.

Preanaesthetic fasting time: 1. < 8 hours. 2. 8 - 24 hours. 3. 24 - 48 hours. 4. > 48 hours.

Activity: 1. Calm. 2. Active. 3. Excited.

Demeanor: 1. Depressed. 2. Alert. 3. Aggressive. 4. Apprehensive.

Environmental temperature: _ _ _ _ ^{o}C.

Physical status:
1. Class I normal health.
2. Class II mild disease.
3. Class III more severe disease.
4. Class IV chronic severe disease.
5. Class V unlikely to survive anaesthetic.

Immobilizing conditions:
1. Free ranging.
2. Large exhibit, cage or pen.
3. Small exhibit, cage or pen.
4. Squeeze cage.
5. Manual restraint.

Body condition: 1. Obese or fat. 2. Good. 3. Fair or thin. 4. Poor or emaciated.

1. Isolated animal.
2. In a group.

Dose	Drug	Amount	Route	Time given	Success	Effect	Time of effect	Bottle #

Anaesthetic dose:
Pre-immobilizing tranquilisation.
Immobilising dose.
Supplemental dose.
Maintenance dose.
Antagonist dose.
Other drugs.

Drug delivery route:
Blow dart
Metal dart
Non-metal Dart
Hand syringe
Face mask
Oral
Pole syringe
Endotracheal tube

V = Intravenous
M = Intramuscular
P = Intraperitoneal
SQ = Subcutaneous

Effect produced:
0 = None.
1 = Mild sedation.
2 = Heavy sedation.
3 = Light anaesthesia.
4 = Surgical anaesthesia.
5 = Excessively deep anaesthesia.
6 = Death.

Success of delivery: **C**omplete **P**artial

Endotracheal size: _ _ _ mm

Time of initial effect: _ _ _ _ _

Time of sternal / lateral recumbency: _ _ _ _ _

Weight: _ _ _ _ _ kg g Actual weight. Estimated weight.

Anaesthetic complications: 1. None. 2. Minor. 3. Major. 4. Fatal.

Anaesthetic recovery: 1. Normal. 2. Abnormal. 3. Prolonged. 4. Violent. 5. Renarcotised.

Rating Anaesthetic Induction 1. Excellent 2. Good 3. Fair. 4. Poor.

Degree of muscle relaxation: 1. Excellent. 2. Good. 3. Fair. 4. Poor.

Overall anaesthetic rating: 1. Excellent. 2. Good. 3. Fair. 4. Poor.

Recovery Data **Time:** _ _ _ _ **Effect:** _ _ _ _ **Time:** _ _ _ _ **Effect:** _ _ _ _

Veterinarian: **Recorded by:**

Appendix 8 - ISIS anaesthetic record form

Physiological data

Time	Body temp	HR / min	RR / min	0_2 saturation	BP systolic	BP diastolic	BP mean

Blood sample data **Time collected**: _ _ _ _

Haematology anticoagulant::

EDTA.
EDTA - Liquid.
EDTA - Dry
Heparin.
Heparin - Liquid.
Heparin - Dry.
Oxalate.
Citrate.
Other: _ _ _ _ _ _ _ _

Chemistry sample:

Serum.
Plasma.
Whole blood.

Collection site:

Brachial vein.
Cardiac.
Cephalic vein.
Ear vein.
Femoral artery.
Femoral vein.
Jugular vein.
Metatarsal vein.
Saphenous vein.
Tail vein.
Ulnar vein.
Other _ _ _ _ _ _ _ _

Collected by:

Anaesthetic comments

Clinical examination.
Preshipment examination.
New arrival examination.
Radiographs.
Surgery.
Biopsy.
Serum bank.
Urine.

Clinical notes

Appendix 9 - Cassowary transport container

Source: DERM

Appendix 9 - Cassowary transport container

Source: DERM

Appendix 10 - Body condition evaluation and scoring

This body condition evaluation and scoring is a numerical guideline that expresses the amount of fat a cassowary is carrying.

Cassowaries, as in all animals, have nutrient requirements that significantly contribute to factors such as body maintenance, moult, egg production and growth. Energy fed in excess of maintenance activities is stored as body fat, which is then utilized throughout the low-activity and low appetite period (breeding season).

Dry plumage, particularly over the back and hips, can be problematic when trying to visually determine the body condition of a cassowary, generally giving the impression that fat stores are greater than they actually are. Subsequently, this score was developed based on birds with wet plumage, giving a clearer picture of the birds' actual body condition as opposed to the fullness of plumage, without having to palpate the bird.

The condition of a cassowary naturally and significantly fluctuates on a seasonal basis. Identifying the expected condition for a particular individual at a given time of year provides keepers and veterinarians with a useful reference point for assessing health concerns in subsequent examinations. It is also an easy way for anyone to evaluate an animal if scales are not an option.

The body condition and weight of a cassowary are directly correlated with food consumption, and hence are predicted to fluctuate seasonally according to appetite (See Ch Nutrition and Feeding, Figure 1). Season, sex, health (including illness, injury, activity level, fitness, stage of moult, body maintenance), and reproductive/parental duties (factors such as egg laying, incubation, presence of dependant chicks) also influence body condition, and consequently the score for each bird is a subjective determination to be evaluated in the context of all factors mentioned here. Score will vary between individuals.

