

Husbandry manual

Spotted Tailed Quoll *(Dasyurus maculatus)*



(Source:Carnivora)

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1 Introduction

The Spotted Tailed Quoll (*Dasyurus maculatus*) is the largest member of the marsupial family Dasyuridae on mainland Australia and among marsupial carnivores and is second in size only to the Tasmanian Devil (*Sarcophilus harrisii*) (Burnett and Holmes, 2008). The Spotted tailed Quoll was one of the first Australian animals to be encountered by Europeans, Arthur Phillip's party collected one at Port Jackson in 1788 (Wild QLD, 2013).

They are more than 50 per cent larger than other quolls (eastern, western and northern) and, unlike other species, have white spots that extend along their tail. They have bright eyes, a moist pink nose and sharp teeth. They have a pointed snout and a long tail. Their fur has a coarse texture and is red-brown to dark brown with white spots of varying size (Australian Government, 2013). Spotted-Tailed quolls hunt mostly at night being largely nocturnal and solitary. Their diet appears to consist primarily of medium-sized mammals including gliders, possums, rabbits, and even small wallabies. They like carrion (dead animals), birds and eggs as well (Australian Government, 2013).

The Spot-Tailed Quoll was previously widely distributed from South-East Queensland, Eastern NSW, Victoria, South-East South Australia and Tasmania (Jones, Rose and Burnett, 2001). The subspecies' mainland range has reduced by 50–90% (Jones *et al*, 2001). Detailed distribution records and abundance estimates are generally lacking due to the scale and intensity of surveying that is required to detect the species across its entire range (Jones *et al*, 2001).

Dasyurus maculatus is found in Australia. There are two subspecies; *D. maculatus gracilis*, which inhabits northern Queensland, and *D. maculatus maculatus*, which is found from southern Queensland to Tasmania (Encyclopedia of life, n.d). The spotted-tailed (Southern subspecies and northern subspecies) is Endangered nationally (Australian Government, 2013). This is due to threats that include loss of habitat, deliberate killings at chicken pens, competition and predation with introduced carnivores animals such as domestic cats (*Felis catus*), red fox (*Vulpes vulpes*) and wild dogs/dingo (*Canis lupus*). Others include road kills, poison laid for feral carnivore animals and poisoning from predation on cane toads (*Bufo marinus*) (Burnett and Holmes, 2008).

2 Taxonomy

2.1 Nomenclature

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Infraclass: Marsupialia

Order: Dasyuromorphia

Family: Dasyuridae

Genus: Dasyurus

Species: *D. maculatus*

The orders Dasyuromorphia are carnivorous marsupials (Vogelnest and Wood, 2008). They are characterised by having three pairs of approximately equal sized lower incisors and an absence of fusion between the second and third digits of the hind foot (Vogelnest and Wood, 2008). The order is divided into three families: Thylacinidae, which contains the extinct Thylacine (*Thylacinus cynocephalus*), Myrmecobiidae, which contains the Numbat (*Myrmecobius fasciatus*) and Dasyuridae which contains the remaining 66 species. This is the group that contain the Spotted Tailed Quoll, Tasmanian Devil and dunnarts etc (Vogelnest and Wood, 2008).

2.2 Subspecies

There are two subspecies of Spotted Tailed Quoll. *Dasyurus maculatus* (Northern subspecies) from the wet tropics of North Eastern Queensland and *Dasyurus maculatus maculatus* (Southern subspecies) from South East Queensland, New South Wales and Victoria (Wildlife QLD, 2013).

2.3 Other common names

Spotted-tail Quoll, Tiger Quoll, Spot tail Quoll, Tiger Cat, Spotted-tailed Native Cat, Spotted-tailed Dasyure (Verjinski, 2014)

3 Morphometrics

3.1 Weights and basic measurements

Spotted Tailed Quoll is the largest marsupial carnivore on mainland Australia (Otway ranges, 2001). Males have a head and body length of 380-760mm, a tail length of 370-550mm and weigh up to 7kg but with the average weight being 3kg (Otway ranges, 2001). Females have a head and body length of 350-450mm, a tail length of 340-420mm and weigh up to 4kg but with the average weight being 2kg (Otway ranges, 2001).

3.2 Sexual dimorphism

Male Spotted Tailed Quolls are typically larger than females in mass and overall size (Verjinski, 2014).

3.3 Diagnostic features

This medium robust marsupial has a rich fur that can be described as Rufus ranging from orange-brown, olive- brown to grey- brown with both fawn and black markings evident (Australian Government, 2013). The underside is paler, ranging from light brown to creamy white and the spots are white to cream and extend onto the tail which is used to identify them from other species as they are the only species to have spots (Australian Government, 2013).

3.4 Distribution and habitat

The Spotted-Tailed Quoll (Northern Subspecies) inhabits coastal ranges (usually 600m or more above sea level) between Townsville and Cooktown. There have also been unconfirmed sightings to the west of Townsville and as far south as the Mackay-Whitsunday area (Australian Government, 2013).

The Spotted-Tailed Quoll (southern subspecies) occurs in coastal areas and adjacent ranges throughout south-eastern Australia from southern Queensland to South Australia and Tasmania (Australian Government, 2013).

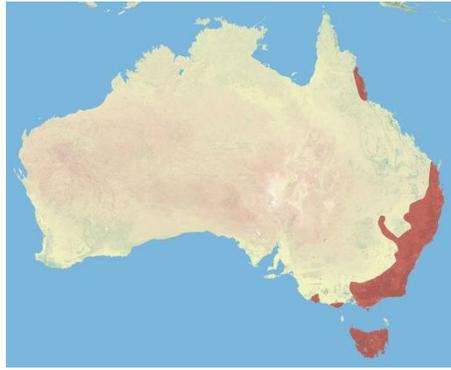


Figure 1: Australian distribution of the STQ (Source: Australian Government, 2013)

The Spotted-Tailed Quoll has a preference for mature wet forest habitat (Australian Government, 2013), especially in areas with rainfall 600 mm/year (Australian Government, 2013). Unlogged forest or forest that has been less disturbed by timber harvesting is also preferable (Australian Government, 2013). The STQ has been recorded from a wide range of habitats, including:

- temperate and subtropical rainforests in mountain areas
- wet sclerophyll forest
- lowland forests
- open and closed eucalypt woodlands
- inland riparian and River Red Gum (*Eucalyptus camaldulensis*) forests
- dry 'rainshadow' woodland
- sub-alpine woodlands
- coastal heathlands
- occasional sightings from open country, grazing lands, rocky outcrops and other treeless areas

(Australian Government, 2013)

The Spotted-Tailed Quoll is predominantly nocturnal and rests during the day in dens (Australian Government, 2013). Habitat requirements include suitable den sites such as hollow logs, tree hollows, rocky outcrops or caves (Australian Government, 2013). Individuals also require an abundance of food, such as birds and small mammals, and large areas of relatively intact vegetation through which to forage (Australian Government, 2013). This subspecies is moderately arboreal and approximately 11% of travelling is done in trees (Australian Government, 2013).

