

**Captive Husbandry Manual**  
for the  
**Sacred Kingfisher**  
*(Todiramphus sancta)*



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May, 2009

Cover photograph by Ian Montgomery (2004).

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## **1.0 Introduction**

### **1.1 General features**

Kingfishers are known for their vibrant colours, mainly blues and oranges (Holland, 1999). Other characteristic features of kingfishers include an oversized bill, tubby body and a short tail. They vary in size from 10g up to 500g and are found all over the world. Out of the 91 species found worldwide, Australia has 10 species of kingfisher. One of which is the sacred kingfisher (*Todiramphus sancta*) (Holland, 1999). Found in temperate woodland areas, they feed on worms, insects, small crabs, fish and small lizards (Strahan, 1994; Knowles and Nitchen, 1995; Holland, 1999). During winter the sacred kingfisher migrates northward to north Queensland, Indonesia and Papua New Guinea (Fry, Fry and Harris, 1992; Knowles and Nitchen, 1995). During the breeding season sacred kingfishers establish nests in tree hollows or termite mounds (Fry et al, 1992; Strahan, 1994; Knowles and Nitchen, 1995).

### **1.2 History in captivity**

The sacred kingfisher can be found in various zoos throughout Australasia. This species was previously managed at level 1b to minimize inbreeding and manage captive population size. However captive populations are now at acceptable levels and the species is no longer under population management by ARAZPA (Lekos, pers. comm.; ARAZPA, 2009). Sacred kingfishers are kept in captivity for educational reasons as it is one of the most abundant and recognisable species of kingfisher in Australia (Strahan, 1994).

### **1.3 Taxonomy**

#### **1.3.1 Nomenclature**

Class: Aves

Order: Coraciiformes

Suborder: Alcedines

Family: Alcedinidae

Subfamily: Halcyonidae

Genus: *Todiramphus*

Species: *Todiramphus sancta*

Common name: Sacred Kingfisher

(Knowles and Nitchen, 1995; Holland, 1999; del Hoyo, Elliott and Sargatal, 2001).

#### **1.3.2 Subspecies**

*Todiramphus sancta sancta* – Australian mainland and Tasmania

*Todiramphus sancta macmillani* – Loyalty islands of Mare, Lifou and Uvea

*Todiramphus sancta canacorum* – New Caledonia

*Todiramphus sancta vagans* – New Zealand, Lord Howe Island, and Norfolk Island

*Todiramphus sancta recurvirostris* – Western Samoa  
(Fry et al, 1992; Knowles and Nitchen, 1995; del Hoyo et al, 2001).

### 1.3.3 Other common names

New Zealand Kingfisher, Green Kingfisher, Wood Kingfisher, Tree Kingfisher, Flat billed kingfisher.  
(Strahan, 1994; Knowles and Nitchen, 1995; del Hoyo et al, 2001).

## 2.0 Natural History

Sacred kingfishers are very common throughout Australia. They therefore are easily recognisable and are useful animals for educational purposes (Strahan, 1994). Sacred kingfishers have adapted so well to European settlement that the increase in forest clearance has actually resulted in an increase in suitable habitat and therefore an increase in population size (del Hoyo et al, 2001).

Taxonomy for kingfishers has undergone many changes due to recent genetic studies. Previously sacred kingfishers were part of the genus *Halcyon* but it is now recognised as part of a different genus, *Todiramphus* (Christidis and Boles, 2008). There is also some confusion over which species are subspecies of the sacred kingfisher and which are full species. The above listed subspecies are what are currently recognised (del Hoyo et al, 2001). However further changes may need to be made as new genetic evidence comes to light.

There have been very few studies conducted on the biology of the sacred kingfisher specifically. However biological similarities exist between kingfishers. Much of the information presented in this husbandry manual has been taken from individual observations of keepers who work with this species as well as information presented for similar species of kingfisher, such as the Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*). In particular, further studies need to be conducted on the growth and development of sacred kingfishers, so as to make available growth and development charts for future reference.

## 2.1 Morphometrics

### 2.1.1 Measurements

Length: 19.0-23.0 cm  
Wing: 8.7-9.9 cm  
Tail: 5.8-6.5 cm  
Bill: 4.1-4.7 cm  
Tarsus: 1.3-1.8 cm  
Weight: 35-51.5 g  
(Strahan, 1994)

### 2.1.2 Description

The sacred kingfisher is a medium-sized kingfisher. It has a turquoise crown and back, while the wings and tail are more blue. The chest, throat and underparts are off white (buff) with a off white collar forming a ring around the neck (most other subspecies have pure white chest, throat and underparts). Above this ring is a black collar that rings each eye and runs around to the nape of the neck. The sacred kingfisher has a black bill, brown eyes and the legs and feet are dirty brown to black (Fry et al, 1992; Strahan, 1994; Knowles and Nitchen, 1995; del Hoyo et al, 2001; Simpson and Day, 2004). The female is generally duller in colour, with a whiter chest and collar and is slightly larger in body length than the male (Strahan, 1994; Knowles and Nitchen, 1995).

## 2.2 Distribution and habitat

The sacred kingfisher and its subspecies are found throughout coastal Australia, New Zealand, Papua New Guinea, Indonesia and surrounding islands. It is abundant across much of Australia, although there is only a small population found in Tasmania (Fry et al, 1992; Strahan, 1994; Knowles and Nitchen, 1995; del Hoyo et al, 2001).

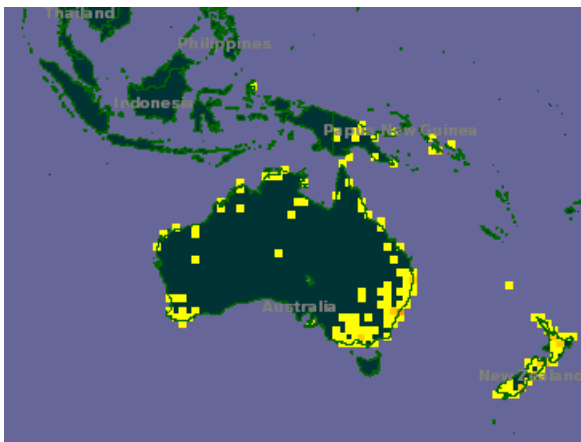


Figure 1 Distribution map of the sacred kingfisher (*Todiramphus sancta*) (Global biodiversity information facility, n.d.). See appendix 1 for distribution maps throughout the year as this displays migratory patterns.

The sacred kingfisher is found in open eucalypt and malaleuca forests, near water as well as in mangroves (Fry et al, 1992; Strahan, 1994). They avoid spinifex, mallee and saltbush areas and are mainly found in lowlands, although they have been found up to 2500 m. During the winter they migrate northward to northern Queensland and Papua New Guinea and surrounding islands. During this time they prefer parkland where they have clear view of food on the ground below (Fry et al, 1992; del Hoyo et al, 2001).

## 2.3 Conservation status

This species is listed as of Least Concern on the IUCN redlist due to the fact that the population is not decreasing and may in fact be increasing (del Hoyo et al, 2001; IUCN Species Survival Commission, 2008). Total estimated population in Australia is

60,000,000 birds (del Hoyo et al, 2001). However sacred kingfishers do face competition from introduced species, such as the common myna (*Acridotheres tristis*).