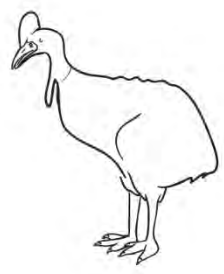
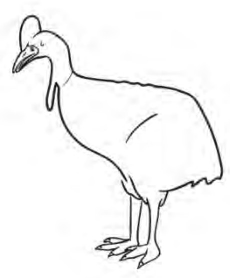
Both male and female adult cassowaries naturally lose condition during the breeding season, and therefore it is important that a BCS of 3.5-4.5 is reached prior to the breeding season. During lean fruiting seasons in the wild, cassowaries have been observed with fewer chicks, so too low a score is likely to negatively affect investment in reproduction and the ability to reproduce. In commercially farmed ratite species, too high a score is also reported to negatively affect the ability to reproduce.

Body condition of birds younger than two years does not appear to fluctuate as broadly as that observed in birds over the age of two years.

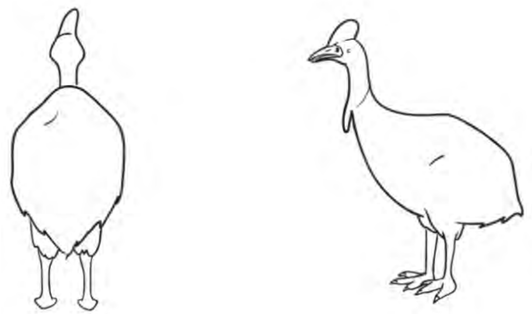
Using the following pictures and descriptions, keepers and veterinarians are advised to systematically evaluate the body condition of each bird at an institution such that a natural pattern of fluctuation can be recorded for later use. Recording a total body weight with each score will also assist when conducting health examinations. If an increase in weight does not correspond with an increase in overall score, consider behavioural observations to determine whether or not there is a health problem.

Appendix 10 - Body condition evaluation and scoring

The ventral and lateral profile examples are examples only, and the prominence of hips and vertebrae may be exaggerated or understated in different individuals. As a general rule, the hips of a female may be slightly more prominent during the breeding season than what is listed here, but again, this will vary.

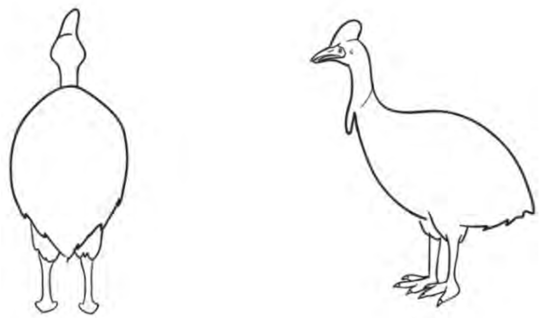
Ventral profile	Lateral profile	*Condition score & season*	Description
		1 - Emaciated	
		Generally not observed in captive birds, but may be encountered if condition before breeding season was less than ‘fair’.	Backbone prominent (raised and sharp) - Pronounced depression of epaxial musculature and fat stores surrounding thoracic vertebrae and synsacrum. Skeletal body outline - Vertebral shape unmistakable through plumage. Hips prominent (pointed) - Marked depression of iliotibialis, gastrocnemius and fibularis musculature/ Femur and tibiotarsus obvious through plumage.
		2 - Thin	
		Occasionally observed in last month of breeding/incubation season	Backbone visible - Depression of epaxial musculature and fat stores surrounding thoracic vertebrae synsacrum. Body outline bony - Vertebral shape obvious through plumage. Hips visible - Depression of iliotibialis, gastrocnemius and fibularis musculature/femur and tibiotarsus visible through plumage.

Appendix 10 - Body condition evaluation and scoring



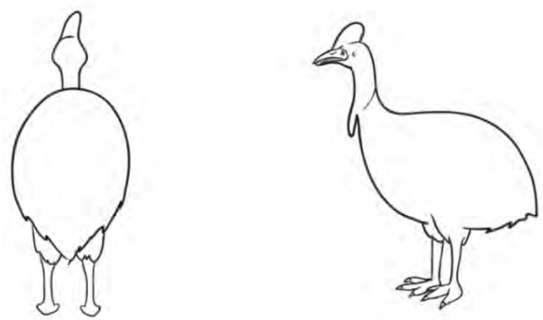
3 - Fair

Regularly observed in last 2-3 months of breeding/incubation season and for 1-2 months post-season. May appear 'fair' during moult	Backbone faintly visible - Minor depression of epaxial musculature and fat stores surrounding thoracic vertebrae. Body outline almost smooth - Vertebral shape visible but not obvious through plumage. Hips faintly visible - Iliotibialis, gastrocnemius and fibularis musculature discernable/femur and tibiotarsus visible but not obvious through plumage.



4 - Optimal

Generally observed at onset of breeding/incubation season	Backbone not visible - Laterally flat appearance of epaxial musculature and fat stores surrounding thoracic vertebrae. Body outline smooth - Vertebral shape not visible through plumage. Hips not visible - Iliotibialis, gastrocnemius and fibularis musculature pronounced/femur and tibiotarsus not visible through plumage.



5 - Good

Occasionally observed pre-breeding/incubation season	Backbone not visible - Pronounced expression of epaxial musculature and fat stores surrounding thoracic vertebrae. Body outline rounded. Hips not visible - Iliotibialis, gastrocnemius and fibularis musculature markedly pronounced.