3.5 Conservation status

The spotted-tailed (Southern subspecies) is Endangered nationally (*Environment Protection and Biodiversity Conservation Act 1999*). It is ranked as a high priority under the Department of Environment and Heritage Protection (EHP) (Australian Government, 2013). The northern subspecies is listed as Endangered nationally (*Environment Protection and Biodiversity Conservation Act 1999*). It is ranked as a critical priority under the Department of Environment and Heritage Protection (EHP) (Australian Government, 2013).

3.6 Wild diet

The Spotted-Tailed Quolls is an agile hunter with opportunistic tendencies (Ulyatt, 2013) and they kill their prey by biting on or behind the head (Parks and wildlife service Tasmania, 2010). Spotted Tailed Quolls are predators of mainly medium sized mammals ranging from 500g to 5kg. The main prey items include Ringtail Possums (*Pseudocheirus pererinus*), Common Brushtail possum (*Trichosurus vulpecula*), Mountain Brushtail Possum (*Trichosurus caninus*), Greater Gilder (*Petauroides volan*) and Rabbit (*Oryctolagus cuniculus*) (Australian Government, 2013). Insects are also frequently consumed however birds and reptiles are consumed less frequently which forms a smaller portion of their diet (Ulyatt, 2013). As mentioned the Spotted Tailed Quoll has opportunistic tendencies this means that carrion is frequently eaten and they are also known to tip scavenge, beach comb and eat refuse that is discarded by humans (Parks and Wildlife Service Tasmania 2010). Seasons and different habitats provide different primary feeding resources. An example is the tall wet forests of the escarpment ranges of southern NSW where Greater Gilders occur in high densities and are the main prey item for Spotted Tailed Quolls in that area (Australian Government, 2013). Another example is the dry rain shadow woodland habitat of the Kosciusko National Park where Common Brushtailed possums are the prey most utilised and following wildfires in the area rabbits and hare are the prey that would be most utilised (Australian Government, 2013).

Once prey has been killed the Spotted Tailed Quolls will often eat the entire animal including the skull (Ulyatt, 2013). The Spotted Tailed Quoll only eats the bones of its smaller prey (Jones, Rose, Burnett, 2001). The size and type of the prey taken appears to be divided based on sex. Males consume larger prey while females consume smaller species (Ulyatt, 2013) but sub adults eat smaller prey than that of the adult males and females (Jones *et al*, 2001) .The

Spotted Tailed Quoll is adept at climbing high into trees and can capture possums, tree roosting domestic chickens etc (Jones *et al*, 2001)

3.7 Longevity

Spotted-Tailed Quolls in the wild have a life span ranging from 2 years in smaller quolls to 4 to 5 years in larger quolls. In captivity, Spotted-Tail Quolls live slightly shorter lives ranging 3 to 4 years on average. The longest living Spotted-Tail Quoll lived 6 years and 3 months in captivity (Verjinski, 2014)

4 Housing Requirements

Enclosure design and good husbandry have developed to incorporate the requirements and needs of many stakeholders, but there are three principle groups whose needs should or have to be considered when designing zoo housing and husbandry guidelines (Hosey, Melfi, Pankhurst, 2009). These are

- The animals, to ensure that they have good welfare and the five freedoms are fulfilled and also that they form self sustaining populations (Hosey *et al*, 2009).
- The keepers, so they are able to adequately care for the animal (Hosey *et al*, 2009).
- Zoo visitors, who want to enjoy their visit to the zoo and who zoos want to educate about conservation and the environment (Hosey *et al*, 2009).

4.1 Exhibit design

The floor should ideally have wire mesh buried about 30-60cm below the surface for quolls although this may not be needed if the footing to the outside of the exhibit descends at least 50cm (Jackson, 2003). The enclosure should be made to look natural by adding soil or leaf litter with grass tussocks, hollow logs, small branches, rocks and bark over the substrate to provide stimulation, shelter and reduce stress (Jackson, 2003). Large enclosure furniture should be secured to the floor so animals can't dig them up (Jackson, 2003).

If using mesh the size of the holes is always an important point to consider and also double layers are not recommended due to animals entangle their limbs and hang themselves (Jackson, 2003). A double gate system is highly recommend to reduce the potential risk for the animal escaping while people are entering especially with outdoor enclosures (Jackson, 2003).

4.2 Holding area design

Spotted Tailed Quolls can potentially be quite aggressive so holding areas could be needed to assist with cleaning and maintenance. However these aren't the only reason, others may include separation for feeding, introduction of new animals and veterinary reasons.

4.3 Spatial requirements

The minimum dimension of an enclosure that houses two Spotted Tailed Quolls has a minimum area of 30m² and a minimum height of 240cm. With any additional animal there needs to be an increase of the enclosure area of 3 metres by 3 metres (NSW DPI, 2006). Carnivore marsupials must be contained in fully enclosed displays or facilities with solid smooth unclimbable partitions of a height that prevents escape (NSW DPI, 2006). So in the case of the Spotted Tailed Quoll the enclosure needs to be fully enclosed. Openings in the wire mesh should be narrow enough to prevent an animal pushing its head through (NSW DPI, 2006). Also with large carnivore marsupials such as Spotted Tailed Quolls their enclosure must have double door entry this helps minimise the risk of escape (NSW DPI, 2006).

