Javier Nevarez

CHAPTER 6

CROCODILIANS

COMMON SPECIES KEPT IN CAPTIVITY

Modern-day crocodilians date back to the Mesozoic era over 65 million years ago, surviving to the present with relatively few evolutionary changes. Their biology, physiology, and anatomy are unlike those of any other reptiles. However, some species have suffered the effects of a changing environment and human encroachment; this situation has led to the formation of international programs dedicated to the preservation of threatened or near-extinct species. Of the 23 species of crocodilians, 13 can be found on the red list of endangered species.[1] Taxonomic identification varies among all species, and there is debate over the proper classification of species and subspecies (Tables 6-1 and 6-2; Box 6-1). In addition to having wild crocodilian populations, countries such as Australia, India, Mexico, Papua New Guinea, South Africa, and the United States maintain intensive production operations for various species.

In North America, the American alligator *(Alligator mississippiensis)* is the best-known crocodilian. Second to it is the American crocodile *(Crocodylus acutus),* a vulnerable species found in small numbers in Florida. The American alligator was considered a threatened species during the 1960s, but a captive rearing program in Louisiana has been successful at maintaining the estimated population at over 1 million animals.

The first type of captive rearing operations consisted of alligator farming. In farming operations, breeding pairs of alligators were kept in enclosed areas where they could mate and nest (Figure 6-1). The eggs were collected from the nests and incubated. The farming operations led to ranching operations in which eggs are harvested from the wild and incubated in private facilities (Figure 6-2). The alligators hatched on an "alligator ranch" are then raised for their hide and meat. To help maintain the wild populations, 14% of the hatched alligators are eventually returned to the wild. Louisiana is the primary producer of American alligators in the world. Captive rearing operations can also be found in Florida, Texas, Georgia, and other southern states within the United States where alligators naturally inhabit. In Louisiana the majority of the operations are ranches, whereas many farms still exist in Florida. Other crocodilian species, such as the Nile crocodile *(Crocodylus niloticus),* are primarily raised under farming operations in other countries.

In those states where alligator productions are present, there are opportunities for veterinarians to get involved with the industry. Some veterinarians, regardless of practice concentration, have alligator farmers or ranchers as part of their clientele and meet new challenges in their daily practice. A population management approach is necessary when working with these alligator production facilities. It is also advisable for veterinarians and farmers alike to be aware of the rules and regulations imposed by the local department of Wildlife and Fisheries.

In addition to being found in their natural environment, crocodilians are also found in zoos. Zoologic parks house different species of crocodilians for educational purposes, reproductive efforts, or both. As is the case with many other threatened species, zoologic institutions play a critical role in the captive reproduction of threatened species of crocodilians. Here the animals can be observed by specialists in a more controlled environment that mimics their natural habitat, although design and maintenance of the enclosures can be difficult. Disease prevention and control are other important considerations when it comes to oversight of threatened species.

TABLE 6-1 Taxonomy of the Family Alligatoridae

Common name	Scientific name	Geographic distribution
American alligator	*Alligator mississippiensis*	Southeast United States
Chinese alligator	*Alligator sinensis*	Eastern China
Spectacled/Common caiman	*Caiman crocodilus*	Central and South America
Broad-snouted caiman	*Caiman latirostris*	South America
Jacare caiman	*Caiman yacare*	South America
Black caiman	*Melanosuchus niger*	South America
Cuvier's dwarf caiman	*Paleosuchus palpebrosus*	South America

TABLE 6-2 Taxonomy of the Family Crocodylidae

Common name	Scientific name	Geographic distribution
American crocodile	*Crocodylus acutus*	North, Central, and South America
Slender-snouted crocodile	*Crocodylus cataphractus*	Africa
Orinoco crocodile	*Crocodylus intermedius*	South America
Fresh water crocodile/Johnston's crocodile	*Crocodylus johnstoni*	Australia
Philippine crocodile	*Crocodylus mindorensis*	Philippines
Morelet's crocodile	*Crocodylus moreletii*	Central America
Nile crocodile	*Crocodylus niloticus*	Africa and Madagascar
New Guinea crocodile	*Crocodylus novaeguineae*	Papua New Guinea and Irian Java
Mugger crocodile/Swamp crocodile	*Crocodylus palustris*	Indian subcontinent
Saltwater/Estuarine crocodile	*Crocodylus porosus*	Australia and Southeast Asia
Cuban crocodile	*Crocodylus rhombifer*	Cuba
Siamese crocodile	*Crocodylus siamensis*	Southeast Asia
African dwarf crocodile	*Osteolaemus tetraspis*	Africa
False gharial	*Tomistoma schlegelii*	Southeast Asia

BOX 6-1 Taxonomy of the Family Gavialidae

Common Name	Scientific Name	Geographic Distribution
Indian gharial/True gharial	*Gavialis gangeticus*	Indian subcontinent

Veterinarians may also encounter crocodilians as privately kept "pets." In the past, the spectacled caiman *(Caiman crocodilus)* and even the American alligator *(A. mississippiensis)* have been sold to the general public. There are many reasons why crocodilian species should not be maintained as pets. In addition to the physical dangers and risks associated with keeping crocodilians, there is the misfortune of inadequate husbandry, adversely affecting the reptile's health. Most crocodilians grow to be larger than other reptile species and therefore have significant space requirements. Like most animals requiring an aquatic environment, crocodilians need water that is clean and free of disease. Another husbandry issue is an incorrect diet, which can lead to metabolic abnormalities and overall poor health. Many private owners are unable or unwilling to provide these conditions for their crocodilians. In addition to these issues, most states will require special permits to own these animals. Most people lack the proper ownership permits, and veterinarians could be liable if they treat these illegal patients. The biggest challenge that veterinarians face when treating illegally owned animals is that they are often the last chance for humane treatment for these animals. It is the duty of

Figure 6-1 Outside enclosure at a Morelet's crocodile *(Crocodylus moreletii)* farm in Mexico.

Figure 6-2 Building used in the ranching operation of American alligators *(Alligator mississippiensis)* in Louisiana.

veterinarians to educate these clients and persuade them to place these animals in appropriate zoologic institutions or other accredited facilities.

Most of the material presented in this chapter specifically relates to the American alligator *(A. mississippiensis).* Although most of the alligator information will apply to other crocodilian species, there are variations among groups that will be mentioned. The natural environment and geographic distribution of a species will often determine disease exposure. Once in captivity, all species are susceptible to the same diseases within that environment. In addition, there are some inherent differences among the three families of crocodilians—Alligatoridae, Crocodylidae, and Gavialidae—that have emerged from studying them in captivity.

BIOLOGY: ANATOMY AND PHYSIOLOGY

One of the most common questions a veterinarian may encounter regarding reptiles is "What is the difference between alligators and crocodiles?" The first difference is that they belong to two different families: the family Alligatoridae (see Table 6-1) includes the alligators and caimans, and the family Crocodylidae (see Table 6-2) includes all crocodiles. There is a third family, the Gavialidae (see Box 6-1), which contains the gharial, or gavial. Geographic location may help in the identification of some species. Alligators are thought to tolerate colder temperatures and live at higher latitudes, whereas crocodiles and caimans are less cold resistant and live in warmer areas.[2] However, there are some anatomic features that will be most useful in differentiating alligators from crocodiles. The alligators and caimans have a broad, u-shaped snout, whereas crocodiles have a more narrow, v-shaped snout. This difference can be observed by looking at the dorsal aspect of the head (Figure 6-3). A more obvious distinction can be made when looking at their mouth from the side (Figure 6-4). Alligators

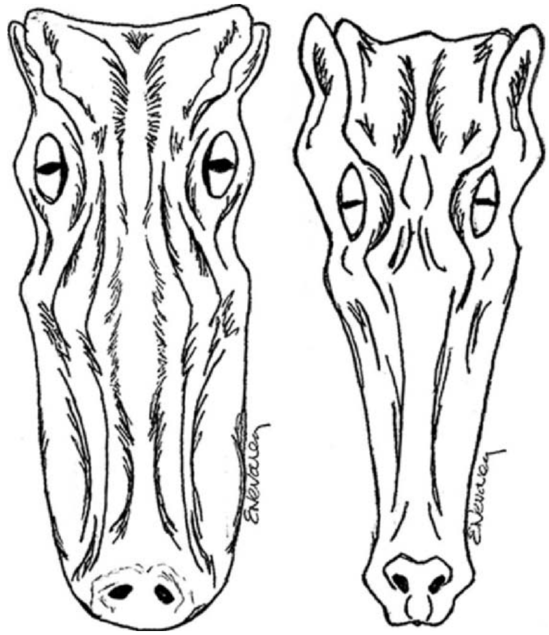

Figure 6-3 The dorsal aspect of the head of a crocodile and an alligator. Notice the V-shaped head of the crocodile vs. the more U-shaped head of an alligator.

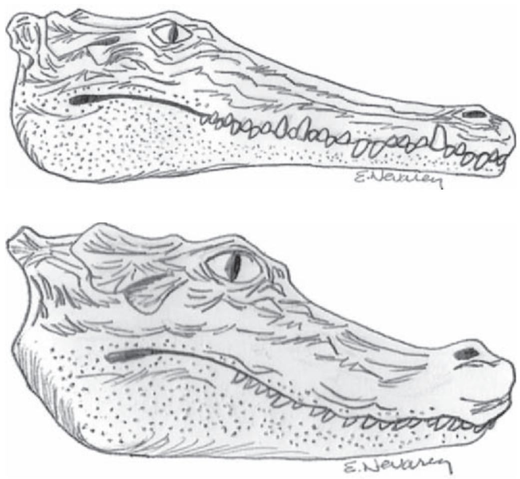

Figure 6-4 The lateral aspect of the head of a crocodile and an alligator. Notice that mandibular teeth are not visible in the alligator, whereas in the crocodile, the fourth mandibular tooth is clearly visible.

and caimans have notches in the maxilla that fit the mandibular teeth. Therefore, they have no mandibular teeth visible if observed from the side with their mouth closed. On the other hand, crocodiles have the fourth mandibular tooth exposed when looking at them from the side with their mouth closed. *Integumentary sensing organs,* also known as *dome pressure receptors* (DPRs), are clear to gray pits present on the skin of crocodilians. Their function is not completely understood, but they may play a role as mechanoreceptors in prey detection or even

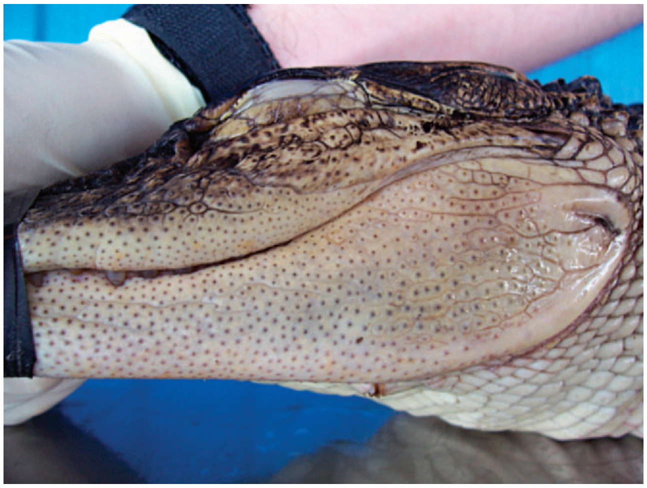

Figure 6-5 Dome pressure receptors (DPRs) on the lateral mandible of an alligator. The DPRs appear as gray dots over the skin.

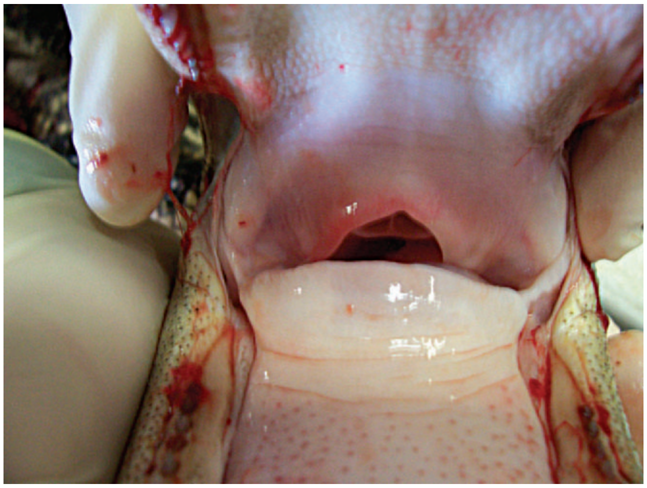

Figure 6-7 The velum palati (dorsocaudal) and gular fold (ventrocaudal) of an alligator. Together these structures comprise the palatal valve.

Figure 6-6 Dome pressure receptors (DPRs) on the ventral scales of a crocodile. The DPRs appear as clear to gray indentations on the scales.

as chemoreceptors aiding in detection of salinity levels.[3,4] Alligators and caimans have DPRs only on the lateral aspect of the mandible (Figure 6-5), whereas crocodiles and gharials have DPRs all over the body, most noticeably on the ventral scales (Figure 6-6). The presence of DPRs can be used to differentiate the two main groups of crocodilian skins in the leather market. An additional feature that could be used for differentiation of alligators and crocodiles is the salt glands, which are absent from the tongue of alligators and caimans but well developed in crocodiles and gharials.

An interesting anatomic feature of crocodilians is the *palatal valve,* also known as the *gular valve.* There is some discrepancy as to the name of this structure and its two components, but I will attempt to describe them based on the anatomic location. Crocodilians have a true hard palate in the roof of the mouth that ends caudally in a soft palate. This soft palate has a ventral flap that is referred to as the *velum palati.* The velum palati is the dorsal component of the palatal valve, with its second and ventral component being the gular fold. This structure projects in a craniodorsal direction from the base of the tongue and has a cartilaginous base to it that is part of the larynx. Together, the velum palati and the gular fold form what is known as the palatal, or gular, valve (Figure 6-7). The function of this valve is to seal the pharyngeal cavity while under water to prevent aspiration. Crocodilians also have control of the nares and are able to open and close them as needed to prevent aspiration of water.

