AVOIDING FEATHER DAMAGE IN HOSPITALISED BIRDS

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INTRODUCTION

The aim of this paper is to present common types of feather damage that occur in a hospital setting and present the methods we use to overcome some of these. It is not the intention of this paper to review the types of feathers, feather growth or moulting. For more information on these topics you are advised to consult previous AAVAC proceedings (Gartrell, 1999).

One of my first cases in practice was the successful treatment of a rosella with heavy metal poisoning but its tail feathers broke in the cages I had available. While I was congratulating myself on the successful resolution of the life threatening condition, the owners were disappointed in how their bird looked. While this may seem like a minor issue in companion animal medicine, in some species damage to the primary feathers may reduce reproductive success (Fitzpatrick, 1998; Barbosa et al., 2003). For racing pigeon flyers, maintaining feather plumage is essential for the sport performance of their birds. For falconry, good flight performance is again essential (Samour, 2006). In wild bird rehabilitation, loss or damage to feathers may result in prolonged rehabilitation periods, decreased fitness and reproductive success and increased mortality (Swaddle et al. 1996).

The flexibility, thermal insulation, pigment deposition during feather formation, waterproofing and structural quality of the feathers depend on adequate nutrition (Klasing, 1999; Schreiber et al., 2006). Dark melanistic feathers are more durable than non-melanistic feathers (Cooper, 2002). Stressors can influence the structural strength of feathers via the effects of corticosterone during the growth of the feather (DesRochers et al., 2009).

Maintenance of the feather depends on the combination of regular preening, and protective secretions produced by the epidermis (Menon and Menon, 1999) and uropygial gland (Sandilands et al., 2004; Versteegh et al., 2006; Reneerkens et al., 2008; Haribal et al., 2009). The role of powder down fragments in feather protection is suggested by the poor quality of the feathers of cockatoos with PBFD induced damage to the powder down (Cooper, 1994). However I was unable to find any direct studies of the powder down.

In this paper I will examine the following types of feather damage that can occur in hospital:

- Damage to primary feathers
- Feather matting from food and faeces
- Damage to feather structure from hands, topical agents and heat
- Stress moulting
- Loss of waterproofing in sea birds
Our group has developed and borrowed techniques to try to deal with these problems. They are mostly low-tech, simple fixes but I hope that these may be of some benefit to you and stimulate discussion of this often over looked area.

**PRIMARY FEATHER DAMAGE**

Damage to the primary feathers of the wing and tail (remiges and retrices) is a common complication of hospitalisation. This is particularly important in long tailed birds such as macaws, poultry (such as pheasants) raptors, some passerine birds and columbiformes.

Damage often occurs at prior areas of weakness in the feathers (such as stress bars) and is exacerbated by:

- poor handling of feathers;
- abrasive wiring on cage floors or walls;
- matting of feathers in faeces and urates; and
- adhesive bandage material.

Removal of primary feathers for surgical preparation is best avoided due to the high energetic cost of regrowing these feathers, the increased chance of damage to the growing feathers, and the extended period of hospitalisation required for wild patients. The primary feathers also insert directly into the periosteum of the appendicular skeleton (Cooper, 1994) and removal is painful.

Damaged primary feathers can be repaired by imping, which is the grafting of donor feathers onto the shaft of the damaged feather, and was developed in falconry. A good description of the technique of imping is given by Samour (2006). It is far preferable however to avoid damage in the first place.

Key factors in avoiding damage to the primary feathers are straightforward and include:

- Using absorbent towels rather than newspaper in cages
- Provide perches of adequate height to allow the tail feathers to sit off the ground
- Bandaging damaged wings to keep the primary feathers clear of the ground and the birds feet
- Use of non-adhesive bandaging materials
- Keeping the cage clean
- Gentle handling that takes account of the feathers natural position
- Cleaning blood and exudates from feathers post-operatively with warm water
- Using tail protectors

Tail protectors are simply a protective sheath that is placed around the tail and stapled to the shafts of the retrices. In the past we made tail protectors from old radiographic film but have moved to using simple plastic zip-lock bags. These are lighter, cheaper and still protective (plus the uni has shifted to digital radiography). In our practice these are routinely applied to most birds of prey and longer tailed parrots such as macaws.

**FEATHER MATTING FROM FOOD AND FAECES**

Spillage of food material or regurgitation onto the feathers of the face and neck can result in matted material accumulating around the commissures of the beak. In seabirds this can be enough to result
in loss of waterproofing as water tracks in under the damaged feathers and spreads out down the body. In companion birds, especially nectarivores and nestlings this matted food material can predispose to superficial Candidiasis (Gelis, 2006).

This kind of feather damage is best prevented by gentle washing of the facial feathers with warm water or a low pressure water jet (eg Dental water pick). Care must be taken not to simply rub the food material deeper into the feathers. Severely matted plaques must be plucked and the feathers allowed to re-grow.

At the other end of the bird, matting of the vent feathers occurs with diarrhoea, polyuria or any condition that alters the ejection of droppings cleanly from the vent. This occurs in obesity, cloacal prolapses, abdominal swelling for any reason or in birds that are recumbent. Superficial dermatitis of the vent margin is commonly seen in the intensive poultry industry, where it is known as vent gleet and has been associated with overcrowded and unhygienic conditions. Daily cleaning of the vent with warm water in patients that show vent matting can prevent the progression to vent gleet. In some severe cases, vent matting can result in faecal and urinary obstruction and can be fatal. If vent gleet has occurred then the feathers around the vent should be plucked and barrier creams used to prevent faecal and urate contamination of the dermatitis (Lumeij, 1994).

**DAMAGE FROM HANDS, TOPICAL AGENTS AND HEAT**

It is widely accepted that oily material can be transferred from hands of operators to bird’s feathers. Some veterinarians will dust their hands with talcum powder before handling birds (Doneley et al., 2006). We recommend simply washing hands between patients as this has the dual purpose of minimising nosocomial infections as well as the transfer of sebaceous oils to a bird’s plumage. We also use towels to wrap most birds as this minimises disruption to the feathers, and prevents transfer of material to the plumage. Our rule of one towel per bird does create a lot of washing, but a birds towel can be hung on the front if its cage and used until it becomes soiled.

Topical medications should be used sparingly in birds to prevent plumage contamination, particularly if they are oil based (Cooper, 1994). I advocate avoiding all spray based medications on the basis that they all leave a residue in the feathers that damage waterproofing and feather structure.

Surgical preparation for birds involves plucking a minimum sterile field and not removing primary feathers unless damaged. Surgical preparation solutions that contain detergents should be used sparingly, attempting to avoid contamination of the plumage where possible. We clean blood and exudates from feathers post-operatively with warm water.