Source: Illustrations by Lachlan Phillips.

Appendix 11 - Vocal repertoire

Appendix A.2.4: Brief Description of the Cassowary's Vocal Repertoire.

I recorded a total of 723 vocalisation bouts[1] during this study. In the normal course of the day when no direct interactions with conspecifics were observed, solitary adult cassowaries vocalised rarely (0.24 calls per hour of observation, n = 211 hours). In contrast during two periods of direct interactions between an adult and subadult, vocalisation frequency reached 16.4 vocal bouts per hour, with intervals between vocalisations ranging from 1 to 50 mins (mean ± SD = 7.1 ± 11.7 mins). Although I did not tape record vocalisations, detailed written notes of vocal behaviour including descriptions of the call, the birds' posture and the circumstances of the vocal bout formed the basis of my description of the cassowary's vocal repertoire. From this information I was able to identify eight discernible sounds which fitted into four categories according to the main format of the vocalisation. I describe the physical aspects, structure, context, and possible function of these vocalisations.

Boom This is perhaps the most unusual but impressive of cassowary vocalisations particularly because of the time taken and physical effort involved in its production. To produce this vocalisation, the adult cassowary lowers and at the same time stretches its head and neck forward while in a standing position. With its beak slightly open it slowly inhales, gradually inflating its neck and in turn air sacs to full capacity. During this inhaling period, which lasts for at least 5 to 10 seconds, no sound is heard. Toward the end of inhalation it slowly withdraws its head and neck toward its body. At this point it suddenly exhales the air audibly through its fully open mouth. The amount of air inhaled is obviously determined by body size, which in turn determines intensity and types of sound emitted. Subadults lack the body size required to produce the depth and intensity of the call produced by adults.

I identified three different boom calls. The first was a very long and deep continuous *rumble* boom which was normally emitted only once or twice in a vocal bout. All air inhaled was assumed to have been exhaled in order to make the call. *Rumble* booms were rarely heard (n = 12) and appeared to be associated with breeding activity. In this context it is suggested to function as a long-distance contact or advertisement call, communicating availability, location and perhaps even identity. For example, all but two of these calls were made by females and provoked an immediate response from the male. He would either immediately walk toward the call or present a full stretch display and then walk toward the call.

The second was a *long* boom, a slightly shorter and less intense version of the *rumble* boom. It was the most frequently used call, accounting for 49.4% of all vocalisations heard. In one vocal bout of the *long* boom, 4.3 calls per bout (± 1.5 SD, n = 360) were produced. This was the average number of *long* booms that were emitted from one inhalation. The *long* boom bouts lasted between 5 and 15 seconds). Although this call was used in at least three different contexts, in general, it appeared to function as a notification of presence and warning of aggressive intent. As such it could be considered as a territorial marker. In an environment where visibility is rarely greater than 30m this was valuable information. *Long* booms appeared to be most often used when another bird was perceived to be in the area [2]. The *long* boom was also used in situations of conflict particularly agonistic encounters between females during which vocalisation was a very important aspect of the display (see Section 6.3.2.3). In this context it may have been

[1] A vocal bout is defined as the period during which one particular vocalisation event takes place.
[2] On a number of occasions a bird would vocalise in this way in response to my presence.

Source: Bentrupperbäumer, Joan (1997) *Reciprocal ecosystem impact and behavioural interactions between cassowaries, Casuarius casuarius, and humans, homo sapiens: exploring the natural-human environment interface and its implications for endangered species recovery in north Queensland, Australia.* PhD thesis, James Cook University.

Appendix 11 - Vocal repertoire

Appendix A.2.4 (Cont.....)

used to communicate size and strength and thereby the intent to avoid aggressive contact. And finally, *long* booms were used to communicate an impending approach, that is, to notify of an intent to approach another bird, particularly during breeding. In this context it would also function as a means of avoiding conflict, as well as assisting in individual recognition.

In the third boom call, the *short* boom, successive short calls were emitted, average 4.1 calls per vocal bout (± 1.7 SD, n = 83). While this is the same frequency as the long boom, a *short* boom bout was considerably shorter (3 to 5 seconds). This type of vocalisation was used less frequently than the *long* boom, accounting for 11.5% of all vocalisations. Again it appeared to be emitted when sensing the presence of myself or another bird, which may be communicating mild distress together with threatening lightly.

Grunt The cassowary's grunt accounted for 18.5% of all vocalisations heard. It was a low-pitched clear sound reminiscent of that of a pig. Grunts did not require the physical effort involved in producing the boom vocalisations. Instead it could be emitted instantaneously by forcing air from the chest into the throat and against a closed mouth. The grunt vocalisation pattern consisted of two discernible calls, a *discrete* and *continuous* grunt. The *discrete* grunt consisted of a succession of short but distinct sounds each lasting between 0.5 and 1 sec. On average 6.02 grunts per grunting session (± 3.9 SD, n = 98) were emitted. On average O recorded 1.6 grunting sessions per vocal bout (± 1.2 SD, range 1 - 7, n = 53).