The respiratory system of crocodilians consists of well-developed lungs benefiting from a very effective inspiration aided by the intercostal muscles and the septum post hepaticum. The septum post hepaticum is a diaphragm-like muscle that creates a partial separation of the thoracic and abdominal viscera. A number of membranous connections separate the lungs and the liver, and an intricate mesentery system encompasses the gastrointestinal tract and viscera. All of these tissue structures may be necessary for allowing the changes in pressures that occur during diving.

The cardiovascular system of crocodilians also has special characteristics. Crocodilians have a four-chambered heart as opposed to the three-chambered heart found in other reptiles and amphibians. The circulation of blood through the crocodilian heart is like that in the heart of mammals, but the crocodilians possess a viable foramen of Panizza. This opening is located at the base of the heart between the left and right aortic arches and allows for venous admixture, which is essential during periods of diving to conserve oxygen.[5] During diving, there is pulmonary hypertension. This in turn creates increased pressure in the pulmonary artery and the right ventricle, which forces deoxygenated blood through the foramen of Panizza

Figure 6-8 The submandibular glands of an alligator. These sometimes appear everted while an animal is being restrained.

into the left side of the heart and the aorta to be distributed through the body. This mechanism allows for conservation of oxygen and supplies oxygenated blood to those organs that require it the most, allowing some crocodilian species to stay submerged for up to 6 hours.[6] A second anastomosis may be present in other crocodilian species as a vessel connecting the two aortic arches.[2]

Submandibular (Figure 6-8) and paracloacal glands and a gall bladder are present in crocodilians. The hard dorsal scales are known as *osteoderms,* bony plates lined by skin. Crocodilians have a smaller gastric compartment distal to the stomach that is a gizzard-like structure in which rocks and other materials may be found. It does not appear as evolved as the ventriculus in birds, however. Crocodilian intestines have a thick wall and can have well-developed diffuse aggregates of lymphoid tissues like Peyer's patches. There is no urinary bladder, but the colon can hold large amounts of urine and water. Sexing can be performed by palpation of the cloaca; males have a phallus that can be palpated and extracted from the cloaca. Females have a well-developed clitoris that, depending on size, can be confused with a phallus. Internally paired gonads are found near the ventral surface of the kidneys.

Physiologic data, including body temperature, heart rate, and respiration, vary with species, age, and environmental factors (e.g., environmental temperature, season of the year).

HUSBANDRY

Environmental Considerations

Environmental considerations are variable depending on where a crocodilian species lives or is farmed. The aim of captive rearing operations is to produce a large number of animals in the most efficient way possible. In a zoologic or other educational institution, the goal is to exhibit the animals in an environmentally accurate artificial environment. The underlying policy of any aquatic enclosure should be clean water, appropriate diet, and enough space to accommodate the growth of the animals. As with most exotic animals, the challenge is to mimic a captive animal's natural environment.

ENCLOSURE SIZE

There are no specific references for the enclosure size of crocodilian species in captivity. The size of the enclosure will largely depend on the species of reptile and the purpose of their captivity. A general understanding of biology and natural behavior of the captive species is essential to designing appropriate enclosures. Although a zoologic institution housing the species might provide more specific advice, there are some general enclosure guidelines for the commercial production of American alligators: 1 square foot per alligator up to 24 inches in length (snout to tip of tail), 3 square feet per alligator for those between 25 and 48 inches in length, and an additional square foot of space for every 6 inches in body length beyond 48 inches.[7] These are the recommendations for the maximum stocking rate for alligators in commercial operations.

The recommendations for a zoo or educational facility are to make the exhibit as large as possible, taking into consideration the species being housed. A consideration for larger species is territoriality requiring an expanded enclosure. Male crocodilians may become more aggressive during the reproductive season, and keeping them separated should be a consideration if space is a concern. Exhibits can be outdoor, indoor, or a combination of both. Outdoor exhibits can closely mimic the natural environment but also present more challenges for maintaining water and environmental quality as well as for controlling diseases. Geographic location will also play a role in the creation of outdoor exhibits, as not all species of crocodilians can tolerate cold weather. Finally, some species can dig considerably, and measures must be taken to prevent an escape.

TEMPERATURE AND HUMIDITY

The temperature and humidity requirements for crocodilians in captivity vary with the species. Once again, an understanding of crocodilian biology and natural history is needed to try and duplicate their natural environment. An important consideration is the allowance of circadian variations in light cycle and temperatures to mimic their natural environment. This is not the case in many commercial operations, where they are maintained at a fairly constant temperature and humidity to achieve faster growth. From a health standpoint, this may allow for cross exposure of reptiles in commercial operations to infectious organisms that typically affect mammals. As the commercial reptiles are maintained at higher temperatures, new diseases commonly associated with mammals may adapt to living inside a reptile host and lead to clinical disease. In an enclosure, the temperature can be maintained via heating elements contained within the concrete slab, in line water heaters, or both. The water temperature must also be maintained during the refilling of the pen or enclosure to avoid significant temperature variations.

LIGHT

Light requirements for reptiles are still a controversial subject. In general, a source of ultraviolet B (UVB) light for herbivorous and omnivorous reptiles is recommended. Ultraviolet light is essential for the synthesis of vitamin D_3, specifically its active form 1, 25 dihydroxyvitamin D, which is essential for the metabolism of calcium and phosphorus. A lack of vitamin D_3 can lead to inappropriate calcium absorption, which in turn creates a metabolic imbalance resulting in metabolic bone disease. Metabolic bone disease, specifically secondary nutritional hyperparathyroidism, is recognized in many reptile species housed with an inappropriate source of UVB light, fed a diet deficient in calcium, or both. Carnivorous reptiles may also benefit from UVB light but are thought to obtain enough vitamin D_3 and calcium from their prey. The UVB light requirement of crocodilians is unknown, but as true carnivores they may thrive with minimal exposure to UVB light. It is a common practice on alligator ranches to raise animals in darkness with no source of UVB light or a normal light cycle. Most animals will grow well under these conditions, and some have reached adulthood without signs of metabolic diseases. However, I have also observed evidence of metabolic bone disease in a subset of captive American alligators being fed a commercial diet with no exposure to UVB light. In these cases veterinarians must also consider the possibility that the commercial diet may be deficient in calcium. Anecdotal stories from alligator ranches claim that weak, anorectic animals appear to improve after being exposed to sunlight over a period of time. Further research is needed to determine the UVB light requirements of crocodilians and the potential benefits of exposure to UVB light. Natural unfiltered sunlight is the best source of UVB light, but various artificial sources are available (e.g., fluorescent UVB light bulbs, mercury vapor light bulbs).

SUBSTRATE

The two main substrates in crocodilian exhibits are water and soil/sand. The species, age, and feeding habits must be taken into account; avoid substrates that may be ingested by accident and may lead to impactions. It is also important to prevent the public from throwing coins and trash into exhibits, as this may represent a source of toxicity and a cause of impactions. In commercial operations, a smooth covering is applied to the concrete to preserve the quality of the hide. Either an epoxy coating or plastic liners are routinely used as substrate.

NUTRITION

Dietary Requirements

Crocodilians are true carnivores, as evidenced by their short gut and oral cavity. As such, they require a high protein diet, low in fiber. Their feeding habits in the wild will vary with age and food availability. Early on, their diet will consist of small invertebrates, amphibians, and reptiles. As they grow, they will eat larger prey of the type described earlier and will incorporate fish and birds into their dietary regime. With time, and depending on the species, size, and food availability, crocodilians will start eating mammals. There have been few studies investigating the nutritional requirements and feeding protocols of alligators.[8-10] Various commercial feeds are available for alligators maintained in captivity. The commercial rations consist of dry pelleted diets that try to provide full nutritional requirements. These diets can be found with a 45%, 47%, or 56% protein content, less than 11% fat, and approximately 3% fiber content.[11] Refined commercial alligator diets are widely used in production operations but may prove too expensive and/or inappropriate for the long term. A variety of whole prey feeds, such as chicken, nutria, and fish, are also recommended. If using nutria, be sure that it has not been killed using lead shot; if the lead is ingested, toxicosis can occur.[12] When feeding frozen fish to crocodilians, provide a vitamin B supplement or another meat source to prevent thiamine deficiency. To prevent dietary associated problems, purchase meat from a reputable source.

PREVENTIVE MEDICINE

Quarantine

All animals should be quarantined before their introduction to a production or zoologic facility. A detailed history should be obtained from the source facility, including information regarding diseases to which the animals in question may have been exposed. One should always purchase animals from a reputable individual or institution. Little information will be known about wild-caught animals. A minimum quarantine period of 60 to 90 days is recommended in a building that is separate from the main facility. During the quarantine period, the animals can be examined for any sign of illness, and diagnostic tests (complete blood count [CBC], plasma or serum chemistry, West Nile virus antibodies, etc.) can be performed to assess their overall health status. If the alligators originated from an area where WNV is endemic, it is advisable to test for previous exposure to this virus.

Unfortunately, a true quarantine process does not often occur. Quarantine is limited by the availability of appropriate facilities, as well as by the time and production budget. Quarantine is also a challenge in commercial operations where there may be a large population of animals. Nonetheless, zoologic institutions and production facilities should try to establish an adequate quarantine program for their crocodilians.

Routine Exams

Routine physical exams of crocodilians may be incorporated into a zoologic institution's preventive health program. As animals get larger in size, performing physical exams becomes more hazardous. Chemical immobilization can be used, if needed, to perform necessary examinations, particularly on large crocodilian species. In commercial operations, the skins of a subset of the production animals will be examined at intervals before the anticipated time of slaughter. The time of hide examination presents an opportunity for veterinarians to examine the animals in more detail. Other than hide examinations, routine physical exams are not commonly performed in crocodilians from commercial operations.

Disinfection and Sanitation

Biosecurity is an essential part of disease prevention in any animal facility. The creation of a sanitation station at the entrance of each building is recommended to prevent introduction of disease organisms. These stations should contain a foot bath and a hand-washing station to decrease the opportunity of disease transfer between exhibits or buildings. A brush should be provided at each foot bath to thoroughly clean boots and shoes. The solution for the bath can be made of bleach or other commercial disinfectants, preferably with virucidal activity, and should be changed daily. Organic material will contaminate a foot bath, rendering it ineffective. The foot bath should be used before and after entering the building. A hand-washing station should consist of a water source, a sink, hand soap, and disposable hand towels. A waterless hand sanitizer product or exam gloves will suffice in lieu of a hand-washing station. In addition to the sanitation station, separate tools for working in each building are required. Separate working tools also prevent the transfer of diseases via nets, brooms, rakes, and so on. The buildings themselves must also be maintained free of pests and thoroughly cleaned whenever possible. In commercial operations, it is common practice to empty and disinfect the buildings after the slaughter period, before the introduction of new animals. Water quality is one of the main issues of concern when keeping crocodilians in captivity, and many health problems can be prevented if attention is paid to acceptable water quality.

RESTRAINT

Manual restraint of crocodilians is essential for physical examination, administration of medications, administration of anesthetics, and relocations. The size and species of crocodilian will determine the best and safest restraint methods to be used. An experienced crocodilian handler must be available to help restrain the animal. Although alligators and caimans are usually thought of as being less aggressive than crocodiles, this may not always be true. All sizes and species should be handled with the safety of the people as well as the animal in mind. Crocodilians less than 1 m in length (snout to tip of tail) may be handled by one or two individuals. Those between 1 and 2 m in length should be handled by at least two or three individuals. Those longer than 2 m in length will require at least four to five individuals. Various tools (e.g., pole snares, nets, squeeze cages, traps) also can be used to restrain crocodilians. The head, tail, and limbs must be immobilized and controlled. Once the animal is under control, the mouth is secured with strong tape or a rope. Albino and leucistic animals can have increased skin sensitivity compared to the normal pigmented individual; therefore, additional care should be employed to avoid irritation of the skin. Restraint is stressful for the animal, and contact must be limited to the time it takes for the procedures being performed. (See Anesthesia for more discussion on chemical restraint.)

HISTORY AND PHYSICAL EXAMINATION

Signs of illness in captive crocodilians are usually nonspecific. Anorexia, lethargy, a change in behavior, or death may be the first indication that something is wrong in a collection of animals or commercial operation. Adequate observations of the animals made by the personnel in the facility should be taken seriously. A visit to the facility is best undertaken during feeding time to avoid additional stress to the animals. At this time, the feeding and water quality policies can be evaluated. A thorough history should include information about the number of animals, source, age, most recent introduction, quarantine practices, feed, frequency of feeding, water quality parameters, clinical signs, time since first signs were observed, recent changes in management techniques, and any treatments such as salt, bleach, or antibiotics. Within a commercial operation, a subset of animals should be collected for disease diagnostics and necropsy. In addition to the obtaining of routine samples, tissues should be frozen for possible bacterial, fungal, or viral cultures. Within a zoologic institution, sacrificing live animals may not be possible, but veterinarians should obtain diagnostic samples from those with and without clinical signs. Necropsies should be performed in all dead animals. Live animals should undergo physical examination.

Once the animal is properly restrained, a physical examination can be performed. For safety purposes, veterinarians must be aware of the location of the head and tail at all times when performing the examination. A protocol should be followed for the examination process in crocodilians as in any other species. The oral examination can be performed if a speculum (e.g., PVC pipe, piece of wood) is inserted in the mouth before securing it with tape or a rope (Figures 6-9 and 6-10). Examine the eyes for evidence of discharge and assess their function (Figure 6-11). Examine the skin for any evidence of trauma or dermatitis, and then palpate the extremities, joints, musculature of neck, pelvic region, and tail. Joint swelling is often noted with infectious disease such as mycoplasmosis or trauma. Poor body condition may be reflected in atrophy of the muscles. In commercial operations, it is important to examine the skin on the animal's ventral aspect because this is the area where many disease manifestations will be noted. It is also common to find tooth marks, scratches, and lacerations on the ventral

Figure 6-9 A PVC pipe used as a speculum. This allows for oral examination, endotracheal intubation, and any other procedure that requires access to the oral cavity.