Radiant heat sources can destroy the mechanical structure of feathers and result in loss of quality. These devices must be kept far enough away from the plumage so that they do not singe the feathers. We have seen penguins that have lost their waterproofing by over enthusiastic application of heat lamps and these birds have had to moult to recover.

**STRESS MOULTING**

There is an antipredator defence of many birds that involves the rapid loss of large amounts of feathers. This is particularly common in Columbiformes and poultry and can result in the wide-scale loss of contour feathers. This is disastrous in a racing pigeon and is guaranteed to result in a very grumpy client. For this reason, poultry should never be grabbed by the tail.
To prevent stress moulting occurring, the birds should be handled securely wrapped in towels or in a confident firm enclosing grip rather than a clutching one.

On an anecdotal note we have seen native wood pigeons (kereru - Hemiphaga novaeseelandiae) in New Zealand lose all their primary feathers one to two weeks after an intensely stressful event or hospitalisation. The exact cause and mechanism of this loss is still to be determined but has made us cautious in rapid release of these birds.

LOSS OF WATERPROOFING

Any veterinary care of wild seabirds, shorebirds and waterfowl must have the maintenance of waterproofing as a key outcome. In a recent case where we looked after 20 godwits with capture myopathy loss of waterproofing resulted in the deaths of several birds after release (Ward JM et al In prep).

Maintaining waterproofing in hospital can be challenging, especially when birds have undergone surgical procedures or bandaging is required. We have also seen several cases of mechanical feather damage from heat or over-washing resulting in loss of waterproofing (see earlier section). If the structure of the feathers is damaged the birds will need to moult and re-grow new feathers before waterproofing can be achieved.

Wherever possible we encourage the maintenance of waterproofing by the following:

- Providing bathing or swimming facilities for aquatic birds
- Handling birds with clean hands and towels
- Misting of birds which cannot be swum. This is particularly useful after feeding and handling as it encourages a bird to preen. Clean water only is used for misting.
- Removing spilled material (food, faeces, blood and exudates) from feathers as quickly as possible

In some instances, birds are sent to us from members of the public, or wildlife rehabilitators where the waterproofing is damaged by oil or other chemicals on the coat. Only in these cases will we progress to washing the birds. Bird washing is complicated by the fact that detergents strip from the feather the products secreted by the skin and uropygial gland. Further there is a loss of surface tension of the feathers complex structure resulting in immediate loss of waterproofing. As a result surgical scrubs containing detergents should be applied sparingly in birds.

The following detailed material on bird washing is taken directly from our Oiled Wildlife Response SOP (McConnell, 2009) that relates to cleaning feathers with oil contamination but can apply to any noxious topical agent that adheres to feathers and removes waterproofing. It can take a number of weeks for birds to fully restore the waterproofing abilities of their plumage.

Waterproofing is achieved by preening activities, whereby the bird repairs the plumage structure. Preening is encouraged by the presence of moving water; hence the sooner birds can remain permanently outdoors with access to water, the sooner they will regain their waterproofing. Note that contamination of plumage continues to be an issue through the rehabilitation phase. Potential avenues for contamination are from fish oil during feeding, from natural oils or hand creams via the handler, or from secretions via any wounds that the bird may have.
Cleaning:

The process of cleaning, rinsing and drying can be an exhausting experience for birds. Therefore it is important to conduct these steps in a professional and efficient manner to minimise stress. Plumage must be cleaned and rinsed thoroughly to remove all traces of oil and detergent without damaging feather structure. The cleaning phase culminates in birds entering the drying area and then postcleaning stabilisation area to regain strength before moving into the rehabilitation phase.

The detergent of choice varies depending on oil type. During the first day of cleaning you might like to trial a few different detergents to ascertain which performs the best under the circumstances. These tests are best conducted on sample feathers. Detergents trialed must:

- Be able to remove oil without damaging feathers or irritating skin or mucosal surfaces
- Be non-toxic
- Leave no residue

Tergo Birdwash® is the detergent stockpiled in regional response trailers and at Massey University for oiled wildlife response.

Water for washing and rinsing should be 40 – 41.5°C in temperature.

The use of ‘hard water’ during cleaning can extend the length of time it will take for individual birds to regain waterproofing due to deposits of conjugated detergent particles and calcium carbonate particles on the feathers. Softened water (30-50 mg calcium carbonate per litre) should be used for washing for optimal results. This is particularly important for those species which need to spend considerable lengths of time in the water.

Washing:

- Administer pre-cleaning warmed oral fluids before washing to mitigate dehydration. These fluids should be administered approximately 20 minutes before cleaning commences to avoid regurgitation during the cleaning process.
- Gentle, but firm handling of the bird by the ‘holder’ will minimise stress to the bird and allow the ‘washer’ to complete the wash process as effectively as possible. The ‘holder’ is fully responsible for monitoring the birds condition throughout the wash process and needs to ensure that the birds head remains above water. Generally the birds head should face slightly downwards to prevent water from entering nostrils and the tip of the beak should be held.
- If necessary, pre-treat tar patches with a minimal amount of warmed (39°C) methyl oleate or canola oil. Massage into tarred area until it softens. This usually takes 4 – 5 minutes. Precleaning agent must be rinsed or wiped off as soon as possible to avoid further damage to the feathers. Under no circumstances should a pre-cleaning agent be left on plumage for longer than 15 minutes.
- Select an appropriate sized tub for the individual bird. The tub should be deep enough to allow for the entire body (except the head) to be submerged, spacious enough to allow the person cleaning to move without undue restriction, while minimising the amount of water required.
- Select an appropriate detergent using as little as necessary to effectively clean, while minimising detergent residue to be rinsed.
- Set up three tubs ready with warm (40-41.5°C) softened water and detergent
- Clean the bird through a succession of tubs with decreasing concentrations of detergent – starting at 5% for the first few tubs, then 3%, then 1%. Move the bird between water changes as the tub water becomes oily.

**General washing rules:**
- Work against the grain for soft body feathers
- Work with the grain for primary and secondary feathers
- Do not rub feathers
- The washer should follow the systematic process outlined below to ensure all areas of the body are cleaned before the bird moves to the rinsing phase.