In *continuous* grunts, the succession of short distinct sounds were emitted much more rapidly (<0.5 secs) than in the *discrete* grunt. In addition the number of sounds emitted in one grunting session was higher, average 8.1 (± 3.6 SD, n = 263), as was the number of grunting sessions per vocal bout, average 3.4 (± 5.5 SD, range 1-35, n = 81). A grunting bout could last up to 10 mins. The contexts and functions of the *discrete* and *continuous* grunt were similar and a bird would often switch from one to the other in the same vocal bout. The grunt was the most common vocalisation heard when males, particularly with chicks, encountered other conspecifics, other animals and sometimes myself. It was clearly communicating anxiety and distress about the intrusion and notifying the intruder of aggressive intent. This intent was often carried through to action with the male charging at or chasing the intruder, in particular, subadults but also other males, other animals such as feral pigs and monitor lizards and even myself. Both sexes and all age classes except chicks used the grunt vocalisation.

Rumble The *rumble* was another low-pitched vocalisation that was produced by vibrating the throat. It was a continuous sound that was not as deep and intense as the *rumble* boom as it did not use the considerable volume of air required to produce the rumble boom. Therefore, it was a vocalisation that could be produced by subadults as well as adults. The *rumble* was rarely heard (n = 14), and since it was most often directed at me, particularly during the early stages of habituation, it may have been signifying apprehension, threatening lightly, yet conveying a lack of aggressive intent.

Wheeze / Moan The *wheeze/moan* was a vocalisation that was emitted by a male when he was accompanied by chicks. It was normally a fairly soft, medium- to low-pitched sound that the male would use frequently while foraging. This call, together with the sound of a clicking beak, would attract the chicks to a food item the male had either prepared for them or identified its location[3]. Since it was a vocalisation that was only ever heard in this context it was obviously a specific male-chick communication signal that

[3] Details of this foraging interaction between male and chicks are presented in Chapter 8.

Source: Bentrupperbäumer, Joan (1997) *Reciprocal ecosystem impact and behavioural interactions between cassowaries, Casuarius casuarius, and humans, homo sapiens: exploring the natural-human environment interface and its implications for endangered species recovery in north Queensland, Australia.* PhD thesis, James Cook University.

Appendix 11 - Vocal repertoire

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Appendix A.2.3 (Cont.....)

appeared to not only function as an expression of an internal state but also to signal feeding.

Whistle Chicks vocalised by producing a whistle-like call which varied from being either short- or long-drawn, low- or high-pitched. This has enabled the whistle to be categorised as either a normal or distress call. The chick emitted a *normal whistle* intermittently throughout the day which may have functioned as a security check and/or foraging call between chick and parent. Often the male would respond to this whistle with a wheeze. However, when apparently distressed in some way chicks would emit a long and high-pitched whistle - the greater the distress, the louder and higher the pitch. This *distress* whistle was associated with four situations. Firstly, in the first few days after hatching this *distress* whistle increased in intensity until the male left the nest. In this context it may have been communicating hunger. Secondly, whenever the chicks lost sight of the male they would also vocalise in this way. The male would respond immediately by running toward the call. Thirdly, one of Dillenia's chicks, Boronia, used this call frequently during the last month of its life even though it was constantly at Dillenia's side. In this context the call may have been conveying ill health. And fourthly, the chick Alata used this *distress* whistle when, on reaching independence age it was abandoned by the male. This was the time of loudest and highest pitched distress whistle. Obviously the chick was desperately trying to attract the attention of the male.

Source: Bentrupperbäumer, Joan (1997) *Reciprocal ecosystem impact and behavioural interactions between cassowaries, Casuarius casuarius, and humans, homo sapiens: exploring the natural-human environment interface and its implications for endangered species recovery in north Queensland, Australia.* PhD thesis, James Cook University.

Appendix 12 - Suggested adult diet

All fruit to be washed to remove any pesticide residue
When cutting fruit, vary the size from 1/8 of an apple to a billiard ball
All stickers to be removed from fruit
Cut enough fruit to fill two 10L buckets, ad-lib according to appetite (usual increase from end of spring to summer)
See specific days for additional supplements
Apart from Lysine, Watermelon as it holds very little nutritional value, do not add excess to diet
Collect native fruits from around the park whenever possible, wash, and add to diet (Australia only)
There is no need to peel any of the fruits apart from watermelon
Take note of when native trees are fruiting in the enclosure (Quandong, Cassowary plum, Fig, Native olive, Lilypily, Bandicoot Berry) (Australia only)

Daily:
Rockmelon
Honeydew
Pawpaw
Apple
Pear
Banana
Kiwifruit
Grapes
Watermelon, peeled

When available:
Mango
Plum
Peach
Nectarine
Strawberry
Cluster Figs
Native Olives
Quandong
Davidson's Plum
Cassowary Plum
Foxtail Palm Fruit
Alexandra Palm Fruit
Peas
Lemon Aspen
Lightly boiled Sweet Potato
Lightly boiled Carrot

Day	SUMMER	AUTUMN	WINTER	SPRING
SUN	sol + iv + 1 bs	sol + iv + 1 bs	sol + iv + 1 bs	sol + iv + 1 bs
MON	ivore + 1 mouse	ivore + 1 mouse	ivore + 2 mice	ivore + 2 mice
TUE	calc + 1 doc	calc + 1 doc	calc + 2 doc	calc + 2 doc
WED	sol + iv + 1 bs	sol + iv + 1 bs	sol + iv + 1 bs	sol + iv + 1 bs
THU	ivore + 1 mouse	ivore + 1 mouse	ivore + 2 mice	ivore + 2 mice
FRI	alf + prob	alf + prob	alf + prob	alf + prob
SAT	1 doc	1 doc	calc + 2 doc	calc + 2 doc