Figure 6-10 View of the pharyngeal cavity of an alligator through a PVC speculum inserted in the mouth.

Figure 6-11 Severe conjunctivitis and periocular edema in a Morelet's crocodile *(Crocodylus moreletii).* Chlamydiosis and mycoplasmosis should be a differential for this presentation.

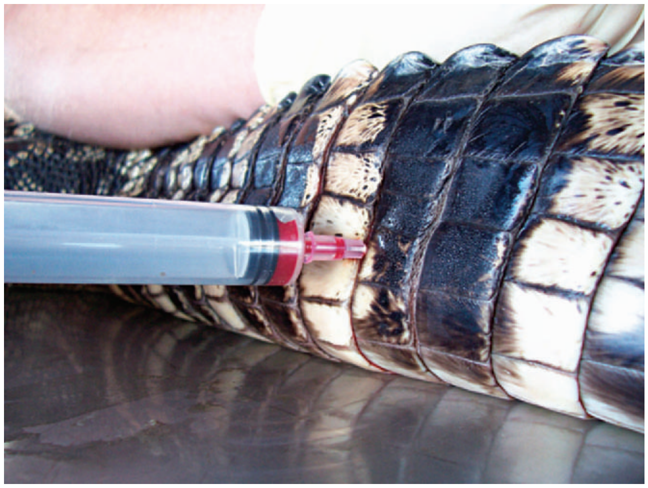

Figure 6-12 Blood draw from the ventral coccygeal vein approached from the lateral aspect of the tail in an alligator.

epithelial surface. Finally, examine the vent and cloaca for abnormalities. If working in a commercial operation, a veterinarian must examine multiple animals to determine if an observation is associated with disease. If working in a zoologic institution and any findings are suspected to be infectious in origin, other animals in the exhibit should be examined. As with any species, an examiner must know what a normal presentation is in order to recognize clinical signs of disease.

DIAGNOSTIC TESTING

Diagnostic tests used to determine crocodilian health status are no different than those used with other animal groups. CBCs, chemistry panels, and bacterial cultures can all be performed in crocodilians. However, there are limitations when it comes to the interpretation of test results because of the lack of reference ranges available for the multiple crocodilian species. In addition, other diagnostic tests, such as those based on polymerase chain reaction (PCR) technology, enzyme-linked immunosorbent assay (ELISA), and other antibody or antigen serologic tests, are usually not validated for crocodilians. A clinician must inquire about the specifics of the tests being performed to make an accurate interpretation of the results. Published literature and the experience of other colleagues are invaluable for interpreting diagnostic test results of crocodilian species. Also there may be generally accepted diagnostic tests for diseases that have been recognized and studied in crocodilians, such as mycoplasmosis and WNV.

Venipuncture

There are various sites for venipuncture in crocodilians. The ventral coccygeal vein can be accessed from either the ventral or the lateral aspect of the tail (Figure 6-12). This vessel lies

Figure 6-13 Blood draw from the supravertebral sinus in an alligator. Care must be employed to avoid inserting the needle too deep.

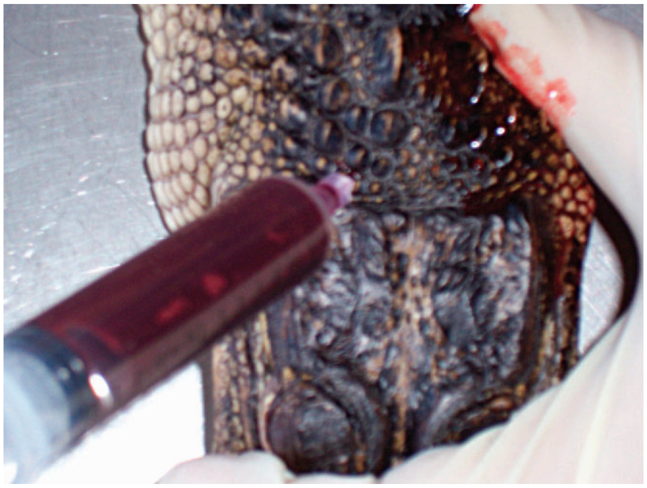

Figure 6-14 Blood draw from the lateral occipital sinus (unnamed) on the lateral aspect of the head/neck of an alligator.

ventral to the vertebral processes and on midline with the vertebrae. A second alternative is the supravertebral sinus, located on midline at the junction of the head and the neck (Figure 6-13). The examiner must be careful not to go too deep at this site, or physical damage may occur. A third site is an unnamed vessel located on both the left and right sides of the neck. This vessel can be approached from the dorsal aspect of the neck and is surrounded by muscles, decreasing the risk of coming in contact with nervous tissue (Figure 6-14).[13] A 3-ml syringe and a 22-gauge needle are recommended for collecting blood from crocodilians. Lithium heparin and EDTA tubes are used for plasma chemistry analysis and CBCs, respectively. If collecting serum, the tubes may have to sit for at least 45 to 60 minutes before centrifugation to allow proper separation of the serum from the blood cells.

Clinical Pathology

As with other species, CBCs and chemistry panels are a fundamental part of diagnostic testing of crocodilians. These tests can help assess the overall health status of the animals. A CBC can show evidence of acute or chronic inflammation that may prompt further investigation or lend direction to a definitive diagnosis. Chemistry panels can give insight into the hydration status and the health of the liver and kidneys. Also of importance are electrolyte values, which can show abnormalities related to poor diet and husbandry. A measurement of packed cell volume and total solids and/or total proteins is also an essential health indicator for crocodilian species. Fine needle aspirates, impression smears, and fluid analysis are diagnostic tools that can be useful in determining a definitive diagnosis. Urinalysis is not a practical test in crocodilians due to the absence of a urinary bladder and the fact that urine will be highly contaminated in a voided sample.

The hemocytometer with the Unopette Eosinophil Determination for Manual Methods stain (Becton Dickinson and Company, Franklin Lakes, NJ 07417-1885) is often used to obtain a CBC of crocodilian species and other reptile and avian species. A blood smear stained with Diff-Quick (Quik-dip stain, Mercedes Medical Physician and Laboratory Products, 7490 Commerce Ct., Sarasota, FL 34342) is also needed to complete the total estimated white blood cell count and obtain the cell differential count. Interpretation of CBCs from crocodilians can be challenging for veterinarians unfamiliar with the morphology of their white blood cells, which can vary from that of other reptile species. This variation found in crocodilian species is typical and more pronounced among reptiles. To become familiarized with the different cell types and their appearance, veterinarians should spend time scanning blood smears. This will often help veterinarians differentiate heterophils from eosinophils before the initiation of the differential count. Alternatively the samples can be submitted to a commercial laboratory that runs CBCs on blood collected from exotic animal species.

Imaging

Most imaging modalities (radiographs, computed tomography [CT] scan, magnetic resonance imaging [MRI], ultrasound, etc.) can be used on crocodilian species as long as there is a general understanding of their anatomy. Knowledge of normal anatomy is crucial for the interpretation of radiographs, CT scans, and MRI images. Knowledge of the anatomy will also help locate organs during ultrasound examination. Radiographs can be used to locate foreign bodies as well as diagnose fractures. Contrast studies can also be performed if the facilities and personnel are allowed to hospitalize the animal for an extended period of time. Barium sulfate (Liquid E-Z-Paque, E-Z-EM Inc., Westbury, NY 11590) and iohexol (Omnipaque, Amersham Health Inc., Princeton, NJ 08540) can be administered at 5 to 20 ml/kg PO. Iohexol can be diluted with water at a 1 : 1 to 2 : 1 ratio depending on the concentration.[14] Depending on the size of the animal and the site of interest, some imaging procedures may be performed with manual restraint or, if needed, chemical restraint. Neuromuscular blocking agents may be beneficial as chemical restraint agents if used appropriately and if the animal is monitored closely.

COMMON DISEASE PRESENTATIONS

Stress and Immunosuppression

Stress has been defined as "a physiological answer to a perceived threat that includes, but is not restricted to, increased adrenal secretion."[15] Stress can also be any event that challenges homeostasis. The response of the body to that event is complex and involves more than an adrenal response. The autonomic nervous system, the hypothalamic adrenal axis, neuropeptides, neurotransmitters, and neuroimmunologic mediators all have a role in the response of the immune system to stress.[16] Measuring stress and immunosuppression is a challenge in veterinary medicine. There are no specific tests available to provide a clinical measure of stress. Veterinarians concentrate on identifying a combination of physiologic changes that give them an idea of what is involved in a stress response. The stress response in crocodilians has been examined in relation to restraint, long-term corticosterone implants, cold shock, and stocking densities.[15,17-20] Lance et al. provides an overview of the physiology and endocrinology of stress in crocodilians.[21] Catecholamines, glucocorticoids, glucose, and lactate have been implicated in the stress response of crocodilians. Changes in the white blood cells have also been implicated with immunosuppression and the stress response.[17-19,21] There is enough evidence to suggest that stress plays an important role in the physiology of crocodilians and may indeed predispose them to illness. Overcrowding, handling, excessive noise, diet changes, temperature irregularities, and so forth, should be considered as predisposing or confounding factors of disease. All of these factors must be considered in the history of a clinical case and when determining treatment.

An example of how stress can play a role in disease susceptibility was observed in a case at a commercial alligator facility. This facility had animals with a history of chronic dermatitis. The alligators with the most severe lesions were consistently located on one end of the building, whereas those at the other end were unaffected or only mildly affected. The location of the severely affected animals was consistent in all buildings. One building had no affected animals. Based on a thorough history and observation of the operation, a possible explanation was determined for the occurrence of the dermatitis problem. All of the buildings with affected animals had PVC pipes on the inside walls that delivered water to each individual pen. A strong water stream fell from the pipes down into the water and the strength of the stream decreased from one end of the building (inflow) to the other end (outflow). The strength of the water stream was considerable near the inflow. The building with no affected animals did not have any source of falling water into the pens. Water quality, temperature, and feed were the same in affected and nonaffected buildings. The most affected animals happened to be in the pens at the inflow side of the building with the number of affected animals decreasing toward the outflow side of the building. This constant flow of water was creating a constant movement of the water surface and consequently stimulating the alligators via the DPRs. Once this watering system was changed, the cases of dermatitis decreased and no new cases were reported. Although other factors, such as water quality, may have contributed to the dermatitis, the change in the watering system decreased the progression and occurrence of the disease. This case demonstrates the importance of addressing the environment, as well as the animals, when working in commercial operations.

Bacterial Diseases

Bacterial diseases in captive crocodilians occur primarily as opportunistic infections. Poor water quality, trauma, and stress are some of the factors that contribute to bacterial infections in crocodilians. In their natural environment, crocodilians appear to have a stronger ability, compared with other species, to withstand bacterial infections. Reports of antibacterial properties in serum and tissues of crocodilians[22,23] offer a possible explanation. The possibility of increased antibacterial properties in the serum and tissues of alligators should not mislead people into thinking that crocodilians are resistant to bacterial infections. It is true that they appear to tolerate trauma and other lesions that would be fatal in many species, but crocodilians are still capable of succumbing to an array of microorganisms, including bacteria. In fact, a number of bacterial infections have been reported in crocodilians, and septicemias are thought to be a frequent finding. Septicemias can be diagnosed in postmortem examinations and are often associated with a wide number of bacteria, many of them normal gut flora. There is an abundance of information about bacteria recovered from the American alligator *(A. mississippiensis)*[24-39] (Table 6-3) and from African dwarf crocodiles *(Osteolaemus tetraspis)*.[40]

SALMONELLA INFECTION

Salmonella spp. are normal inhabitants of the gut in most reptile species and crocodilians.[41-43] The importance of *Salmonella* sp. arises more from its zoonotic potential rather than its ability to cause disease in crocodilians, but it has been reported to cause deaths in Nile crocodile *(C. niloticus)* hatchlings.[44] In most commercial operations the meat is sold as a by-product of the hide production. Various species of *Salmonella* and other bacteria have been isolated from the meat of crocodiles in commercial operations in an attempt to address the concern of zoonoses.[35,38,45-49] Zoologic institutions that have smaller crocodilians as part of a "petting" station should exercise caution, as fecal shedding of *Salmonella* sp. occurs. Although the zoonotic potential exists, there are no well-documented cases of human infections originating from crocodilians.