1. Starting with the chest – ‘lift’ the feathers against the grain to allow detergent penetration to the skin. Then move to the birds back and continue this action.
2. Attention then moves to the wings, where each primary and secondary feather is run between forefinger and thumb to ensure detergent penetration.
3. The side of the tub can be used to steady the bird while the opposite wing is extended.
4. Once most of the oil is removed from the body, the head is ready to be cleaned and at this point the handler swaps to the rear end of the bird, while the washer holds the tip of the beak.
5. The washer then uses a measuring jug to pour water over the head – a little water in the eyes/nares is not a problem. Alternate between pouring soapy water over the head and using a toothbrush to lift the feathers against the grain to allow penetration to the skin. Once soapy water runs clear, then fresh water is poured over the head until no further discolouration or detergent bubbles are seen. A check should now be made by running a cotton tip just below the eye. If there is any discolouration cleaning needs to continue on the head until all sign of pollutant is removed. Some washers find that a Waterpik® is useful to clean the face.
6. Once the head is clean check inside the mouth for oil and remove with a cotton tip.
7. The last part of the body to be washed is the neck – lower the bird as low as possible in the water and use the same technique as on the back and chest to wash the neck.
8. Now move the bird to the last soapy tub for a quick full body once over before it is ready for rinsing. Effective cleaning for a medium sized bird takes between 20 and 40 minutes.

**Rinsing**

As with the previous phase, water for rinsing should be 40 – 41.5°C in temperature and softened (test at 30-50 mg calcium carbonate per litre). The water supply for rinsing should however be pressurised allowing for both 275kPa and 400kPa sprays.

**General notes about rinsing:**
- Once washing is complete, rinsing needs to occur immediately.
- As with washing rinsing of soft feathers occurs by directing the spray of water against the grain of feather growth, but with the grain for primary and secondary feathers.
- Water will bead off feathers and down will fluff up as soon as detergent is rinsed.
from them. Note: the handler’s gloves will need rinsing after each section of the bird is complete to ensure that recontamination is not occurring.

• Gentle, but firm handling of the bird by the ‘holder’ will minimise stress to the bird and allow the ‘rinser’ to complete the wash process as effectively as possible. The bird’s head should face slightly downwards to prevent water from entering nostrils.
• The 400KPa spray can be used for all parts of the body but the head where the 275KPa spray is used.
• Effective rinsing for a medium sized bird can take between 20 and 40 minutes.

Follow the steps below to ensure all traces of detergent are removed from the bird’s plumage.

1. Start by rinsing the back and the top side of the wings, then turn the bird over to access the chest area and the underside of the wing. Feathers on the breast are the densest and need particular care.
2. Be particularly diligent around skin folds (between legs and body, and between wings and body).
3. Once the body has been rinsed, rinse the head by spraying against the grain while being very careful to ensure the spray does not hit the eye.
4. Now closely inspect under the plumage of the entire body for ‘wet spots’ and re-rinse these areas as necessary. Note – wet spots will be evident as patches of ‘soggy’ feathers and damp skin.
5. Once no further wet spots can be found, finish by re-rinsing the handling areas and the head.
6. The bird is then wrapped in a towel before being placed in a drying pen.

Cleaning Errors

From time to time the following problems may occur during cleaning:

• Aspiration of contaminated (by oil or detergent) water
• Aspiration of regurgitated food or fluids
• Hypothermia – the holder needs to watch for shivering.
• Exhaustion
• Plumage damage
• Asphyxiation
• Other injuries

It is the responsibility of the ‘holder’ to monitor the bird’s condition and to halt the cleaning process if any problems are identified. If the cleaning process is stopped before completion the bird should proceed to solitary drying confinements and cleaning should resume only once the bird has re-stabilised (usually the following day).

Note that the loss of some soft feathers and down is normal during the cleaning process; down will re-grow in 2-3 days in areas where there are gaps in the plumage.

It is useful to have a white board in the cleaning room where notes about particular individuals can be written as observations are made. These notes should later be transferred to the birds individual record.
**Drying**

Birds will be exhausted as they exit the rinsing area. For this reason, special attention to the birds comfort should be afforded during drying. In particular thermoregulatory stress needs to be eliminated during this period and frequent surveillance should be undertaken to check for signs of heat stress (wings outstretched and/or panting indicate that birds are receiving too much heat / Shivering indicates that they are not receiving enough). Should these signs be noted, temperature should be moderated accordingly. Oral hydration may need to be administered during drying depending on time elapsed since last re-hydrated. Individual medical records should be consulted for notes on hydration routine.

Drying is largely a benign process whereby birds are held in drying pens with clean net bottoms and shade-cloth (or similar) covers. The drying room temperature is regulated between 25 - 30°C and heater-blowers or heat lamps are used to dry remaining water droplets from clean plumage by moving large volumes of moderately warm air. Ventilation is important during this phase to allow water vapour to escape and prevent the temperature from progressively increasing. The drying room should be quiet and darkened to ensure a restful environment for the birds and fresh drinking water should be provided.

Individuals may be dried in solitary pens or communally with others of the same species or compatible species. Care must be taken not to overcrowd communal pens. Indoor holding area density should allow 0.6 – 1.0 m² per bird. Routine checks should be made of all birds for signs of heat stress. Heat supplies need to be adjusted accordingly.

**References**


A CRITICAL ANALYSIS INTO THE CAPTIVE MANAGEMENT VARIABLES SURROUNDING THE OCCURRENCES OF REGURGITATION IN HAND REARED SPIX’S MACAWS CYANOPSITTA SPIXII AT AL WABRA WILDLIFE PRESERVATION

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ABSTRACT: The Spix’s macaw (Cyanopsitta spixii) is one of the most critically endangered bird species in the world and in 1990, the Brazilian Nature Conservation Authority established a permanent committee to oversee the captive breeding of about twenty individual Spix’s macaws held in various locations throughout the world. Al Wabra Wildlife Preservation (AWWP) successfully bred ten Spix’s macaws in the 2005 and 2006 breeding seasons but intermittent episodes of post-feeding regurgitation in hand-raised chicks prompted the need to better understand and monitor the nutritional and physiological requirements of growing nestlings. We undertook a critical analysis of the feeding, growth and health data recorded for each individual hand-raised chick in order to ascertain and rank the possible causes of regurgitation in chicks. Parameters such as the total daily food intake, growth curves, nursery room climate (temperature and humidity) and nutritional requirements were investigated as well as any health issues. Chicks attained a maximum body weight of 375 ± 25 g at 45 days and then gradually lost weight until they reached a weaning BW of 300 ± 30 g. The maximum daily volume of food that each chick received was 101 ± 29 g and this occurred at 42 days of age. This was also the age that experienced a peak in post-feeding regurgitation episodes. The total daily feed intake as a percentage of BW peaked (83.1 ± 12.3%) at day 3 of age and dropped to 30.1 ± 2.3% by day 45 and then to 19.6 ± 1.1% at day 92. Detailed analyses of the 2005 and 2006 hand rearing records indicate that the regurgitation episodes may primarily be the result of over-feeding (meal volume overload) during the second trimester of hand rearing. It is predicted that smaller meals during the period where chicks are attaining their maximum body weights may contribute to a decrease in the occurrence of regurgitation episodes in hand reared Spix’s macaws.