Sol = Soluvet
Iv = Insectivore
Calc = Calcivet (on fruit)+ Balanced Calcium (on DOC)
Prob = Probotic
Alf = finely chopped alfalfa
BS = beef strip/per bird
DOC = Day old chick/per bird

Appendix 13 - Suggested juvenile diet

All fruit to be washed to remove any pesticide residue
All stickers to be removed from fruit
Cut enough fruit to satiate appetite, (usual increase from end of spring to summer)
See specific days for additional supplements
Apart from Lysine, Watermelon as it holds very little nutritional value, do not add excess to diet
Collect native fruits from around the park whenever possible, wash, and add to diet (Australia only)
Take note of when native trees are fruiting in the enclosure (Quandong, Cassowary plum, Fig, Native olive, Lilypily, Bandicoot Berry) (Australia only)

Daily:
Rockmelon
Honeydew
Pawpaw
Apple
Pear
Banana
Kiwifruit
Grapes
Watermelon, peeled

When available:
Mango
Plum
Peach
Nectarine
Strawberry
Cluster Figs
Native Olives
Quandong
Davidson's Plum
Cassowary Plum
Foxtail Palm Fruit
Alexandra Palm Fruit
Peas
Lemon Aspen
Lightly boiled Sweet Potato
Lightly boiled Carrot

For birds up to 4 months:

- Peel all fruit except bananas, apples and berries
- Leave all seeds in fruit (except apple)
- Cut up to 2 cm cubed
- Include mealworms, crickets, earthworms
- See protein variation below

Day	SUMMER	AUTUMN	WINTER	SPRING
SUN	sol + iv + bs	sol + iv + bs	sol + iv + bs	sol + iv + bs
MON	ivore + ¼ mouse	ivore + ¼ mouse	ivore + ½ mouse	ivore + ½ mouse
TUE	calc + ¼ doc	calc + ¼ doc	calc + ½ doc	calc + ½ doc
WED	sol + iv + bs	sol + iv + bs	sol + iv + bs	sol + iv + bs
THU	ivore + ¼ mouse	ivore + ¼ mouse	ivore + ½ mouse	ivore + ½ mouse
FRI	alf + prob	alf + prob	alf + prob	alf + prob
SAT	calc + ¼ doc	calc + ¼ doc	calc + ½ doc	calc + ½ doc

Appendix 13 - Suggested juvenile diet

For birds up to 6 months:

- Leave some skin on melons
- Leave all seeds in fruit (except apple)
- Cut between 2-3cm cubed
- Include mealworms, crickets, earthworms
- See protein variation below

Day	SUMMER	AUTUMN	WINTER	SPRING
SUN	sol + iv + bs	sol + iv + bs	sol + iv + bs	sol + iv + bs
MON	ivore + ½ mouse	ivore + ½ mouse	ivore + 1 mouse	ivore + 1 mouse
TUE	calc + ½ doc	calc + ½ doc	calc + 1 doc	calc + 1 doc
WED	sol + iv + bs	sol + iv + bs	sol + iv + bs	sol + iv + bs
THU	ivore + ½ mouse	ivore + ½ mouse	ivore + 1 mouse	ivore + 1 mouse
FRI	alf + prob	alf + prob	alf + prob	alf + prob
SAT	calc + ½ doc	calc + ½ doc	calc + 1 doc	calc + 1 doc

For birds over 6 months:

- Leave some skin on melons
- Leave all seeds in fruit (except apple)
- Cut between 2-3cm cubed
- Include mealworms, crickets, earthworms
- See protein variation below

Day	SUMMER	AUTUMN	WINTER	SPRING
SUN	sol + iv + bs	sol + iv + bs	sol + iv + bs	sol + iv + bs
MON	ivore + 1 mouse	ivore + 1 mouse	ivore + 2 mice	ivore + 2 mice
TUE	calc + 1 doc	calc + 1 doc	calc + 1 doc	calc + 1 doc
WED	sol + iv + bs	sol + iv + bs	sol + iv + bs	sol + iv + bs
THU	ivore + 1 mouse	ivore + 1 mouse	ivore + 2 mice	ivore + 2 mice
FRI	alf + prob	alf + prob	alf + prob	alf + prob
SAT	1 doc	1 doc	calc + 1 doc	calc + 1 doc

Sol = Soluvet
Iv = Insectivore
Calc = Calcivet (on fruit)+ Balanced Calcium (on DOC)
Prob = Probotic
Alf = finely chopped alfalfa
BS = beef strip/per bird
DOC = Day old chick/per bird

Appendix 14 - DERM feeding receptacle

Source: http://www.premiers.qld.gov.au/publications/categories/news/sectorwide/2011-august/cassowaries.aspx

Appendix 15 - Enrichment ideas

Ideally, for these enrichment techniques to be wholly effective, they should be arranged out of the bird/s' sight – i.e., with the birds in lock off.

Increasing foraging and travelling time by offering various feeder puzzles throughout the enclosure may improve fitness and stimulate mental activity somewhat.

