A review of the nutritional status of wild Australian psittacines

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Abstract

Blood and liver nutrient concentrations were evaluated in a series of studies of three wild Australian psittacine species (*Cacatua galerita, C. tenuirostris* and *Eolophus roseicapilla*). There was little taxonomic variation in serum globulin (13-29 g/L) but greater variation in total protein (20-38 g/L) accredited to differences in albumin content (6-15 g/L). While ranges for plasma total calcium (0.8-6.0 mmol/L) were larger than serum total calcium (1.79-2.43 mmol/L) there was little taxonomic variation in ionised calcium (0.92-1.14 mmol/L). Taxonomic differences in total phosphorus (1.97-13.24 mmol/L) were smaller than phosphate levels (0.63-4.57 mmol/L). Taxonomic differences were recorded for plasma iron (36-484 µmol/L) and zinc (16.8-94 µmol/L) but these differences were not correlated with concentrations of hepatic iron (110-1030 mg/kg) or zinc (24-64 mg/kg). Taxonomic variation was evident in serum vitamin A (0.46-1.85 µmol/L), vitamin D (19.3-46.43 nmol/L), vitamin E (3.6-23.3 µmol/L) and hepatic vitamin A (33.2-823.5 mg/kg), with little taxonomic variation in hepatic vitamin E (1.9-4.7 mg/kg).

Introduction

Evaluating the nutritional status of captive birds is fraught with difficulties as reference data is mostly confined to agricultural species or captive birds influenced by varying husbandry regimes. In addition, the use of inappropriate analytical procedures can provide erroneous results leading to inappropriate prescription of dietary supplements or other treatments. A number of studies have recently been undertaken on three wild Australian psittacine species, including the sulphur-crested cockatoo (*Cacatua galerita*), long-billed corella (*C. tenuirostris*) and galah (*Eolophus roseicapilla*) (McDonald and Stanford, 2003; McDonald, 2004a,b; McDonald et al, 2004). The data presented here is a summary of this work with comparisons made to published data on captive psittacines.

Macrominerals

Calcium nutrition receives a lot of attention in the avicultural community but supplementation requirements of psittacines are often misunderstood. Seed-based diets are commonly associated with hypocalcemia, characterised by seizures in adults and osteodystophy in chicks. In contrast, hypercalcemia, and resultant soft tissue calcification, is generally correlated with excessive calcium/vitamin D_3 supplementation or commercial diets high in these nutrients.

Measures of calcium status are best evaluated from the biologically active ionised form of calcium. Fluctuations in protein levels, disease state or laying state can alter measures of total calcium without any pathophysiological significance. Measures of albumin alone are generally not adequate for evaluating calcium status. Exposure to UV-B radiation is limited in Europe and the

UK, with vitamin D_3 supplementation or UV-B lighting recommended for canopy species that have evolved in regions of high light intensity (Stanford, pers. comm.). However, more than adequate vitamin D_3 is usually added to commercially formulated foods, with various species susceptible to vitamin D_3 toxicity (Roset et al, 2000).

Plasma macromineral concentrations were evaluated from three species (Table 1; McDonald et al, 2004). There were no statistically significant gender differences in any aspect of mineral nutritional status. Mean total calcium concentrations (1.7-2.0) reported in this study reflect values reported for captive psittacines, Table 2. While phosphate levels are routinely evaluated in clinical practices, total phosphorous evaluated in this study was marginally lower than values reported for captive Puerto Rican (*Amazona vitatta*: 9.4-11.5 mmol/L) or Hispañolan (*Amazona ventralis*: 8.7-14.5 mmol/L) parrots (McDonald et al, 2001). Serum phosphate concentrations of *C. tenuirostris* (Table 3; McDonald, 2004) reflected values reported for captive birds, Table 2, but the mean phosphate concentration for *C. galerita* was lower than any published data.