4.4 Position of enclosure

Basking opportunities must be provided for all species of dasyurids in the form of direct access to the sun especially for quolls (NSW DPI, 2006). Access to natural sunlight is recommended as it is not known whether artificial lights provide sufficient substitute. Natural light cycles also appear to be important in successful breeding of many species of dasyurids (NSW DPI, 2006).

4.5 Weather protection

Excessive exposure to sunlight may result in sunburn, heat stress, premature loss of vision and solar dermatitis resulting in hair loss in the lower back, so adequate rest areas to seek shade should be given (Jackson, 2003). The animal also needs to be given adequate shelter from all other elements as well as the sun, such as rain and wind if it's an outdoors exhibit.

4.6 Heating requirements

Optimum temperature range is 15°C-30°C, so supplemental heating may be necessary such as heat lamps, heat mats etc (Vogelneust and Wood, 2008).

4.7 Substrate

For Spotted Tailed Quolls a mixture of two parts solite (solite corporation), two parts pine bark and one part peat moss to a depth of 45cm has been used to allow Spotted Tailed Quolls to dig and also good reproductive success. Other substrates such as concrete floors for larger dasyurids have resulted in sore feet, so are not recommended (Jackson, 2003).

Nesting material can also be used as substrates these include dry eucalyptus leaves, wood shavings, shredded paper or sea grass (Jackson, 2003).

4.8 Nest box/ bedding

Nest boxes should be supplied for all species of carnivorous marsupials except the marsupial mole. They help to provide shelter, warmth and security and can assist in capture, so they should have a hinged roof. For Spotted Tailed Quolls they need to be made of solid timber. Nesting materials such as grasses and stringybark should be placed in the enclosure as the animal will use this for nesting (Jackson, 2003).

4.9 Enclosure furniture

In order to minimise stereotypic behaviour it is advisable to provide a number of different furnishings within the enclosure. These can range from small branches, running wheels (Off display only), rocks, hollow logs, climbing branches, pieces of bark, PVP pipe (Off display only), planted trees and shrubs, large logs. Numerous tussocks generally are needed as quolls often dig them up and use them for nesting (Jackson, 2003).

5 Handling and transport

5.1 Timing of capture and handling

Carnivorous marsupials are generally best caught during the day while they are asleep in their nest box. If held in a nocturnal house they can often be caught first thing in the morning before the lights go out. Alternatively they can be netted or trapped in the enclosure (Jackson, 2003).

5.2 Catching bags

Spotted Tailed Quolls should be placed in large thick canvas, cotton, calico or hessian bags. Making sure care is taken that the animal does not bite through the bag. Take care with hessian bags needs to be taken as dust can fall in the animal's eyes and nose (Jackson, 2003).

Specially made canvas sacks with air holes in the corners and air hole eyelets at regular intervals around the bags are another option (Jackson, 2003).

5.3 Capture and restraint techniques

5.3.1 Physical restraint

Physical restraint is only used for minor procedures or to induce general anaesthesia as it will result in considerable struggling and attempts to bite. Spotted Tailed Quolls can inflict serious injuries (Vogelnest and Wood, 2008).

Animals in bag tend to relax as outside stimuli and visual threats are removed (Vogelnest and Wood, 2008).

Spotted Tailed Quolls can easily be held by the tail for short periods and to avoid injury the tail should be grasped towards the base. The animal should not be transported over long distances by the tail (Vogelnest and Wood, 2008).



Figure 2: Handling and capturing a Spotted Tailed Quoll (Source: ABC)

5.3.2 Chemical restraint

Most dasyurids are not prone to regurgitation under anaesthesia but pre anaesthetic fasting for 6-8 hours is recommended (Vogelnest and Wood, 2008).

Sedation for transport is generally not required but very nervous animal may benefit from the administration of 1-2 mg/kg of diazepam IM. Effects should be obvious after approximately 20 minutes (Vogelnest and Wood, 2008).

Inhalation anaesthesia is the method of choice for dasyurids. If the animal can be manually restrained the safest way to induce general anaesthesia is via a non re-breathing circuit (e.g. Ayres T piece) and a mask (Vogelnest and Wood, 2008). For animals in bags anaesthesia can be induced through the bag or by extracting the head and place it in the mask. It is important to grasp a Spotted Tailed Quoll by the back of the head as they will attempt to pull back out of the mask and potentially bite the operator (Vogelnest and Wood, 2008).

5% isoflurane delivered in oxygen at a flow rate of 200ml/kg/min with a minimum of 1L/min is used for induction. Maintenance of anaesthesia generally requires 2% isoflurane but varies between species and individuals (Vogelnest and Wood, 2008). Spotted Tailed Quolls have a wide gap and are easily intubated for more prolonged procedures. If isoflurane is unavailable halothane is an acceptable substitute but is not safe and requires close monitoring (Vogelnest and Wood, 2008).

Injectable agents can be used if gaseous anaesthesia is not available to induce general anaesthesia Tiletamine/Zolazepam can be administered at 7-10g/kg IM (Vogelnest and Wood, 2008). The advantage of this combination is its low volume and rapid effect. Relaxation varies with hyper salivation and constant limb and jaw movement sometimes occurring (Vogelnest and Wood, 2008).

5.4 Weighing and examination

The muscles of the pouch of the Spotted Tailed Quoll are strong enough to deter a person using only one hand trying to look inside, so both hands are usually needed which means two or three people are recommended (Jackson, 2003). One person restrains the animal with its dorsal surface closest to the substrate and its head region laterally, while the other person uses two or three fingers to open and investigate inside the pouch (Jackson, 2003). Take care to reduce the amount of cold air entering the pouch if the young are un-furred (Jackson, 2003). The Spotted Tailed Quoll can be weighed in a bag that it was captured in using scales with 1g increments for accuracy and always remember to subtract the weight of the bag (Jackson, 2003).

5.5 Release

Best released onto the ground (Jackson, 2003).

5.6 Transport requirements

For short distances (e.g. few hours) they can be transported in a catching bag which should also be in a nest box with the hole plugged to provide a secondary barrier in case of escape from the bag (Jackson, 2003). The nest box also provides protection from objects that may crush them. When travelling longer distances the animal needs to be placed inside a travel box without the bag and with nesting material (Jackson, 2003).