- Training and conditioning;
- Hide food;
- Hang food, bunches or individual pieces (on branches, spikes, strings);
- Decrease size of food items fed;
- Feeder puzzles (in netting);
- Scatter feed;
- Randomise feed time;
- Multiple feed stations;
- Vary feed location;
- Vary feed frequency;
- Change feed types seasonally;
- Offer live invertebrates;
- Offer different protein sources;
- Offer rotting logs with inverts;
- Substrate changes;
- Sprinklers/mist system;
- Move furniture;

Appendix 16 - ISIS blood reference ranges

	UNIT	Mean	S.D.	Minimum	Maximum	(N)
WBC	x10 ^9/L	17.55	7.604	8.58	31.6	7
RBC	x10 ^12/L	3.1	2.65	1.55	7.07	4
Hb	g/L	174	34	135	200	3
PCV	%	48.1	7.9	33.5	58	8
MCV	fl	167.3	103.8	47.4	229.3	3
MCH	pg/L	97.3	9.1	87.1	104.5	3
MCHC	g/L	451	9	444	457	2
Heterophils	x10 ^9/L	11.14	4.749	6.43	20.9	7
Lymphocytes	x10 ^9/L	5.063	2.878	2	9.45	7
Monocytes	x10 ^9/L	1.09	0.987	0.086	2.844	6
Eosinophils	x10 ^9/L	0.3	0.149	0.194	0.405	2
Basophils	x10 ^ 9/L	0.429	0.268	0.186	0.81	4
Glucose	mmol/L	9.63	2.92	5.45	12.8	7
BUN	mmol/L	1.07	0.357	0.357	1.43	7
Creatinine	umol/L	26.5	8.84	8.84	35.4	3
Uric Acid	mmol/L	65.2	170	0.242	450	7
Calcium	mmol/L	2.73	0.3	2.28	2.98	7
Phosphate	mmol/L	1.81	0.517	1.16	2.36	6
Sodium	mmol/L	141	2	138	143	6
Potassium	mmol/L	2.7	0.8	1.8	4.1	6
Chloride	mmol/L	100	2	97	102	6
Bicarbonate	mmol/L	21.7	4.6	17	28	6
Total protein	g/L	56	9	45	75	8
Albumin	g/L	31	11	18	44	6
Globulin	g/L	23	15	11	42	6
AST	U/L	581	351	269	1399	8
ALT	U/L	49	27	21	84	4
Alk. Phos.	U/L	241	291	54	821	7
T. Bilirubin	umol/L	3.42	1.71	1.71	6.84	6
Bile Acids	umol/L					
Cholesterol	mmol/L	1.92	0.416	1.25	2.37	6
CPK	U/L	736	442	365	1335	4

Appendix 17 - Therapeutics

SEDATION / RESTRAINT AND ANAESTHESIA

Drug	*Dose and Route*	Comments / indications	Reference
Acepromazine maleate (liquid)	0.5-1.0 mg/kg PO	Good result 50 % of time	Stefan 1990
Acepromazine maleate (granules)	5 mg/kg PO	Very successful	Stefan 1990
Acepromazine	1 mg/kg	Light sedative effect	Graham Lauridsen personal communication
Atipamazole	1.5-2.5 mg/kg IM	Reverse medetomidine	Unwin 2004
	15-80 mg/kg IM	Reverse medetomidine	Westcott & Reid 2002
Azaperone	1-2 mg/kg IM	Following induction, smooth recovery	Speer 2006
	0.2-0.3 mg/kg IM	Aid smooth recovery	?
	1 mg/kg PO	Good result, remain upright	?
Carfentanil/Midazolam/Ketamine	0.04-0.06 mg/kg IM / 0.1-0.2 mg/kg IM / 2.5-4.9 mg/kg IM	Possible stormy induction	Cintino in: West et al 2008
Diazepam	0.2-0.3 mg/kg IV during recovery	Smooth recovery	Stewart in: Ritchie et al 1996
Diprenorphine	0.2mg/kg IM	Reverse Etorphine	Ensley et al 1984
Etorphine	3-10 mg/kg IM		Stoskopf et al 1982
Etorphine/Ketamine	0.1 mg/kg / 5-6.5 mg/kg IM	Reverse etorphine with Diprenorphine	Ensley et al 1984
	7-12 mg/kg IM / 100-300 mg/kg IM		
Halothane	0-5%	Use isoflurane – much safer	Ensley et al 1984
Isoflurane	0-5%	Excellent, save; (also sevoflurane)	Peter Barratt personal