INTRODUCTION

The Spix’s macaw Cyanopsitta spixii is one of the most critically endangered bird species in the world (IUCN, 2007) and presumed extinct in the species natural range in the Caatinga region of northeast Brazil. Trapping and the loss of the native “caatinga baiana” or savannah scrubland, habitat contributed to the species decline (Collar, 1997) and the last known wild individual disappeared at the end of 2000. Fortunately, in 1990, the Brazilian Nature Conservation Authority (IBAMA) established a permanent committee for the recovery of the Spix’s macaw and there are currently 68 birds in an international managed captive breeding program. Al Wabra Wildlife Preservation (AWWP)
in the State of Qatar, owned by Sheikh Saoud Bin Mohd Bin Al-Thani successfully bred fourteen Spix’s macaws in the 2005, 2006 and 2007 breeding seasons, and has a total current captive population of 52. The intention of the AWWP Spix’s macaw captive breeding program is to provide individuals for potential future release into their native habitat in North-eastern Brazil.

In 2004, proventriculit dilatation disease (PDD) was confirmed responsible for the death of three adult Spix’s macaws at AWWP. Despite intensive treatment all three birds developed advanced gastro-intestinal or central nervous disease and died between April 2004 and January 2005 (Hammer et al., 2005). These three birds were part of a group of twenty five individuals that had been transferred from a facility in the Philippines to AWWP in November 2003 and January 2004. Fortunately, in-contact birds have not developed clinical signs of PDD but irregular occurrences of transient post-feeding regurgitation in hand-reared chicks were of concern in a PDD affected population, and prompted the need to better understand and monitor the feeding and physiological requirements of hand-reared nestlings. In this paper we present a critical analysis of the growth data recorded for each individual hand-reared chick reared in 2005 and 2006 in order to ascertain the possible causes of the regurgitation in chicks. Parameters such as the total daily food intake (TDFI), growth curves, environmental factors (temperature and humidity) and nutritional requirements were investigated as well as underlying possible health issues.

**MATERIALS AND METHODS**

**Al Wabra Wildlife Preservation hand-rearing facility**

AWWP is a privately owned wildlife breeding and research facility located on a 2.5 km² area close to the town of Al Shahaniyah in central Qatar\(^1\). The facility has a high success rate in breeding difficult and sensitive animals and it is not open to the visiting public. The experienced staff have successfully bred and hand-reared several other endangered avian species. Due to the extremely high environmental temperatures (up to 45°C) reached in the Qatari Desert during the summer months, hand-reared birds were held in separate temperature-controlled incubation and hatching rooms and then onto rearing rooms maintained at 25°C to 28°C. Room temperatures were monitored and recorded up to ten times per day. For the first 35-40 days the Spix’s macaw chicks were housed inside a brooder where the temperature and humidity levels were monitored. Brooder temperature for newly hatched chicks began at 36.5°C and gradually and carefully decreased to a room temperature of approximately 28°C by 35 days of age. From here the chicks were moved to a larger holding cage, where the room temperature was maintained at 25°C to 28°C.

Strict quarantine regulations were followed when working with the Spix’s macaw and this included the requirement for staff to change clothes and shoes before entering the nursery area. Staff were also required to observe strict hygiene controls including hand-washing between stations within each room of the facility.

**Hand-rearing formula**

Several commercially available hand-rearing formulas including Kaytee Macaw Exact Hand Feeding Formula (Kaytee Products Inc, Chilton, WI, USA) and Nutribird A19 and A21 (Veresele-Laga, Deinze, Belgium) were used to feed nestlings. Kaytee Exact Macaw Formula was the preferred formula to use.

\(^1\) http://awwp.alwabra.com
for rearing larger macaw species and was used to feed the first three chicks (chick 1-5158, chick 2-5170 and chick 3-5829) reared during the 2005 breeding season. Nutribird hand rearing formula was used to feed the seven chicks (chick 4-6353, chick 5-6347, chick 6-6359, chick 7-6200, chick 8-6212, chick 9-6299 and chick 10-6293) reared in 2006. Macaw chick 4-6353, chick 5-6347 and chick 6-6359 were fed Nutribird A19 until they were 3 weeks of age and then A21 thereafter. Whereas chick 7-6200, chick 8-6212, chick 9-6299 and chick 10-6293 were only fed Nutribird A21. Nutribird A19 contains slightly more fat than Nutribird A21 and, according to the manufacturer, is suitable for young birds like macaws, eechus parrots (Eclectus roratus) and African grey parrots (Psittacus erithacus) that need a concentrated energy diet. All formula, pellets and processed foods were checked before use to ensure the use by dates had not expired as well as ensuring that all foods had been stored correctly and were not contaminated.

Record keeping

All chicks were assigned a unique identification number and name, this and other relevant data such as the chick’s parentage, hatch date and hatch weight was recorded on a nursery record sheet (Fig 1). This subsequently became a part of the Individual Record (IR) of each bird along with health and management data. Before and after each feeding, each chick was weighed and body weights recorded for each feed along with the chick’s demeanour and other observations such as the temperature and humidity. For reference, the mean body weight of adult Spix’s macaws at AWWP was 318 g for males and 288 g for females and a pair was offered 120 g of a maintenance diet per day. In addition birds may or may not consume supplementary fresh fruit and vegetables provided daily. It is estimated that individual adults consume approximately 30-40 g of maintenance diet per day.

Hand rearing methodology

For the first 3-5 feeds newly hatched chicks were fed a mixture of sterile lactated Ringer’s solution containing 1% glucose and a parrot-specific Lactobacillus species (Institute for Avian Disease, LMU, Munich, Germany). This was provided every 1½ - 2 hours to prevent dehydration. After these initial fluid feeds, the neonatal chicks were gradually introduced to increasing concentrations of formula and by 7 days of age each feeding consisted of formula mixed 25% (w/w) with bottled water. This was increased to a mixture of 27-30% (w/w) with water at between 30-50 days of age. Feeding formula was mixed to a smooth consistency and warmed to a temperature of 40–42°C for young chicks and 36–40°C for older chicks. Chicks were fed by a 3 mL transfer pipette for the first fourteen days before switching to tube-feeding using a syringe and soft silicon tubing. Disposable surgical gloves were used for mixing feeds and handling chicks. All feeding equipment was cleaned and disinfected along with all bench tops and floors on completion of each feed.

