Long-term monitoring of endoparasites in birds-of-paradise at Al Wabra Wildlife Preservation, Doha

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Abstract

We evaluated results of over 4400 documented faecal parasitological examinations between 2000 and 2007 in more than 90 individuals of six species of Birds of Paradise (BoP). Between 2000 and 2007, 83.2% of investigated samples were negative for parasites, and the number of negative samples increased consistently over the years; in positive samples, the proportion of Capillaria sp decreased (from 100% to 4.8%) and that of Coccidia sp increased (from 0% to 67.5%). Differences in prevalence of endoparasites between species, epidemiological units (houses) and sexes were found. The Twelve-wired bird-of-paradise Seleucidis melanoleuca, which has the highest reported proportion of insects in its natural diet, had the highest prevalence of tapeworms, indicating a high propensity to ingest intermediate hosts. Coccidia sp were particularly prevalent in an epidemiological unit with high exposure to free-ranging birds. The number of offspring per female and year correlated with the percentage of negative samples taken in the according year and species. The results indicate that consistent antiparasitic management leads to a reduction of parasite species; that parasites with intermediate hosts are more difficult to control; that exposure to free-ranging birds should be minimized; and that a tight antiparasitic management potentially contributes to the improved breeding success in bird species.
Long-term monitoring of endoparasites in captive birds-of-paradise at Al Wabra Wildlife Preservation, Doha

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Right-hand running title: PARASITES IN BIRDS-OF-PARADISE
Left-hand running title: THE DEVELOPING ZOO WORLD

Received: 5 September 2007
ABSTRACT
We evaluated results of over 4400 documented faecal parasitological examinations between 2000 and 2007 in more than 90 individuals of six species of Birds of Paradise (BoP). Between 2000 and 2007, 83.2% of investigated samples were negative for parasites, and the number of negative samples increased consistently over the years; in positive samples, the proportion of Capillaria sp decreased (from 100% to 4.8%) and that of Coccidia sp increased (from 0% to 67.5%). Differences in prevalence of endoparasites between species, epidemiological units (houses) and sexes were found. The Twelve-wired bird-of-paradise Seleucidis melanoleuca, which has the highest reported proportion of insects in its natural diet, had the highest prevalence of tapeworms, indicating a high propensity to ingest intermediate hosts. Coccidia sp were particularly prevalent in an epidemiological unit with high exposure to free-ranging birds. The number of offspring per female and year correlated with the percentage of negative samples taken in the according year and species. The results indicate that consistent antiparasitic management leads to a reduction of parasite species; that parasites with intermediate hosts are more difficult to control; that exposure to free-ranging birds should be minimized; and that a tight antiparasitic management potentially contributes to the improved breeding success in bird species.

Key-words: breeding success, Capillaria, captivity, Coccidia, coproscopic examination, faecal samples, infestation, Paradisaeidae, Raillietina, tapeworms

INTRODUCTION
Birds of Paradise (BoP) have long attracted interest because of their display habits and exaggerated display plumes of adult males (Diamond, 1986). They are found in regions of eastern Indonesia, New Guinea and north-eastern Australia. Their main food consists of fruit, seeds and small insects. Differences in the diets between the species have been documented by Beehler & Pruett-Jones (1983); in particular, Twelve-wired bird-of-paradise Seleucidis melanoleuca ingest a higher proportion of insects than most other BoP species.

At Al Wabra Wildlife Preservation (AWWP), Doha, six species of BoP have been kept in the time between 2000 and 2007 (Table 1). As part of a prophylactic veterinary-care programme for these animals, faecal samples are taken and investigated for parasites on a routine basis.