Appendix 17 - Therapeutics

			communication
Ketamine HCl	5-6.5 mg/kg IM		Ensley et al 1984
	7.5 mg/kg IM	Sufficient sedation – difficult recovery	Stefan 1990
	7.5-9 mg/kg IM	Long procedures. Top up 5 times	Stefan 1990
	15-18 mg/kg	Induction. Surgical plane	Stefan 1990
	25-50 mg/kg	Difficult recovery	Stoskopf et al 1982
Ketamine/Diazepam	2-5 mg/kg IV / 0.2-0.3 mg/kg IV	Smoother recovery	Stewart in: Ritchie et al 1996
Ketamine/Xylazine	2-5 mg/kg IV / 0.2-0.3 mg/kg IV	Smoother recovery	Stewart in: Ritchie et al 1996
Medetomidine	0.26-0.31 mg/kg IM	Sufficient to approach and handle captive birds only	Westcott & Reid 2002
	0.38-0.54 mg/kg IM	Sufficient to handle wild birds	Westcott & Reid 2002
	0.5 mg/kg IM	Heavy sedation	Unwin 2004
Medetomidine/Ketamine	0.09-0.13 mg/kg IM / 3.4-4.3 mg/kg IM	Heavy sedation	Cintino in: West et al 2008
Medetomidine, Medetomidine/Midazolam	0.12-.013 mg/kg IM, 0.04 mg/kg IM /0.02 mg/kg IM	First dart, second dart combo	Cintino in: West et al 2008
Medetomidine/Butorphanol/Propofol	0.5 mg/kg IM / 0.05-0.5 mg/kg IM / 6-10 mg/kg IM to effect		Unwin 2004
Naloxone	2 mg IV	Reverse Butorphanol	Unwin 2004
Tiletamine-Zolazepam	2-8 mg/kg IM IV	Agent of Choice. Adult – can be difficult recovery	Speer 2006; Graham Lauridsen personal communication

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	2-3 mg/kg IV		Unwin 2004
Xylazine	0.2-1.0 mg/kg IM	Sedation combined with ketamine as above. Can reverse Yohimbine	Peter Barratt personal communication
Yohimbine	0.125 mg/kg IV	Agonist Xylazine	Peter Barratt personal communication

ANALGESIA / ANTI-INFLAMMATORY

Drug	***Dose and Route***	**Comments / indications**	**Reference**
Dexamethasone	2-4 mg/kg BID	Short course only. NB is corticosteroid	Romer 1997
Flunixin meglumine	0.2 mg/kg SID	Short course only	Romer 1997
Meloxicam	0.1-0.5 mg/kg IM PO SID	Appears well tolerated	Peter Barratt personal communication

ANTIBIOTIC

Drug	***Dose and Route***	**Comments / indications**	**Reference**
Amoxicillin	15-20 mg/kg IM BID		Romer 1997
	15-22 mg/kg PO BID		Tully & Shane 1996

Appendix 17 - Therapeutics

Amoxyl/Clavulinic acid	7-15 mg/kg IM SID		Peter Barratt personal communication
	10-15 mg/kg PO BID		Peter Barratt personal communication
Cefazolin sodium	16 mg/kg IV	Presurgical	Ensley et al 1984
Cephalexin monohydrate	8 mg/kg PO BID		Ensley et al 1984
Enrofloxacin	2.5-5 mg/kg BID		Peter Barratt personal communication
	PO SC IM	IM pain, potential necrosis	Peter Barratt personal communication

ANTIFUNGAL

Drug	***Dose and Route***	**Comments / indications**	**Reference**
Ketaconazole	5-10 mg/kg	PO SID	Romer 1997; Tully & Shane 1996
Itraconazole	6-10 mg/kg PO SID		Romer 1997; Tully & Shane 1996

ANTIPARASITIC

Drug	***Dose and Route***	**Comments / indications**	**Reference**
Fenbendazole	15-40 mg/kg PO		Peter Barratt personal

Appendix 17 - Therapeutics

			communication
	5-15 mg/kg PO SID		Tully & Shane 1996
Ivermectin	0.2 mg/kg	PO SC IM or topical preparations. Other products in same class as well	Tully & Shane 1996

Appendix 18 - Artificial incubation complications - faults and causes

Problem	Probable causes	Action	Industry
Clear or infertile eggs	Male undernourished	Ensure that male is fed to satiety for at least 8 weeks prior to season	Poultry
	Interference from other species (emu)	Remove emu's from auditory range	
	Male is post-reproductive	Seek permission to replace old bird, retire to education	Poultry
	Male is sterile	Assess reproductive status of male. If sterile, seek permission to replace. Retire to education	Poultry
	Eggs kept too long or under wrong conditions before setting in incubator	Do not keep hatching eggs longer than 20 days. Store in a cool temperature, relative humidity (75%)	Poultry
Smelly, brown coloured albumen	Contamination of eggs	Review hygiene	Ratite
Liquid seeping from eggs	Contamination of eggs	Review hygiene	Ratite
Blood rings, which indicate very early embryonic death; or small embryo (no feathering seen) – early death	Incubator temperature too high or low	Check thermometers, thermostats and electricity supply; follow manufacturers instructions	Poultry
	Incubator temperature too high during beginning period of incubation		Ratite
	Incorrect egg treatment	Do not fumigate or liquid treat between 24-96 hours after setting	Poultry
	Eggs kept too long or under wrong conditions before setting	Do not keep hatching eggs longer than 20 days. Store in a cool temperature, relative humidity (75%)	Poultry
Dead in shell/ Malpositioning	Incubator temperature too high or low	Check thermometers, thermostats and electricity supply; follow manufacturers instructions	Poultry
	Eggs not turned properly	Turn the eggs regularly at least three to five times a day; turn the eggs in the reverse direction each time	Poultry