All water used for rinsing rearing equipment, washing fruit and vegetables, drinking water and formula preparation was filtered through a “So Safe” triple filter (triple ultraviolet water purifier, So-safe Products LLC, Sharjah, United Arab Emeritas), which involved a primary 5 µm pre-filter, a 1 µm activated carbon filter and final UV sterilisation.

Health and Disease Monitoring

It was normal practice for all chicks to have buccal and cloacal swabs taken weekly for microbiological culture. Swabs were taken immediately before tube feeding or before feeding solids. Food samples were also regularly sampled for microbiological culture. All samples were taken to the AWWP laboratory immediately after collection. Signs of possible food aspiration or illness such increased
respiratory sounds, sniffing, snicking, coughing, abnormal behaviour were investigated by veterinary examination and microbiological culture where indicated.

**RESULTS**

Chicks attained a maximum body weight of 375 ± 25 g at 45 days and then gradually lost weight during the weaning period until they reached a fledging body weight (BW) of 300 ± 25 g (Fig 2). The maximum daily volume of food that each chick received was 101 ± 29 g and this occurred at 42 days of age. This was also the age that experienced a peak in post-feeding regurgitation episodes. Post-feeding regurgitation events were observed as periods where the chick used rhythmical pumping of the head and neck in a way to return food from the crop to the oral cavity. The total daily feed intake as a percentage of BW peaked (83.1 ± 12.3%) at day 3 of age and dropped to 30.1 ± 2.3% by day 45 and then 19.6 ± 1.1% at day 92.

Humidity levels for the first thirty days were maintained between 45% - 65% but varied considerably (27% to 71%) for the remaining rearing period. There appeared to be no correlation between temperature or humidity variables and episodes or the onset of post-feeding regurgitation in any of the chicks. Chick 3 first regurgitated at day 17 when the temperature was 33°C with a final regurgitation at 89 days of age. Chick 8 regurgitated less than ten times during its entire hand rearing period whereas chick 7 started regular regurgitation at day 33 when the temperature was 27°C. Episodes of post-feeding regurgitation continued up until 89 days of age when the temperature had decreased to approximately 26°C. Chicks 9 and chick 10 were hatched and reared together and chick 9 regurgitated more frequently compared to chick 10. Chick 9 first began to regurgitate at 16 days of age and continued up until 63 days of age, with only a few days without any regurgitation observed. At 29 days of age chick 10 regurgitated for 5 days in a row and then again for a period of 16 days in a row from 41 days of age and three more times at days 63, 70 and 80 days of age.

Chicks 4, 5 and 6 were hatched and reared together. Frequent post-feeding regurgitation episodes for chick 5 began at day 24 through to day 44 and only 2 times after this; once at age 47 and 63 days, respectively. Chick 4 regurgitated at least once after feedings on day 27 through to day 67. Chick 6 regurgitated once daily after feeding on days 28, 29, 37, 38, 42, 45, 51 and 54.

**Growth records for individual birds**

Despite very frequent episodes of post-feeding regurgitation Chick 3 reached a maximum body weight of 394 g at 44 days of age and maintained a growth rate and fledging body weight similar to the other chicks. In an effort to minimise the regurgitation, daily food intake was reduced on alternating days by about 20% from day 25 through to day 45 to try and reduce the regurgitation occurrences (Fig 3). This was primarily achieved by feeding twice daily instead of the more usual 3 feeds per day at this stage of development. However, regurgitation episodes did not decrease and increased on days 41 to 43 and the bird continued to regurgitate until day 89. From day 46, the TDFI decreased continually until the bird was weaned.

Chick 9 reached a maximum body weight of 350 grams on day 48 and regurgitation episodes started at 29 days of age and occurred each day for the following 5 days. From day 41 through to day 57, regurgitation episodes continued.

Chicks 1 and 2 raised during the 2005 season attained significantly higher maximum body weights of 470 g and 522 g respectively, but not fledging body weights (Fig 4). Although accurate recordings of
each regurgitation event were not made, staff notes confirmed that both of these chicks frequently regurgitated after feeding even during the early hand rearing period.

In the analysis of the growth rate data these two birds (Fig. 4) were treated as outliers. Using SigmaPlot 7.0 the first 50 days of growth rate data for the remaining 8 chicks was used to define the logistic regression curve below (and Fig 5).

**Health and Disease**

No potential pathogens were isolated from water or food samples but mixed cultures of presumed non-pathogenic Gram positive cocci and rods were the main bacteria isolated from cloacal swabs (n=50) and buccal cavity swabs (n=42). In chicks aged 37 days or older, potentially pathogenic bacterial isolates occasionally or intermittently cultured from cloacal or buccal isolates and never as pure heavy growths. On 3 occasions low numbers of mixed growths containing *Escherichia coli* were cultured from cloacal swabs. Similarly *Pseudomonas aeruginosa* was cultured once from a cloacal swab from a chick aged 123 days and 11 times from buccal swabs from other chicks. On one occasion *Yersinia enterolitica* was cultured from a cloacal swab of a chick aged 81 days. *Citrobacter freundii* was cultured once from the buccal cavity of one chick aged 61 days; a *Klebsiella* species was isolated from one chick aged 110 days; and an *Enterobacter* species was cultured once from the buccal cavity of a chick aged 52 days. Yeasts morphologically consistent with *Candida* species were occasionally cultured from the buccal cavities (n=7) and twice from cloacal swabs of four chicks aged 27 days or older.

Oral antimicrobial therapy such as Enrofloxacin suspension (BAYTRIL® 0.5%, Bayer Vital GmbH, Germany) at the dose rate of 15mg/kg BW twice a day for 5 days was used occasionally for prophylaxis following the isolation of potentially pathogenic bacterial isolates. Nystatin (MYCOSTATIN® Oral Suspension, 100 000IU/ml, Squibb Industria Farmaceutica, Barcelona, Spain) at the dose rate of 0.03ml/10g BW once a day for 10 days was also used occasionally for prophylaxis against potentially harmful yeast infections.

**DISCUSSION**

Under natural conditions nesting parrots hatch asynchronously and their growth rates can vary within sibling groups due to environmental factors and food availability (AWWP 2007). While there have been some studies that have documented growth rates in wild Australian and neotropical psittacine birds (Hammer et al., 2005; Saunders, 1986; Renton, 2002, Navarro and Winkler, 1990) there are few published reports of the expected growth rates for hand-raised macaw (Smith, 1991). In this paper we present some important parameters that can be used as a comparative guide for the future captive breeding of the Spix’s macaw. The growth rate curves obtained for Spix’s macaw chicks were of a similar shape to those published for other macaw species (Smith, 1991). Chicks attained a maximum body weight of 360 g or approximately 20% larger than the final fledging weight of 300 g. It is normal for many species, but particularly altricial nestlings, to attain maximum body weights that are much higher than those of adults. This presumably provides them with adequate reserves to cope with the energetically expensive final phase of primary flight feather development and their first days of flight.