Literature reports on the veterinary management of BoP are rare. The only report on parasites in captive BoP by Varghese (1987) documented a very high parasite infestation rate of up to 63% of all birds with coccidia and 67% of all birds with helminths in a sanctuary in Papua New Guinea. In this study, we evaluate the results of the coproscopic examinations performed between November 2000 and March 2007 in the AWWP BoP collection, thus expanding a previous evaluation of a shorter time period (Schulz et al., 2004). Although, in captivity, low mortality rates
are observed even with very high parasite infestation (Varghese, 1987), parasites represent an important mortality factor: of 40 BoP casualties observed at AWWP over the years, a maximum of 12 (30%) could possibly be attributed to intestinal parasites (C. Schwarz and S. Hammer, pers. obs), and parasite infestation could have a negative influence on disease susceptibility or breeding success. We wanted to find specific patterns for the different species, bird houses (the epidemiological units) and seasons, and to demonstrate the relevance of a strict antiparasitic treatment in relation to health and breeding.

MATERIALS AND METHODS
AWWP is currently housing a large number of BoP individuals, including, at the beginning of 2007, 1.1 Magnificent bird-of-paradise Cicinnurus magnificus, 16.9 King bird-of-paradise Cicinnurus regius, 24.16.2 Greater bird-of-paradise Paradisaea apoda (2.2.1 hybrid, 4.5.1 from the “Mainland” and 18.9 from Aru Island), 2.3.1 Lesser bird-of-paradise Paradisaea minor, 2.2 Red bird-of-paradise Paradisaea rubra, 6.1.1 Twelve-wired bird-of-paradise S. melanoleuca, 1.3.1 Flame bowerbird Sericulus aureus and 1.1 Long-wattled umbrellabird Cephalopterus penduliger. The Flame bowerbird S. aureus and the Long-wattled umbrellabird C. penduliger were also considered in this study as they are kept in the same epidemiological units as the BoP at AWWP.

The birds are kept individually or (for breeding) in pairs. All the BoP-species living in AWWP are polygamous (Diamond, 1986). Birds breed from February to June, with a peak in April. For breeding, males are brought into the females’ aviaries.

The birds are kept in large wire-fenced aviaries 9 m x 5 m x 4 m high in five different houses (B15, B16, B17, B18 and B19), covered with shade net, with soil flooring and tropical vegetation, and with a small attached concrete-floored feeding cage 2 m x 2 m x 3 m high. Each house has between eight and 21 aviaries. In the last three cages of B19, a group of ground-dwelling Pheasant pigeons Otidiphaps nobilis is kept in addition to the BoP. Some surplus males not used for breeding are kept in a large free-flying-aviary (B14) with several other birds from different species. The remaining individuals are kept in quarantine-like houses (P1 and P2) with concrete flooring. To minimise disease transmission, the keepers use different footwear for each house.

Since the end of 2000, faecal samples of individuals have been examined for parasites with increasing frequency until 2003 when a monthly routine screening was established. The samples were collected by the keepers from the feeding cages or, when no faeces could be found there, from the aviaries in plastic screw cap vials. The samples were directly transported to the in-house laboratory, where they were examined using standard sedimentation-flotation techniques and microscopic examination. Two to three grams of faeces, each, were used for flotation and sedimentation. For flotation, the faeces were mixed with 20 ml zinc sulphate (336 g zinc sulphate in
1000 ml distilled water) up to the brim in a flotation container, and allowed to flotate for 10–20 minutes; the flotating eggs were sampled on a microscope slide cover slip placed on top of the flotation container. For sedimentation, faeces were mixed with water and centrifuged for 5 minutes at 1350 rpm (EBA 20 centrifuge, Type 2002), and the sediment was transferred to a microscope slide. All examinations were performed by the same investigator using a Primolab Type G microscope. Findings were documented in a semi-quantitative way (0, +, ++, ++++, ++++). In the present analysis, results were encoded as either positive (including all +, ++, ++++, ++++) or negative (0). The parasites were identified as Capillaria sp, “other nematodes”, Raillietina sp and Coccidia sp (Eimeriidae). Birds with a positive result of “++” or higher were treated with fenbendazole, mebendazole, ivermectin, clazuril or praziquantel. The current, detailed dosing and treatment plan is given in Table 1.