Appendix 18 - Artificial incubation complications - faults and causes

	Eggs not positioned properly in incubator		Ratite
	Breeding stocks nutrition deficient if deaths are high in days 15-22	Ensure that breeders are fed to satiety for at least 8 weeks prior to season	Poultry
		Check that feeding is sound	Poultry
	Incubator's ventilation faulty	Increase ventilation	Poultry
	Infectious disease	Assess health status of breeders; check that hatchery hygiene is sound	Poultry
Little formation of air cell, failure to pip by embryo	High incubator humidity		Ratite
Low water loss within eggs, edema seen in chicks	High humidity in incubator, Vitamin E/ Calcium/ Selenium deficiencies		Ratite
Pipped eggs failing to hatch, many dead in shell	Insufficient moisture in incubator	Increase evaporating surface of water	Poultry
	Too much moisture at earlier stages	Check wet bulb readings	Poultry
	Breeder diet deficient in pantothenic acid	Review breeder nutrition	Poultry
Hatching too soon	Incubator's temperature too high	Ensure temperature regulating gear is working at set at the correct operating temperature	Poultry
Hatching too late	Incubator's temperature too low		Poultry
Sticky chicks	Incubator's temperature too high		Poultry
Malformed chicks	Incubator's temperature too high	Check thermometers, thermostats and electricity supply; follow manufacturer's instructions	Poultry
	Incubator's temperature too low	Check thermometers, thermostats and electricity supply; follow manufacturers instructions	Poultry
	Eggs set incorrectly or not properly turned after setting	Turn the eggs regularly at least three to five times a day; turn the eggs in the reverse direction each time	Poultry

Appendix 18 - Artificial incubation complications - faults and causes

	Breeder diet deficient in riboflavin	Review breeder nutrition	Poultry
Enlarged hock/slipped Achilles tendon	Breeder diet deficient in Biotin, choline and manganese		Poultry
Missing or small lower jaws	High/Low Selenium, Low calcium		Ratite
Weak chick	Incubator or hatching unit overheating	Ensure temperature regulating gear is working at set at the correct operating temperature	Poultry
	Setting small eggs	Only set eggs equal to and above average size	Poultry
Small chick	Insufficient moisture in incubator	Increase evaporating surface of water	Poultry
Heavy breathing	Too much moisture in hatcher	Check wet bulb readings	Poultry
	Low average temperature during period of incubation	Check thermometers, thermostats and electricity supply; follow manufacturers instructions	Poultry
Mushy chick	Incubator has poor ventilation	Increase ventilation, carefully clean out and fumigate incubator, disinfect all equipment	Poultry
Chicks hatched with large amounts of yolk exposed	Late high temperatures in incubator and hatcher, low water loss during incubation		Ratite
Decreased hatchability and poor survival of hatched chicks	Breeder diet deficient in B12		Poultry

Source: Jeffrey *et al*. 2007, Spencer 2010.

GLOSSARY

IUCN – International Union for the Conservation of Nature

CBSG – Conservation Breeding Specialist Group

CRT – Cassowary Recovery Team

CHW – Cassowary husbandry workshop

OZOO – Australia Zoo

CTZ – Cairns Tropical Zoo

HCA – Hartley's Crocodile Adventures

IUDZG – International Union of Directors of Zoological Gardens

DERM – Department of Environment and Resource Management

extant – still in existence

TCS – Taronga Conservation Society

agonistic – behaviour related to fighting

Koppers Log – wooden landscaping material produced by Koppers Australia

Soluvet – animal multivitamin supplement produced by Vetafarm

Insectivore – insect supplement produced by Wombaroo

Probotic – water soluble gut flora supplement produced by Vetafarm

conspecific – belonging to the same species

precocial – hatched or born in an advanced state and able to feed itself immediately

integument – outer protective layer – skin, keratin etc

IM – Intra-muscular

IV – Intravenous

SC – Subcutaneous

BID – twice a day

SID – once a day

PO - orally

pathogen – a microorganism that can cause disease

fasting – to abstain

sternal – relating to the sternum

recumbent – the act of lying down or leaning

peroneal nerve paralysis – loss of nerve function in the leg

urogenital – relating to both the urinary and genital organs

myopathy – a disease of muscle tissue

disarticulate – to separate (at the joints)

pneumatised – containing air cavities

aponeuroses - A sheet of pearly-white fibrous tissue that takes the place of a tendon in sheetlike muscles having a wide area ofattachment.

vestigial – having become functionless through the course of evolution

rudimentary - undeveloped

epaxial – sitting on the dorsal side of the torso

nephrotoxic – toxic to the kidney

intromittent – a modified male part used to introduce sperm to a female

coprophagy – to eat faeces

intra-sexual – within sexes

inter-sexual – between sexes

facultative – capable of but not restricted to a particular function or mode of life

obligate – restricted to a particular function or mode of life

podzolic – soils typical to boreal forests

comminuting – the act of breaking down a material into smaller pieces

gastrolith – gizzard stone

bradycardia – abnormally slow heart action

hypocapnia – a state in which the level of carbon dioxide in the blood is lower than usual

exertional rhabdomyolysis – rapid breakdown of skeletal muscle due to injury to muscle tissue

DNA – Deoxyribonucleic acid

CBC – complete blood count

KY Jelly – a water-based, water-soluble personal lubricant produced by Johnson & Johnson

ZAA – Zoo and Aquarium Association (Australasia Region)

LH – leutenizing hormone

Betadine – povidone/iodine topical antiseptic produced by Purdue Pharma

Roccal-D – disinfectant produced by Pfizer

F10 – disinfectant

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