HUSBANDRY AND MEDICAL MANAGEMENT OF KOMODO DRAGONS (*Varanus komodoensis*) AT THE WHITE OAK CONSERVATION CENTRE

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Abstract: At present, the captive population of Komodo dragons in North America is 6.4.55 (male, female, unknown sex) of which 6.4 represent wild caught adults. With the recent breeding success by the National and Cincinnati zoos, many more institutions will have to manage these lizards. The techniques discussed here can be adapted for use in other large lizards such as monitors and iguanas which are routinely seen in the pet trade.

Housing Komodo dragons has been compared to that of housing big cats with similar caging parameters of space and environment. The keys to successfully maintaining these lizards in captivity is related to: adequate space and visual barriers, earthen substrate for denning and nesting, natural sunlight, and basking temperatures. These parameters are reviewed with respect to the design of the new Komodo dragon facilities at White Oak Conservation Centre (WOCC). WOCC is currently developing standard husbandry protocols through the study of thermoregulation patterns, using remote sensing devices, on two of their juvenile Komodo dragons. Some of the unique aspects of White Oak's enclosure design include the open top enclosure with masonry and chain link walls, denning area, and a plexiglass chute system for capturing and handling the animals remotely.

Medical management issues include a review of handling with the plexiglass chute system, proper nutrition, routine health checks, normal metabolic parameters, sampling techniques, anesthesia, and sexing techniques including, ultrasound, radiography, and the hormone ELISA method. Even though these techniques have been developed for use in Komodo dragons they can easily be modified and adapted for use in other large lizard species routinely seen in the pet trade.

Key words: Komodo dragon, husbandry, medical management, restraint techniques, sexing techniques

INTRODUCTION

Komodo dragons (*Varanus komodoensis)* are the largest lizard living on the planet with adult males measuring up to 3 m total length and weighing up to 90 kg. Their large size, limited distribution (less than 1000 km^2), and small population (less than 6000 lizards) have given the Komodo dragon a place on the Convention International Trade Endangered Species (CITES) Appendix 1 listing as an endangered animal[1]. Indeed, the Komodo dragon is one of the most endangered large carnivores, mammalian or reptilian, alive today.

Until recently the entire captive North American population of Komodo dragons was 5.3.0 (male, female, and unknown sex) wild caught adult dragons. Successful breedings by the National Zoo and the Cincinnati Zoo have increased the captive population to 6.4.55[10]. These successful breedings have placed Komodo dragons in 27 institutions across the United States and Canada. The husbandry and medical management of these charismatic megacarnivores is now a prime concern for zoo keepers and veterinarians alike. With growing numbers of Komodo dragons in zoos it is important to develop standard protocols for husbandry and medical management to ensure the safety and well being of the Komodo dragons and their caretakers.

At this time the White Oak Conservation Centre (WOCC) houses 2 subadult Komodo dragons (4-year-old and 5-year-old) which were acquired from the National Zoo in 1994.

HUSBANDRY

Housing

Due to the large size and keen intellect of Komodo dragons, their housing requirements have been compared to that of large cats[10]. Indonesian zoos have kept Komodo dragons in large natural outdoor enclosures up to 400 m^2, while in the past North American zoos have typically kept these lizards in small, sterile concrete enclosures. Following the lead of the National Zoo, WOCC has developed more natural enclosures taking into account the needs of the dragons, keepers, and veterinary staff.

For the first three years the juvenile Komodo dragons were housed in four indoor enclosures (two enclosures measuring 6.7 m x 3.5 m, the third enclosure measuring 5 m x 3.5 m, and the fourth enclosure measuring 4 m x 3.5 m). The indoor facilities include an earthen floor, large flat rocks, climbing log, water tub, basking spot, ultraviolet lighting (UV) and forced air heating. All enclosures have wooden walls 1.3 m high, with 2 cm x 2 cm plastic coated wire mesh which continues to the ceiling (2.6 m). Each pen also has a 1 m foundation which supports all walls and discourages tunneling under the walls. All indoor and outdoor enclosures are connected by remotely operated guillotine slide doors with a plexiglass chute system which will be discussed later.