In the time period evaluated in this study, there were more than 4300 documented faecal sample results, which could be related to individual birds in most cases. The samples from the free-flying aviary were almost always noted as a group-sample.

Additional data for the evaluation of the findings, like the number of adult males, females and newborns for every species, were taken from the AWWP stocklist management system. Data were encoded into EXCEL spreadsheets and statistically analysed applying simple non-parametric tests: the Spearman correlation coefficient (SCC) to examine a potential monotonous relationship between parasite load and breeding success and the Wilcoxon test to compare the parasite loads of males and females. The statistical tests were performed using the SPSS 15 statistical package (SPSS, Inc.). The significance level was set to \( \alpha = 0.05 \).

RESULTS

Development of general parasite infestation

Between 2000 and 2007, 83.2% of all samples were negative for parasites. Coccidia sp was found in 50.4% of all positive samples (8.5% of all samples analysed), followed by Capillaria sp in 28.5% (4.8%) and Raillietina sp in 20.2% (3.4%). The minimum (24/59=40.7%) number of negative samples was found in 2001 and the maximum (900/970=92.8%) number in 2005. Between these years, the number of negative samples increased consistently. Then the number stagnated for one year before decreasing in November 2006 up until February 2007, when only 72% of all samples taken were negative (Fig. 1).

Development of specific parasite infestations

When the relative prevalence of different endoparasites was examined (Fig. 2), the data revealed that the number of samples positive for Capillaria sp, which were the major problem in 2000, decreased from 100% of all positive samples in 2000 to merely 4.8% in February 2007.
Conversely, the number of samples positive for Coccidia sp increased from 0% in 2000 to 67.5% in 2006, before declining to 47.6% by the beginning of 2007. *Heterakis* sp were only identified in 2002 and 2003. The prevalence of samples positive for *Raillietina* sp increased between 2000 and 2003 from 0 to 30%, decreased by 2005 back to 0%, only to increase again to 28.6% by 2007.

**Development in particular bird species**

Through all the years, the Twelve-wire bird-of-paradise showed the greatest susceptibility to parasite infestations, with a major relapse in 2003, when only 29.7% (35/118) of the samples were negative. At the beginning of 2007, only 33.3% of the samples of the Twelve-wire bird-of-paradise were negative. A more positive development with respect to the endoparasite management was seen in the Magnificent bird-of-paradise. The prevalence of parasite infestation decreased consistently from 50% in 2002 to 0% in 2005. Since then, the Magnificent bird-of-paradise at AWWP have been free of parasites. Similarly, the Red bird-of-paradise were free of parasites until 2006, the Umbrella birds from 2004 till 2006, and the King bird-of-paradise were nearly free of parasites in 2006 (99.6% negative samples). Relapses in parasite prevalence in 2007 were observed in the King bird-of-paradise, the Greater bird-of-paradise, the umbrella birds and the Flame bowerbird.

**Development of separate epidemiological units**

Apart from the nursery and B17 in 2002, no house was ever free of parasites. The prevalence of parasite infections decreased more or less constantly in every house except B17. Since 2002, the general parasite prevalence in B17 has increased to 29.6%. The predominant parasites in this house were *Coccidia* sp (80.4% of all positive samples between 2003 and 2007). In the houses B14 (2006: 92.3%, 2007: 28.6%) and B16 (2006: 80.6%, 2007: 50%), there were drastic relapses in the per cent of negative samples in 2007 caused by *Raillietina* sp.

**Sex differences**

A difference between the parasite prevalence of males and females was evident in the Flame bowerbird ($P=0.031$; higher prevalence in females), the King bird-of-paradise ($P=0.063$; higher prevalence in males) and the Greater bird-of-paradise ($P=0.031$; higher prevalence in males).

**Parasites and breeding performance**

Figure 3 gives the number of offspring per female (NoOpF) correlated to the negative samples in per cent of all samples taken according to the year and species. The NoOpF is calculated from the number of born chicks divided by the number of adult females (all females of a species, i.e. breeding and non-breeding) in the corresponding year. Because there can be a lot of reasons of non-breeding, species that did not breed at all during the evaluation period (such as the Magnificent or the Twelve-wire BoP) were not included. The correlation between the NoOpF and
the percentage of negative samples was significant \((P=0.001, \text{ Spearman's correlation coefficient } = 0.767)\).