CHLAMYDIOSIS

Chlamydiosis has also been reported in crocodilian species.[44] There is a report of an isolate, closely associated to

TABLE 6-3 Bacteria Isolated from *A. mississippiensis* With and Without Clinical Signs of Disease

Isolate	Tissue	Clinical signs/lesions	Reference
Aeromonas hydrophila	Blood	Yes	32
	Lungs, heart, liver, kidneys, intestines, oral cavity	Yes, No	24
	Lungs, blood	Yes	25
	Eye	Yes	26, 33
	Oral cavity, water	No	28
Aeromonas sp.	Lungs	Yes	34
Acitenobacter calcoaceticus	Oral cavity	No	28
Aerobacter radiobacter	Oral cavity	No	28
Bacillus sp.	Not specified	Yes	35
Bacteroides asaccharolyticus	Oral cavity	No	28
Bacteroides bivius	Oral cavity, water	No	28
Bacteroides loescheii/denticola	Oral cavity, water	No	28
Bacteroides oralis	Oral cavity	No	28
Bacteroides sordellii	Oral cavity	No	28
Bacteroides thetaiotamicron	Oral cavity	No	28
Bacteroides vulgatus	Oral cavity	No	28
Bacteroides sp.	Water	No	28
Citrobacter freundii	Blood	Yes	29
	Oral cavity	No	28
Clostridium bifermentans	Oral cavity, water	No	28
	Lungs	Yes	34
Clostridium clostriidoforme	Oral cavity	No	28
Clostridium innoculum	Water	No	28
Clostridium limosum	Oral cavity	No	28
Clostridium sordellii	Oral cavity, water	No	28
Clostridium sporogenes	Blood	Yes	34
Clostridium tetani	Oral cavity	No	28
Clostridium sp.	Blood	Yes	34
Corynebacterium sp.	Tail abscess	Yes	25
Dermatophilus sp.	Skin	Yes	36, 37
Diphtheroid sp.	Oral cavity	No	28
Edwardsiella tarda	Kidney, feces	Yes	30
	Fat body, pericardial fluid	Yes	34
Enterobacter agglomerans	Blood	Yes	29
Enterobacter cloacae	Oral cavity, water	No	28
Enterobacillus sp.	Lungs	Yes	25
Escherichia coli	Systemic	Yes	38
Fusobacterium nucleatum	Oral cavity	No	28
Fusobacterium varium	Oral cavity	No	28
Klebsiella oxytoca	Skin	Yes	29
	Oral cavity	No	28
Klebsiella sp.	Lungs	Yes	59
Micrococcus kristinae	Blood	Yes	32
Moraxella sp.	Oral cavity, water	No	28
Morganella morganii	Blood	Yes	29
	Oral cavity	No	28
	Lung	Yes	34
Mycoplasma alligatoris	Multiple tissues	Yes	32, 39
Pasteurella haemolytica	Oral cavity	No	28
Pasteurella multocida	Lungs	Yes	31
Pasteurella sp.	Oral cavity, water	No	28
Peptococcus magnus	Oral cavity	No	28
Peptococcus prevotii	Oral cavity	No	28
Proteus mirabilis	Blood	Yes	32

TABLE 6-3 **Bacteria Isolated from *A. mississippiensis* With and Without Clinical Signs of Disease—cont'd**

Isolate	Tissue	Clinical signs/lesions	Reference
Proteus vulgaris	Oral cavity	No	28
	Oviduct	Yes	30
	Blood	Yes	32
	Lung	Yes	34
Proteus sp.	Blood	Yes	29
Pseudomonas cepacia	Oral cavity	No	28
Pseudomonas diminuta	Water	No	28
Pseudomonas fluorescens	Water	No	28
Pseudomonas pickettii	Oral cavity	No	28
Pseudomonas vesicularis	Water	No	28
Pseudomonas sp.	Lungs, pharynx	Yes	25
	Water	No	28
Salmonella typhimurium	Gastrointestinal tract	Yes	25
Salmonella braenderup, anatum	Cloaca	No	25
Serratia marcescens	Skin	Yes	29
Serratia odorifera	Oral cavity	No	28
Staphylococcus aureus	Lungs	Yes	31
Staphylococcus cohnii	Blood	Yes	32
Streptococcus sp. β-hemolytic	Lungs	Yes	34
Vibrio parahemolyticus	Blood	Yes	32

Chlamydophila psittaci, obtained from the livers of Nile crocodiles *(C. niloticus)* in Zimbabwe.[44] This infection is thought to have an acute course characterized by a hepatitis in which hatchling mortalities are observed. A chronic form of reptilian chlamydiosis characterized by conjunctivitis has also been reported and may be more common.[44] There have been reports of concurrent *Chlamydia* sp. isolates in cases of mycoplasmosis and adenoviral infections.[2]

DERMATOPHILOSIS ("BROWN SPOT DISEASE")

Dermatophilosis or "brown spot disease" is thought to be caused by *Dermatophilus* sp., with most of the cultures resembling *Dermatophilus congolensis,* and affects both crocodiles and alligators.[36,37,50-52] The characteristic brown to red lesions are located usually at the junction of the ventral abdominal scales, which may become ulcerated over time. This has occurred in both alligator and crocodile operations. This disease does not respond well to antimicrobial therapy; therefore, intensive hygiene practices are required to prevent and control outbreaks.

MYCOPLASMOSIS

Mycoplasma alligatoris is a recognized respiratory pathogen of crocodilians. It has been documented in *A. mississippiensis* and in the broad-nosed caiman *(Caiman latirostris).*[32,39,53] Other crocodilian species closely related to alligators also may be susceptible to this intracellular organism. Clinical signs are nonspecific and include lethargy, weakness, anorexia, white ocular discharge, paresis, and edema (facial, periocular, cervical, limbs).[34] Pathologic examination often reveals evidence of pneumonia, pericarditis, and polyarthritis. Helmick et al. reported antimicrobial susceptibility for *M. alligatoris* with doxycycline, oxytetracycline, enrofloxacin, sarafloxacin, tilmicosin, and tylosin showing effectiveness against the bacteria.[54] A second mycoplasma species, *M. crocodyli,* was also described in Nile crocodiles with lesions similar to those observed with *M. alligatoris.*[55] Some studies have examined the use of an autogenous vaccine for *M. crocodyli,* but its efficacy has yet to be determined.[56,57]

MYCOBACTERIOSIS

Cases of pulmonary and enteric mycobacterial infections are mentioned by Huchzermeyer[2] and Youngprapakorn et al.[58] These reports include *Mycobacterium marinum* and *M. fortuitum* from different spectacled caimans *(C. crocodilus), M. avium* from an unspecified species of crocodile and from Nile crocodiles *(C. niloticus),* and *M. ulcerans* from Johnston's crocodiles *(C. johnstoni).*[2] Many other reported cases are based on gross findings and histopathology with acid-fast positive organisms identified microscopically. There are also some observed clinical cases of suspected yet unconfirmed pulmonary mycobacteriosis, based on necropsy and histopathologic evaluation.[59] Difficulties of growing *Mycobacterium* spp. make obtaining a definitive diagnosis challenging. Other diagnostic tools, such as PCR technology, may be beneficial in the identification of future mycobacteriosis cases.

Viral Diseases

Virus identification and diagnosis in reptiles has lagged compared to virus identification and diagnosis in other species. This delay has occurred primarily because of difficulties in developing diagnostic tests and lack of knowledge of viruses that affect reptiles and crocodilians. Many conditions that go undiagnosed may be caused by viruses. These may be new viruses or just viral diseases unknown to occur in reptilian or crocodilian species. There are only a few recognized viruses that have been documented in crocodilians.

Jacobson et al.[33] described an adenovirus-like infection in captive Nile crocodiles *(C. niloticus)* characterized by nonspecific clinical signs, lethargy, and anorexia. Conjunctivitis and blepharitis were also observed in one of two crocodiles.[2,33] Histopathologic examination revealed intranuclear inclusions, primarily in the liver but also in the intestines, pancreas, and lung. Both horizontal and vertical transmission have been postulated for this adenovirus-like infection.[2] Diagnosis is obtained through postmortem examination, and no treatment regimes have been established.

Coronavirus, influenza C virus, and paramyxovirus have been identified by transmission electron microscope in the feces of crocodilians.[2] Herpesvirus-like particles were identified by electron microscopy in the skin of a salt water crocodile *(C. porosus)*.[60] There is a second finding of herpesvirus identified from the cloaca of an American alligator *(A. mississippiensis)* via PCR.[61] The clinical significance of these findings is unknown. Seroconversion to paramyxovirus and eastern equine encephalitis virus has also been reported in crocodilians.[2]

POXVIRUS

Parapoxvirus or pox-like viruses have been identified in five different crocodilian species: spectacled caiman *(Caiman crocodilus fuscus)*,[62,63] Brazilian caiman *(Caiman crocodilus acre)*,[64] Nile crocodile *(Crocodylus niloticus)*,[65,66] saltwater crocodile *(Crocodylus porosus)*,[67] and freshwater crocodile *(Crocodylus johnstoni)*.[67] Pox lesions in caimans will be 1 to 3 mm in diameter, gray to white in color, and coalescing to macular. They may appear on the head, palpebra, maxilla, mandible, limbs, palate, tongue, and gingiva.[62-64] Palpebral and generalized edema also may be present. Resolution of clinical signs has been observed with and without changes in husbandry practices.[63,64] In crocodiles the lesions are described as 2 to 8 mm in diameter, yellow to brown, wart-like, sometimes firm, and unraised to raised nodules with occasional shallow ulcers. In crocodiles pox lesions appear on the head, palpebra, nostrils, sides of the mouth, oral cavity, limbs, ventral neck and coelom, and at the base of the tail.[65,66] Resolution of lesions was reported to occur as early as 3 to 4 weeks from the onset of clinical signs.[65] Histopathologic findings include epithelial hyperplasia, acanthosis, hyperkeratosis, and necrosis, with intracytoplasmic Borrel and Bollinger's bodies being visible in some cases.[62-66] Secondary bacterial and fungal infections may occur concurrently with the viral infection. At this time there are no specific treatment recommendations. The use of an autogenous vaccine to treat poxvirus in Nile crocodiles *(C. niloticus)* has had some success.[65] Mosquito control and good hygiene are essential in preventing and controlling poxvirus outbreaks.

WEST NILE VIRUS

West Nile virus (WNV) has been reported to affect various crocodilian species, including the American alligator *(A. mississippiensis)*,[68] the Nile crocodile *(C. niloticus)*,[69] and the Morelet's crocodile *(C. moreletii)*.[70] Crocodilians likely become infected, as birds and mammals do, via a mosquito bite. There is also the possibility of infection after ingestion of an animal with a high viral load of WNV, as reported by Klenk et al.[71] This last scenario is more likely to occur when crocodilians are housed outdoors and not in enclosed buildings, as in most ranching operations. It has been demonstrated that alligators can serve as amplifiers of WNV.[71] Although there is a lot to be learned about WNV in crocodilians, it is believed that once infected, they can develop high viremias and shed the virus in the feces. Fecal shedding leads to horizontal transmission of the virus. There is clinical evidence for horizontal transmission to occur in commercial operations. Fecal shedding and high viremias also raise the concern of zoonosis, especially in commercial operations where animals are being slaughtered and people come in contact with blood and tissues. A strict building quarantine and hygiene strategies should be implemented to prevent the spread of WNV to other animals in the facility as well as to the personnel. In the state of Louisiana there are a number of recommendations provided to help alligator producers cope with episodes of WNV and prevent spread of the disease (Box 6-2).

BOX 6-2 Recommendations Made to Alligator Producers in Louisiana on How to Prevent and Manage West Nile Virus

1. Buildings with affected animals should be maintained under isolation from other buildings in the farm.
2. Feeding and cleaning of affected buildings should be performed last, after all other nonaffected buildings.
3. A foot bath (1 part water, 1 part bleach) should be placed at the entrance of the building to disinfect the shoes and boots of farm employees before and after entering the building. This foot bath should be changed on a daily basis. In addition, a set of shoes or boots may be kept only to be used inside affected buildings.
4. Hands should be washed before and after entering the building.
5. The water should be changed more frequently in affected buildings, at least once a day. This may create additional stress on the animals but should decrease the amount of feces and therefore viral organisms possibly present in the water. Any special treatment of the discharge water still remains to be determined.
6. Affected animals should not be transported to other alligator farms for processing of hides or meat.
7. Additional care should be exercised during the slaughter process to avoid direct contact with the blood and organs of animals known as exposed to, or affected with, West Nile virus.
8. Dead animals should be disposed of by burning the carcasses.
9. Aggressive mosquito control is required to help in the prevention of the disease.

Affected animals in captive operations have ranged in age from 1 month to over 12 months. In younger animals infection is usually acute and severe, with as much as 60% mortality. The pattern of deaths is peracute, usually seen as a sudden onset of mortalities followed by a peak and subsequent decline in the number of deaths. However, sporadic mortalities may also be noted, especially in older animals. Clinical signs of WNV in alligators include swimming in circles, head tilt, muscle tremors, weakness, lethargy, and anorexia.[72] Bloating and difficulties swimming have also been observed but occur less commonly.[72]

Gross findings from WNV-infected alligators are nonspecific. Light microscopy of tissues from infected animals may reveal diffuse severe heterophilic, histiocytic, and necrotizing enterocolitis; heterophilic meningoencephalitis; necrotizing and heterophilic hepatitis; heterophilic and histiocytic splenitis; generalized heterophilic and histiocytic lymphoid folliculitis; and necrotizing and heterophilic pancreatitis. Veterinarians may also observe a mild multifocal heterophilic and lymphohistiocytic interstitial nephritis, gastritis, and mild pulmonary congestion and edema. Strong immunopositivity results have been observed in the brain, liver, spleen, pancreas, kidney, and gastrointestinal tract after immunohistochemistry testing for WNV. Proliferative enteritis has been diagnosed in a group of alligators positive for WNV. The colon lesions tested positive for WNV via reverse transcriptase polymerase chain reaction (RT-PCR), culture, and immunohistochemistry[59,72] (Figure 6-15). These affected alligators were bloated and unable to submerge themselves; these symptoms may have been due to a blockage caused by the fibrinous membrane in the colon.

There is no known treatment for WNV-infected crocodilians. Mosquito control, strict quarantine, and biosecurity are essential for the prevention of WNV. Once WNV is present within an operation, it is critical to maintain infected and exposed animals in strict isolation. The ill and exposed animals must not be moved to other areas or buildings where WNV has not been observed. Failure to maintain strict isolation may result in the spread of the virus throughout the facility. In addition, there should be strict biosecurity measures, especially in the affected areas or buildings. Tools such as nets, feeding utensils, boots, and so forth, must be left in the affected area and not introduced to other, "clean" areas or buildings. The surviving animals will continue to thrive after the WNV infection has run its course, but it is unknown for how long thereafter they can shed the virus. Antibody titers of 1 : 640 and 1 : 320 were observed in two alligators 14 months after exposure to WNV. These antibody titer results were obtained via a plaque reduction neutralization test. Definitive diagnosis of WNV infection should be based on history, clinical signs, and the results of diagnostic tests. Postmortem diagnosis can be performed via RT-PCR and/or viral culture of brain, spinal cord, or liver, with immunohistochemistry providing additional supportive evidence of WNV infection. Immunohistochemistry may prove useful as an antemortem test when applied to biopsies of the colon mucosa.