5.7 Box design

Spotted Tailed Quolls can be transported in plastic crates designed for holding cats and small dogs (Vogelnest and Wood, 2008). For longer distance they must be placed in a wooden box with nesting material, water and small dish of food (Vogelnest and Wood, 2008).

5.8 Furnishing

Wood shavings or shredded paper should be provided to minimise the animal being moved around during transport and to provide insulation against heat and cold (Jackson, 2003).

5.9 Water and food

Water should be provided on all except very short trips (less than one hour) in cool weather. Although they often don't eat food during transport a small dish of food should be provided for the journey (Jackson, 2003).

5.10 Animals per box

Only one individual should be placed per box or per compartment within a box. Females with pouch young should not be transferred unless only recently born and still attached to the teat. Although even then there is some risk that a stressed female will remove her young (Jackson, 2003).

5.11 Timing of transportation

Whenever possible transport should be done either in the early morning or overnight so that the animal doesn't become over heated (Jackson, 2003).

5.12 Release from the box

Best released by placing the box on the ground inside the enclosure and allowing the animal to take its time and leave the box when it's ready (Jackson, 2003).

6 General Husbandry

'Husbandry' is the term used to describe the processes undertaken to care for animals and include many routine and some infrequent events (Hosey *et al*, 2009). The most important point to remember when considering zoo animal husbandry is that as a zoo professional is ultimately responsible for the lives of zoo animals and determine what, how and when many events occur in their lives, from their conception to their development and finally how and when they die (Hosey *et al*, 2009).

6.1 Hygiene and cleaning

All enclosures should be cleaned daily to remove faecal matter and uneaten food. Spotted Tailed Quolls use latrines so all faeces are located in the one place making it easy to find and clean (Jackson, 2003). Drinking water dishes should be cleaned and refilled daily (Jackson, 2003). When all individuals permanently leave an enclosure it should be scrubbed out if possible and thoroughly cleaned before the new arrivals (Jackson, 2003).

Pens should be well drained. Sick or injured animals should be removed from public viewing areas into isolation or treatment facilities supervised by the veterinarian and examined at least once daily (State Government Victoria, 2010).

The use of strong-smelling disinfectants is not recommended for all animals except in exceptional circumstances, as these chemicals can cause discomfort and sickness in some animals. Herbal disinfectants may be an appropriate alternative (State Government Victoria, 2010).

6.2 Record keeping

It is important to establish a system where by health, condition and reproduction statuses of captive carnivorous marsupials are routinely monitored (Jackson, 2003). Records should be kept of

- Identification numbers
- Any veterinary examination conducted
- Treatments provided
- Behavioural changes or problems
- Reproductive behaviour or condition
- Weights and measurements

- Change in diet
- Movements of individuals between enclosures or institutions
- Births with dam and sire if known
- Deaths with post mortem results

(Jackson, 2003)

The collection of information on physical and behavioural patterns of individuals can contribute greatly to the husbandry of the species. It also allows individual histories to be transferred to other institutions if required and greatly facilitates a cooperative approach to data collection amongst institutions (Jackson, 2003).

6.3 Method of identification

Spotted Tailed Quolls can be permanently identified by inserting a passive integrated transporter or micro chip SC between the scapulae (Vogelnest and Wood, 2008). Tissue glue is used to seal the entry wound to prevent the microchip from tracking out along the injection site (Vogelnest and Wood, 2008). A non invasive method that should be the first considered as Spotted Tailed Quolls have unique marking is using these natural markings (coat colour and markings) as a way of identifying the animal (Vogelnest and Wood, 2008). Ear notching and ear tattoos are other options that have been used as identification techniques (Vogelnest and Wood, 2008).

6.4 Health requirements

Assessing good health in a wild animal in captivity is not always straight forward (Hosey *et al*, 2009). Signs of disease or even injury may not be outwardly obvious and an accurate picture of an animal's health may only be possible after invasive procedures such as blood testing for immune function (Hosey *et al*, 2009). Failure to reproduce can be due to underlying health problems, but can also be due to lack of compatibility between individuals (Hosey *et al*, 2009). Weight change can be a sign of disease or could occur due to seasonal change or breeding (Hosey *et al*, 2009).

Maintaining good health in zoo animals requires minimum and routine monitoring of the animals by knowledgeable members of staff who are familiar with the animals in their care (Hosey *et al*, 2009). Keepers and the managers should have an understanding of species life

history traits and should maintain detailed and current records of the animals in their care to identify any recurring health problems or other issues (Hosey *et al*, 2009).

6.5 Daily health checks

Each individual should be observed daily for any signs of injury and illness. The most appropriate time to do this is generally when the enclosure is being cleaned or when the animal is being fed (Jackson, 2003). During these times each animal within the enclosure should be checked and the following assessed:

- Coat condition
- Discharges- eyes, ears, nose, mouth or cloaca
- Appetite
- Faeces- number and consistency
- Eyes for cloudiness
- Changes in demeanour
- Injuries
- Presences and development of PY by observation of the bulge in the pouch
- Stereotypic behaviours

(Jackson, 2003)

6.6 Detailed physical examination

When an animal is caught and being examined, look for wounds and the presence of lumps throughout the body, which maybe tumours (Jackson, 2003). The eyes should be checked closely for cloudiness and general clarity (Jackson, 2003). Body weight is also a useful indicator of condition. The physical examination may include the following:

- Body condition- best assessed by the muscle palpation in the area over the scapula spine and temporal fossa.
- Temperature- normally 35-36.5% and can be taken through the anus via the cloaca
- Weight- Recorded and compared to previous weights. Animals in captivity should be weighted at least once a month.
- Pulse rate- Should be taken under anaesthesia as it would increase with the capture of the animal.
- Respiratory rate- Should be taken under anaesthesia as it would increase with the capture of the animal.

- Fur- Check for alopecia, ectoparasites, fungal infections and traumas.
- Eyes- Should be clear, have normal bilateral papillary light response, normal corneal reflex and should not have any discharge.
- Cloaca- Should be clean and checked for faeces around the area
- Pouch- Condition, check for lactation is occurring by milking teats and if PY are present record sex, stage of development etc.
- Males- Check testes for size (length, width and depth) and consistency (firm, not squishy), extrude the penis and assess and also check the size and activity of the sterna gland.