## **2.4 Diet and feeding behaviour in the wild**

Sacred kingfishers feed on worms, insects (such as locusts and grasshoppers), small crabs, fresh water fish, small lizards (such as skinks) and sometimes mice (Fry et al, 1992; Strahan, 1994; Knowles and Nitchen, 1995; Holland, 1999; del Hoyo et al, 2001). Sacred kingfishers perch, scanning the ground for prey, pouncing down when they see prey. They have also been known to dive into the water for fish, take food, such as insects, in the air and hover briefly to catch food in shrubbery (Fry et al, 1992; del Hoyo et al, 2001).

## **2.5 Longevity**

### **2.5.1 In captivity**

Approximately 7-10 years (Lekos, pers. comm.).

### **2.5.2 In the wild**

Kingfishers may live longer in the wild than in captivity (Bahner, Baltz and Diebold, 1998) due to the fact that overfeeding may occur, decreasing their life span in captivity (Lekos, pers. comm.).

## **3.0 Housing Requirements**

### **3.1 Exhibit design**

An exhibit in a zoological institution should abide by standards set out in state or national legislation. Exhibits should provide a safe place for the animal to reside in which the health and well being of the animal is maintained. Exhibits not only prevent the escape of the animal but protect the animal from predators, vermin, disease and the weather whilst also protecting visitors from injury. A good exhibit can also serve to educate the public about the animal being displayed (Bureau of Animal Welfare, 2001).

Sacred kingfishers can be housed singly, in pairs or in mixed exhibits (providing the correct species choices) (Lekos, pers. comm.). For this reason sacred kingfishers can be housed in large walk through exhibits as well as smaller view only exhibits. However both types of exhibits should be large enough to allow keeper entry into the exhibit for ease of maintaining hygiene standards (Bureau of Animal Welfare, 2001). Keeper entry should be through 2 doors to prevent the birds from escaping.

Depending on the size of the enclosure and the number of species being kept in the enclosure, a separate feed area or areas may be needed that can be closed off to allow for



capture of the birds, additional breeding areas or for extra holding areas. This area(s) should have more than one entrance/exit (that can be closed if necessary) so that the birds are not trapped when going into feed and can escape out another entrance if being chased by another bird (Lekos, pers. comm.). See appendix 2 for photos of an example of this area found at Healesville Sanctuary.

The enclosure can be made of wire mesh, glass or other solid material. Mesh size should not be larger than 2.5cm and for outdoor enclosures smaller mesh sizes are preferred to prevent pests entering the exhibit. Kingfishers have been known to attack reflections in glass so sacred kingfishers kept in this type of enclosure should be monitored. Piano wire can not be used for this species as kingfishers of this size can escape from this type of enclosure (Bahner et al, 1998).

### **3.2 Holding area design**

Holding areas do not have to be as large as the exhibit areas. Bahner et al, (1998) recommends that holding areas be a minimum of 1.2m<sup>3</sup>. Holding areas should be placed away from the permanent exhibit so that animals can also be quarantined in this area (Lekos, pers. comm.). Holding pens should be easily accessible to maintain ease of cleaning. It is recommended that holding areas have a concrete or other easily cleaned material as flooring so that these areas can be adequately disinfected after the birds have been moved to their permanent enclosures (Foresio, pers. comm.). See appendix 3 for examples of these areas at Melbourne Zoo.

### **3.3 Spatial requirements**

Legislation regarding exhibit sizes does not specifically cover this species of bird, however it does include minimum exhibit sizes for the kookaburra of 15 m<sup>2</sup>, with a minimum height of 3 m, for two animals (Bureau of Animal Welfare, 2001). The Micronesian kingfisher husbandry manual recommends a minimum enclosure size, for a breeding pair of kingfishers (of similar size to the sacred kingfisher), of 3m by 2.4m with a height of 3m (Bahner et al, 1998). However larger sizes are recommended, especially if both kingfishers are to remain in the enclosure all year round or the kingfishers are to be kept with other species (Lekos, pers. comm.). It has been seen that kingfishers can get up to high speeds during flight in large enclosures, resulting in injuries when they hit the wire mesh. This can be prevented by suitably planting the enclosure so that there are numerous landing places for the kingfishers. They will then quickly learn the limits of their enclosure (Lekos, pers. comm.).

### **3.4 Weather protection**

If the exhibit is planted correctly, sacred kingfishers do not need a covered up area to escape the weather (if the zoological institution displaying them is found in a similar environment to their natural habitat, such as zoos in Melbourne or Sydney). However the feed area should have a roof covering, such as plastic so that the food trays do not become overly wet. Shade cloths can also be used over parts of the enclosure to increase

shaded areas (Lekos, pers. comm.). If an overseas institution, that is found in very cold areas, such as in parts of North America, is looking at displaying sacred kingfishers, the exhibit should be built to include a covered, heated area (Foresio, pers. comm.). For temperature needs within the enclosure see temperature requirements below.

### **3.5 Position of enclosures**

Sacred kingfishers can be kept in open wire mesh aviaries and therefore no particular position is required for this exhibit as long as the exhibit is adequately planted to provide cover for the kingfishers.

### **3.6 Temperature requirements**

The sacred kingfisher is found throughout Australia, New Zealand and Papua New Guinea. Most migrate north during the winter months. Average temperatures throughout Australia during the summer period (November – March) are around 25°C (Bureau of Meteorology, 2009). While the average temperature in Papua New Guinea during the winter months (May – September) is 30°C (World Meteorological Association, 2009). Therefore similar temperatures are required in the enclosure. See appendix 4 for monthly temperature charts for both Melbourne, Australia and Port Moresby, Papua New Guinea.

### **3.7 Substrate**

Bahner et al, (1998) recommends a substrate that can easily be cleaned and disinfected such as concrete covered with bark mulch or wood chip shavings. Most enclosures however, use a soil substrate covered with back mulch (Bahner et al, 1998). The choice of substrate depends largely on the type of enclosure being built. For instance a walk through enclosure has to be built to incorporate aesthetic appeal and a soil substrate would be much better suited to this type of enclosure. However if the enclosure is small, or is not subject to public scrutiny, such as a holding area, other easier to clean substrates can be used. The choice of substrate may also depend on whether breeding is a priority as some sacred kingfishers may choose to burrow into the ground (as opposed to using tree hollows or nest boxes). If the institution is wanting to breed sacred kingfishers, allowing them their choice of nesting material is the best way to maximize the chances of a successful pairing (Lekos, pers. comm.).

### **3.8 Enclosure furnishings**

The enclosure for the sacred kingfishers should be adequately planted to provide shelter, perches, and tree hollows for nesting. Hollow logs, rocks and smaller plants may also be included in the enclosure, not only for aesthetic appeal but to also give the kingfishers some cover if they decide to burrow into the soil substrate. Nest boxes can also be provided to give the kingfishers choice of nest site. A pond should also be included in the enclosure as the kingfishers need a water source, not only for drinking but for bathing. This pond should have a drain at the bottom to allow for cleaning and an overflow drain in case the area is subject to heavy rainfall (Lekos, pers. comm.).