Two of the three outdoor enclosures measure 6.7 m x 5 m and 6.7 m x 6.7 m with 1.3 m high wooden walls, plastic coated wire mesh sides and top (2.6 m high) , and a 1 m foundation. Each outdoor enclosure has an earthen floor, live foliage, a large flat rock, and a tree stumps. A number of large polyvinylchloride (PVC) pipes have been cut in half to act as hide spots on the ground.

Each dragon is kept separately and has access to both indoor and outdoor enclosures most of the time (based on ambient air temperature). The dragons are routinely shifted between the enclosures to familiarize each dragon with the other's scent. The Komodos are able to observe each other through plexiglass sliding doors and the chain link fencing. Constant shifting also keeps activity levels high as the Komodos are very curious.

Young Komodos are fond of climbing and spend a vast majority of their time climbing and basking on the logs or on the chain link fencing. They are also fond of digging under the large flat stones and will retreat underneath the stone if threatened. It is important to make sure that the stone can be lifted if access to the dragon becomes necessary. Large, black horse-watering tubs are used to hold water and are changed every day.

A new outside enclosure encompasses 240 m^2 and has a running water fall and shallow pool as its main features. As the Komodos are getting older and larger (14 kg body weight) they spend less time climbing and more time on the ground. At WOCC more large rocks have been placed in the new enclosure; however, there are limited vertical stumps on which the dragons may climb. This enclosure is constructed of cinder block wall 1.7 m high with a 1 m foundation. At the top of the cinder block wall a 10 cm overhang and a electrified wire are used to discourage climbing. An additional 1.3 m of chain link fence is above the cinder block wall. The enclosure has no roof which provides the Komodos with maximum exposure to UV light. Ultraviolet light is considered to be important; however, to what extent is not yet known[10]. This open top enclosure design has been proven to work well with no escapes or close calls during the year it has been operational.

To provide for denning behavior, a large open sided cinder block cube was constructed in the back of the waterfall and measures 1.2 m high, 1.2 m deep and 2.7 m long. The cube is filled with top soil in hopes that when denning or digging occurs, it will happen in this accessible mound. Other large rocks and the shallow pool have cement pads and wire placed beneath them to discourage digging. The numerous live plants in the enclosure have not been damaged with the exception of the banana plants. Some climbing attempts have been made and these soft stemmed plants were damaged. To correct this, large pieces of PVC pipe were cut in half, painted and placed around the trunk of the banana plants for the first 4 ft. This technique stopped the damage and the plants are doing well.

Socialization

In the wild, Komodo dragons are solitary lizards but may be seen congregating when feeding[1]. Indonesian zoos keep similar sized wild-caught Komodos and captive born juveniles together with minimal problems. These zoos report aggression problems when new individuals are added to an established group; however it is not clear if a hierarchy is present[10].

In most North American zoos Komodo dragons are kept singly or in pairs where they can be monitored more closely. At WOCC the Komodos were kept separate until they were approximately the same size. At this point they were introduced to each other after all enclosure doors were opened to provide numerous escape routes. Bouts of chasing by the older Komodo dragon were monitored until the risk of injury became too great. The keepers split the two lizards up using brooms to avoid injury to the dragons. This process was repeated several times until it was deemed to be too risky. Subsequently both of the dragons were sexed as males and the two Komodo dragons are now kept separately.