**DISCUSSION**

**Development of general parasite infestation**

Owing to hygienic standards and isolation of individuals, a decrease in the prevalence of endoparasites with time in wild-caught animals kept in captivity can be expected, especially if antiparasitic treatment is regularly applied. However, to our knowledge, no such pattern has been described in the bird literature so far. At AWWP, this expected pattern was evident (Fig. 1), but a completely parasite-free status of the population was not reached. Nevertheless, the management at AWWP (monthly routine screening, consistent treatment of all animals with a result above “+”) achieved a percentage of individuals negative at faecal examination of 83.3% between 2000 and 2007. In comparison, the captive BoP population managed at the Baiyer River Sanctuary (Mount Hagen, New Guinea) between 1977 and 1984 only had a percentage of parasite-free individuals of 20–40 % (Varghese, 1987). At Basel Zoo (Switzerland) in 1978, 25% of the birds with contact to free-living birds in one bird-house and 77% of all faecal samples (indoor and outdoor) were negative for parasites (Wagner & Rüedi, 1981). At the Tierpark Berlin-Friedrichfelde (Germany), Fietzke (1976) found 55.7% negative samples in 1966. These comparative data suggest that the parasite control regimen at AWWP is comparatively efficient, at least in comparison to published observations. However, the recent relapse in an increased number of positive faecal samples, for which no reason, such as a change in treatment routine, was evident, underlines that parasite screening must be performed consistently in a captive environment.

**Development of specific parasite infestations**

The change in the relative prevalence of nematodes and cestodes can probably be explained by the difference in life cycles. Parasites without intermediate hosts should be easier to eradicate than parasites with intermediate hosts; for the latter group, there will be a more deliberate intake of dangerous material (infested intermediate hosts) by the birds, whereas the intake of coccidia and nematode eggs – although these will be particularly difficult to control in exhibits where “natural” soil is used as flooring substrate (Lloyd, 2003) – should be less deliberate but rather accidental. As, owing to different experiences, a soil flooring seems to be necessary for the well-being and especially the breeding success in captive BoP (Searle, 1980; Jensen & Hammer, 2003), an environment that is easier to clean and control hygienically, such as tiled or concrete floors, is not a practical option for these animals. Evidently, the alternative possibility that certain groups of parasites are less reliably controlled because of a comparatively less efficient drug or because of drug resistance should also be considered.

**Development in particular bird species**
Differences in parasite prevalences between BoP species have also been demonstrated by Varghese (1987) for *Cicinnurus magnificus* and *Paradisaea raggiana* as compared to other BoP. Reasons for interspecific differences in parasite load could not be given in that study, and they are also difficult to give for the AWWP situation. The only exception might be the Twelve-wire bird-of-paradise at AWWP. This species had a higher prevalence for *Raillietina* than the other bird-of-paradise at AWWP. The Twelve-wire bird-of-paradise is the BoP species with one of the highest recorded percentage of insects in its natural diet (50%) and even searches for prey by digging in the ground (Beehler & Pruett-Jones, 1983). Tapeworms such as *Raillietina* are dependent on insects as intermediate hosts (Reid *et al.*, 1938; Mond *et al.*, 2001). Therefore, it can be suspected that the particular feeding habits of this species, most likely also performed in the semi-natural, soil-covered aviaries at AWWP, led to a particular ingestion of potential intermediate hosts and the high load of tapeworms observed. In order to interrupt the life cycle of the tapeworms, the use of insecticides and insect-proof facilities have been suggested (Lloyd, 2003). Another suggestion might be to feed more insects (either dead or alive but in suspended cages used for feeding) bred for feeding under controlled conditions in order to reduce insect uptake from the enclosures; whether such an approach would actually help to decrease the prevalence of tapeworm infestation would have to be tested.