## **4.0 General Husbandry**

### **4.1 Hygiene and cleaning**

Most aviaries found in zoological institutions have a soil substrate, limiting the ability to clean and disinfect adequately. However, if food areas are hosed everyday, food bowls kept clean and pest free, and soil areas, plants and perches are hosed regularly to remove bird excretions, enclosures should stay relatively clean and disease free (Foresio, pers. comm.).

Water sources in these enclosures should always be constantly flowing to prevent stagnation. However, small ponds can be cleaned out regularly, for example once or twice a week. If need be, chlorine can be used to aid in cleaning ponds. Large water sources cannot be cleaned out in this manner and therefore should only be done once per year. This is mainly to minimize water wastage, but in mixed exhibits specific species of birds may require the food that can be found on the bottom of such ponds (Foresio, pers. comm.).

Nest boxes should be removed from the exhibit after the breeding season and cleaned and disinfected with a veterinary disinfectant, such as F10 SC. Nest boxes should only be replaced at the beginning of the breeding season. During the breeding season nesting material should not be removed as it may disturb the breeding pair (Foresio, pers. comm.).

In quarantine and hospital areas that have concrete floors, disinfecting should be carried out more regularly. Again the disinfectant that should be used is F10 SC (which can be bought from various distributors). Floors should be cleaned daily with F10 SC and cages can be disinfected with F10 SC once an animal has been permanently moved from the cage, for example, once the quarantine period is over (Foresio, pers. comm.).

### **4.2 Pest control**

Pests such as rats and mice can carry diseases, get into food sources and disrupt kingfisher nests (Bahner et al, 1998). Food trays should be placed in rat/mice proof areas and if possible outdoor enclosures should have wire small enough to prevent access by rats and mice (Bahner et al, 1998; Foresio, pers. comm.). This will also prevent larger predators, such as foxes, from accessing the enclosure (Bahner et al, 1998). Poisoning and trapping of rats and mice should be handled with care to avoid accidental poisoning/trapping of the birds (Bahner et al, 1998).

### **4.3 Record keeping**

Records should be kept on:

- date of birth
- sex
- tag number

- births
- deaths
- transfers
- internal movements
- captures
- physical condition
  - weight
  - body condition
- medical notes
  - veterinary treatments
  - veterinary diagnosis
  - veterinary procedures
- diet and feeding
- behaviours
  - reproductive behaviours
  - social behaviours
- breeding
  - matings
  - clutch size
  - chicks hatched

All records should be kept on ARKS which should be updated regularly by the records officer at the zoo (Foresio, pers. comm.).

#### **4.4 Methods of identification**

Birds in zoological institutions can be banded for identification purposes. The band size and type recommended for the sacred kingfisher by the Australian Bird and Bat Banding Scheme is a size 05 alloy band (internal diameter: 4mm; height: 5.5mm; gauge: 0.5mm). Alloy bands are light weight and durable and are estimated to last 15 years (Australian Bird and Bat Banding Scheme, 2000).

#### **4.5 Sex identification methods**

The sacred kingfisher is sexually dimorphic. The male has buff chest and collar while the female is whiter in these areas. The male has a turquoise crown and back, with blue wings and tail, while in the female these colours are duller. The female is also slightly larger than the male. Juvenile sacred kingfishers are similar in colour to the adults of each sex but the female has dark brown on collar and underparts while the male has a bright light blue rump (Strahan, 1994; Knowles and Nitchen, 1995). However as these differences are slight it is possible to genetically assess the sex of the bird. This can be done by plucking a couple of feathers from the kingfisher and sending it to a laboratory for testing (Foresio, pers. comm.).

## **5.0 Feeding Requirements**

### **5.1 Captive diet**

#### **5.1.1 Non breeding season**

- Daily diet at Healesville Sanctuary, Victoria:

20g Meat mix (see appendix 5 for details of how to make the meat mix).  
2g meal worms.  
1 or 2 small goldfish (live).

Mice (fuzzy or pinky) can be fed in addition to the above diet as necessary.  
(Lekos, pers. comm.).

- Daily diet at Melbourne Zoo, Victoria:

10g Meat mix (includes chicken mince).  
1 or 2 pinky mice/ chopped mice  
6 meal worms  
3 or 4 crickets  
(Foresio, pers. comm.).

Both the above diets meet the nutritional requirements of sacred kingfishers (Foresio, pers. comm.; Lekos, pers. comm.). Differences in diet are due entirely to the fact that the kingfishers are at different institutions with different keeper and veterinary staff. However, Healesville Sanctuary have a breeding pair of sacred kingfishers while Melbourne Zoo only has one sacred kingfisher. This may influence diet choices at these institutions.

#### **5.1.2 Breeding season**

- Daily diet at Healesville Sanctuary, Victoria:

20g Meat mix  
5g meal worms.  
1 or 2 small goldfish (live).

Mice (fuzzy or pinky) can be fed in addition to the above diet as necessary  
(Lekos, pers. comm.).

### **5.2 Supplements**

A calcium supplement can be added as a powder to the food or mealworms and crickets can be gut-loaded with calcium (so exact amount ingested can be calculated from amount of mealworms/crickets ingested). Calcium is especially important during the breeding

season. Other vitamin supplements can be added to the meat mix such as vitamin E, to prevent such problems as myocardial degeneration (Bahner et al, 1998; Foresio, pers. comm.).

### **5.3 Presentation of food**

Food can be presented in a number of ways. Main feedings are usually fed on trays in feed areas. A scatter feed can also be used daily in the mornings. This allows for the keepers to note any health problems as the birds come down to feed. This type of feeding also has the added advantage of providing behavioural enrichment as the sacred kingfishers would naturally take prey off the forest floor. Live fish are fed in a shallow bowl of water as opposed to being placed in the pond in the exhibit where they may go uncaught (Lekos, pers. comm.).

## **6.0 Handling and Transport**

### **6.1 Timing of capture and handling**

The birds should be caught directly after feeding as feed areas can be closed off to allow for easier netting. Once the kingfisher has come into the feed area to feed, doors can be closed and the kingfisher can easily be netted and placed in a capture bag (Foresio, pers. comm.; Lekos, pers. comm.). See appendix 6 for photos of the types of nets used and appendix 7 for contact details of the net manufacturer. Some birds after being caught once may take longer to return to the feed area if they think they are going to be caught again. Therefore it may take up to several weeks before a capture can take place (Foresio, pers. comm.)

### **6.2 Capture bags**

These bags are made from calico and are used for short distance transportation of birds (Lekos, pers. comm.). The bags do not need to be very large but there needs to be enough room for the bird to be placed into or removed safely from the bag without injury.

### **6.3 Capture and restraint techniques**

#### **6.3.1 Physical restraint**

As sacred kingfishers are not very large, they can easily be restrained using one hand. The forefinger and middle finger should be placed either side of the head while the other fingers and thumb lightly wrap around the body to restrain the feet (Greco, n.d.). If needed, a small towel can be placed over the head to reduce stress (Bahner et al, 1998).



*Figure 2 Physical restraint technique for small birds (Greco, n.d.).*

### 6.3.2 Chemical restraint

Darting or other means of chemical restraint is not needed in a bird this size (Foresio, pers. comm.).