Detailed analysis of the 2005 and 2006 hand rearing records indicate that the regurgitation episodes had minimal effect on the chick’s growth rates. There was no pattern of regurgitation associated with temperature or humidity variations or with any particular feed formula. However, there was a peak
in regurgitation during the period when chicks are attaining their maximal body weight and thus entering a phase of less energy dependent development. Thus the regurgitation episodes may be primarily the result of over-feeding (meal volume overload).

Regurgitation in parrots is a non-specific clinical sign that may be associated with a multitude of definitive diagnoses including some potentially fatal diseases. Physiological regurgitation is common in birds that feed altricial young and the parent bird does this by pumping the neck in a way that returns food from the crop to the oral cavity. Careful observations indicated that physiological regurgitation is the common occurrence in the Spix’s macaw chicks rather than an involuntary vomiting action. True vomiting from the glandular stomach is not possible in birds because they lack a diaphragm to rapidly increase abdominal pressure (Waltman and Beisenger, 1992). However the term vomiting is used to describe the expulsion of contents from the crop and or proventriculus from birds by a rapid, usually single, flicking action of the head and neck which can expel small amounts of vomitus a considerable distance away. Vomiting in birds is most often associated with primary alimentary tract lesions affecting the oesophagus, crop and or stomach.

An ideal temperature for rearing psittacine birds ranges from 36.6°C at day 1, gradually decreasing to approximately 33°C at 14 days of age to 28-24°C by 29 days of age (Watson, R, 2007, pers.com., 18th August, 2009). Humidity levels can vary markedly in a rearing room. A number of different psittacine species have been reared in the same nursery in previous years, all of which did not suffer from regurgitation episodes, even though similar variations in humidity presumably occurred throughout their rearing period.

The maintenance energy requirement is the amount of dietary metabolisable energy (ME) needed to support basal metabolism, as expressed by basal metabolic rate (BMR), plus additional energy to fuel activity and thermoregulation. The total energy requirements vary depending upon the environment, stage of life cycle and genetics of the individual. Knowledge of the energy requirements is very important because they are the primary factor that determines the amount of diet that should be fed or will be voluntarily consumed (Cambell and Lack, 1985). In a study of temperate parrots, it was concluded that the BMR of psittacine birds is dependant upon the thermal climate of the species’ origin but is unrelated to feeding habits or water availability (Schoemaker et al., 1999). It is speculated that Spix’s macaws were adapted to a dry environment in the wild, one of semi-desert habitat which provided, at best, a seasonal abundance of food (Jensen, S. 2006, pers.com., 1st August). Therefore the Spix’s macaw BMR may have been lower than what might be expected for a parrot of their size, allowing a lower food consumption level to suit the seasonal food abundance in the wild.

The energy requirements for chick growth are based upon the fractional growth rate of the species. Birds in the order Psittaciformes are among the slowest growing of altricial species (McNab and Salsbury 1995) and also develop endothermy at an earlier age (Bauck, 1995). Their energy requirements are likely to be similar to precocial species than to highly altricial species, which grow faster and thermoregulate later.

When provided ad libitum access to foods, birds generally eat an amount that satisfies their daily energy expenditure (Pearson, 1998). In the case of crop feeding psittacine birds, food is provided at certain time intervals and in a measured amount, which is common practice in rearing of psittacine birds. Determining if the bird is hungry and requires a feed is sometimes hard to analyse due to a learned behavioural response of vocalising and/or increased activity levels when a hand rearer is near. This can lead to individuals being fed a larger amount than required. In this instance, regurgitation
may occur; this is the most likely scenario with the captive population of Spix’s macaws. Certain individual Spix’s macaws may also fall into the habit of regurgitating after each feed which makes it harder to eliminate the problem; this is an area that requires further research.

Spix’s macaw chicks 1, 2 and 3 were hand reared on Kaytee Exact Macaw hand feeding formula during the 2005/06 breeding season. Kaytee Exact Macaw hand feeding formula is specifically formulated for young Macaws, Eclectus, Hawk-headed and African grey parrots, or other birds requiring an increased energy diet. Communication with Ryan Watson (2006) has confirmed that the first three hand reared birds regurgitated daily and possibly at each feeding session. Unfortunately regurgitation data was not collected at regular intervals for chicks 1 and 2, therefore a comparison of regurgitation occurrences between the 2005 and 2006 birds can not be made accurately. It is confirmed that the 2006 birds reared on Nutribird hand rearing formula regurgitated less than the birds reared on Kaytee Exact Macaw hand feeding formula. This result emphasises that the higher fat and fiber content in Kaytee may be linked to increased regurgitation in the first three reared Macaws as well as the higher TDFI and higher maximum body weight. Kaytee Exact Macaw hand feeding formula is high in fat compared to both Nutribird A19 and A21 and is an ideal formula for the larger macaw species. Personal communication Ryan Watson (2006) has also suggested that Kaytee could be too rich for Spix’s macaw during the middle and final trimesters of hand rearing; this is an area that requires further investigation.

A weight monitoring regime was conducted during 2005 for the adult Spix’s macaw, which provided a clear indication that the Spix’s macaw maintenance requirements were below the amounts anticipated for their size and in relation to what is consumed by other macaw species of similar size (Jensen, S. 2006, pers. comm., 1st August). Investigation into captive diets for species of similar size to the Spix’s macaw, like the Red-bellied macaw Orthopsittaca manilata, which has an adult weight range between 280 and 350 grams (Collar, 1997), has proven difficult. Adult Spix’s macaw captive weight range is 318 grams for males and 288 grams for females and they are offered a maintenance diet of 120 grams per day (AWWP records 2007). It is assumed that the Spix’s macaw has a lower nutritional requirement than species of similar size but this area requires further investigation.

Currently the Spix’s macaw weaning phase begins once they have reached 350 grams approximately. By feeding smaller feeds a maximum weight of approximately 350 grams could still be reached. This change in the rearing method may decrease or eliminate regurgitation episodes and a maximum weight could still be reached under the same 40 – 55 day time frame.

Bacterial infections of the alimentary tract due to Escherichia coli (E coli), Pseudomonas species and Aeromonas species are a common cause of alimentary tract disease, particularly in juvenile psittacine birds and neonates (Downs, 2000). Infections with E coli, P aeruginosa, Klebsiella, Enterobacter spp., Y enterocolitica and C freundii have been diagnosed in a number of Spix’s macaws from the sample group. Clinical signs of illness where not observed and a select few individuals underwent treatment for the infections.