Mineral (mmol/L)	**Galah (*Eolophus roseicapilla*)**	**Long-billed Corella (*Cacatua tenuirostris*)**	**Sulphur-crested Cockatoo (*Cacatua galerita*)**
Calcium	1.8 ± 0.16 (1.45-2.20)	1.7 ± 0.09 (1.6-1.9)	2.0 ± 0.89 (0.8-6.0)
Magnesium	0.83 ± 0.13 (0.66-1.15)	0.70 ± 0.06 (0.62-0.78)	0.99 ± 0.5 (0.37-3.2)
Phosphorus	6.97 ± 1.99 (3.55-13.24)	7.03 ± 1.46 (3.88-10.17)	5.95 ± 2.0 (1.97-12.9)
Potassium	10.3 ± 3.6 (6.7-19)	8.0 ± 0.7 (7.2-10.0)	9.0 ± 3.9 (2.8-25.8)
Sodium	106 ± 4.7 (98.8-114)	108 ± 6.6 (92-115)	104 ± 43 (47.9-297)

Table 1. Mean plasma macromineral content depicting standard deviations with ranges presented in parentheses (McDonald et al, 2004).

	Calcium mmol/L	Phosphorus mmol/L	Potassium mmol/L	Sodium mmol/L
Cockatoo spp[a]	1.6-2.8	1.0-3.6	n.d.	n.d.
Cacatua leadbeateri[b]	0.93-1.22*	n.d.	n.d.	n.d.
Eclectus roratus	2.25-2.55	2.10-2.91	2-4.6	138-158
Ara ararauna[d]	2.5	2.13	2.71	142
Macaws spp[d]	2.12-2.70	1.49-2.23	2-4.2	135-156
Rhynchopsitta pachyrhyncha[e]	1.90-2.37	0.0-1.68	1.7-3.5	147-155
Psittacus erithacus[f]	2-3.24	n.d.	2.6-4.2	134-152
Psittacus erithacus[a]	1.75-2.35	1.0-5.2	2.2-3.5	146-167
Psittacus erithacus[g]	2.37-8.08	0.94-2.84	3.7-5.2	149-158

Table 2. **Serum mineral concentrations in captive psittacines.** ([a]Hochleithner, 1989; [b]Clubb et al, 1990; [c]Clubb et al 1991; [d]Drew et al, 1994; [e]Candeletta et al, 1993; [f]Lane, 1991, [g]McDonald et al, 2004).

Further studies were undertaken on serum samples from *C. galerita* and *C. tenuirostris* (Table 3; McDonald, 2004). Calcium and phosphate concentrations compared favourably with data from other captive psittacines (Table 2) but are not indicative of biologically active (ionised) calcium. There was little taxonomic variation in ionic calcium, with greater variability in phosphate and vitamin D_3 concentrations (Table 8). Ionic calcium was weakly correlated with total calcium (R^2=0.66) with a stronger relationship once ionic calcium was normalised for pH changes (R^2=0.94) in *C. galerita,* highlighting the importance of minimising exposure of samples to oxygen. However, these correlations were species specific with similar relationships not detected for *C. tenuirostris*.

	Calcium (total) mmol/L	Calcium (ionised) mmol/L	pH	Calcium (Ionised/Total) %	P mmol/L	Total Ca:P
Long-billed Corella	2.26 ± 0.2	1.01 ± 0.06	7.71 ± 0.29	43.35 ± 2.95	2.41 ± 0.91	1.06 ± 0.37
Cacatua tenuirostris	(1.79-2.43)	(0.92-1.13)	(7.29-8.15)	(39.75-46.01)	(1.25-4.57)	(0.39-1.78)
(Count)	10	12	12	4	10	10
Sulphur-crested Cockatoo	2.04 ± 0.16	1.08 ± 0.04	7.37 ± 0.07	52.80 ± 3.41	0.79 ± 0.25	2.76 ± 0.65
Cacatua galerita	(1.85-2.24)	(1.04-1.14)	(7.29-7.46)	(47.77-56.77)	(0.63-1.28)	(1.56-3.52)
(Count)	6	5	5	5	6	6

Table 3. Serum ionised calcium concentrations of Australian psittacines (McDonald, 2004).