### 6.3.3 Precautions to take during capture

When netting a kingfisher, caution should be taken to prevent missing the bird and hitting it with the side of the net. Netting should be fast and accurate to prevent stress and injury to the bird from flying into the wire to escape (Lekos, pers. comm.). Precautions should also be taken to prevent stress to the kingfisher while restrained, such as placing a towel over the kingfishers head (Bahner et al, 1998).

## 6.4 **Weighing and examination**

Kingfishers can be weighed by placing them in a capture bag on a set of scales (Foresio, pers. comm.). Kingfishers should not be weighed more than twice a year and then only if necessary, and never during the breeding season (Bahner et al, 1998).

## 6.5 **Release**

The kingfisher should be released in the morning so that it has enough hours of light to adjust to the enclosure and to relax after the stress of being caught (Foresio, pers. comm.).

## 6.6 **Transport requirements**

### 6.6.1 Box Design

Please see appendix 8 for photos of a transport box designed and made at Healesville Sanctuary. The box is approximately half a metre in length, and approximately 25-30cm high and 15-20cm wide. The box is made of plywood with wire mesh on both sides that can be covered by a sliding piece of plywood containing air holes to reduce stress during longer trips. The box can be split into two compartments, and includes a door at each end

that slides off to reveal a rubber door that allows the captured bird to be placed inside the box, easily, without escape (Lekos, pers. comm.). The ceiling of the transport box may also need to have a soft covering for long trips, such as foam rubber (Bahner et al, 1998).

#### 6.6.2 Furnishings

Straw can be placed on the ground of the transport box for insulation. A perch may also be placed inside the box (Bahner et al, 1998).

#### 6.6.3 Water and food

Spill proof water dishes and meal worms can be placed inside the box for extended trips (Lekos, pers. comm.).

#### 6.6.4 Animals per box

Two birds can be placed inside the box provided the box is separated into two compartments. The box is unable to hold more than two birds (Lekos, pers. comm.).

#### 6.6.5 Timing of transportation

Animals should be transported only when the weather is moderate. They should not be transported during very hot or very cold days (Bahner et al, 1998).

#### 6.6.6 Release from box

The kingfishers should be pulled out head first (the same way it should be placed into the box) so as not to ruffle or destroy any feathers (Lekos, pers. comm.).

### **7.0 Health Requirements**

#### **7.1 Daily health checks**

Daily health checks are undertaken by using a scatter feed to entice the birds down to the ground where observations such as general appearance, feather structure and flight patterns can be made. Behavioural changes should also be noted during the day, such as increased displays of aggression towards other birds. Appearance of faecal matter can also be noted, however this would be impossible to accomplish in a mixed species exhibit (Lekos, pers. comm.).

#### **7.2 Detailed physical examination**

If a detailed physical examination is needed due to injury or ill health a gas anaesthetic (isoflurane) should be used to anaesthetise kingfishers as the depth of anaesthesia can easily be controlled. Induction and recovery times are also fast when using this technique.



A mask can be held over the kingfisher while restrained during short procedures. However longer procedures may require the kingfisher to be intubated and attached to a nonrebreathing circuit (Bahner et al, 1998).

#### 7.2.1 Parameters used gauge the health of the species

These would include feather colour, feather loss, amount of food consumption, perching ability and flight ability. In addition physiological parameters for the Micronesian kingfisher have been collated which may be referenced until data for the sacred kingfisher becomes available (Bahner et al, 1998). See appendix 9 for this data.

### 7.3 **Routine treatments and vaccinations**

There are no routine treatments or vaccinations. However when new birds are bought into a zoological institution and placed in quarantine they are routinely tested or observed for signs of internal parasites (worms), various species of mycobacteria, and chlamydiosis (Foresio, pers. comm.).

### 7.4 **Known health problems**

#### 7.4.1 Avian mycobacteriosis

Avian mycobacteriosis is a contagious disease which is shed in the faeces of infected birds. Disease spreads when other birds either ingest or inhale the mycobacteria (Bahner et al, 1998; Witte, Hungerford, Papendick, Stalis and Rideout, 2008). Incubation periods vary between species of birds and some birds once exposed do not develop an active infection (Bahner et al, 1998).

Cause: This disease is mainly caused by four species of mycobacteria: *Mycobacterium avium*, *Mycobacterium intracellulare*, *Mycobacterium genavense* and *Mycobacterium simiae* (Shivaprasad, 2002; Travis, Junge and Terrell, 2007; Witte et al, 2008).

Signs: This disease is hard to diagnose pre-mortem and clinical signs that do appear only do so after the disease is well established in the individual. Clinical signs include lethargy, loss of feather condition, weight loss, anaemia and decreased egg production (Bahner et al, 1998; Shivaprasad, 2002).

Diagnosis: Is usually accomplished post-mortem when characteristic intestinal and respiratory lesions can be seen and tissue cultures can be used to confirm the presence of the disease (Witte et al, 2008). However, cultures of faeces may provide diagnosis (Bahner et al, 1998).

Treatment: There is no treatment for avian mycobacteriosis and often euthanasia is the only acceptable solution (Bahner et al, 1998; Witte et al, 2008).

Prevention: To prevent the spread of the disease, infected individuals should be removed from the population and either euthanized or placed in quarantine. The enclosure should then be disinfected with a disinfectant such as F10 SC and soil substrate and perches removed (Bahner et al, 1998; Foresio, pers. comm.).

#### 7.4.2 Chlamydiosis

Chlamydiosis is a common disease found in many species of birds and is spread through the inhalation of infected faecal or feather dust (Bahner et al, 1998; Association of avian veterinarians, 2008). This disease can be transferred to humans (although rarely) and precautions need to be taken around suspected cases of chlamydiosis (Association of Avian Veterinarians, 2008).

Cause: This disease is caused by the bacteria *Chlamydia psittaci* (Bahner et al, 1998; Shivaprasad, 2002; Association of Avian Veterinarians, 2008).

Signs: Clinical signs include respiratory and intestinal disease, laboured breathing, nasal discharge, diarrhoea, excessive urination, weight loss, loss of appetite and lethargy (Bahner et al, 1998; Shivaprasad, 2002; Association of Avian Veterinarians, 2008).

Diagnosis: This is usually accomplished using cultures and serological tests such as ELISA or latex agglutination (Bahner et al, 1998; Association of Avian Veterinarians, 2008). Post-mortem diagnosis usually involves identifying lesions in various organs as well as observing characteristic LCL bodies (Bahner et al, 1998).

Treatment: Involves quarantining the infected kingfisher and long term treatment with tetracycline, which has been used to good effect in other bird species (Bahner et al, 1998). Further research needs to be done on the effects of this disease and its treatment in kingfishers.

Prevention: Good hygiene practices and adequate quarantine measures usually reduces the spread of this disease (Association of Avian Veterinarians, 2008).

#### 7.4.3 Parasites

This includes both nematodes and protozoa that infect various species of birds and are found in the gastrointestinal tract of bird species (Bahner et al, 1998; Shivaprasad, 2002).