(Jackson, 2003)

6.7 Known health problems

Carnivore marsupials suffer few problems in captivity. Most of the parasites and diseases that have been recorded in Spotted Tailed Quolls are listed below

- **Ectoparasites:** Various species of ectoparasites such as fleas, ticks and mites can be found on STQ. This can result in considerable irritation and which result in severe scratching and hair loss (Jackson, 2003). Generally visible signs can be seen and can be treated by using Carbaryl topically or Ivermectin 1% injectable (Jackson, 2003). Prevention can include changing nest material and scrubbing nest boxes regularly (Jackson, 2003).
- **Endoparasitic worms:** These are not obvious unless diagnosed by using faecal flotation and the presence of eggs or proglottids (Jackson, 2003). Can be treated using anthelmintics such as Droncit (Jackson, 2003). Prevention is generally not required by routine treatment with anthelmintics could be applied and also it's important to remove faeces from the enclosure (Jackson, 2003).
- **Protozoans:** Can be observed when the animal shows a variety of abnormalities including altered behaviour, blindness, in coordination, paralysis or death without warning (Jackson, 2003). Signs may include clouding of the cornea or lens of one or both eyes, difficulty walking or dragging one or both hind limbs (Jackson, 2003). This can be confirmed by serological testing to detect rising IgG (*Toxoplasma gondii* *tirtve*) and treatments include medication with anti protozoan drugs such as Sulphonamides including Amprolium and Toltrazuril (Jackson, 2003).

- **Nutritional osteodystrophy:** This is caused by inappropriate diets that are deficient in calcium and/or an incorrect ration of calcium to phosphorus (Jackson, 2003). Signs include abnormalities including growth defects, lameness in gaunt or posture and dragging of limbs in extreme cases. Radiography of the vertebral, pelvic and long bones can show low bones density (Jackson, 2003). If identified early condition may respond to high calcium, high vitamin D₃ diet and strict cage rest (Jackson, 2003). To prevent this correct diet is essential and a meat only diet can have added calcium in the form of calcium carbonate (Jackson, 2003).
- **Neoplasia:** Are non inflammatory growths of tissue that is outside the normal control mechanisms of the body (Jackson, 2003). They are generally age related and usually occur after reproductive senescence of age when individuals would normally have died in the wild (Jackson, 2003). These are diagnosed by clinical signs and biopsies of tumours. They are generally untreated and the affected animal is given supportive care or euthanized (Jackson, 2003). It is very difficult to prevent (Jackson, 2003).

7 Behaviour

Maintaining natural behaviour in captive bred animals is a top priority for zoo professionals because all 3 levels of change may compromise ex situ and in situ conservation efforts for endangered animal species (Kleiman, Thompson, Baer, 2010). For an individual animal the presence of normal species specific behaviours that are similar to those observed in the wild is one potential indicator that its needs are being met, these are that the animal's captive environment is optimal and it has good health and well being (Kleiman *et al*, 2010). In exhibited animal's natural behaviour is also a signal to zoo visitors that the animal is a viable representative of its wild counterparts (Kleiman *et al*, 2010). Visitors who witness captive animals displaying abnormal behaviours are more likely to perceive those animals as 'un happy' and increased aberrant behaviours can detract from the educational messages of the exhibit (Kleiman *et al*, 2010). Such negative experiences with captive animals can potentially cause visitors to reject the concept that zoos are authorities in the preservation of that species and biodiversity in general (Kleiman *et al*, 2010).

7.1 Activity

This diurnal hunting strategy fits this ecological pattern, with their bodies not adapted to chase, the Spotted Tailed Quoll exploits prey species during periods of vulnerability while minimising energy expenditure (Ulyatt, 2014). In captivity Spotted Tailed Quolls are most

active at dawn and dusk but activity periods are strongly influenced by feeding times (Jones *et al*, 2001).

Spotted Tailed Quolls also stalk their prey by either walking or running forward when the preys head is down and stopping when it's raised (Jones *et al*, 2001). The Spotted Tailed Quolls will then leap or pounce on their prey, depending on the size of the prey and kill it with a bite at the base of the skull or top of the neck (Jones *et al*, 2001). The Spotted Tailed Quoll will move in both a walk and a bounding gait along the ground, although trails are not used extensively (Jones *et al*, 2001).

Spotted Tailed Quolls use fallen logs as runways wherever possible and they also use roads for foraging and scent marking (Jones *et al*, 2001). Spotted Tailed Quolls climb vertically up and down the tree trunks, including climbing down head first. They even travel on the thin outer branches and cross between contiguous trees canopy (Jones *et al*, 2001). Spotted Tailed Quolls lack large feet or furred footpads which means they have difficulty moving in deep snow (Jones *et al*, 2001). The physical hunting characteristics of this species is an evolutionary trait that enables access to ground burrows and tree hollows of the obligate prey species (Ulyatt, 2014). Spotted Tailed Quolls have been observed 10-25 metres above the ground hunting for greater gliders in tree hollows and have also been observed hunting in rabbit warrens (Ulyatt, 2014).

Olfactory and auditory signals are more important than visual communications in STQ (Jones *et al*, 2001). When foraging Spotted Tailed Quolls sniff along the ground as they move and have the ability to pick a cross trail of a rabbit which suggest a keen sense of smell (Jones *et al*, 2001). During intra specific encounters, Spotted Tailed Quolls sniff nose to nose and males sniff the rumps of females in oestrus (Jones *et al*, 2001). Face washing besides from cleaning, may function as self marking behaviour as mouth and ear secretions are smeared on the head (Jones *et al*, 2001). In some populations communal latrine sites are used but not in others (Jones *et al*, 2001).

7.2 Social Behaviour

The Spotted Tailed Quoll is largely nocturnal and solitary. They have large home ranges and can cover considerable distances (more than 6km) overnight. (Foundation for National Parks and Wildlife, 2001).