Microminerals

Plasma microminerals were evaluated from three Australian psittacine species (Table 4; McDonald et al, 2004), with serum concentrations confined to *C. galerita* and *C. tenuirostris* (Table 5; McDonald, 2004). Mean plasma copper levels of birds in this study were significantly higher than those reported for captive Hispañolan Amazons (1.89 µmol/L; Osofsky et al, 2001) but within the range reported for poultry (1.26-7.09 µmol/L; Puls, 1994). Mean plasma copper concentrations were 67-80% higher in females of *C. tenuirostris* (females 4.55 µmol/L vs. males 3.05⁻ µmol/L) and *E. roseicapilla* (females 3.85 µmol/L vs. males 3.1 µmol/L) but differences were not statistically significant and similar patterns were not reflected in *C. galerita.* However, these results are higher than data reported for captive Hispañolan Amazons (McDonald et al, 2001), implying both taxonomic and gender variation in copper status of psittacines.

Mineral (µmol/L)	**Galah (*Eolophus roseicapilla*)**	**Long-billed Corella (*Cacatua tenuirostris*)**	**Sulphur-crested Cockatoo (*Cacatua galerita*)**
Copper	3.44 ± 0.6 (1.89-4.56)	3.97 ± 1.4 (2.2-7.9)	2.97 ± 0.99 (1.1-5.7)
Iron	90 ± 49 (38-174)	57 ± 20.6 (36-102)	124 ± 91 (37-484)
Lead	0.29 ± 0.03 (0.24-0.34)[a]	0.35 ± 0.09 (0.24-0.53)	n.d.
Selenium	11.9 ± 2.5 (7.6-16.5)	12.9 ± 4.0 (7.6-21.5)	11.3 ± 4.6 (3.8-27.9)
Zinc	28.5 ± 6.7 (18.4-41.3)	29.8 ± 7.8 (18.4-44.4)	37.4 ± 12.7 (16.8-84)

Table 4. Mean plasma micromineral levels depicting standard deviations with ranges presented in parentheses (McDonald et al, 2004).

	Copper umol/L	**Magnesium mmol/L**	**GPX (Se) ug/HB**	**Zinc umol/L**
Long-billed Corella *C. tenuirostris*	3.02 ± 0.93 (1.5-4.3)	1.07 ± 0.13 (0.9-1.3)	152.56 ± 38.26 (111-268)	48.32 ± 8.13 (34.8-60.3)
(Count)	10	10	18	10
Sulphur-crested cockatoo *C. galerita*	n.d.	1.15 ± 0.05 (1.1-1.2)	n.d.	36.98 ± 5.56 (31.9-47.2)
(Count)		6		6

Table 5. Serum mineral concentration depicting means ± standard deviations with ranges presented in parentheses (McDonald, unpublished data).

Iron toxicicosis is problematic for a number of frugivorous and insectivorous birds and has also been reported in some psittacines (Rosskopf et al, 1992; Rupiper and Read, 1996; Gerlach et al, 1998). Plasma iron concentrations for birds in this study varied significantly ranging from 36-484 µmol/L, with mean value for *C. galerita* (124 µmol/L) more than twice that of *C. tenuirostris* (57 µmol/L). The higher values exceed reports for serum levels in macaws (14.14-24.17 µmol/L: Raphael, 1980) and Hispañolan Amazons (40.3-112 µmol/L, Osofsky et al, 2001). Temporal variation in plasma iron concentration was detected in *E. roseicapilla* (autumn values were nearly double that of winter). Recommendations for serum iron concentrations in birds susceptible to iron storage disease to be maintained at less than 26.87 µmol/L (Worrell, 1999) are not supported in studies of wild Australia psittacines. These recommendations may only be applicable to frugivorous species.

It is generally accepted that blood iron concentrations are not indicative of liver stores (Worrell, 1993; Redrobe et al, 2003) but organ biopsies are not always convenient or recommended in severely ill birds. Liver stores of the wild birds (mean 417 mg/kg) exceeded values reported for captive psittacines (60-300 mg/kg; Rupiper and Read, 1996) and granivorous birds (50 mg/kg; Dierenfeld and Shepherd, 1989) but lower than 3,750 mg/kg reported for a hawk-headed parrot (*Deroptyus accipitrinus*) diagnosed with hemochromatosis (Rupiper and Read, 1996). There were no correlations between hepatic and plasma iron concentrations in wild psittacines.