**Epidemiological units**

When evaluating the data with respect to differences between the epidemiological units (the bird houses), the constant increase in the percentage of positive faecal samples in B17 was striking. This increase was mainly caused by increasing cases of *Coccidia* infestation. As described by Wagner & Rüedi (1981), *Coccidia* can be transferred by free-living birds. Contact with these free-living animals is usually restricted in zoological institutions and, if at all, mostly occurs through the contamination of aviaries with free-ranging birds’ faeces (Wagner & Rüedi, 1981; Lloyd, 2003) as these are dropped from above the aviary. Therefore, intact roofing is an important prophylactic measure against parasite transmission from free-ranging birds. A closer inspection of B17 showed that in this house, the shade-net that covered the external aviaries had a particularly compromised integrity compared to similar nets of the other houses. The deterioration of this cover was most likely a gradual process, leading to a gradual increase in *Coccidia* prevalence in this house. As a direct measure, the roof cover was repaired during the course of this data evaluation. Different infestation levels between different epidemiological units within one zoological facility should be accounted for, for example by restriction of movement of animals between these units and the practice of within-facility quarantine.

**Sex differences**

Differences in parasite load between the sexes have been described in wild populations of Gouldian finches *Erythrura gouldiae* (Tidemann *et al.*, 1992) and Dark-eyed juncos *Junco hyemalis*.
(Deviche et al., 2001). In the finches, juvenile females had a higher infestation of air-sac mites than juvenile males. In Indian poultry, *Raillietina* infestation peaked particularly in females, during the breeding season, which the investigators suspected to be the result of reduced host defence capacity owing to the high energetic investment in reproduction (Mond et al., 2001). In our data, the differences in the King bird-of-paradise, the Greater bird-of-paradise and the Flame bowerbird were significant over the whole year; in the case of the Flame bowerbird, the same explanation (higher energetic requirements potentially reproducing females resulting in decreased parasite resistance) could be used. However, in the other two species, males, not females, were affected more intensely. This may be owing to the increased stress (Lafferty & Kuris, 1999; Saeij et al., 2003; Jokela et al., 2005) experienced by the male individuals, which were shifted between aviaries more often: breeding pairs at AWWP are brought together by placing the male into the female’s aviary; additionally, AWWP enhances intraspecific male competition by housing one male each on either side of a female to encourage breeding behaviour. The information extracted in this study will induce a more careful monitoring of the respective individuals of the different species.

**Parasites and breeding performance**

Only few studies have investigated the influence of parasites on the breeding success of wild birds; most of these describe a correlation between breeding success and blood parasites (Ilmonen et al., 1999; Merino et al., 2000; Sanz et al., 2001; Marzal et al., 2005; Tomas et al., 2007). Hudson (1986) performed an experiment in free-living Red grouse *Lagopus lagopus scoticus*, including a control group treated with an anthelminic drug; the ratio of young to old birds seen in a year was used as an estimate of breeding success. He found a significant, negative correlation between breeding success and helminth numbers. A similar correlation could also be shown in our data. Although in our case, the evidence is correlational rather than causal (controlled, experimental studies would have to be performed for that), it provides an additional incentive to reduce parasite loads in birds that are part of a breeding program. In many bird species, it has been described that females actively choose their male reproduction partner (Catchpole, 1980; Andersson, 1982; Kodric-Brown, 1985; Pruett-Jones et al., 1990a), using indicators of its health status, especially its parasite status (Pomiankowski, 1987; Pruett-Jones et al., 1990b). It is not possible to test such an effect in the captive birds at AWWP, as partner choice of females was limited.