Cause: Species is usually host specific but some genera that may be found in kingfishers include *Ascaridia*, *Capillaria* (nematodes) or *Giardia* (protozoa) (Bahner et al, 1998; Shivaprasad, 2002).

Signs: Weight loss is one of the few clinical signs to indicate the presence of worms in the gastrointestinal tract (Shivaprasad, 2002).

Diagnosis: Can be diagnosed by taking a faecal sample for laboratory testing using cultures (Foresio, pers. comm.; Lekos, pers. comm.).

Treatment: The main anthelmintic used is ivermectin (one dose injected at 0.2mg/kg; repeated after two weeks) but this would depend on the type of worm present in the kingfisher (Bahner et al, 1998).

Prevention: Good hygiene practices and adequate quarantine measures usually reduces the spread of this disease (Foresio, pers. comm.; Lekos, pers. comm.).

#### 7.4.4 Metabolic disease: Hemochromatosis

This is the clinical disease. Accumulation of iron in the liver is not that uncommon and rarely results in the clinical disease (i.e. liver disease) presenting but does indicate an underlying problem (Bahner et al, 1998).

Cause: Excessive deposition of iron into the liver resulting in liver disease. May be the result of genetics or more likely an excess of iron in the diet (Bahner et al, 1998; Shivaprasad, 2002).

Signs: Hepatic degeneration, fibrosis and myocardial degeneration (Shivaprasad, 2002).

Diagnosis: Can be diagnosed pre-mortem using a liver biopsy but is most likely diagnosed post-mortem (Bahner et al, 1998).

Treatment: No treatment

Prevention: Reduce dietary intake of iron (Bahner et al, 1998).

#### 7.4.5 Obesity

Captive kingfishers have been known to suffer from obesity due to a diet too rich in fat and protein. Obesity reduces breeding potential and life span. Therefore monitoring of the diet and half yearly weighing of birds to monitor weight gain will reduce obesity in captive birds (Bahner et al, 1998; Lekos, pers. comm.).

#### 7.4.6 Other injuries

Sacred kingfishers are often bought into zoological institutions with injuries related to hitting windows, cars etc. This usually occurs during the migratory season. Injured birds should be placed in a warm, dry, dark place to recover (please see appendix 10 for photos of the recovery boxes at Melbourne Zoo). If injuries are not too severe the birds may be able to be released back into the wild once recovery is complete (Foresio, pers. comm.).

## **7.5 Quarantine requirements**

All birds when they come into a new institution (no matter where they have come from) should be quarantined for a minimum of 30 days. During this time observations are made about health and tests are carried out for mycobacteriosis, chlamydiosis and parasites. Any treatment required is given during this period. After the 30 day period, if the bird is healthy, it can be moved to its new enclosure (Foresio, pers. comm.; Lekos, pers. comm.).

## **8.0 Behaviour**

### **8.1 Activity**

Sacred kingfishers are diurnal and crepuscular (Strahan, 1994). They prefer to forage during the day when prey are easier to see (del Hoyo et al, 2001). They are quiet, solitary birds during the non breeding season, only pairing up when the breeding season begins (Strahan, 1994). During the non breeding season sacred kingfishers spend the day searching for food, bathing, or sitting perched high up in the trees. At night they roost in trees or shrubs in their territory (Strahan, 1994; del Hoyo et al, 2001). During the winter months (usually beginning in March) sacred kingfishers migrate northward to northern Australia, Indonesia and Papua New Guinea. Sacred kingfishers migrate directly north at night (Fry et al, 1992). Flying swiftly, young kingfishers are frequently killed by collisions with windows (Strahan, 1994).

### **8.2 Social behaviour**

Sacred kingfishers are solitary except during the breeding season (Strahan, 1994). When the breeding season begins, the amount of vocalisations heard increases dramatically. The kingfisher has several vocal calls: the territorial “staccato call” (kek kek kek), mainly given by the male kingfisher; an “ascending note” given when approaching a mate; a “shriek” which is heard mainly from the female to attract attention; an “attack screech” when attacking predators; and a “predation scream” heard when the kingfisher is caught by a predator (del Hoyo et al, 2001). The male territorial “staccato call” is also used to let unattached females know that he is looking for a mate. Once the mate appears this call is often heard interspersed with the female “shriek” (Hollands, 1999). Sacred kingfishers are aggressively territorial during the breeding season, often attacking other birds and animals in their territory. When attacking another bird or animal they utter the “attack screech” and dive at the animal, striking it with its bill (del Hoyo et al, 2001).

### **8.3 Reproductive behaviour**

The breeding season begins in September and can finish as late as March. Courtship displays by sacred kingfishers often involve loud vocalisations by the male to attract a mate. Afterwards the male is seen chasing the female around his territory (Lekos, pers. comm.). Courtship feeding is also undertaken by the male who feeds the female, strengthening the pair bond (del Hoyo et al, 2001; Lekos, pers. comm.). Pairs of sacred

kingfishers then undertake the task of finding a suitable nest site. Nest choice depends on what is available within their territory. Nests have been found in hollow trees, termite mounds, or burrows in the ground. Sacred kingfishers excavate nests in these places, often having to fly repeatedly at the surface of the tree or termite mound and hitting it with force (Hollands, 1999; del Hoyo et al, 2001).

#### **8.4 Bathing**

Sacred kingfishers, like many other species of kingfisher, bathe by diving into and out of the water. Afterwards they perch on a branch and preen themselves. Kingfishers can spend up to several hours a day preening (del Hoyo et al, 2001).

#### **8.5 Captive behavioural problems and signs of stress**

In captivity sacred kingfishers can get easily spooked when approached, so care has to be taken when moving through the enclosure (Lekos, pers. comm.). Signs of stress might include not eating, breeding or bathing.

#### **8.6 Behavioural enrichment**

Behavioural enrichment for this species mostly includes food enrichment activities such as scattering the food around the enclosure or feeding live food that must be caught (Lekos, pers. comm.).

#### **8.7 Introductions and removals**

When introducing a pair of sacred kingfishers, the process should begin with the monitoring of interactions between the two kingfishers while in adjacent cages. This is due to the fact that sacred kingfishers display intraspecies aggression in the wild and therefore this step should continue for a minimum of 2 weeks (Bahner et al, 1998; del Hoyo et al, 2001; Lekos, pers. comm.). During this time aggressive behaviours, vocalisations, and perch preferences should be noted (Bahner et al, 1998). After this, if behaviours toward each other are acceptable, the kingfishers should be placed in a neutral enclosure and monitored (Bahner et al, 1998). If this is not possible the resident kingfisher should be removed from the enclosure and the new kingfisher allowed time to settle into the enclosure before the resident kingfisher is replaced (Lekos, pers. comm.). Interactions between the sacred kingfishers should be continuously monitored for aggression once placed together.

#### **8.8 Intraspecific compatibility**

Sacred kingfishers are aggressively territorial, especially during the breeding season, towards other sacred kingfishers (except their mate) and so in captivity should be housed singly or in mating pairs (del Hoyo et al, 2001; Lekos, pers. comm.). Once the young from any mating has reached independence, they should be removed from the enclosure so as to prevent aggressive encounters (Lekos, pers. comm.).