Chicks 8, 9 and 10 were treated for Pseudomonas infections with Baytril at 15 mg/kg body weight for 5 days/ 2 times per day. Nystatin antifungal antibiotic was also administered at the same time as the baytril antibiotic at 0.03 mls/10g body weight for 10 days/ once daily. Some antibiotic and antifungal treatments have been known to cause regurgitation episodes in some avian species during the treatment period. Due to the fact that regurgitation occurrences were apparent before and after antibiotic or antifungal treatments, it is unlikely that the treatments were the causative agent for the regurgitation episodes amongst the Spix’s macaws at AWWP.

2009 Proceedings
Fungal infections such as candidiasis are frequently found in neonatal psittacine birds (Downs, 2000) but were relatively uncommon in macaw chicks. Candidiasis is primarily an upper intestinal tract disease that mainly affects the crop and oesophagus and is often secondary to other underlying diseases or malnutrition. Due to only four out of the ten birds testing positive to yeast infections, it is an unlikely cause for the regurgitation episodes seen in each individual chick. Considering that individuals tested negative to the infection after Nystatin treatment but continued regurgitating, also rules out Candida albicans as being the causative agent for the regurgitation episodes.

Birds may aspirate food during feeding or following regurgitation. Aspiration occurs most often in birds that are reluctant to feed or when food is introduced when there is no feeding response. Death from asphyxiation can occur if the bird inhales large amounts of food. It’s not always possible to recognise aspiration in a bird, and later the bird may develop foreign body pneumonia. Poor weight gain, respiratory difficulty and persistently elevated white blood cell count indicates an aspiration affected bird (Girling, 2004). Younger birds will regurgitate if overfed and this can lead to aspiration pneumonia. Repeated regurgitation in a chick which is too young to wean, or regurgitation of large volumes may indicate disease or mechanical blockage (Ritchie et al., 1994).

Mild cases of aspiration were suspected occasionally during the hand rearing of the first two Spix’s macaws bred at AWWP, mainly due to the chick’s rapid onset of increased respiratory noises but these situations rapidly resolved. Investigation into possible occurrences of aerophagia (swallowing or gulping of air), goitre, crop impaction, stasis, crop burn or trauma by AWWP staff over the past two breeding seasons have eliminated the question of the regurgitation episodes being caused by the above.

Regurgitation is a major clinical presentation of PDD which is a debilitating wasting syndrome that was first described in the late 1970’s (Flammer and Clubb, 1994). It has now been reported in more than fifty different psittacine species as well as in multiple families of birds suggesting it’s cause is not restricted to any particular host (Clark, 1984). PDD has been reported more often in adult macaws than chicks (mean age 3.8 years; median age 2 years) (Gregory et al., 1994), however characteristic microscopic changes have been noted in birds from twenty eight days to seventeen years. The ten individual Spix’s macaws reared in 2005 and 2006 are currently in a very healthy status which lowers the possibility of PDD being the cause of the repeated regurgitation episodes. All recently reared birds have been isolated from all other individual Spix’s macaw and other bird species. Strict quarantine procedures have been instituted for all movements in the breeding facility.

Lead and zinc toxicities are also commonly recognized as a cause of regurgitation in captive psittacine birds (Graham, 1991; Doneley, 1992) but are highly unlikely to cause problems in hand-raised birds fed commercial formulated diets. Clinical signs of heavy metal toxicity include regurgitation, diarrhoea, anorexia, polydipsia, and polyuria, dyspnea, depression, weakness, ataxia, seizures, weight loss and death (Van Sant, 1998). The daily behaviour of the Spix’s macaws at AWWP are observed and monitored closely and there has been no evidence of adult birds chewing wires or other aviary furniture which could have resulted in a heavy metal toxicity poisoning. Regular health checks and blood testing has also failed to detect any evidence of heavy metal toxins. Regurgitation is a non-specific clinical sign with many different physiological and pathological causes. Medical reasons must be investigate when clinical signs of regurgitation affect the growth rate of hand-raised chicks. Detailed analysis of the 2005 and 2006 Spix’s macaw hand rearing records have indicated that the regurgitation episodes were not associated with any evidence of a decline in growth rate and may well have been due to overfeeding during the period when the chicks initial rapid growth rate is declining. The two “outliers” Chicks 1 and 2 reached a maximum body weight much higher than the
remaining eight Spix’s macaws despite episodes of regurgitation and the total daily food intake for the “outliers” was also much higher than the other eight individual birds. These results also coincide with the increased regurgitation episodes for the two 2005 reared birds. Since 2005, the rearing team at AWWP have been carefully monitoring the rearing methods which has lead to a gradual decrease in the total daily food intake and maximum body weights reached for the eight 2006 birds. Although regurgitation still occurred in the seven 2006 chicks the total number of occurrences have been steadily decreasing as the amount fed at each meal is revised and this has not interfered with chicks attaining a goal weaning weight of 350 g.

Whilst the 2006 chicks reared on Nutribird regurgitated less than the birds reared on Kaytee Exact Macaw hand feeding formula no firm association can be made between these products with the absence or occurrence of regurgitation episodes. Further investigation into this possibility is required. Nutribird® A19 formula had been fed to the last three 2006 reared Spix’s macaws for the first trimester. This method is still being assessed and due to an ongoing regurgitation syndrome in the Spix’s macaw, it can be suggested that by feeding Nutribird® A21 from the first trimester through to weaning may provide adequate nutritional requirements and may minimise regurgitation occurrences. Consistency in the hand rearing methods is essential for successful outcomes. Feeding A21 for the entire rearing duration may decrease regurgitation and provide continuity in the rearing methods. This proposed method will need to be analysed during the 2007 hand rearing season to assess its potential success in eliminating or lower the regurgitation episodes in the Spix’s macaw.

In conclusion, hand-reared Spix’s macaws require a lower total daily food intake during the hand rearing period than what has previously been believed. It has already been proven with individual Spix’s macaw chicks 1 and 2 that by decreasing the maximum body weight, regurgitation occurrences can be reduced. By trialling a lower total daily food intake during the second rearing trimester, regurgitation episodes could be reduced if not eliminated from the future hand reared Spix’s macaws at Al Wabra Wildlife Preservation.