Vocalisations are infrequent in Spotted Tailed Quolls but are given in all social interactions, including agonistic, mating and maternal care (Jones *et al*, 2001). During agonistic

encounters with other Spotted Tailed Quolls or when disturbed by humans, Spotted Tailed Quolls emit a guttural huff, cough and hissing sounds and abrupt piercing screams likened to a short blast of a circular saw (Jones *et al*, 2001). Agonistic behaviour involves both vocal and open mouth behavioural threats. In the latter the mouth is opened wide displaying their teeth to the opponent, the ears are laded back and eyes are narrowed. Males will fight each other in vigorous tumbles, grasping each other with their fore paws, kicking with their hind feet, biting and screeching (Jones *et al*, 2001).

7.3 Reproduction behaviour

The female may show agonistic response to the approach of the male, who chases her for a long time in the periods leading up to oestrus (Jackson, 2003). There can be significant injuries to the females in captivity, as she can't escape (Jackson, 2003). At oestrus the female will show behavioural oestrus by standing still and allow the male to approach and investigate her mouth and genital region and groom her flank (Jackson, 2003). The male then grasps the female by the scruff of the neck with its mouth and clasps her abdomen which results in intromission if not resisted (Jackson, 2003).

7.4 Behavioural problems

Most species of dasyurid suffer from stereotypic behaviour and the Spotted Tailed Quolls is no exception (Jackson, 2003). These behaviours can be very hard to stop once established. Pacing is a major one where the animal continually runs up and down alongside the enclosure wall or along a circuit. This can range from wanting to be fed or waiting for a keeper to walk by to feed them (Jackson, 2003).

7.5 Signs of stress

Signs of stress in Spotted Tailed Quolls include increased irritability (e.g. vocalising, fighting or attacking more), listlessness and signs of depression, rough fur and alopecia and also stereotypic behaviour (Jackson, 2003).

7.6 Behavioural enrichment

- Making the enclosure surface as variable as possible by changing the soil profile and adding hollow logs and branches to climb which the animals can climb through and up. This may include obstructing the chosen stereotypic path with obstacles (Jackson, 2003).
- Scattering or hiding small pieces of food so that it takes them time to hunt for it (Jackson, 2003).

- Feeding at different times of the day so the animals do not time their activity with feeding time (Jackson, 2003).
- Providing raw bones as they provide access to bone marrow and helps keep teeth clean (Jackson, 2003).
- Providing live insects and other food types (eg fish), where ever possible to promote hunting behaviour (Jackson, 2003).
- Using passive insect feeders and suitable logs as temporary refuge for the insects (Jackson, 2003).
- Freezing blocks of blood or food items such as rats, rabbits or chickens inside the blocks of ice to stimulate olfactory and taste senses (Jackson, 2003).
- Using various scents. Including prey faeces such as wombat, possum or kangaroo. Dragging food items around the enclosure and hiding them or novel smells such as spices or aromatherapy oils (Jackson, 2003).
- Varying diet throughout the week (Jackson, 2003).
- Planting various species of plants such as brass tussocks and bushes (Jackson, 2003).

7.7 Introduction and removals

Males should ideally be introduced into the females' enclosure (Jackson, 2003). Male Spotted Tailed Quolls have been known to kill and partially consume the intended mate during breeding encounters, so it may be advisable to increase the food up to 20% just prior to introduction and keep a very close eye on them (Jackson, 2003). Male Spotted Tailed Quolls should be introduced (under supervision) just prior to the breeding season, particularly once the female starts calling (Jackson, 2003). If the female appears uninterested the male can be moved to the next prospective mate's enclosure and the process repeated until a receptive female is found (Jackson, 2003).

7.8 Interspecific compatibility

Spotted Tailed Quolls are generally incompatible with most species due to their carnivorous nature, which results in them eating most things their own size or smaller (Jackson, 2003). Their ability to escape and the difficulty of properly managing them in large enclosure are also factors (Jackson, 2003).

7.9 Intraspecific compatibility

Although not much is known of the social behaviour of many of the carnivorous marsupial they are generally not very social and usually only come together during mating, after which

the males seek further mates (Jackson, 2003). Therefore in most cases they should be held in pairs or ideally the male should be introduced to the female when they are in oestrus (Jackson, 2003).

8 Captive diet requirements

Feeding wild animals successfully in captivity requires knowledge of basic nutritional concepts, an understanding of different animal types and digestive physiologies, an appreciation for natural feeding behaviours, a familiarity with appropriate food sources and an awareness of potential diet related diseases (Kleiman *et al*, 2010). In the wild animals satisfy their nutritional requirements by foraging over a large range for a variety of food items. In captivity it is not possible to feed the animals regularly with the diversity of the food contained in their natural diet (National health and medical research council, 1990). Food suitable for the particular species should be provided in a manner which is consistent with the species requirements to maintain good health and to encourage the natural feeding behaviours of the species (State Government Victoria, 2010). The food should be of high quality and free from contamination by rodents, insects and chemicals. Diets should be complete and balanced and food items provided in quantities necessary for growth and maintenances of healthy body conditions (State Government Victoria, 2010).

8.1 Captive diet for a STQ

Spotted Tailed Quolls are fed on the ground. Small feeds to increase activity for public display are generally provided by randomly throwing in food, ideally at different times of the day, to any part of the floor or up branches (Jackson, 2003). To encourage foraging and hunting behaviour live insects in the mulch or leaf litter work well as a way of encouraging natural feeding behaviours. Thought the use of activity feeds is an important role but care needs to be taken to ensure that such feeds do not lead to obesity (Jackson, 2003).

Table 1: Average size of male and female Spotted Tailed Quolls

	Male	Female
Weight	3-7 kg	1.6-4 kg
Head/body length	45-51 cm	40.5-43 cm
Tail length	39-49 cm	34-44 cm

(Arkive, 2013)

Table 2: Metabolism measurements of a specific STQ in captivity

Metabolism	Measurements
Typical body temperature	36.9°C
Average basal metabolic rate	3.142 W
Average body mass	1782.0g
Metabolic rate per body mass	0.001763 w/g

(Encyclopedia of Life, n.a)

Table 3: Weekly diet plan and supplements for one STQ in captivity

Day	Food type and portion size
Monday	2 pilchards and 1 bone
Tuesday	½ rat
Wednesday	Fast day
Thursday	¼ rabbit
Friday	75g pet health food
Saturday	2 mice
Sunday	2 one day old chicks
Supplements	3 crickets (3-4 times per week as available) 5 mealworms (3-4 time per week) 9 advance cubes (once per week) 15g Pet health food (once per week)

8.2 Water

Clean cool water at the species optimal preferred temperature should be available at all times, except if it is an arid zone species or for the temporary withholding of standing water during periods of pre mating stimulation. Water containers should not be located in direct sunlight and should be designed to suit the animals needs which may include swimming, sloughing, wallowing, bathing and drinking (State Government Victoria 2010). Containers need to be non spill able and designed so they can be easily drained and cleaned and also so it doesn't cause injury or harm to the animal (State Government Victoria, 2010).