## **8.9 Interspecific compatibility**

Sacred kingfishers are aggressively territorial, especially during the breeding season, towards other species of birds (del Hoyo et al, 2001). However sacred kingfishers have successfully been housed with other species at various institutions including Healesville Sanctuary and Melbourne Zoo. This is due to the fact the exhibits are large walk through enclosures with enough space for all species, preventing aggressive encounters (Lekos, pers. comm.). Most of the species found in these enclosures are larger than the sacred kingfisher, such as the gang gang cockatoo (*Callocephalon fimbriatum*), and the satin bowerbird (*Ptilonorhynchus violaceus*), however smaller species such as finches are also housed in the exhibit at Healesville Sanctuary and there is some evidence to suggest the sacred kingfishers have resulted in the death of a number of these smaller birds, due to head injuries (Lekos, pers. comm.). Therefore, although sacred kingfishers can be housed with other species of birds, it is not recommended that significantly smaller species of birds be housed with the sacred kingfisher.

## **8.10 Suitability to captivity**

Sacred kingfishers have been housed successfully in captivity for a number of years, and given the right environment can thrive and reproduce in captivity (Lekos, pers. comm.). These kingfishers do not need an especially large enclosure and can be housed singly, in breeding pairs or in multi-species exhibits. Feeding requirements are relatively normal and disease susceptibility is low. Sacred kingfishers are striking birds because of their colouring and are easily recognisable to the public making them an excellent educational species.

## **9.0 Breeding**

### **9.1 Mating System**

Monogamous: pairs remain together for breeding season, separating during the non breeding season (Strahan, 1994, del Hoyo et al, 2001), although pairs can live continuously together throughout the year in captivity given an appropriately sized enclosure (Lekos, pers. comm.).

### **9.2 Ease of breeding in captivity**

Given an adequate sized enclosure, the right pairing, a number of suitable nest sites to choose from, and a suitable diet, sacred kingfishers breed relatively easy in captivity. At Healesville Sanctuary the sacred kingfisher pair even double clutched during the last breeding season (2008-2009) (Lekos, pers. comm.). An increase in food availability is the key to how well kingfishers will breed in captivity (Kelly and Van Horne, 1997).

### **9.3 Breeding data**

#### **9.3.1 Timing of breeding**

Sacred kingfishers are seasonal breeders with breeding occurring during the months of September through to March (mainly October to January) (del Hoyo et al, 2001).

#### **9.3.2 Age at first and last breeding**

It is thought sacred kingfishers reach sexual maturity at one year of age (del Hoyo et al, 2001). Kingfishers can continue breeding throughout their lives (the female sacred kingfisher at Healesville Sanctuary is seven years old, while the male is nine years old) (Lekos, pers. comm.). However peak fecundity for the Micronesian kingfisher is between 2 and 5 years and this may be similar for the sacred kingfisher (Bahner et al, 1998).

#### **9.3.3 Ability to breed every year and more than once in a year**

Sacred kingfishers are able to breed every year and can raise up to two clutches per season (del Hoyo et al, 2001).

### **9.4 Nesting/hollow or other requirements**

Sacred kingfishers create their nest in a variety of mediums, including tree hollows, termite mounds and burrows in the ground (del Hoyo et al, 2001). Therefore a number of nesting options should be provided in the enclosure. For example, logs, trees (of an appropriate species) and nest boxes could be provided to give the sacred kingfishers some choice on where to nest.

### **9.5 Breeding diet**

-Diet at Healesville Sanctuary, Victoria:

20g Meat mix  
5g meal worms.  
1 or 2 small goldfish (live).

Mice (fuzzy or pinky) can be fed in addition to the above diet as necessary (Lekos, pers. comm.).

The difference between this diet and the non breeding season diet is the amount of meal worms given. More meal worms are given during this period as they are very high in protein (Lekos, pers. comm.).

### **9.6 Incubation period**

Incubation takes 16-18 days (Strahan, 1994; del Hoyo et al, 2001; Lekos, pers. comm.).

## **9.7 Clutch Size**

Average clutch size for sacred kingfishers is 4-6 eggs with a hatching success of 77-85%. (del Hoyo et al, 2001; Lekos, pers. comm.). Eggs are glossy white and nearly spherical. Size: 26 by 22 mm (Strahan, 1994).

## **9.8 Age at Fledging**

Nestling period is 24-29 days: young are fed every 20 minutes in the first week and then every 10 minutes. Young are fed by both parents. Age at fledging is between 24 and 29 days. The fledging success rate is 68% (del Hoyo et al, 2001; Lekos, pers. comm.).

## **9.9 Age at removal from parents**

The chicks become independent from the parents at approximately 8 weeks of age and will need to be removed from the enclosure shortly after independence is reached to prevent aggression between the parents and the young (Lekos, pers. comm.).

## **9.10 Growth and development**

No growth and development charts have been developed for this species. However growth and development charts have been developed for the Micronesian kingfisher (Bahner et al, 1998). This species has a similar fledging age and therefore if need be these growth and development charts may be referred to until ones for the sacred kingfisher have been developed. Please see appendix 11 for these charts.

## **9.11 Techniques used to control breeding**

To prevent breeding from occurring the easiest way is to separate the pair of kingfishers. As kingfishers are solitary when not breeding there should be no effect on their welfare in captivity (Strahan, 1994, del Hoyo et al, 2001). Another way to control breeding would be to remove the eggs from the nest, however this may either upset the pair of kingfishers so that behavioural problems may begin to be seen, or may induce the pair to clutch again.

## **10.0 Artificial Incubation and Rearing**

### **10.1 Benefits of artificial incubation**

Artificial incubation can be useful when the parents abandon the eggs (due to a variety of reasons) or the eggs need to be pulled to induce the breeding pair to clutch again (Gauge and Duerr, 2007). This would only be done if the species being cared for was an endangered or threatened species under a population management plan. At this point in time sacred kingfishers are not threatened and therefore none have been hand-reared in captivity to date. This section is therefore only a guide to general kingfisher artificial



incubation and hand-rearing protocols as there is no specific information for the sacred kingfisher.

## **10.2 Record keeping**

Detailed records need to be kept in order for the process to be repeated, if successful.

Records should be kept on the following:

- location of institution
  - identification of eggs/chicks
  - genetic history, i.e. their parents
  - age of eggs/chicks when removed
  - reason for removal
  - condition of egg/chick at time of removal
  - diets, feeding schedules, target feeding amounts, actual feeding amounts
  - weight gain/loss
  - incubation temperatures and humidity
  - brooder temperatures
  - general appearance and behaviour
- (Gauge and Duerr, 2007).

## **10.3 Incubation data**

### **10.3.1 Incubation temperatures and humidity**

The incubator should be kept at a temperature of 37.5°C and the relative humidity should start at 50-66%. The relative humidity can be adjusted according to the egg's weight loss. If the eggs are not losing enough weight the humidity should be lowered while if the eggs are losing too much weight the humidity can be increased. This can be done by changing the surface area of water found in the incubator. Relative humidity should be changed slowly, not all at once, and should not be increased or decreased by more than 10% each week (Gauge and Duerr, 2007).