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![Sample record-keeping sheet for an individual Spix's macaw chick showing 2 days’ of body weight measurements and other data.](image_url)

**Figure 1.** Sample record-keeping sheet for an individual Spix's macaw chick showing 2 days’ of body weight measurements and other data.
Figure 2. Growth rates of Spix’s macaw chicks \((n=8)\) demonstrating a peak in regurgitation at 42 days at the same time as chicks attained their maximum body weight of 360 g. The highest weight gains as a percentage of body weight occurred in the first 2 weeks (peak \(24.1 \pm 3.4 \%\) at day 5) and the maximum daily food intake as a percentage of body weight gradually dropped from a maximum of \(83.1 \pm 12.2 \%\) to \(31.1 \pm 1.1 \%\) at age 42 days. Abbreviations: WG indicates weight gain; TDFI, Total daily food intake; BW, body weight.

Figure 3. Growth rate of Spix’s macaw chick 5829 demonstrating an attempt to minimise post-feeding regurgitation by reducing the daily food intake on alternating days between 25 and 45 days of age. Abbreviations: BW, body weight; FI, food intake.
Figure 4. Growth records for two Spix’s macaw chicks raised in 2005. Both birds experienced frequent post-feeding regurgitation episodes. Abbreviations: BW, body weight; FI, food intake.
Figure 5. Logistic regression analysis of the growth rates of hand-raised Spix’s macaw chicks (n=8) during their first 50 days of life. Abbreviations: BW, body weight.
TRICHOMONAS SPECIES IN WILDLIFE AND THE ROLE OF PARASITES AND OTHER PATHOGENS IN UNDERSTANDING AVIAN MIGRATION

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Very little is known of the key principles that govern pathogen emergence and maintenance and the legitimate role pathogens may play as natural accelerants of diversity and change in ecosystems. The aim of this PhD project is to assess pathogen and host diversity in migratory and sedentary populations of the pied imperial pigeon (*Ducula bicolor*) as a model to explain key principles that govern pathogen emergence, survival and diversity in spatially isolated versus open, interconnected, ecosystems. The project will take a theoretical and practical approach to show how knowledge of the pathogenic microbial organisms and endoparasites of a host species can provide and explain life history information about that host.

Most of the research into the ecological effects of host:parasite relationships has been done on metazoan or protozoan parasites with little consideration to viral, bacterial or fungal infectious agents. Here it is proposed to capitalise on the unusually extensive knowledge base of *Columbiforme* pathogens to explain how the diversity and prevalence of pathogens impacts on the ecology of migratory pied imperial pigeons. The project aims to detect and genetically analyse key, well characterised pigeon pathogens, namely *Trichomonas gallinace*[^7,21,22,29,30,33-35] *Haemoproteus columbae*[^7,6,16,17,19,23,25,31,32] *Enterococcus columbae*[^5,15,24,27] *Columbid circovirus*[^1,20,26,36] and *Chlamydophila psittaci*[^1,4,37] in oropharyngeal and cloacal swabs as well as blood samples collected from pied imperial pigeons. This range of infectious agents provides a spectrum of relatively well host-adapted organisms that should behave as independent genetic markers of pathogen dispersal. Particular emphasis will be placed on better understanding the phylogeography of Trichomonads, because the prevalence of infection is likely to be high and this will enable sensitive analysis of genetic information.

TRICHOMONAS SPP. AS A SIGNATURE TOOL

*T. gallinace* is host adapted to *Columbiformes* whereby it resides in the oropharynx and crop of infected but otherwise clinically normal adults. It is capable of causing severe disease in other bird species including predatory raptors which are very susceptible to the infection. Transmission of trichomonads between pigeons is by direct contact with oral secretions.

Trichomoniasis is one of the earliest diseases recognised in birds, having been described in literature initially as a disease of birds of prey. While the metamonad protozoan responsible for this disease, *Trichomonas gallinace*, is still observed to cause disease in a range of wild birds of prey, it has come to be associated more with the pigeons and doves (Order Columbiformes) which appear to be its natural host. *T. gallinace* is found worldwide where pigeons and doves occur. It has been described from many species of Columbiformes of various genera. Most significantly it has been reported from species such as the Mauritius Pink Pigeon (*Columbia mayeri*) which are threatened or endangered.

2009 Proceedings 179
This organism inhabits the upper gastrointestinal tract, especially the oral cavity, oesophagus and the crop and in the Rock Dove or domestic pigeon (*Columbia livia*), typically does not cause lesions. This is likely to be the case in other columbid species. When it does cause clinical disease, this is characterised by the development of caseous stomatitis, ingluvitis or oesophagitis, with lesions occasionally penetrating the epithelium into the deeper soft tissues of these regions, especially the head. In severe cases, most commonly seen in young birds, these lesions can result in loss of condition and death. Experimental trials in *C. livia* and *Patagioenas fasciata*, the Band-tailed Pigeon, the development of clinical signs has been associated with infection with particular strains of *T. gallinae*. These trials also experimentally demonstrated the potential for *T. gallinae* to cause acute mortalities in columbiform birds.

The potential for trichomoniasis to cause declines in wild dove or pigeon populations or to confound captive breeding programs has been documented in several species, most notably the endangered Mauritius Pink Pigeon, however the mechanisms for emergence of this apparently widely distributed organism as a pathogen of significance in particular species is poorly understood.

**MARKERS OF DISEASE EMERGENCE**

Disease emergence in wildlife is a significant threat to biodiversity, agriculture and human health. Examples include emerging infectious diseases such as chytridiomycosis, pilchard herpesvirus and the henipaviruses, which amongst many others have attracted international attention. Disease emergence is commonly associated with a change in connectivity between and within populations of organisms. This can include the direct or indirect connection or fragmentation of populations through mechanisms such as introduction and movement of species and changed population ecology.

The recent expansion of highly pathogenic H9N2 Avian Influenza across Eurasia and Africa has illustrated that there is a need to understand the dynamics of infectious disease emergence, transmission and maintenance in migrating wild birds.

Tools for assessing population connectivity in migratory birds have long been in use. Methods for locating individual birds in space and time such as ring banding, radio and satellite telemetry are popular, as is light stable isotope analysis which can provide an historical account of individual bird movement. Genetic analytical tools such as microsatellite analysis of bird populations help to demonstrate reproductive connectivity between populations. However, these tools do not address levels of connectivity relevant to disease transmission (such as the sharing of food or water resources for example), which is of great relevance to understanding the emergence and maintenance of disease in populations. These complex population interactions are very hard to elucidate using traditional ecological methods.

Recent investigation of *Helicobacter* spp in people has demonstrated that genetic analysis of infectious organisms can provide an understanding of historical host movement and connectivity. There is a need to investigate whether the phylogenetic analysis of multiple infectious organisms within a host can provide finer scale information on host population connectivity and to validate this tool as a method for investigating such connectivity in migratory birds.

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Known distribution and presumed migration corridors for the pied imperial pigeon