8.3 Water supply for a Spotted Tailed Quoll

A clean flowing man made stream or waterfall could be built inside the Spotted Tailed Quolls exhibit, this would be an ultimate water source for the Spotted Tailed Quolls. Alternatively containers that are easily cleaned and that cause no harm to the animal can be placed out of direct sunlight on the ground or water could be placed off the ground in a tree to simulate water in a tree hollow which Spotted Tailed Quolls also used a water supply in their natural environment.

9 Breeding

9.1 Mating system

Male and female dasyurids are generally maintained separately outside breeding season (Vogelnest and Wood, 2008). To maximise breeding success it is important to be able to detect oestrus when it occurs. In quolls the pouch skin becomes moist and reddened and the vulva oedematous (Vogelnest and Wood, 2008). This can be detected by inserting a swab into the urogenital sinus. These samples can be examined microscopically. A predominance of cornified epithelial cell is inductive of oestrus in quolls (Vogelnest and Wood, 2008).

Another mating strategy for quolls is to place a male in an adjacent enclosure to a female and if the female elicits a clucking response then she is in oestrus, then the male can be released into the enclosure (Vogelnest and Wood, 2008).

Males need to be removed following the birth of young because of aggression from the female to prevent serious injury and even the possibility of fatal injury and also to prevent infanticide (Vogelnest and Wood, 2008).

9.2 Ease of breeding

A detailed knowledge of the lifecycle of some species is essential if successful breeding groups are to be maintained (Jackson, 2003). Most are kept as pairs, until young are born and pairings of animals is often required until a compatible pair is found (Jackson, 2003). Good breeding success has been achieved when the male is introduced when the female is in oestrus, which is determined by the presence of cornified epithelial cells (Jackson, 2003).

Spotted-Tailed Quolls are difficult to breed in captivity (Verjinski, 2014).

9.3 Females

Carnivore marsupial are generally placed in several categories. These include

- Non parous (Females that have never bred)- pouch is small with no skin folds, clean and dry and the teats are very small (Jackson, 2003).
- Parous (females who have bred previously but not presently) - pouch small but distinct, dry and dirty and the teats are slightly elongated (Jackson, 2003).
- Pregnant- pouch pink in colour and glandular in appearance (Jackson, 2003).
- Pouch young present- attached to the teat (Jackson, 2003).
- Lactating (Young absent from pouch but still suckling)- pouch area large, hair sparse and stained, skin smooth and teats elongated (Jackson, 2003).
- Post lactating- teats expressing only clear liquid and or regressing (Jackson, 2003).

9.4 Males

Sternal gland that develops with age and reaches maximal development during the breeding season can be measured from the following scale

- Little or no activity- Little or no stain on the surrounding hair (Jackson, 2003).
- Medium level activity- Some staining of surrounding hair, some hair loss and some signs of a waxy glandular product (Jackson, 2003).
- High activity- A lot of staining of surrounding hair, total loss of hair over gland area and a waxy glandular product prominent (Jackson, 2003).

9.5 Techniques used to control breeding

To prevent breeding males and females can be maintained separately or males can be vasectomised or castrated (Vogelnest and Wood, 2008). There is no indication for the use of hormonal contraception in dasyurids (Vogelnest and Wood, 2008).

9.6 Occurrence of Hybrids

None known at this stage (Jackson, 2003).

9.7 Timing of breeding

The breeding season of Spotted-Tail Quolls is between April and July (Verjinski, 2014).

9.8 Age at first breeding and last breeding

Females 1 year, Spotted -Tailed Quoll females older than three years did not produce litters (Verjinski, 2014)

Males 1 year, males up to the age of five and half years sired young (Verjinski, 2014)

9.9 Ability to breed every year

Yes however many Dasyurid often don't breed at all if they do not breed in their first year, so all attempts should be made to breed them in their first year in order to maximise their reproductive output (Jackson, 2003).

9.10 Ability to breed more than once per year

Spotted-tail quolls breed once yearly. (Verjinski, 2014)

9.11 Nesting requirements

Nest boxes and/or hollow logs should be provided along with nesting material for comfort and warmth (Jackson, 2003).

9.12 Breeding diet

Additional food should be provided to the males prior to breeding as they have been known to kill and partially eat their proposed mate and for lactating females as a shortage will often result in cannibalism of the young (Jackson, 2003).

9.13 Oestrus cycle and gestation period

Gestation period is 21 weeks (Verjinski, 2014)

9.14 Litter size

Ranges between 2-6 and the average is 3 (Verjinski, 2014)

9.15 Age at weaning

18-21 weeks (Verjinski, 2014)