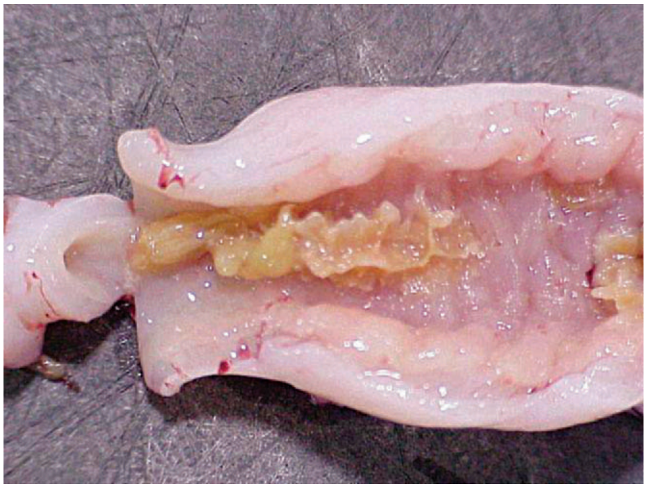

Figure 6-15 Fibrinous colitis in an alligator with West Nile virus. This animal was unable to submerge itself.

Fungal Diseases

Fungal infections also occur with some frequency in captive crocodilians. Most fungi are opportunistic invaders of the integument, respiratory system, and gastrointestinal tract. Poor water quality, trauma, stress, and extreme temperatures can contribute to the occurrence of fungal disease. It is thought that most fungal infections in crocodilians are of enteric origin and occur in other tissues secondary to an immunocompromised state.[2] It is important to remember that fungi are considered ubiquitous organisms in nature. Therefore, it is not uncommon to isolate fungi from tissues (e.g., skin, intestines) that are in contact with water and soil. The presence of fungi will vary with geographic location and management techniques that affect the different environments for their growth. There are a number of fungi that have been isolated from crocodilians[2,40,51,73-80] (Table 6-4). Some of these fungal organisms were associated with disease, whereas others were incidental findings. Diagnosis of fungal disease requires the identification of a fungal organism via culture or special stains of infected tissues. Positive identification of genus and species may be difficult. Treatment is expensive and may be affordable only when administering to a small number of animals. It also requires a long treatment period of at least 2 or 3 months. For these reasons, many fungal infections go untreated, and recommendations are made for prevention of disease.

Parasites

A number of parasites are known to affect crocodilians. Protozoa, nematodes, trematodes, and pentastomes have all been reported in crocodilians.[2] Cestode larvae have been found in some species, but no adult tapeworms are reported from crocodilians.[2] External parasites, such as leeches, flies, mosquitoes, ticks, and mites, can also affect crocodilians.[2] The presence of scales has created a misconception about the possibilities for external parasitism in crocodilians. However, there are a

TABLE 6-4 Fungi Isolated from Crocodilians Around the World

Fungus	Lesions	Species	Reference
Acremonium sp.	Intestinal contents	*Osteolaemus tetraspis*	40
Alternaria alternata	Skin	*Alligator mississippiensis*	73
Arthrinium sp.	Intestinal contents	*Osteolaemus tetraspis*	40
Aspergillus clavatus	Intestinal contents	*Osteolaemus tetraspis*	40
Aspergillus flavus	Not specified	*Crocodylus porosus*	2
	Skin	*Crocodylus porosus*	51
	Intestinal contents	*Osteolaemus tetraspis*	40
Aspergillus fumigatus	Skin	Caimans (species not specified)	2
	Lungs	*Alligator mississippiensis*	2
Aspergillus niger	Not specified	*Crocodylus porosus*	74
	Skin	*Crocodylus porosus*	51
	Intestinal contents	*Osteolaemus tetraspis*	40
	Skin	*Alligator mississippiensis*	73
Aspergillus ustus	Lungs	*Alligator mississippiensis*	2
Aspergillus versicolor	Not specified	*Crocodylus porosus*	2
Beauveria bassiana	Lungs	*Alligator mississippiensis*	75
	Lungs	*Crocodylus niloticus*	2
Beauveria sp.	Intestinal contents	*Osteolaemus tetraspis*	40
Candida albicans	Oral cavity	Caimans (species not specified)	2
Candida guillermondii	Intestinal contents	*Osteolaemus tetraspis*	40
Candida krusei	Intestinal contents	*Osteolaemus tetraspis*	40
Candida parasilosis	Skin	*Crocodylus porosus*	51
Candida sp.	Skin	*Crocodylus porosus*	51
Cephalosporium sp.	Muscle	*Caiman crocodilus*	2
	Lungs	*Caiman sclerops*	76
Chaetomium globosum	Skin	*Alligator mississippiensis*	73
Chaetomium sp.	Skin	*Alligator mississippiensis*	73
Chrysosporium sp.	Intestinal contents	*Osteolaemus tetraspis*	40
Cladosporium cladosporioides	Skin	*Alligator mississippiensis*	73
Cladosporium oxysporum	Skin	*Alligator mississippiensis*	73
Cladosporium sp.	Skin	Caimans (species not specified)	2
Cryptococcus lipolytica	Intestinal contents	Osteolaemus tetraspis	40
Cryptococcus luteolus	Intestinal contents	*Osteolaemus tetraspis*	40
Curvularia lunata	Skin	*Alligator mississippiensis*	73
Curvularia lunata varaeria	Skin	*Crocodylus porosus*	74
Curvularia sp.	Intestinal contents	*Osteolaemus tetraspis*	40
Epicoccum purpurascens	Skin	*Alligator mississippiensis*	73
Eurotium chevalieri	Skin	*Alligator mississippiensis*	73
Fusarium moniliforme	Lungs	*Alligator mississippiensis*	77
Fusarium solani	Internal organs	*Crocodylus porosus*	2, 74
Fusarium sp.	Not specified	*Crocodylus porosus*	2
	Gingivae	*Caiman crocodilus fuscus*	2
	Skin	*Crocodylus porosus*	51
	Intestinal contents	*Osteolaemus tetraspis*	40
Geotrichum candidum	Not specified	*Crocodylus porosus*	2
	Intestinal contents	*Osteolaemus tetraspis*	40
Geotrichum sp.	Not specified	*Crocodylus porosus*	2
Metarhizium anisopliae	Lungs	Crocodile (species not specified)	2
	Lungs	*Osteolaemus tetraspis*	2
	Lungs	*Alligator mississippiensis*	2
Monascus ruber	Skin	*Alligator mississippiensis*	73
Mucor circinelloides	Skin	Caimans (species not specified)	2
	Gastric ulcers	*Osteolaemus tetraspis*	2
	Skin	*Alligator mississippiensis*	73
Mucor sp.	Lungs	Crocodile (species not specified)	78
Nannizziopsis vriesii	Skin	*Crocodylus porosus*	79
Paecilomyces lilacinus	Liver	*Crocodylus porosus*	80

TABLE 6-4 **Fungi Isolated from Crocodilians Around the World—cont'd**

Fungus	Lesions	Species	Reference
Paecilomyces farinosus	Lungs	*Alligator mississippiensis*	2
Paecilomyces variotii	Skin	*Alligator mississippiensis*	73
Paecilomyces sp.	Not specified	*Crocodylus porosus*	2
	Intestinal contents	*Osteolaemus tetraspis*	40
Penicillium citrinum	Skin	*Alligator mississippiensis*	73
Penicillium lilacinum	Lungs	Alligators and crocodiles (species not specified)	2
Penicillium oxalicum	Skin	*Crocodylus porosus*	74
Penicillium sp.	Not specified	*Crocodylus porosus*	2
	Intestinal contents	*Osteolaemus tetraspis*	40
Phoma sp.	Intestinal contents	*Osteolaemus tetraspis*	40
Syncephalastrum racemosum	Skin	*Alligator mississippiensis*	73
Syncephalastrum sp.	Skin	*Crocodylus porosus*	51
Trichoderma sp.	Skin	*Alligator mississippiensis*	2
	Intestinal contents	*Osteolaemus tetraspis*	40
Trichophyton sp.	Skin	*Alligator mississippiensis*	2
Trichosporon beigelii	Intestinal contents	*Osteolaemus tetraspis*	40
Trichosporon capitatum	Intestinal contents	*Osteolaemus tetraspis*	40
Trichosporon cutaneum	Skin	*Crocodylus porosus*	51
Trichosporon sp.	Tongue, gingivae	*Crocodylus niloticus, C. fuscus*	2

number of areas in a crocodilian's body that have soft skin and allow an external parasite to attach and/or obtain a meal. The recent cases of WNV in the American alligator *(A. mississippiensis)* are a reminder that arthropods can play an important role in disease transmission. Internal parasites are not a common problem in ranching operations where animals are maintained in concrete buildings with no organic substrate. Parasites are of major concern in wild crocodilians or those kept captive outdoors on organic substrates. External parasites are more ubiquitous, affecting both captive and wild populations. To determine the best prevention and control methods to use, veterinarians must assess the environment as well as the life cycle of the parasite.

Nutritional Diseases

With the increased knowledge of crocodilian dietary requirements, nutritional diseases are diagnosed less frequently than they were in the past. Better understanding of the biology, natural history, and physiology of the different crocodilian species has allowed implementation of better feeding schemes and diets. Over time, there has been a desire to develop commercial diets that will allow for high feed to weight gain ratios. These commercial diets are available for feeding American alligators *(A. mississippiensis),* and although the diets are not perfect, if fed appropriately, captive-hatched American alligators *(A. mississippiensis)* will grow up to 36 inches in length within a 12-month period. For zoologic institutions the goal is not rapid growth but rather normal development and a foundation for excellent health. Zoologic institutions and crocodile farms commonly provide crocodilians with fresh and/or frozen prey (e.g., poultry, swine, beef, fish, nutria, native prey, etc.) with bones providing a source of calcium. To prevent lead toxicity in crocodilians, veterinarians must use a reputable fresh or frozen prey source that has not been killed with lead projectiles (e.g., shotgun pellets, bullets). Despite better feeding schemes and diets, veterinarians will still see crocodilians with diseases associated with nutritional deficiencies.

A common nutritional disease of reptiles is metabolic bone disease (MBD). Clinical signs of MBD include weakness, lethargy, kyphosis, scoliosis, osteodystrophy, pathologic fractures, paresis, and tooth decalcification. Various possible causes of MBD have been proposed, but it is usually associated with a calcium-phosphorus imbalance that leads to increased bone resorption. Calcium and vitamin D_3 are the two main nutritional compounds deficient in reptiles with MBD. Vitamin D_3 deficiencies are associated with a lack of exposure to UVB spectrum light, which comes naturally from the sun. Light bulbs and light tubes are commercially available to help provide adequate amounts of UVB light for reptiles. MBD is primarily observed in herbivorous or omnivorous reptiles. It appears that MBD is not commonly observed in commercial crocodilian operations, even in those were animals are raised in the dark with no source of UVB light. The carnivorous nature of crocodilians may allow them to obtain vitamin D_3 from the diet without a true requirement for UVB light. However, if an appropriate calcium source is not offered, these animals will develop MBD. Adult alligators without MBD have been observed growing in enclosed buildings with no light source while being fed a commercial diet supplemented with fresh prey meat with bones. However, anecdotal comments from various ranchers indicate that the animals appear to thrive better if exposed to sunlight. This is an area where more research is needed to determine the UVB and calcium requirements of crocodilians and their effects on growth and health.

Articular and visceral gout also have been reported in crocodilians. Some predisposing factors for gout include high protein diets, dehydration, and stress. Clinical signs associated with chronic gout in crocodilians are primarily nonspecific, but limb paresis or paralysis and joint enlargement can occur. Ariel et al. reported a case of visceral and articular gout with concurrent hypovitaminosis A in crocodile hatchlings.[81]

Deficiencies of vitamins A, B, C, or E also can lead to a variety of musculoskeletal disorders. These are thought to be less common in crocodilians fed commercial diets in addition to fresh meat products.