**Conclusion**

As a result of our evaluation, several propositions for husbandry measures were made. In order to avoid the transfer of parasites with an infected bird to a new aviary, at least three consecutive faecal samples should be negative prior to any transfer of birds. Birds receiving antiparasitic medication should be kept in the concrete-floor feeding cages without access to their aviaries, to avoid shedding of potentially infectious stages of parasites (e.g. *Raillietina* proglottids) as a consequence of the deworming medication. Our observations during antiparasitic treatment
applied to the food of the birds showed that substance applied to the fruit rather than the pelleted part of the diet would most likely be ingested with greater consistency across individuals; inconsistent consumption of the medication will result in inaccurate dosing and reduced success of the antiparasitic program. Although the effect could not be tested in our evaluation, it is believed that the instigation of re-testing and repetitive treatment until a negative faecal result is obtained (Table 1) contributed significantly to the success of the AWWP parasite control program. Because there is no correlation between the parasite load and the number of eggs, oocysts or parasites detected in faeces (Marti & Koella, 1993; Rapsch et al., 2006), all positive animals, including those with a finding of “+” only, should be treated. Over time, resistance of parasites against certain drugs may develop. In practice, such resistances are not tested for; however, a regular change in medication is usually considered preventive against such developments. In birds, however, due to varying species-specific tolerances against major antiparasitic drugs such as fenbendazol (e.g. Bonar et al., 2003) or ivermectin (e.g. Perpinan & Melero, 2003), choices for a rotating treatment system may be limited. Due to an absence of negative reports on the use of both fenbendazol and ivermectin in birds of paradise, these drugs are used on an alternating basis in this collection (Table 1).

ACKNOWLEDGMENTS
This project was carried out as part of the Zoo Research Camp (ZRC) 2007, organized by AWWP and the Division of Zoo Animals, Exotic Pets and Wildlife of the Vetsuisse Faculty, Zurich. The authors thank Sheik Saoud Mohamed Bin Ali Al-Thani for his support of the ZRC, as well as the Vetsuisse Faculty and the “Gesellschaft Schweizer Tierärztinnen und Tierärzte” for additional financial support, Felix Grimm and Hubertus Hertzberg for support with the literature research and answering our questions about the parasites, and Dean Tugade for his patience with all our questions about the bird-of-paradise at AWWP. We thank three anonymous reviewers for their comments on the manuscript.

PRODUCTS MENTIONED IN THE TEXT
Clazuril: anti-parasite medication, manufactured by Appertex, Janssen Cilag GmbH, Neuss, Germany.
EBA 20: small-sample volume centrifuge, manufactured by Andreas Hettich, D-78532 Tuttingen, Germany.
Fenbendazole: anti-parasite medication, manufactured by Ascapilla, Chevita GmbH, Pfaffenhofen, Germany.
Ivermectin: anti-parasite medication, manufactured by Ivomec-S, Merial GmbH, Hallbergmoos, Germany.
Mebendazole: anti-parasite medication, manufactured by Telmin KH, Janssen Cilag GmbH, Neuss, Germany.
**Praziquantel:** anti-parasite medication, manufactured by Cestocur, Bayer Health Care, Leverkusen, Germany.

**Primolab, Type G:** microscope, manufactured by Gundlach, DK-8462 Harlev, Denmark.

**SPSS 15:** statistical programming, developed by SPSS, Inc., Chicago, IL 60606, USA.

**REFERENCES**


**TABLE LEGEND**

Table 1. Anti-parasitic treatment plan for birds of paradise currently in use at Al Wabra Wildlife Preservation. Treatment is done based on the individual positive results of the routine monthly faecal checks and repeated based on positive “faecal re-testing” results. “Fecal re-testing” is performed 14 days post-treatment to evaluate efficacy of the antiparasitic treatment. Individual treatments are repeated until negative results are achieved.

**CAPTIONS**

Fig. 1. Prevalence of endoparasites in faecal samples of birds of paradise at Al Wabra Wildlife Preservation.

Fig. 2. Prevalence of parasite groups in per cent of all faecal samples tested positive for parasites.

Fig. 3. Number of offspring per female (NoOpF) in relation to the percentage of faecal samples (grouped per year) for breeding species of birds of paradise at Al Wabra Wildlife Preservation. The correlation was significant ($P=0.001$, Spearman’s correlation coefficient = 0.767).