9.16 Growth and development

The female Spotted Tailed Quoll stands quietly for about 1.5h with the hindquarters raised and the tail curled beside her (Jones *et al* , 2001). The first 3 weeks of pouch life, females elevate their hindquarters as they walk. Females with pouch young rest on their sides or crouch with hind legs raised so that no pressure is on the pouch (Jones *et al*, 2001). Nest-building behaviour becomes pronounced at 4 weeks (Jones *et al*, 2001). Mobility of a female with large pouch young is reduced (Jones *et al*, 2001) and, after young emerge permanently from the pouch, she spends long periods of time in the nest (Jones *et al*, 2001). At 50–60 days, before their eyes open, young locate siblings and mother by calling (the female replies), by moving around the nest, and by curling up next to warm objects. These behaviours cease by 70 days when eyes open (Jones *et al*, 2001). Agonistic play behaviour between litter mates

and self-grooming, by scratching the head with the hind foot, start at this time. By 90 days, social play is well developed and involves stalking, chasing, wrestling, and playing with objects, accompanied by much vocalizing (Jones *et al*, 2001). A female does not carry young on her back but will tolerate them climbing on her while in the nest or clinging to her back with teeth and claws if frightened (Jones *et al*, 2001). Sometimes a female will stalk her young, pinning them to the ground while gently biting them. This behaviour is observed in play, if the young have strayed too far or are persistent in jumping on her (Jones *et al*, 2001). As young grow, they stray farther and the female recalls them with a soft clucking sound (Jones *et al*, 2001). Beyond 100 days, the female spends progressively less time with her offspring and displays more aggression toward them (Jones *et al*, 2001). By 95 days, young can kill a mouse within 5 days of its introduction into an enclosure, despite no previous experience with live prey (Jones *et al*, 2001) and by 8 months young spotted-tailed quolls can kill adult rabbits (Jones *et al*, 2001).

10 Artificial rearing

10.1 Housing

With all native mammals that have been taken into care. Minimising stress is major consideration (Jackson, 2003). Choosing suitable housing can help to create a stress free environmental (Jackson, 2003). This is achieved using several factors

- Securing the area from children and animals
- Maintaining the area in a hygienic manner
- Escape proofing the area
- Clearing the area of obstacles and hazards
- Ensuring the area offers shelter from the weather and noise

(Jackson, 2003).

Furless and furred joeys are best kept inside an artificial pouch made of non synthetic fibres such as cotton or wool (Jackson, 2003). Use cotton pouch liner and put it inside the woollen pouch for warmth and keep in a warm environment (Jackson, 2003). Pouches need to be washed and disinfected everyday as bacteria and yeast thrives in these warm conditions (Jackson, 2003). Pouches should have the corners sown out so that the joeys do not get their

heads caught and also ensure that there are no loose threads that can wrap around their toes (Jackson, 2003).

10.2 Temperature

The temperature should be 34°C-36°C if the joeys are furless (Jackson, 2003). As the joeys grow fur the temperature can be reduced to 30°C (Jackson, 2003).

10.3 Milk formulas

Dasyurids are generally lactose intolerant due to low levels of intestinal lactase and should be reared on low lactose milk (Vogelnest and Wood, 2008). Di-Vetelact, Biolac and Wombaroo are all satisfactory milk substitutes for Dasyurids (Vogelnest and Wood, 2008).

There are main low lactose milk formulas that can be used for hand rearing marsupials (Jackson, 2003). These include

- Biolac: which has three formulas, M100 for furless joeys, M150 which is transitional milk to use when dense fur has developed and M200 which is used when the animal produces solid dark pellets.
- Di Vetelact
- Wombaroo

(Jackson, 2003).

10.4 Feeding apparatus

Larger carnivore marsupials can be fed with plastic feeder bottle, 50 or 100ml type D teats for Quolls. The teat should be punctured with a hot needle (Jackson, 2003).

10.5 Feeding

Feeding should be every 2 hours and the PY (pouch young) maintained at 34°C-36°C until well furred, then the temperature can be reduced to 30°C (Vogelnest and Wood, 2008). When the fur has started to appear feeding can be reduced to every 3-4 hours. Daily milk consumption varies from 10% to 20% of the animal's body weight.

Once the animal's teeth start to emerge and the young starts leaving the pouch, solid foods such as chicken pieces and live mealworms and crickets should be offered (Vogelnest and Wood, 2008). Feeding could be decreased to every 4-6 hours. The amount of milk should be

gradually reduced and solid food increased until milk is totally eliminated from the diet (Vogelnest and Wood, 2008).

10.6 Specific requirements

Their skin must be treated regularly with an emollient, such as Sobolene and Lanolin to prevent it drying out and cracking (Vogelnest and Wood, 2008). Baby oil does not appear to be properly absorbed (Jackson, 2003).

At first appearance the animal may be dehydrated so the animal can be given plain boiled water with 5g of glucose to 100ml water or 1 electrolyte replacer (Jackson, 2003).

Stress needs to be kept to an absolute minimum (Jackson, 2003).

Hand rearing furless animals has a poor success rate as they are normally attached to the mothers' teat, they have an extremely immature immune system and are heavily dependent on passive maternal immunity and are very susceptible to infection (Vogelnest and Wood, 2008).

10.7 Data recording

When the animal is first brought in for hand rearing its sex and approximate age, using growth charts needs to be recorded (Jackson, 2003). Then during the hand rearing process the following information needs to be recorded on a daily basis

- Date
- Time when information is recorded
- Body weight to the nearest 1g
- General activity and demeanour
- Characteristics and frequency of defecation and urination
- Amount (g) of different food types offered
- Food consumption at each feed
- Veterinary examination and results

(Jackson, 2003).

10.8 Identification

Generally not needed (Jackson, 2003).

10.9 Hygiene

- Clean pouch lining at all times
- Personal hygiene, wash and disinfect hands before and after handling animal
- Wash hands between feeding different animals
- Use boiled water to make up feed bottles
- Clean any spilt milk formula, faeces and urine from the animal skin and fur
- Wash all feeding equipment in warm soapy water and sterilise it in a suitable antibacterial solution such as Halexsept or Milton.
- Only heat up milk once then discard any leftovers
- Use a new liner for the animals pouch after each feed.

(Jackson, 2003).

10.10 Behavioural considerations

Larger species of Dasyurids such as a STQ can become bonded with their carer, so minimised contact between feedings should be practiced (Jackson, 2003). Ideally they should be raised in a group so they are familiar with other member of their species (Jackson, 2003).

10.11 Use of foster species

Fostering has not been widely used for any of the carnivorous marsupials (Jackson, 2003).

10.12 Weaning

Once teeth begin to emerge, small amounts of lean beef with one teaspoon of calcium per 500g can be offered (Jackson, 2003). The type of food offered should simulate the wild. The natural diet may be supplemented with a Wombaroo insectivore mix or meats mix (Jackson, 2003). Once teeth are well developed in STQ they can be given large insects, day old chickens, mice and rabbit or wallaby meat (Jackson, 2003).

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