Thermoregulation

In the wild, Komodo dragons are exposed to a temperature gradient between 17-45 °C[1]. At WOCC thermoregulation is accomplished by using a forced air heating system with supplementary heating elements in the indoor enclosures. The indoor ambient air temperature is heated to 24°C with heating elements providing basking spots at 40°C. The Komodos have unrestricted access to the outside enclosures when night-time temperatures are above 12°C; indoor access is never restricted. Surface body temperatures of the lizards are routinely checked with a Rayngor PM Plus remote thermal sensing gun (Rayteck Inc., 1201 Shaffer Road, Box 1820, Santa Cruz, CA, 95061-9924, USA). This unit can remotely measure the infrared energy produced by an object and translate it into thermal units (°C, temperature). The surface body temperature of the Komodo dragons can be measured remotely and recorded. During the summer months (May to October) the outside ambient temperatures range between 20-40 °C which is very similar to that of Komodo Island. By carefully monitoring the behavioral thermoregulation at this time, it is hoped that a thermoregulation protocol can be developed to be used in other zoos where the temperature is artificially controlled.

Nutrition

Upon arrival at WOCC the youngest Komodo dragon weighed 1 kg and was fed 40 g of mice twice weekly. The older dragon weighed 2 kg and was fed 200 g of rats twice weekly. Food levels have been gradually increased until the present level of 1.5 kg of rats a week was reached, with each Komodo dragon weighing between 13-14 kg. The defrosted rodents are placed in a large pet transport kennel and placed into each Komodo's enclosure. It is thought that by feeding in this manner that the Komodo dragons will associate the feeding with the kennel and not the keeper. This may provide a safer working environment for the keepers when the Komodos become adults. The kennels are placed in each enclosure in the late afternoon, 1500 hr, and are then rechecked the following morning. Whole prey items, natural sunlight, and adequate access to basking spots provide adequate conditions for healthy growth and development. To date, the Komodo dragons at WOCC have shown high growth rates when compared to their siblings at other institutions.

MEDICAL MANAGEMENT

Manual Restraint

It is possible to manually restrain young Komodo dragons (less than 1.2 m total length) by grasping the lizard behind the neck and around the pelvis as one would with other large lizard species. This technique does pose some obvious risk to both the handler and the lizard. A safer, plexiglass chute technique for handling large lizards has been developed at WOCC by Pat Rider, reptile keeper, and Earl Johnson, construction foreman. The chute system consists of a plexiglass tube with sliding guillotine doors on each end (capture tube). The plexiglass tube diameter must be large enough to allow the lizard to easily squeeze through the tube, but not so large that the lizard may turn around within the tube. The tube must be long enough to accommodate 90% of the lizards total snout-tail length.

A smaller length of the tube (short tube) is permanently attached within the sliding guillotine door between enclosures. This is to habituate the dragons to passing through the tube when they move between enclosures. The Komodos quickly adapt to moving through this tube on their normal daily movements between enclosures. The "capture tube" is mounted to the "short tube" a few days before the actual capture day. On the day of the capture a clear plexiglass sliding door is placed at the guillotine end of the tube where the sliding door occurs. A keeper then enters the enclosure and pressures the Komodo to leave the enclosure. Once the lizard enters the tube the second sliding door is placed at the tail end of the tube and the capture is complete. This capture technique places the lizard under a minimal amount of stress as they are never physically restrained. It is also very safe for keepers, as no physical contact is made during the capture. If a clear plexiglass tube is used, a close range visual inspection of the dragon can be made. Snout-vent and total body length measurements can also be easily taken. A towel may be placed over the tube to further reduce stress on the lizard during transport. This entire unit can be easily transported to a clinic and weighed, with the lizard inside, and then reweighed after removal of the lizard. Blood samples may be easily obtained by opening the caudal door and extracting the posterior end of the dragon from the tube. Blood samples, ultrasound, and radiographs can all be easily obtained by this method. This provides a very safe and effective method for obtaining diagnostic samples and completing routine physical examinations on Komodo dragons. The minimal physical manipulation minimizes the stress and potential injury to the animal.