Measures of plasma zinc are generally considered poor indicators of zinc status, with hepatic zinc concentrations more reliable indicators. However, zinc concentration in most soft tissues varies little with nutritional status, with excess zinc stored in bone and only birds deprived of adequate zinc generally exhibit low plasma levels. Plasma zinc concentrations in wild psittacines fell with the normal range reported for serum zinc in parrots (7.65-38 µmol/L; Van Sant, 1998) and symptomatically normal Hispañolan parrots (27-89 µmol/L: Smith 1995; 19-35 umol/L: Osofsky et al, 2001), with seasonal increases in plasma concentrations in *C. tenuirostris*. Plasma zinc concentrations in wild psittacines fell below those reported for other birds exhibiting signs of toxicity (approximately 150 µmol/L: Doneley, 1992; Dorrestein, 2002; Wolf, 2002) but exceeded plasma and serum concentrations considered diagnostic for zinc toxicity (30 µmol/L21; Puschner et al, 1993; Dumonceaux and Harrison, 1994; Bauck and LaBlonde, 1997), suggesting that equating zinc toxicity with plasma concentrations above 30.1 µmol/L may lead to the erroneous diagnosis of toxicity in some species. There was little taxonomic variation in hepatic zinc content of wild birds in this study with values falling below published data for various psittacines maintained in captivity, especially those diagnosed as suffering from zinc toxicity, Table 6. Doneley (1992) also reported a lack of correlation between hepatic zinc and clinical diagnosis of zinc toxicity as was evidenced in this study.

Species	**Zn mg/kg** Physiological Status	**Zn mg/kg** Toxication
Budgerigar[a] (*Melopsittacus undulatus,* n=10)	50.5 ± 12.7 (37.6-70.5)	153-250
Budgerigar (aviary bred)[b] (*Melopsittacus undulatus,* n=8)	64.7 ± 37 (29-126)	No clinical signs of toxicity
Monk Parakeet[c] (*Myiopsitta monachus*, n=14)	57.9 ± 34.5 (28.1-156)	179 ± 737 (n=7)
Lovebird[d] (*Agapornis roseicolli*, n=5)	42.5 ± 8.9 (37.5-50.2)	75-156
Macaws[c] (*Ara chloroptera, A. macao*, n=77)	38.9 ± 22 (12.0-115)	150 ± 37 (n=3)
Rosellas, lorikeets[b] (*Platycercus* spp, *Trichoglossus* spp, n=4)	74 ± 63 (27-166)	Wild caught
Galah (*Eolophus roseicapilla*, n=16)	31.6 ± 5.4 (24.45)	Wild caught
Sulphur-creasted Cockatoo (*Cacatua galerita*, n=21)	37.5 ± 7.8 (25-59)	Wild caught
Long-billed Corella (*Cacatua tenuirsotris*, n=13)	37.3 ± 9.8 (29-64)	Wild caught

Table 6. **Hepatic zinc concentrations in psittacines.** ([a]Wolf, 2002[a]; [b]Doneley, 1992; [c]Dorrestein, 2002; [d]Reece et al, 1996)

Protein

A large proportion of total calcium is bound to protein (albumin) and biologically inactive. Measures of total calcium are vulnerable to fluctuations in protein levels, disease state or laying state (circulating calcium can increase 100% in laying hens; Bentley, 1988) without any pathophysiological significance and the biologically active form of calcium (ionised calcium) provides a more accurate indicator of calcium status (Stanford 2003a). Some clinicians estimate bioavailability of calcium from total protein concentrations, assuming positive correlations between total protein and albumin concentrations. However, these relationships are not evident in *Amazona* spp (Lumeij, 1990) or African grey parrots (*Psittacus erithacus*; Stanford 2003a) and were not evident in the studies on Australian psittacine species.

An evaluation of protein levels in wild Australian psittacines indicates near identical concentrations of globulin, but greater taxonomic variation in albumin and therefore total protein levels, Table 7.