### **10.3.2 Desired percent egg mass loss**

In kingfishers the desired percent egg mass loss is 10-14%. Eggs are weighed two times a week and the equation to calculate percent egg mass loss is:  $\frac{((S-E)/D) \times I}{S}$  where S= set weight; E= end weight; D= number of days incubated since set weight; I= incubation period (Gauge and Duerr, 2007).

### **10.3.3 Hatching temperatures and humidity**

Eggs should be removed from the incubator three days before hatching and placed into hatchers where temperatures are set at 0.3-0.6°C lower than the incubator and relative humidity is set at 63-73% (Gauge and Duerr, 2007).

#### 10.3.4 Normal pip to hatch interval

The pip to hatch interval is between 12 and 71 hours (Bahner et al, 1998).

### 10.4 **Housing after hatching**

#### 10.4.1 Brooder types/description

Chicks are housed in electronic acrylic brooders. Chicks are placed in plastic bowls (nest cup) lined with paper towel, tissue paper and vinyl mats to prevent the chicks from slipping. Brooders should be covered to simulate a nest cavity and reduce stress to the chicks (Gauge and Duerr, 2007). Paper should be changed daily. Chicks should not be housed in the same nest cup as aggression between siblings may occur (Bahner et al, 1998)

#### 10.4.2 Brooder temperatures and humidity

The brooder temperature begins at 34.4-35.6°C and is reduced daily by 0.3-0.6°C, while the brooder humidity is kept at 50-59% for 10 days.

### 10.5 **Diet and feeding routine**

Diets for newly hatched chicks should be high in protein but avoid insects that may create indigestible chitin. Neonate mice, 3 week old crickets and white molted mealworms are all high in protein. Food should be cut up small to begin with and pieces should become larger as the kingfisher grows. Adult foods should be incorporated slowly in to the diet as the chick grows to ensure that the kingfisher will eat a well balanced diet after weaning. Calcium and other vitamin supplements can also be added to the food to ensure nutritional requirements during growth and development are met (Gauge and Duerr, 2007).

In the beginning chicks should be fed between 6 and 8 times a day, every 1 and a half -2 hours, and should be fed approximately 20% of their body weight. This should increase to approximately 50% of their body weight in the first week after hatching. This amount can then be reduced slowly as the chick reaches weaning age (Bahner et al, 1998; Gauge and Duerr, 2007).

Chicks should be weighed daily before feeding and comparisons about weight gain should be made with known growth charts (in this case, comparisons can be made with the Micronesian kingfisher growth chart (appendix 7)) (Bahner et al, 1998; Gauge and Duerr, 2007).

## **10.6 Weaning**

Weaning begins when the chick can pick up food on its own and starts to refuse hand feeding and is complete when the chick does not need prompting to start feeding and refuses any hand feeding (Gauge and Duerr, 2007).

## **10.7 Imprinting**

This can be prevented by the use of puppets that look like parent birds that cover the hand. Sheets can be used to cover the body of the keeper while feeding (Bahner et al, 1998; Gauge and Duerr, 2007).

## **10.8 Cross fostering**

It is unknown at this stage whether this species could be used as a foster species for chicks of another species. However, it may be possible even though the species is known for its aggression. Previously other aggressive species (such as the Yellow-tufted honeyeater) have been used for cross fostering without problems (Underwood, pers. comm.). Therefore more research needs to be completed on this subject to make a definitive judgment.

## **Acknowledgments**

I would especially like to thank both Chris Lekos at Healesville Sanctuary and Ange Foresio at Melbourne Zoo for letting me talk their ears off! Without their help I would have been unable to complete this husbandry manual as there is very little information available for the sacred kingfisher. I hope this manual rectifies this situation. Thank you again to both of you. I would also like to thank Margaret Watson at Charles Sturt University and Geoff Underwood at Australasian Zoo keeping for their valuable insights in editing this manual.

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Great in the year.

**Sacred Kingfisher**  
*Todiramphus sanctus*

Atlas number: 326  
Max. rep. rate: 51% at 23 S 116 E  
1° grids with records: 514 (63%)

**Breeding**

• Breeding recorded

Breeding months  
J F M A M J J A S O N D  
○ 1-5 Records ○ >5 Records

Incidental +

Reporting rate (%)  
● >0 ● 20 ● 40 ● 60

Surveys per 1/4° grid  
0 20 40 60+

**Spring (15 Sep-15 Nov)**

Reporting rate (%)  
● >0 ● 20 ● 40 ● 60 ● 80

**Summer (15 Dec-15 Feb)**

Reporting rate (%)  
● >0 ● 20 ● 40 ● 60 ● 80

**Winter (15 Jun-15 Aug)**

Reporting rate (%)  
● >0 ● 20 ● 40 ● 60 ● 80 ● 100

**Autumn (15 Mar-15 May)**

Reporting rate (%)  
● >0 ● 20 ● 40 ● 60

30



**Appendix 2** Photos of feed area in the walk through exhibit that houses the sacred kingfishers at Healesville Sanctuary. Note the doors that can be closed so area can be used for trapping birds. Photos taken by Claire Gilder (2009).