Chemical Restraint

To date chemical restraint has not been required or used on the Komodo Dragons at WOCC. The National Zoo has developed protocols for anesthesia in Komodo dragons[9]. Young Komodo dragons were manually restrained and masked down with 3% isoflurane (Aerrane, Ohmeda PPD Inc, Liberty Corner, NJ, 07938, USA) and 1 L/min oxygen for induction using a small canine mask. Lizards greater than 3 kg were then intubated with an endotracheal tube while smaller lizards were maintained on a mask with a maintenance dose of 1-2% isoflurane. The dragons did not appear to hold their breath during induction and both induction and maintenance went well with an uncomplicated recovery in 5-7 min.

Adult Komodo dragons (15-25 yr and 11-55 kg) were induced with either 5.5 mg/kg tiletamine-zolazepam (Telazol, Fort Dodge Laboratories Inc., Fort Dodge IA, 50501, USA) or 10-12 mg/kg ketamine (Ketaset, Atech Co., Fort Dodge, IA, 50501, USA) mixed with 0.2-0.5 mg/kg midazolam (5 mg/ml, Versed, Hoffman-LaRoche, Nutley, NJ, 07110, USA). Induction agents were administered intramuscularly via dart (Telinject USA, Saugus, CA, 91350, USA) or hand syringe in the forelimb. Maintenance was obtained by administering isoflurane 1-2% via endotracheal tube. There was a prolonged recovery with the tiletamine-zolazepam, however, both techniques were proven to be successful[9].

Routine Health Checks

A protocol for routine health checks in both adult and juvenile Komodo dragons has been developed at WOCC and is summarized below[7].

Young Komodo dragons:

- physical exam - every 2-3 wk, body weight and body length are measured
- blood collection - lateral caudal tail vein, manual restraint (tube system), heparin anticoagulant for CBC, plasma biochemical profile, blood parasite screen
- fecal examination - direct and flotation techniques
- sexing - discussed below
- transponder chip - placed in the right shoulder
- bone density - monitor bone density through radiographs
- vaccinations - no vaccines required

Adult Komodo dragons:

- physical exam - biannual, pay attention to skin and oral lesions
- blood collection - lateral caudal tail vein, manual restraint (tube system), tail vein, heparin anticoagulant for CBC, plasma biochemical profile, and parasite screen
- fecal parasite screen - direct and flotation techniques

Clinical Pathology

Analysis of hematology and clinical pathology (ISIS, 1996)[5] values are as follows:

Hematology Profile	Mean (n=14)	Standard Deviation
WBC x 10^3 µl	9.798	+/- 6.861
PCV %	40.0%	+/- 4.4
Heterophils x10^3 µl	5.372	+/- 5.160
Lymphocytes x10^3 µl	2.33	+/- 1.268
Monocytes x10^3 µl	1.036	+/- 0.704
Azurophils x10^3 µl	2.026	+/- 1.287
Basophils x10^3 µl	0.139	+/- 0.101
Chemistry Profile	**Mean (n=14)**	**Standard Deviation**
Calcium mg/dl	14.0	+/- 1.6
Phosphorus mg/dl	6.5	+/- 2.9
Sodium mEq/L	161	+/- 6
Potassium mEq/L	5.7	+/- 2.9
Chloride mEq/L	112	+/- 7
Iron µg/dl	47	+/- 11
BUN mg/dl	3	+/- 2
Creatinine mg/dl	0.4	+/- 0.1
Uric acid mg/dl	4.8	+/- 3.7
Glucose mg/dl	177	+/- 49
Cholesterol mg/dl	98	+/- 91
CPK IU/L	2146	+/- 2579
Alk Phos IU/L	212	+/- 107
AST IU/L	33	+/- 24
Total Bilirubin mg/dl	0.6	+/- 0.7
Globulin g/dl	5.0	+/- 0.7
Albumin g/dl	2.8	+/- 0.7
Total Protein g/dl	7.6	+/- 1.2

Sexing Techniques

To date, a number of sexing techniques have been described for Komodo dragons of which the transcutaneous ultrasound, radiography, and hormone ELISA methods have been completed at WOCC. Other techniques, such as the transintestinal ultrasound, have been performed at the National Zoo[4].