Albumin was closely correlated with total protein content in both *C. tenuirostris* (R^2=0.76) and *C. galerita* (R^2=0.94), with a strong correlation between protein and globulin confined to *C. tenuirostris* (R^2=0.94). Albumin was weakly correlated with calcium (total calcium R^2 = 0.6, ionic calcium R^2 = 0.63) in *C. galerita,* with stronger correlations between globulin and calcium (total calcium R^2 = 0.77, ionic R^2 = 0.97). However, these relationships were not reflected in *C. tenuirostris* and correlations for this species were confined to a negative relationship between albumin and ionised calcium when expressed as a percent of total calcium (-0.7). It is important to note that some of these regression equations were developed from as little as five data points and a larger sample size or different environmental conditions may result in variable regression equations.

	Protein g/L	**Albumin g/L**	**Globulin g/L**	**A:G**
Long-billed Corella	23.5 ± 5.02	9.9 ± 1.66	16.6 ± 4.81	0.63 ± 0.16
C. tenuirostris	(20-38)	(6-12)	(13-29)	(0.31-0.79)
(Count)	10	10	10	10
Sulphur-crested Cockatoo	29 ± 3.03	12.33 ± 1.75	16.67 ± 1.51	0.74 ± 0.07
C. galerita	(25-35)	(10-15)	(15-18)	(0.67-0.83)
(Count)	6	6	6	6

Table 7. Serum protein concentrations of wild Australian Psittacines.

Vitamins

Concentrations of vitamin D_3 are not expected to fall below 26 nmol/L in poultry (Whittow et al, 2000) levels below this reported in a high percentage of African grey parrots maintained on either seed-based (80%) or formulated diets (55%) in the UK, improving when birds are exposed to UV-B radiation (37.91 nmol/L-116.52 nmol/L; Stanford, 2003a,b,c). In contrast, data from wild psittacines, Table 8, suggest that vitamin D_3 concentrations below 26 nmol/L are normal for *C. galerita* (McDonald, 2004). There were no correlations between vitamin D and either total/ionised calcium or phosphorous in *C. tenuirostris*, with a negative correlation between vitamin D and ionised calcium when expressed as a percent of total calcium. In contrast, there were stronger relationships between vitamin D and various measures of calcium in *C. galerita.*

	Serum				*Liver*	
	Vitamin A umol/L	**Vitamin E umol/L**	**Vitamin D nmol/L**	**Vitamin B_{12} pmol/L**	**Vitamin A mg/kg**	**Vitamin E mg/kg**
Long-billed Corella	0.8 ± 0.16	14.94 ± 3.84	35.36 ± 6.41	148.5 ± 76.71	74.55 ± 141.7	4.21 ± 1.43
C. tenuirostris	(0.46-1.07)	(8.9-23.3)	(24.71-46.43)	(81-327)	(33.2-253.5)	(2-7)
(Count)	16	16	20	10	12	12
Sulphur-crested Cockatoo	1.38 ± 0.28	10.97 ± 5.5	23.33 ± 3.58	n.d.	294 ± 215	3.52 ± 0.95
C. galerita	(1.06-1.85)	(3.6-20.4)	(19.3-29.5)		(107.1-823.5)	(1.9-4.7)
(Count)	6	6	6		11	11

Table 8. Mean serum and hepatic fat-soluble vitamin concentrations depicting standard deviations, with ranges presented in parentheses.

Although symptoms of both hyper/hypovitaminosis A and vitamin E deficiencies are frequently observed in captive birds, nutritional status of these two vitamins are rarely evaluated. Despite up to 95% of vitamin A being stored in the liver, measures of these vitamins are usually confined to blood samples. Hepatic and serum concentrations of these fat-soluble vitamins were evaluated from *C. galerita* and *C. tenuirostris* (McDonald, in prep). Serum and hepatic vitamin A concentrations were only weakly correlated in both species (R^2=0.62), with negative correlations between hepatic vitamin A and serum vitamin D_3 (R^2=-0.7) in *C. galerita*. Stronger correlations were detected between serum and hepatic vitamin E in both *C. galerita* (R^2=0.78) and *C. tenuirostris* (R^2=0.85). There were no strong correlations between vitamin A and vitamin E in either species. Data suggests that while vitamin E can be evaluated from blood samples alone, hepatic stores are a better indicator of vitamin A status.