Respiratory Disease

Respiratory disease is one of the most common presentations of captive crocodilians in commercial operations. It is common to find lesions in the lungs associated with respiratory disease when performing postmortem examinations (Figure 6-16). Although most of the lung pathology is incidental, some animals will have a history of clinical signs associated with respiratory disease before death. Clinical signs of respiratory disease in crocodilians are nonspecific anorexia, lethargy, and weakness but may also include dyspnea, tachypnea, nasal secretion, excessive basking, respiratory stridor, and abnormal swimming (either in circles or on one side of the body). In some cases the animals may appear neurologic as they become weak and ataxic. A clear distinction must be established between respiratory disease and neurologic disease. Respiratory disease may be secondary to neurologic disease as a consequence of weakness, predisposing the animal to aspiration pneumonia. Most respiratory infections are either bacterial or fungal in origin. Upper respiratory diseases, including rhinitis and pharyngitis, also have been reported in crocodilians.[2]

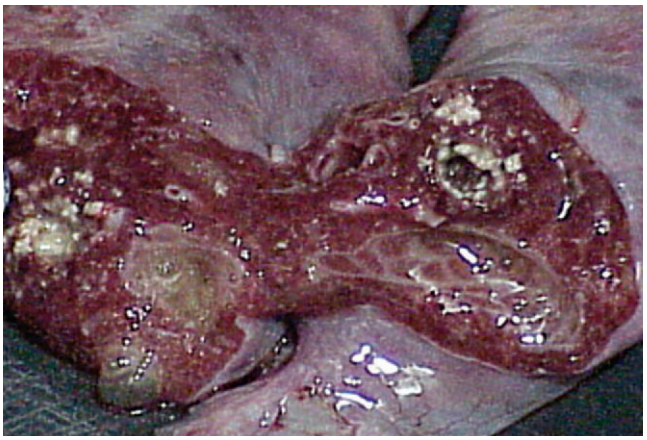

Figure 6-16 Pneumonia associated with *Klebsiella* sp. in an American alligator *(Alligator mississippiensis).*

Neurologic Disease

Neurologic diseases are not common in crocodilians. However, the causes implicated by clinical neurologic presenting symptoms deserve special attention. The most common neurologic clinical sign is abnormal swimming behavior (e.g., swimming in circles, swimming on one side of the body, etc.). Once outside the water, these animals may show signs of lethargy, ataxia, head tilt, and muscle tremors. Anorexia may be the earliest sign observed by the facility personnel. The most recent explanation of signs of neurologic disease in crocodilian species is WNV. This virus should be in the differential diagnosis list for any crocodilian that has neurologic signs and is housed in an area where WNV is endemic. Hypoglycemia also has been reported to cause neurologic signs in alligators.[82]

Neurologic signs and deaths of alligators *(A. mississippiensis)* were identified from a commercial operation where a building was not cleaned according to the maintenance schedule. The water in the building had not been changed in a 72-hour period, and there was evidence of food debris from previous feedings. The owner found a few hundred dead alligators, and of those that remained alive, some had neurologic signs (e.g., slow reflexes, abnormal swimming patterns, ataxia, and lethargy). Necropsy and histopathologic evaluation leaned toward toxicity as the cause of death. Both dead and live animals tested negative for WNV. All other buildings were cleaned on schedule, and there was no evidence of disease in those buildings. Mortalities decreased after the building housing the sick animals was cleaned. Based on the history, clinical observations, and histopathologic findings, veterinarians believe these animals developed neurologic signs as a result of either increased ammonia level in the water, oxygen depletion in the air, or both.[59]

Musculoskeletal Disease

Musculoskeletal disease can be caused by changes in the incubation temperature or humidity; trauma from fighting, transport, or restraint; and infectious diseases (Figure 6-17). Deformities of the head, limbs, and tails are common malformations influenced by incubation rather than true genetics (Figure 6-18). Fractures and limb amputations can occur as a result of trauma and fighting, with many healing without major complications. Healed traumatic injuries are observed in captive and wild crocodilians. If the trauma is severe enough, nerve damage, muscle damage, paresis, and/or paralysis may result. The most common infectious disease known to have effects on the musculoskeletal system is mycoplasmosis. Both *M. alligatoris* and *M. crocodyli* can cause polyarthritis in affected animals.

Gastrointestinal Disease

Ingestion of foreign bodies, gastric ulcers, enteritis, and trauma to the oral cavity are gastrointestinal diseases associated with crocodilian species. Anorexia is a common sequelae to the gastrointestinal diseases listed above.

Figure 6-17 Fracture of the mandible in a wild-caught American alligator *(Alligator mississippiensis).*

Figure 6-18 Deformity of the maxillae in a captive-reared American alligator *(Alligator mississippiensis).* These deformities are common in captivity and thought to be associated with problems during the incubation period.

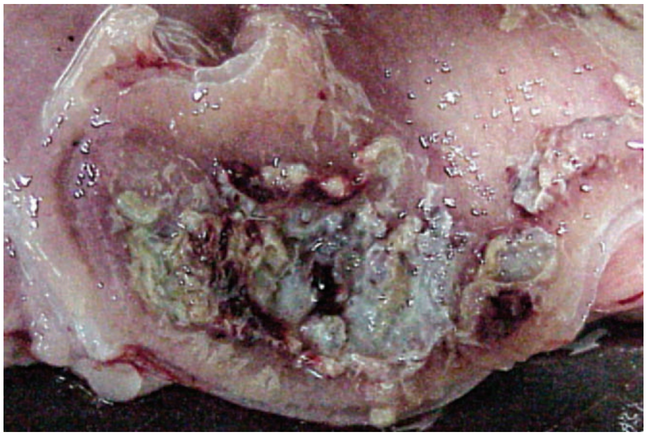

Figure 6-19 Necrosis of the gastric mucosa in an American alligator *(Alligator mississippiensis).*

Ingestion of foreign bodies occurs in both wild and captive crocodilians. Construction, malfunction of water pumps and filters, forgotten objects in the enclosure, and tossed objects by the public are some of the sources of foreign bodies for captive animals. Sharp objects such as nails may cause severe gastrointestinal problems, while other less sharp or pointed ingested material may pass without major difficulties. Infectious enteritis is usually diagnosed post mortem based on gross and histopathologic evaluation. Crocodilians appear to have an aggressive response to insult of the gastrointestinal tract. Grossly one may observe accumulation of fibrinous or fibrous material and/or necrosis of the mucosa (Figure 6-19). In some instances, this can even lead to obstruction due to accumulation of fibrinous/fibrous material. Fecal impactions and torsions are probably rare but can also occur in crocodilians, while gastric ulcerations may be associated with stress and diet. The intestinal tract of crocodilians appears to contain a significant amount of gut associated lymphoid tissue like Peyer's patches. This lymphoid tissue may allow for an aggressive inflammatory response to infectious agents in the intestinal tract.

Integumentary Disease

Integumentary disease is arguably the most significant disease process affecting captive crocodilians. Water quality, temperature, and stressors contribute to the occurrence of integumentary diseases. Secondary bacterial and fungal dermatitis in crocodilians can have a devastating economic impact on commercial operations. Lacerations, abscesses, and draining tracts can serve as a nidus for microorganisms. An additional predisposing factor of integumentary disease in captive operations is the accumulation of fat in the upper water column. This concentration of fat creates a slime layer on the walls and water surface, which is then transferred to the skin of the animals where it creates an ideal environment for fungal and bacterial growth. This is more of a problem when meat is the sole source of food or is provided in addition to a commercial diet. A surfactant disinfectant can be used to break down the fat accumulation in the water and on the walls of the enclosure. In most instances both bacteria and fungi will be present in the skin lesions associated with fat accumulation in the captive environment. It is important to recognize the fat accumulation problem early to institute appropriate cleaning measures and possible therapy. Mixed flora is often found in the dermal lesions, making identification of a single causal agent difficult. Antimicrobial therapy is indicated if bacterial involvement is suspected. Although the use of systemic antifungal medications is cost prohibitive in commercial operations, it can be used if only a small number of animals are affected. Improved hygiene, better water quality, stable temperatures, and decreased stress are essential for managing these dermatitis cases. In most instances those animals that are already showing clinical signs may not recover. The key to preventing and decreasing the spread of disease is improving and implementing appropriate husbandry methods.

Various alligator *(A. mississippiensis)* ranches in Louisiana have reported hatching animals with normal pigmentation that becomes “white” after a few weeks of life (Figure 6-20). Physical examination of these animals does not reveal any abnormalities other than an apparent depigmentation or hypopigmentation of the skin. The white discoloration is not unlike that described as a result of fungal or bacterial dermatitis. Upon palpation, the skin appears thinner and has a flaky nature similar to that observed in leucistic alligators. Affected animals do not appear to grow at different rates than normally pigmented animals. The processing of the hides is not affected by the pigment deficit. A nutritional deficiency or genetics are suspected in this presentation, but there are anecdotal reports of improvement of the condition after vitamin supplementation with a multivitamin formulation.

Miscellaneous Diseases

LYMPHOHISTIOCYTIC PROLIFERATIVE SYNDROME OF ALLIGATORS (“PIX” DISEASE)

Lymphohistiocytic proliferative syndrome of alligators (LPSA), also known as PIX disease, has been recently studied in captive-reared alligators *(A. mississippiensis)* from Florida and Louisiana.[83] LPSA affects the quality of the hides in commercial operations, leading to decreased profits for alligator producers. Gross lesions of LPSA are multifocal, 1- to 2-mm, gray to red foci on the ventral mandibular and abdominal scales (Figure 6-21). They may occasionally be observed on the ventral tail scales. These lesions can be found on any section of a scale and are flush with the scale’s surface; however, they may not be clearly visible in the live animal. Often, the lesions are identified during postmortem examination after close inspection of the hide using an intense backlight (Figures 6-22 and 6-23), appearing as 1- to 2-mm clearings on the scales. The lesions are circular with well-defined margins and can be confused with tooth marks and other imperfections in the skin. Therefore, antemortem identification is not very accurate at this time. Microscopic examination of the skin lesions reveals dermal nodular lymphoid proliferation with perivascular cuffing. The same changes observed in the skin

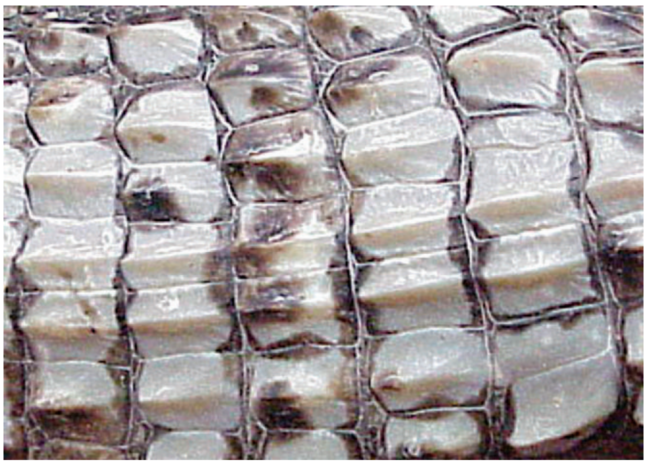

Figure 6-20 Depigmentation/hypopigmentation of the skin of an American alligator *(Alligator mississippiensis).* A nutritional or genetic component is thought to be associated with this presenting symptom.

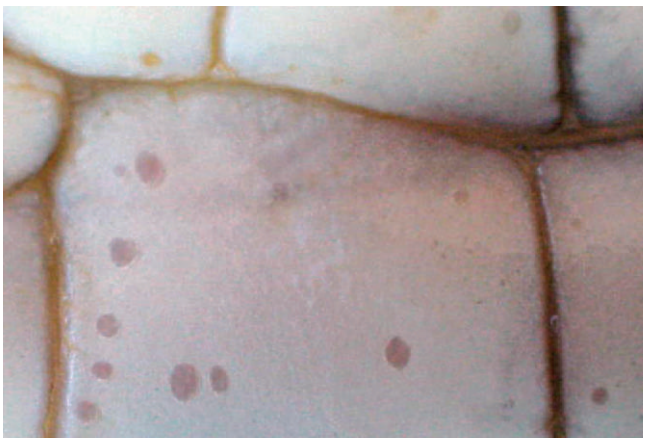

Figure 6-21 Gross lesions of lymphohistiocytic proliferative syndrome of alligators (LPSA) on the scales of an American alligator *(Alligator mississippiensis).*

Figure 6-22 Examination of the hide of an American alligator *(Alligator mississippiensis)* using a light table to identify LPSA lesions.

Figure 6-23 LPSA lesions as observed under a light table. Many of these lesions must be differentiated from tooth marks and other scratches. Histopathologic evaluation is used for confirmation.

have been found in the lungs, intestines, kidneys, ovaries, testicles, thyroid, gall bladder, mesentery, eyes, and nervous tissue.[84] Ongoing research has revealed a strong relationship between exposure to/infection by West Nile virus and the occurrence of PIX lesions.

TOXICITIES

Toxicities are not common in captive crocodilians. However, there have been cases of lead toxicity in alligators being fed nutria that had been killed with lead shotgun pellets.[12] Clinical signs include weakness, lethargy, anorexia, and death. Alligator ranchers and farmers are now more diligent in inquiring about the source and kill method of nutria before feeding their animals. Wild alligators, on the other hand, can be exposed to a number of toxic substances, mostly pesticides and heavy metals. Many of these substances are thought to be endocrine disrupters that affect the development and function of the reproductive organs and result in developmental defects of young crocodilians.[85-89] There is an abundance of information to support the impact of environmental contamination on crocodilians as well as other species. This reiterates the critical state of the natural habitat of many species around the world. Crocodilians have served as sentinels for anthropogenic changes that ultimately may come back to affect human health.

RUNTING

Runting is a phenomenon observed in captive crocodilian operations. It describes a general state of unthriftiness, lack of growth, and weakness. There is a visible size difference in same-age animals between the “runts” and the otherwise normally developing animals. It is not unusual to find some buildings in a commercial operation that contain the runt animals for that year. It is also in this group of animals that disease problems may be observed with higher frequency. Stress factors, including dominance by other animals, environment, and even incubation temperature, contribute to the presence of runts.[90]

THERAPEUTICS

Fluid Therapy

Fluid therapy of crocodilians is accomplished as in other reptile species. Veterinarians must determine hydration status, percentage of fluid deficit, and maintenance requirements to develop a plan for fluid therapy. A maintenance rate of 20 to 30 ml/kg can be administered intracoelomically (ICe), orally (PO), or intravenously (IV). In some instances, food prey items can be injected with fluid and then fed to the animal. If the animal is anorexic, manual restraint will be required for fluid administration. It is important to remember that restraint itself will be an additional stressor that may hinder the recovery of an animal. Therefore, to limit the amount of stress in the animal, treatment protocols including fluid therapy must be planned appropriately and administered quickly.

Antimicrobials

Antimicrobial therapy presents a challenge in crocodilians because of their extra label use. In commercial alligator facilities, antimicrobial treatment is complicated by the lack of drug withdrawal times for crocodilian species. Currently the U.S.