Transintestinal Sonography

This technique has been developed for early sexing of Komodo dragons age 19-36 mo and 0.97-6.10 kg[4]. Juvenile Komodo dragons were anesthetized with isoflurane and the 7.5 MHz endosonographic transducer is placed in the lubricated cloaca and gently moved cranially. Warm water is continuously lavaged into the rectum to provide for an undisturbed image. This technique is able to identify ovarian follicles measuring 2-25 mm in diameter and cigar shaped testis 14 x 6 mm and 20 x 8 mm[4]. Other organs such as the heart, liver, gall bladder, kidneys, adrenal glands, fat bodies and intestinal loops were also identified. This technique has also been used successfully to identify gonads in adult Komodo dragons.

Transcutaneous Ultrasonography

Transcutaneous ultrasonography performed on the juvenile Komodo's at WOCC was inconclusive as neither ovaries or testis could be identified. These results are consistent with findings described by Hildebrandt[4]. It has been proposed that the lack of detail is due to a combination of the small size of the gonads and the hyperechoic skin plates found in the Komodo dragon[4]. Studies conducted by Morris et al.[6] found that ovarian follicles could be visualized in Komodo dragons older than 28 mo, however no reproductive structures could be visualized in male Komodo dragons at the same age.

Hormone Assays

Blood samples can be drawn from the lateral caudal tail vein and collected into heparinized tubes. Plasma was collected and sent to the BET Reproductive Laboratories Inc., (6174 Jacks Creek Road, Lexington, KY, 40515, USA) for testosterone assay testing. Plasma testosterone levels below 1500 pg/ml correspond with known females, while higher testosterone levels may be indicative of male Komodo dragons. Plasma testosterone levels may fluctuate in Komodo dragons less than 24 months-of-age and may not be considered to be accurate[6]. The 1995 plasma testosterone level for the 3-year-old Komodo at WOCC was 6,400 pg/ml which increased to 14,603 pg/ml in 1996. The 4-year-old Komodo had testosterone levels of 16,000 pg/ml in both 1995 and 1996. Both of the Komodo's at WOCC have shown consistently high plasma testosterone levels which is consistent with male Komodo dragons.

Radiology

Radiographing lizards is a noninvasive technique for sex determination which identifies the ossified hemipenes of male lizards. However, radiography has not proven to be successful in identifying the sex of juvenile Komodo dragons[4]. Shea and Radcliff[8] found that radiographing Komodo dragons to visualize hemipenes was not successful in dragons with a snout-vent length of less than 790 mm. This inaccuracy was further demonstrated in both Komodo dragons at the WOCC; both dragons have high testosterone levels, with no visible hemipenal ossification radiographically.

General Health Problems

With the small sample size of Komodo dragons there are very few reported incidences of disease processes in the literature to date. Some of the more common injuries are listed below:

- skin lacerations - due to inter-species fighting during introductions[10] (Citino, pers. comm.)
- amebiasis[2]
- *Salmonella enteritidis* - reported at the Denver Zoo[10]
- neoplasia - pancreatic islet cell carcinoma, thyroid gland carcinoma, colon carcinoma, and interstitial cell tumor[3]
- tail and foot injuries - due to improper housing and cage mate aggression[10]
- avian tuberculosis - at the Rotterdam Zoo (Walsh, pers. comm.)
- obesity - at the Singapore Zoo (Walsh, pers. comm.)

CONCLUSIONS

It is imperative that standard protocols for medical management and husbandry of Komodo dragons are developed and that disease processes are recorded and published. Veterinarians and keepers must work together to develop these protocols, which will ensure a successful future for the world's largest lizard, the Komodo dragon.

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