Vitamin B_{12} is an essential part of several enzyme systems that carry out a number of very basic metabolic functions. It is synthesised only by microorganisms and not usually found in natural feedstuffs. Deficiencies of vitamin B_{12} induce folate deficiency and impair protein synthesis and may result from pancreatic insufficiency (Jorgensen et al, 1991) and gastric juice defects (Carmel, 1994). Measures of vitamin B_{12} are indicative of small intestinal malabsorption problems and excess dietary protein can increase the dietary requirement for vitamin B_{12}. Bacterial overgrowth in the small intestine can result in consumption before the vitamin is absorbed. Deficiencies of this vitamin are implicated in defective feathering, decreased hatchability, embryonic mortality at day 17 and impairment of protein synthesis. Measures of vitamin B_{12} were confined to *C. tenuirostris*, Table 8.

Conclusion

It is clear that there are taxonomic variations in some aspects of nutritional status while other values are not affected. In the absence of adequate data from a range of species of differing feeding ecologies, data should be extrapolated with caution. These studies are part of an ongoing program to evaluate nutritional status of wild birds and correlate this data with nutrient composition of wild food resources.

References

Bauck, L. and J. LaBlonde. “Toxic Diseases.” *In* Avian Medicine and Surgery. R.B. Altman, S.L. Clubb, G.M. Dorrenstein and K. Quesenberry. Philadephia, PA, WB Saunders, 1997: 604-316.

Bentley, P. J. Comparative Vertebrate Endocrinology. Cambridge, Cambridge University Press. 1998.

Candeletta et al. “Diabetes mellitus associated with chronic lymphocytic pancreatitis in an African grey parrot (*Psittacus erithacus erithacus*).” *Journal of the Association of Avian Veterinarians* 7(1):39-43, 1993.

Clubb S.L. et al. “Hematologic and serum biochemical reference ranges in juvenile macaws, cockatoos, and eclectus parrots.” *Proc Assoc Avian Vet* 58-82. 1990.

Clubb S.L. et al. “Hematologic and serum biochemical reference intervals in juvenile cockatoos.” *J Assoc Avian Vet* 5:20-23. 1991.

Doneley, R. (1992). "Zinc toxicity in caged and aviary birds - "new wire disease"." *Australian Veterinary Practitioner,* 1992; 22(1): 6-8.

Drew, M.L. et al. "Laboratory reference intervals for a group of captive thick-billed parrots (*Rhynchopsitta pachyrhyncha*). *Journal of the Association of Avian Veterinarians* 7(1): 35-38, 1993.

Dierenfeld, E.S. and Shepherd, C.D. "Investigations of hepatic iron levels of zoo birds." *Proceedings of the VIII Dr Scholl Conference on Nutrition of Captive Wild Animals*. 1989: 101-114.

Dorrestein, G.M. et al "Zinc intoxication in two parrot flocks." *Proc Deutsche Veterinarmedizinsche Gesellschaft* 2002: V125-133.

Dumonceaux, G. and G. J. Harrison. "Toxins." *In* Avian Medicine: Principles and Application. B. W. Ritchie, G. J. Harrison and L. R. Harrison. Lake Worth, FL, Wingers Publishing, 1994: 1034-1052.

Gerlach, H., F. Enders, and M. Casares. "Discussion of the increased iron content in the liver of some bird species (particularly parrots)." *M.A.R.E.*, Toledo, Ohio, 1998.

Lumeij, J. T. "Relationship of plasma clacium to total protein and albumin in African grey (*Psittacus erithacus*) and Amazon (*Amazona spp.*) parrots." *Avian Pathology* 19: 661-667. 1990.

McDonald, D.L. "Calcium, phosphorous and vitamin D status of wild Australian psittacines: the sulphur-crested cockatoo (*Cacatua galerita*) and long-billed corella (*Cacatua tenuirostris*)." *Vet. Rec.* 2004 (subm).