Food and Drug Administration (FDA) and the Animal and Plant Health Inspection Services (APHIS) have no recommendations on this subject. From a public health standpoint there is hope that this may change in the future. Alligator meat can be purchased from supermarkets and restaurants in the United States, primarily in the southern United States. At this time, a recommended addition of 60 to 90 days to the U.S. Department of Agriculture (USDA) food animal withdrawal time, listed for a particular drug should provide enough time for appropriate withdrawal in crocodilians, but there is no research to support this claim. If the animals are not intended for human consumption, antimicrobials can be used extra label as in other exotic species. There are few pharmacokinetic studies of antimicrobials in crocodilians. Helmick et al. examined the pharmacokinetics of both enrofloxacin and a long-acting oxytetracycline in the American alligator *(A. mississippiensis)*.[91,92] Enrofloxacin was found to be effective when administered at 5 mg/kg IV every 36 hours.[91] The long-lasting oxytetracycline was found to be effective at 10 mg/kg both IV and intramuscularly (IM) every 5 days.[92] Both of these treatment regimes may be practical in a zoologic institution or a commercial operation with a small number of animals. In a large commercial operation where a higher number of animals may need treatment, it may be time, cost, and labor prohibitive to administer medications intramuscularly or intravenously to individual animals. Spectrum of coverage, method and frequency of administration, and cost should be considered when selecting an antimicrobial agent(s). Consideration should be given to those drugs that can be mixed with, or injected into, the feed. One technique of antibiotic administration is making a sausage filled with the animal's feed and placing the drug in the sausage. Manual medication by mouth or injection can be performed in smaller animals. Whenever possible, culture and sensitivity test should be obtained to identify the organism in question and determine the efficacy of the antimicrobial selected. Unless a bacterial infection is suspected, use of antibiotics is strongly discouraged. Most antimicrobial agents and their metabolites will be transported in the wastewater, potentially creating an avenue for future antimicrobial resistance.

Nutritional Support

Nutritional support of crocodilians should be approached as in other carnivorous reptiles. The main difficulties result from the handling and restraint required to force-feed an ill crocodilian. Nutritional support of an ill patient is more likely to occur at a zoologic institution than in a commercial operation. Placing an esophagostomy tube should be considered as a less stressful alternative method of feeding the critical crocodilian. Nutritional support through an esophagostomy tube will require restraint while feeding, but the stress level is reduced because the mouth does not have to be opened. Any high-protein feed (e.g., commercial feed, fresh prey) that can be blended may be used as long as it can easily pass through the tube. In larger and aggressive animals, force-feeding is a serious challenge and must be performed carefully.

SURGERY

Preoperative and Postoperative Considerations

Various factors should be considered before performing a surgery procedure on a crocodilian, with the initial consideration being the ultimate purpose of the animal. Is the animal part of a zoologic collection, is it from a commercial operation, or will it be released back to the wild? The next concern is the expected prognosis and time of recovery. Ultimately the animal should be able to thrive in its future environment whether it be an exhibit or in the wild. Cost of the procedure also is a major presurgical consideration. Whereas cost may not be a major decision factor in some zoologic institutions, in other programs such as conservation programs, the money needs to be carefully allocated to obtain the highest return on the investment. The available facilities, especially for postoperative management, are also an important consideration. If the procedure requires placement of sutures, the animal should be maintained in a clean environment with shallow water for a few days to prevent infection and infiltration of water into the surgical site. Depending on the species, it may be possible to spray the animal with water throughout the day instead of keeping it in water. The final consideration is the ability of the personnel to carry out the postoperative care, especially if force-feeding is required.

It would be beneficial to obtain a CBC and chemistry panel to assess the overall health status of the animal before surgery is performed. Diagnostic test results will help determine if the animal is fit for surgery and can be compared to postsurgical blood work to monitor recovery and healing, although in many instances diagnostic evaluation is an unrealistic expectation.

Anesthesia

To anesthetize crocodilian species, a basic understanding of their physiology and anatomy is needed to ensure safe delivery, induction, and maintenance of the anesthetic agent. There are various anesthetic agents, both injectable and inhalant, that can be used to anesthetize and sedate crocodilians. Procedure type, species, and size are factors that will influence the choice of anesthetic agent(s). There are no established anesthetic protocols for crocodilians, and information is often derived from field research as well as clinical experience of practitioners. Injectable anesthetic agents can be delivered in the tail muscles via a pole syringe or hand syringe or administered intravenously after immobilization or restraint.

Neuromuscular blocking agents, such as gallamine and succinylcholine, are widely used in crocodilians. When transporting large, aggressive animals, veterinarians might use these agents to prevent injury to both the handlers and the animal. However, these drugs do not have analgesic properties and should not be used alone for any surgical procedures. When using neuromuscular blocking agents, veterinarians should ensure the animal is supported with a backboard to minimize injury to the spine. Succinylcholine is a depolarizing neuromuscular blocker with primary action at the nerve end plate, and flaccid or rigid paralysis may occur depending on the dose.[5,93] There is no reversal agent for succinylcholine, so it must be used with caution and the animals monitored closely. Effects can be observed within 5 minutes of administration, and recovery takes up to 1.5 hours. Recovery will depend on the excretion of the drug in the urine and metabolism of the crocodilian. Gallamine is a nondepolarizing neuromuscular agent that competitively blocks acetylcholine at the motor end plate, resulting in flaccid paralysis. Crocodilians immobilized with gallamine will open their mouths following relaxation of the muscles; this is known as the *Flaxidil reaction.*[5] Increased respiratory rate and heart rate may be observed with gallamine immobilization.[94,95] An overdose of gallamine may lead to bradycardia, mydriasis, increased gastrointestinal motility, and paralysis of respiratory muscles.[5] Increased salivation and emesis can be prevented with presurgical use of atropine.[95] An advantage of gallamine over succinylcholine is that it can be reversed with neostigmine methylsulfate. Fatalities have been reported in American alligators *(A. mississippiensis),* Chinese alligators *(A. sinensis),* and false gharials *(Tomistoma schlegelii)* that were administered gallamine.[95] Diazepam can also be administered 20 to 30 minutes before succinylcholine or gallamine for added muscle relaxation.[96] Administration and recovery of animals with neuromuscular agents should be done far from the water to avoid drowning. Noise and light stimuli should be minimized when animals have been sedated with gallamine or any other neuromuscular agent or anesthetic. Table 6-5 shows doses for various neuromuscular agents. Following administration of a neuromuscular agent, it may be possible to intubate a crocodilian for general anesthesia with an inhalant anesthetic such as isoflurane. Remember to always provide analgesics if performing a painful procedure.

Injectable anesthestics have the added benefit of providing analgesia and decreasing the amount of inhalant anesthetics used during surgery. Dissociatives, opioids, benzodiazepines, and barbiturates have been administered to reptiles and crocodilians with various rates of success. Alpha-2 adrenergics are gaining popularity in reptile medicine and show promising results for their continued use as anesthetics in reptiles. A combination of medetomidine and ketamine works well in American alligators *(A. mississippiensis)* and has the added benefit of being able to reverse the medetomidine with atipamezole.[97] In a study involving juvenile alligators, the young animals had a higher requirement of medetomidine (220.1 ± 76.9 μg/kg IM), atipamezole (1188.5 ± 328.1 μg/kg IM), and ketamine (10.0 ± 4.9 mg/kg IM), compared to adult alligators' requirement of medetomidine (131.1 ± 19.5 μg/kg IM), atipamezole (694 ± 101 μg/kg IM), and ketamine (7.5 ± 4.2 mg/kg IM).[97] These findings are similar to those observed for other anesthetic agents used in reptiles. Metabolic differences between age classes usually require higher doses for juvenile animals.

An additional anesthetic agent that has gained popularity in reptile medicine is propofol (Abbott Laboratories, 100 Abbott Park Rd., Abbott Park, IL 60064-3500). Propofol is a lipid soluble drug with fast action and short duration of effects, which makes it an ideal anesthetic agent that allows for intubation of the animal to be followed with inhalant anesthesia. Propofol can be administered at 10 to 15 mg/kg IV[5,14] and as a constant rate infusion. The IV route of administration of propofol presents a disadvantage in cases where manual restraint is not possible or is undesired.

When choosing an anesthetic or immobilizing agent, veterinarians should take into account all the factors previously mentioned while keeping the safety of the animal and personnel in mind.

Common Surgical Procedures

Fortunately, surgeries are not routinely performed in crocodilian species. The most common surgical procedure performed in zoologic institutions is probably the removal of foreign bodies through gastroscopy. This may be performed under immobilization or general anesthesia. Enterotomies are rare but may be required if a foreign body lodges itself beyond the

TABLE 6-5 Doses of Intramuscular Administration of Neuromuscular Blocking Agents Used in Crocodilians

Drug	Dose (mg/kg)	Species	Reference
Gallamine	0.4-1.25	*C. niloticus*	14
	0.6-4.0	*C. rhombifer*	94
	0.6-4.0	*C. niloticus*	5
	1.0-2.0	*C. niloticus*	5
Neostigmine	0.03-0.06	*C. niloticus*	5
	0.03-0.25	*C. niloticus*	94
	0.07-0.14	*C. niloticus*	14
Succinylcholine	0.4-1.0	*A. mississippiensis*	5, 14
	0.5-2.0	None specified	14
Succinylcholine/ Diazepam	0.14-0.37/ 0.22-0.62	*A. mississippiensis*	96

stomach, is too large to pass on its own, or both. The next most common procedure is the repair of fractures and lacerations caused by trauma. Crocodilian fracture repair can present a real challenge to the veterinarian because of an animal's large size, demeanor, and need to live in an aquatic environment. Therefore, it is preferred to perform fracture repairs with internal fixation methods, such as intramedullary pins, cerclage wire, and bone plates. Before attempting a surgical procedure, any veterinarian must realistically determine the prognosis for the animal.