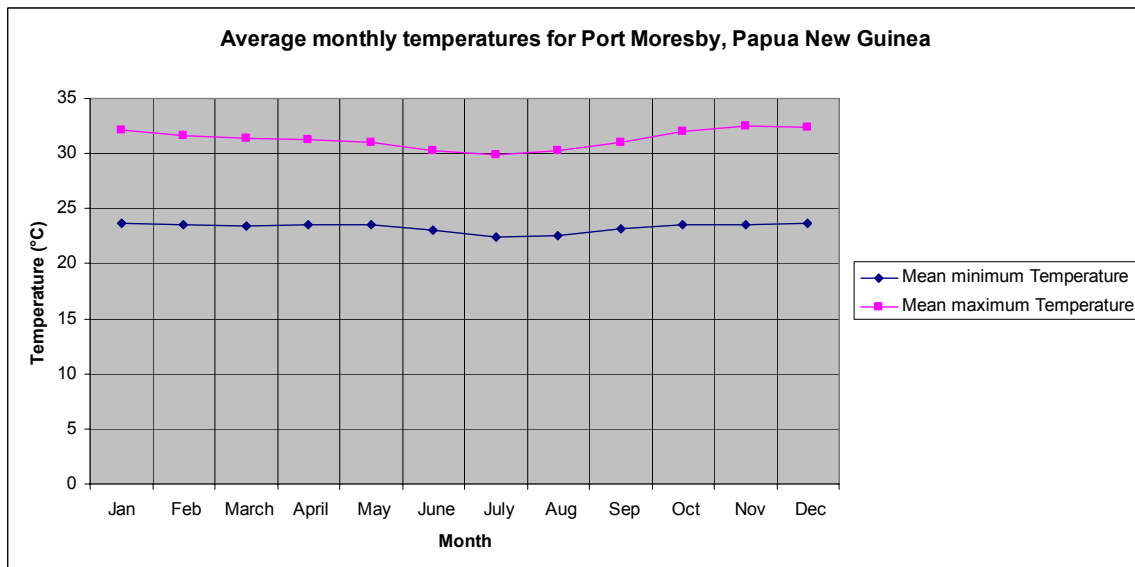
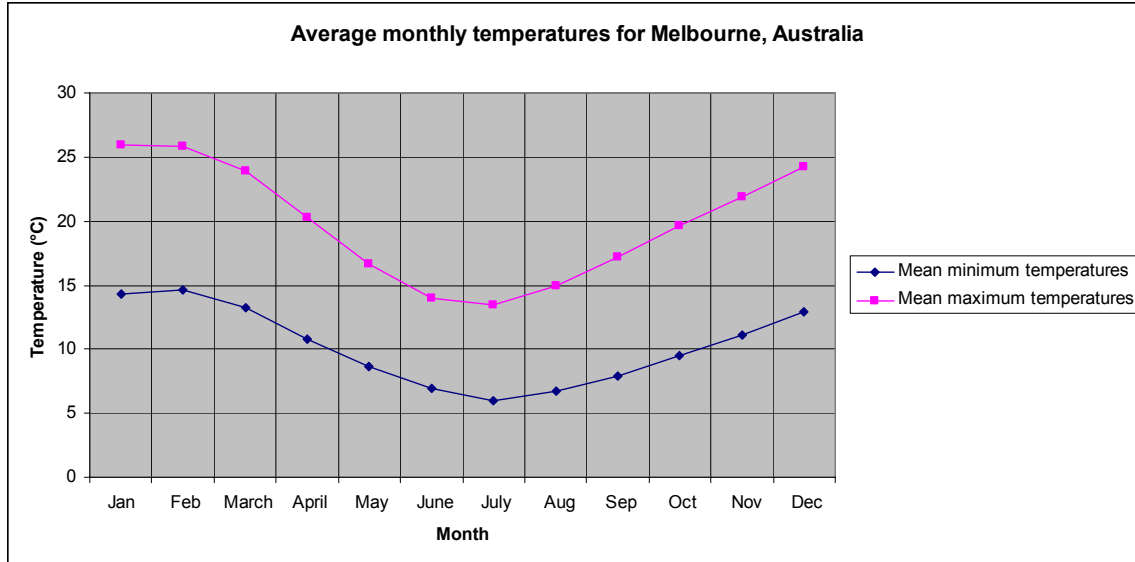


**Appendix 3** Photos of the different quarantine/hospital areas at Melbourne Zoo. Photos taken by Claire Gilder (2009).





**Appendix 4** Monthly temperature charts for both Melbourne, Australia and Port Moresby, Papua New Guinea. Data for graphs sourced from Bureau of Meteorology, (2009) and the World Meteorological Association, (2009).



**Appendix 5** Ingredients found in the meat mix that is fed to the sacred kingfishers at Healesville Sanctuary.

- 5kg Ecopet lamb and vegetable meat loaf
  - 6 Hard boiled eggs, shell included
  - 200g Cheese, grated
  - 200g Frozen fly pupae
- (Lekos, pers. comm.).

**Appendix 6** Photo of type of nets used to catch sacred kingfishers at Healesville Sanctuary and details of where to acquire such nets. Photos taken by Claire Gilder (2009).



## **Appendix 7** Contact details for suppliers.

### **7.1 Identification equipment**

#### **Australian Bird and Bat Banding Database**

##### Postal Address

PO Box 8,  
Canberra, ACT  
Australia, 2601

##### Phone

02 62742407

##### Email

abbbs@ea.gov.au

##### Internet

[www.environment.gov.au/biodiversity/science/abbbs/](http://www.environment.gov.au/biodiversity/science/abbbs/)

### **7.2 Food products**

#### **Wombaroo Food Products**

##### Postal Address

PO Box 151,  
Glen Osmond, SA  
Australia, 5064

##### Phone

08 8391 1713

##### Email

wombaroo@adelaide.on.net

##### Internet

[www.wombaroo.com.au/](http://www.wombaroo.com.au/)

#### **Pet Health Food Products: Ecopet**

##### Postal Address

17 Amberley Crescent  
Dandenong, Vic  
Australia, 3175

##### Phone

03 97921505

##### Internet

[www.ecopet.com.au/](http://www.ecopet.com.au/)

### **7.3 Catching and handling equipment**

#### **Aces Animal Care and Equipment Services**

##### Postal Address

PO Box 591  
Cheltenham, Vic

Australia, 3192

Phone

03 9585 4908

Email

aces@animalcare.com.au

Internet

www.animalcare.com.au

### **Tony's Tackle**

Postal Address

PO Box 66

Lara, Vic

Australia, 3212

Phone

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## **7.4 Cleaning products**

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**Appendix 8** Photos of the transport box used for sacred kingfishers at Healesville Sanctuary. Photos taken by Claire Gilder (2009).



**Appendix 9** Physiological data for the Micronesian kingfisher: to be used as a reference for the normal physiological parameters of the sacred kingfisher (Bahner et al, 1998).

| Parameter  | Units              | ISIS mean | S.D.  | Number |
|------------|--------------------|-----------|-------|--------|
| WBC        | $10^3/\mu\text{l}$ | 4.657     | 3.846 | 7      |
| RBC        | $10^6/\mu\text{l}$ | 3.183     | 0.886 | 7      |
| HGB        | gm/dl              | 14.4      | 0.0   | 1      |
| HCT        | %                  | 43.3      | 1.5   | 7      |
| MACH       | pg                 | 28.0      | 0.0   | 1      |
| MCHC       | g/dl               | 33.5      | 0.0   | 1      |
| MCV        | fl*                | 142.7     | 27.6  | 7      |
| Heterophil | $10^3/\mu\text{l}$ | 2.029     | 2.048 | 7      |
| Lymphocyte | $10^3/\mu\text{l}$ | 1.426     | 0.777 | 7      |
| Monocyte   | $10^3/\mu\text{l}$ | 0.594     | 0.545 | 7      |
| Eosinophil | $10^3/\mu\text{l}$ | 0.424     | 0.711 | 7      |
| Basophil   | $10^3/\mu\text{l}$ | 0.176     | 0.119 | 6      |

**Appendix 10** Photos of recovery boxes for injured sacred kingfishers at Melbourne Zoo.  
Photos taken by Claire Gilder (2009).





**Appendix 11** Growth and development charts for the Micronesian kingfisher: to be used as a reference for the growth and development of sacred kingfishers (Bahner et al, 1998).

#### Estimated Time Of Developmental Markers

| <u>Day</u> | <u>Developmental marker</u>  |
|------------|--|
| 1          | Blind and naked  |
| 2          | Casts have been produced as early as 2 days but, depends on the type of food offered           |
| 5          | Flight feather tracts visible on wings   |
| 6          | Bill mostly black  |
| 7          | Feather tracts visible on back, sides and head   |
| 10         | Eyes begin to open, bill all black   |
| 13         | Feathers begin breaking through skin   |
| 19         | Breast feathers breaking out of sheaths  |
| 20         | Skin is completely covered by pin feathers   |
| 23         | Back and wing feathers breaking out of sheaths; flight, head, and neck feathers still sheathed |
| 27         | All feathers out of sheaths except for tail and a few feathers around the eyes                 |
| 29         | Perching   |
| 27-30      | Fully feathered  |
| 32-35      | Fledging   |