McDonald, D.L. "Nutritional status of the Australian long-billed corella (*Cacatua tenuirostris*) and sulphur-crested cockatoo (*Cacatua galerita*) in the wild: an evaluation of hepatic and serum vitamin and mineral concentrations." (in prep).

McDonald, D.L. and Stanford, M. "Calcium and vitamin D status of wild psittacines: a study of the sulphur-crested cockatoo (*Cacatua galerita*), long-billed corella (*Cacatua tenuirostris*) and grey parrot (*Psittacus erithacus*)." *Proc Aust AAV,* Manly. 2003

McDonald, D.L. et al. "A preliminary assessment of circulating carotenoids and mineral values of the Puerto Rican parrot (*Amazona vittata*) maintained in captivity, with implications for its health and fertility." *Proc. 2nd European Zoo Nutrition Conference*, 2001.

McDonald, D.L et al. "Health and nutritional status of wild Australian psittacines: an evaluation of plasma and hepatic minerals and blood biochemistry." *Journal of Avian Medicine and Surgery.* 2004 (subm).

Puls, R. "Mineral Levels in Animal Health." Clearbrook, Canada, Sherpa International, 1994.

Puschner, B. et al. "Normal and toxic zinc concentrations in serum/plasma and liver of psittacines with respect to genus differences." *Journal of Veterinary Diagnoses and Investigations*, 11: 522-527. 1999.

Osofsky, A. et al. "Determination of normal blood concentrations of lead, zinc, copper and iron in Hispañolan Amazon parrots (*Amazona ventralis*)." *Journal of Avian Medicine and Surgery,* 2001; 15: 31-36.

Raphael, B. L. “Hematology and blood chemistries of macaws.” *Proceedings of the American Association of Zoo Veterinarians*, 1980.

Redrobe, S.P., Drews, A.V. and Patterson-Kane, J.C. Successful reduction of hepatocellular haemosiderin content in toco toucans (*Ramphastos toco*) with haemochromatosis by dietary modification. *Proc EAAV*. pp 211-218. 2003.

Reece, R. L., D. B. Dickson, et al. "Zinc toxicity (new wire disease) in aviary birds." *Australian Veterinary Journal* 63: 199. 1986.

Roset, K. et al. “Determination of safe and adequate dietary calcium and vitamin D_3 concentrations in a companion bird. *Proc AAV*.” 2000

Rosskopf, W. J. J., R. W. Woerpel, et al. “Iron storage disease (hemochromatosis) in a citron-crested cockatoo and other psittacine species.” *Proceedings of the American Association of Avian Veterinarians,* 1992..

Rupiper, D. J. and D. H. Read. "Hemochromatosis in a hawk-headed parrot (*Deroptyus accipitrinus*)." *Journal of Avian Medicine and Surgery,* 1996; 10(1): 24-27.

Smith, A. “Zinc toxicosis in a flock of Hispaniolan Amazons.” *Proceedings of the American Association of Zoo Veterinarians*, 1995.

Stanford, M.. “Determination of 25 hydroxycholecalciferol in African grey parrots (*Psittacus erithacus*): the effect of diet.” *Proc EAAV*, Tenerife. 2003a.

Stanford, M. “Measurement of ionised calcium in African grey parrots (Psittacus erithacus): the effect of diet.” *Proc EAAV*, Tenerife. 2004b.
Stanford, M. "Measurement of ionised calcium in grey parrots." *Vet Rec* **in press**. 2003c.

Van Sant, F. “Zinc and parrots: more than you ever wanted to know.” *Proceedings of the Association of Avian Veterinarians,* 1998.

Wolf, P., C. Hauot, et al. “Zinc intoxication in budgerigars (*Melopsittacus undulatus*).” *Joint Nutrition Symposium*, Antwerp, Belgium, 2002.

Worell, A. “Phlebotamy for treatment of hemochromatosis in two sulfur-breasted toucans.” *Proceedings of the Association of Avian Veterinarians*, 1991.