REFERENCES

1. 2004 IUCN Red List of Threatened Species™, http://www.iucnredlist.org, January 2005.
2. Huchzermeyer FW: *Crocodiles: Biology, Husbandry and Diseases,* ed 1, Wallingford, UK, 2003, CABI.
3. Soares D: An ancient sensory organ in crocodilians, *Nature* 417:241-242, 2002.
4. Britton A: http://crocodilian.com, January 2005.
5. Fleming GJ: Crocodilian anesthesia, *Vet Clin North Am Exot Anim Pract* 4(1):19-145, 2001.
6. Lane TJ: Crocodilians. In Mader DR, editor: *Reptile Medicine and Surgery,* Philadelphia, 1996, WB Saunders.
7. Elsey R: Stocking rates of ranched American alligators *(Alligator mississippiensis),* (personal communication), 2004.
8. Staton MA, Edwards HM Jr, Brisbin IL Jr et al: Essential fatty acid nutrition of the American alligator *(Alligator mississippiensis), J Nutr* 120(7):674-685, 1990.
9. Coulson RA, Coulson TD, Herbert JD et al: Protein nutrition in the alligator, *Comp Biochem Physiol* 87A(2):449-459, 1987.
10. Coulson RA, Coulson TD, Herbert JD: Alligator feed evaluations, *Proc of the Louisiana Aquaculture Conf,* Baton Rouge, La, pp 48-51, 1992.
11. Burris Alligator Feeds, http://www.burrismill.com/Screens/Alligator.aspx, January 2005.
12. Camus AC, Mitchell MA, Williams JF et al: Elevated lead levels in farmed American alligators *(Alligator mississippiensis)* consuming nutria *(Myocastor coypus)* meat contaminated by lead bullets, *J World Aquaculture Society* 29:370-376, 1998.
13. Wilhite DR, Nevarez JG: Unpublished description of a new site for venipuncture in the American alligator *(Alligator mississippiensis),* 2004.
14. Carpenter JW, Mashima TY, Rupiper DJ: *Exotic Animal Formulary,* ed 2, Philadelphia, 2001, WB Saunders.
15. Rooney AA, Guillette LJJ: Biotic and abiotic factors in crocodilian stress: the challenge of a modern environment. In Grigg GC, Seebacher F, Franklin CE, editors: *Crocodilian Biology and Evolution,* p. 214, ed 1, Chipping Norton, 2001, Surrey Beatty and Sons.
16. Dohms JE, Metz A: Stress-mechanisms of immunosuppression, *Vet Immunol Immunopathol* 30:89-109, 1991.
17. Lance VA, Elsey RM: Plasma catecholamines and plasma corticosterone following restraint stress in juvenile alligators, *J Exp Zoolog* 283(6):559-565, 1999.
18. Morici LA, Elsey RM, Lance VA: Effects of long-term corticosterone implants on growth and immune function in juvenile alligators *(Alligator mississippiensis), J Exp Zoolog* 279(2):156-162, 1997.
19. Lance VA, Elsey RM: Hormonal and metabolic response of juvenile alligators to cold shock, *J Exp Zoolog* 283:566-572, 1999.
20. Elsey RM, Joanen T, McNease L et al: Growth rate and plasma corticosterone levels in juvenile alligators maintained at different stocking densities, *J Exp Zoolog* 255:30-36, 1990.
21. Lance VA, Morici LA, Elsey RM: Physiology and endocrinology of stress in crocodilians. In Grigg GC, Seebacher F, Franklin CE, editors: *Crocodilian Biology and Evolution,* ed 1, Chipping Norton, 2001, Surrey Beatty and Sons.
22. Merchant ME, Roche C, Elsey RM et al: Antibacterial properties of serum from the American alligator *(Alligator mississippiensis), Comp Biochem Physiol B Biochem Mol Biol* 136(3):505-513, 2003.
23. Shaharabany M, Gollop N, Ravin S et al: Naturally occurring antibacterial activities of avian and crocodile tissues, *J Antimicrob Chemother* 44(3):416-418, 1999.
24. Gorden RW, Hazen TC, Esch GW et al: Isolation of *Aeromonas hydrophila* from the American alligator *(Alligator mississippiensis), J Wildl Dis* 15(2):239-243, 1979.
25. Shotts EB, Gaines JL, Martin L et al: *Aeromonas*-induced deaths among fish and reptiles in an eutrophic inland lake, *J Am Vet Med Assoc* 161(6):603-607, 1972.
26. Millichamp NJ, Jacobson ER, Wolf ED: Diseases of the eye and ocular adnexae in reptiles, *J Am Vet Med Assoc* 183(11):1205-1212, 1983.
27. Jacobson ER: Immobilization, blood sampling, necropsy techniques and diseases of crocodilians: a review, *J Zoo Anim Med* 15:38-45, 1984.
28. Flandry F, Lisecki EJ, Domingue GJ et al: Initial antibiotic therapy for alligator bites: characterization of the oral flora of *Alligator mississippiensis, South Med J* 82(2):262-266, 1989.
29. Novak SS, Seigel RA: Gram-negative septicemia in American alligators *(Alligator mississippiensis), J Wildl Dis* 22(4):484-487, 1986.
30. Wallace LJ, White FH, Gore HL: Isolation of *Edwardsiella tarda* from a sea lion and two alligators, *J Am Vet Med Assoc* 149(7):881-883, 1966.
31. Mainster ME, Lynd FT, Cragg PC et al: Treatment of multiple cases of *Pasteurella multocida* and *Staphylococcal pneumonia* in *Alligator mississippiensis* on a herd basis, *Proc Am Assoc Zoo Vets,* pp 33-36, 1972.
32. Brown DR, Nogueira MF, Schoeb TR et al: Pathology of experimental mycoplasmosis in American alligators, *J Wildl Dis* 37(4):671-679, 2001.
33. Jacobson ER, Gardiner CH, Foggin CM: Adenovirus-like infection in two Nile crocodiles, *J Am Vet Med Assoc* 185(11):1421-1422, 1984.
34. Clippinger TL, Bennet RA, Johnson CM et al: Morbidity and mortality associated with a new mycoplasma species from captive American alligators *(Alligator mississippiensis), J Zoo Wildl Med* 31(3):303-314, 2000.
35. Barnett JD, Cardeilhac PT: Clinical values associated with opportunistic bacterial diseases in farm-raised alligators, *IAAAM Proc* 26:22, 1995.
36. Newton J: Brown spot disease in the Louisiana alligator industry: what we know about the disease and possible control protocols, *Proc Louisiana Aquaculture Conf,* Baton Rouge, La, pp 46-47, 1992.
37. Bounds HC, Normand RA: Brown spot disease of commercially-raised alligators: a preliminary report, Louisiana Academy of Sciences 54:62, 1991.
38. Russell WC, Herman KL: Colibacillosis in captive wild animals, *J Zoo Anim Med* 1:17-21, 1970.
39. Brown DR, Farley JM, Zacher LA et al: *Mycoplasma alligatoris sp nov,* from American alligators, *Int J Syst Evol Microbiol* 51:419-424, 2001.
40. Huchzermeyer FW, Henton MM, Riley J et al: Aerobic intestinal flora of wild-caught African dwarf crocodiles *(Osteolaemus tetraspis), Onderstepoort J Vet Res* 67(3):201-204, 2000.
41. Harvey RW, Price TH: *Salmonella* isolation from reptilian faeces: a discussion of appropriate cultural techniques, *J Hyg* 91(1):25-32, 1983.
42. Madsen M, Hangartner P, West K et al: Recovery rates, serotypes, and antimicrobial susceptibility patterns of salmonellae isolated from cloacal swabs of wild Nile crocodiles *(Crocodylus niloticus)* in Zimbabwe, *J Zoo Wildl Med* 29(1):31-34, 1998.
43. van der Walt ML, Huchzermeyer FW, Steyn HC: *Salmonella* isolated from crocodiles and other reptiles during the period 1985-1994 in South Africa, *Onderstepoort J Vet Res* 64(4):277-283, 1997.
44. Huchzermeyer FW, Gerdes GH, Foggin CM et al: Hepatitis in farmed hatchling Nile crocodiles *(Crocodylus niloticus)* due to chlamydial infection, *J S Afr Vet Assoc* 65(1):20-22, 1994.
45. Millan JM, Purdie JL, Melville LF: Public health risks of the flesh of farmed crocodiles, *Rev Sci Tech* 16(2):605-608, 1997.
46. Madsen M: Prevalence and serovar distribution of *Salmonella* in fresh and frozen meat from captive Nile crocodiles *(Crocodylus niloticus), Int J Food Microbiol* 29(1):111-118, 1996.
47. Madsen M: Microbial flora of frozen tail meat from captive Nile crocodiles *(Crocodylus niloticus), Int J Food Microbiol* 18(1):71-76, 1993.
48. Manolis SC, Webb GJ, Pinch D et al: Salmonella in captive crocodiles (*Crocodylus johnstoni* and *C porosus*), *Aust Vet J* 68(3):102-105, 1991.
49. Rickard MW, Thomas AD, Bradley S et al: Microbiological evaluation of dressing procedures for crocodile carcasses in Queensland, *Aust Vet J* 72(5):172-176, 1995.
50. Buenviaje GN, Hirst RG, Ladds PW et al: Isolation of *Dermatophilus sp* from skin lesions in farmed saltwater crocodiles *(Crocodylus porosus), Aust Vet J* 75(5):365-367, 1997.
51. Buenviaje GN, Ladds PW, Martin Y: Pathology of skin diseases in crocodiles. *Aust Vet J* 76(5):357-363, 1998.
52. Barnett JD, Cardeilhac PT: Brown spot disease in the American alligator *(Alligator mississippiensis), IAAAM Proc* 29:124-125, 1998.

53. Pye GW, Brown DR, Nogueira MF et al: Experimental Inoculation of broad-nosed caimans *(Caiman latirostris)* and Siamese crocodiles *(Crocodylus siamensis)* with *Mycoplasma alligatoris, J Zoo Wildl Med* 32(2):196-201, 2001.
54. Helmick KE, Brown DR, Jacobson ER et al: In vitro susceptibility pattern of *Mycoplasma alligatoris* from symptomatic American alligators *(Alligator mississippiensis), J Zoo Wildl Med* 33(2):108-111, 2002.
55. Mohan K, Foggin CM, Muvavarirwa P et al: Mycoplasma-associated polyarthritis in farmed crocodiles *(Crocodylus niloticus)* in Zimbabwe, *Onderstepoort J Vet Res* 62(1):45-49, 1995.
56. Mohan K, Foggin CM, Muvavarirwa P et al: Vaccination of farmed crocodiles *(Crocodylus niloticus)* against *Mycoplasma crocodyli* infection, *Vet Rec* 141(18):476, 1997.
57. Mohan K, Foggin CM, Dziva F et al: Vaccination to control an outbreak of *Mycoplasma crocodyli* infection, *Onderstepoort J Vet Res* 68(2):149-150, 2001.
58. Youngprapakorn P, Ousavaplangchai L, Kanchanapangka S: *A Color Atlas of Diseases of the Crocodile,* ed 1, Thailand, 1995, Style Creative House.
59. Nevarez JG: Unpublished data from clinical and research cases, LA, 2002-2003.
60. McCowan C, Shepherdley C, Slocombe RF: Herpes virus-like particles in the skin of a saltwater crocodile *(Crocodylus porosus), Aust Vet J* 82(6):375-377, 2004.
61. Johnson A: (Personal communication), March 2005.
62. Jacobson ER, Popp JA, Shields RP et al: Poxlike skin lesions in captive caimans, *J Am Vet Med Assoc* 175(9):937-940, 1979.
63. Penrith ML, Nesbit JW, Huchzermeyer FW: Pox virus infection in captive juvenile caimans *(Caiman crocodilus fuscus)* in South Africa, *J S Afr Vet Assoc* 62(3):137-139, 1991.
64. Ramos MC, Coutinho SD, Matushima ER et al: Poxvirus dermatitis outbreak in farmed Brazilian caimans *(Caiman crocodilus yacare), Aust Vet J* 80(6):371-372, 2002.
65. Horner RF: Poxvirus in farmed Nile crocodiles, *Vet Rec* 122(19):459-462, 1990.
66. Pandey GS, Inoue N, Ohshima K et al: Poxvirus infection in Nile crocodiles *(Crocodylus niloticus), Res Vet Sci* 49(2):171-176, 1990.
67. Buenviaje GN, Ladds PW, Melville L: Poxvirus infection in two crocodile, *Aust Vet J* 69(1):15-16, 1992.
68. Miller DL, Mauel MJ, Baldwin C et al: West Nile virus in farmed alligators, *Emerg Infect Dis* 9(7):794-799, 2003.
69. Steinman A, Banet-Noach C, Tal S et al: West Nile virus infection in crocodiles, *Emerg Infect Dis* 9(7):887-889, 2003.
70. Rubio A: (Personal communication), Mexico, 2003.
71. Klenk K, Snow J, Morgan K et al: Alligators as West Nile virus amplifiers. *Emerg Infect Dis* 10(12):2150-2154, 2004.
72. Nevarez JG, Mitchell MA, Kim DY et al: West Nile Virus in Alligator *(Alligator mississippiensis)* ranches from Louisiana, *J Herpetol Med and Surg* 15(3):4-9, 2005.
73. Nevarez JG: Unpublished data on fungal isolates from the skin of American alligators *(Alligator mississippiensis),* 2003.
74. Buenviaje GN, Ladds PW, Melville L et al: Disease-husbandry associations in farmed crocodiles in Queensland and the Northern Territory, *Aus Vet J* 71(6):165-173, 1994.
75. Fromtling RA, Jensen JM, Robinson BE et al: Fatal mycotic pulmonary disease of captive American alligators, *Vet Pathol* 16:428-431, 1979.
76. Trevino GS: Cephalosporiosis in three caimans, *J Wildl Dis* 8:385-388, 1972.
77. Frelier PF, Sigler L, Nelson PE: Mycotic pneumonia caused by *Fusarium moniliforme* in an alligator, *Sabouraudia* 23(6):399-402, 1985.
78. Silberman MS, Blue J, Mahaffey E: Phycomycoses resulting in death of crocodiles in a common pool, *Proc AAZV,* pp 100-101, 1977.
79. Thomas AD, Sigler L, Peucker S et al: *Chrysosporium* anamorph of *Nannizziopsis vriesii* associated with fatal cutaneous mycoses in the salt-water crocodile *(Crocodylus porosus), Med Mycol* 40(2):143-151, 2002.
80. Maslen M, Whitehead J, Forsyth WM et al: Systemic mycotic disease of captive crocodile hatchling *(Crocodylus porosus)* caused by *Paecilomyces lilacinus, J Med Vet Mycol* 26(4):219-225, 1988.
81. Ariel E, Ladds PW, Buenviaje GN: Concurrent gout and suspected hypovitaminosis A in crocodile hatchlings, *Aust Vet J* 75(4):247-249, 1997.
82. Wallach JD, Hoessle C, Bennett J: Hypoglycemic shock in captive alligators, *J Am Vet Med Assoc* 51(7):893-896, 1967.
83. Nevarez JG, Mitchell MA, Kim DY et al: Lymphohistiocytic proliferative syndrome of captive-reared American alligators *(Alligator mississippiensis)* from Louisiana, *Proc of the Assoc of Reptil and Amphib Vets,* pp 73-75, 2003.
84. Nevarez JG: Unpublished data on lymphohistiocytic proliferative syndrome of alligators (LPSA), 2004.
85. Vonier PM, Crain DA, McLachlan JA et al: Interaction of environmental chemicals with the estrogen and progesterone receptors from the oviduct of the American alligator, *Environ Health Perspect* (12):1318-1322, 1996.
86. Lind PM, Milnes MR, Lundberg R et al: Abnormal bone composition in female juvenile American alligators from a pesticide-polluted lake (Lake Apopka, Fla), *Environ Health Perspect* 112(3):359-362, 2004.
87. Stoker C, Rey F, Rodriguez H et al: Sex reversal effects on *Caiman latirostris* exposed to environmentally relevant doses of the xenoestrogen bisphenol A, *Gen Comp Endocrinol* 133(3):287-296, 2003.
88. Guillette LJ Jr, Vonier PM, McLachlan JA: Affinity of the alligator estrogen receptor for serum pesticide contaminants, *Toxicology* 181-182: 151-154, 2002.
89. Rauschenberger RH, Wiebe JJ, Buckland JE et al: Achieving environmentally relevant organochlorine pesticide concentrations in eggs through maternal exposure in *Alligator mississippiensis, Mar Environ Res* 58(2-5): 851-856, 2004.
90. Allsteadt J, Lang JW: Incubation temperature affects body size and energy reserves of hatchling American alligators *(Alligator mississippiensis), Physiol Zool* 68(1):76-97, 1995.
91. Helmick KE, Papich MG, Vliet KA et al: Pharmacokinetics of enrofloxacin after single-dose oral and intravenous administration in the American alligator *(Alligator mississippiensis), J Zoo Wildl Med* 35(3):333-340, 2004.
92. Helmick KE, Papich MG, Vliet KA et al: Pharmacokinetic disposition of a long-acting oxytetracycline formulation after single-dose intravenous and intramuscular administrations in the American alligator *(Alligator mississippiensis), J Zoo Wildl Med* 35(3):341-346, 2004.
93. Mitchell MA: Physical and chemical restraint of crocodilians, British Veterinary Zoological Society Autumn Meeting, Regents Park, London, 1999.
94. Lloyd ML, Reichard T, Odum RA: Gallamine reversal in Cuban crocodiles *(Crocodylus rhombifer)* using neostigmine alone versus neostigmine with hyaluronidase, *Proc AAZV,* pp 117-120, 1994.
95. Lloyd ML: Crocodilian anesthesia. In Fowler ME, Miller RE, editors: *Zoo and Wildlife Animal Medicine,* Philadelphia, 1999, WB Saunders.
96. Spiegel RA, Lane TJ, Larsen RE et al: Diazepam and succinylcholine chloride for restraint of the American alligator, *J Am Vet Med Assoc* 185(11):1335-1336, 1984.
97. Heaton-Jones TG, Ko JC-H, Heaton-Jones DL: Evaluation of medetomidine-ketamine anesthesia with atipamezole reversal in American alligators *(Alligator mississippiensis), J Zoo Wildl Med* 33(1):36-44, 2002.