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Review Article

Nontraditional Laboratory Animal Species (Cephalopods, Fish, Amphibians, Reptiles, and Birds)

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Abstract

Aquatic vertebrates and cephalopods, amphibians, reptiles, and birds offer unique safety and occupational health challenges for laboratory animal personnel. This paper discusses environmental, handling, and zoonotic concerns associated with these species.

Key words: amphibians; birds; cephalopods; environmental hazards; fish; handling; reptiles; zoonoses

Introduction

Contemporary research facilities commonly include nontraditional laboratory animal species such as birds, reptiles, amphibians, fish, and cephalopods. While application of general safety principles and practices are sufficient in some areas, housing and caring for these animals can pose rather unique challenges. The following sections provide some specific items to consider when developing comprehensive occupational health and safety programs involving nontraditional species.

Environmental Hazards Associated with Housing Nontraditional Species

Wet Environment

Many of the nontraditional laboratory animal species are housed in environments that are high in moisture; these aquatic facilities are associated with potential hazards such as slips, dermatitis, electric shock, and increased exposure to sharp surfaces due to glass enclosures and wet surfaces.

Personal protective equipment (PPE) should include wearing of closed-toe shoes with nonskid soles to prevent slips and falls. Floors in facilities should be pitched to promote drainage and avoid accumulation of stagnant water along with the formation of puddles. Effort should be made to avoid salt and algae build-up on floors, as deposits are slippery.[1,2]

While wearing gloves is imperative in most laboratory settings, they can also trap water against the skin, exacerbating contact. Prolonged and/or frequent water immersion may macerate skin and cause xerosis from the desiccant effects of water. Irritant contact dermatitis from washing gravel and exposure to sea salt crusts has been reported in the marine aquarium industry.[3] Goggles or eye protection should be worn to avoid splash from water when netting fish or amphibians and when handling and cleaning soiled tanks.

Electrical systems in aquatic facilities present a serious occupational hazard. Electric hazards can cause burns, shocks, and electrocutions. Systems should be professionally installed for operation in wet environments. Equipment should be checked periodically to ensure it is in good condition and free of defects. Frayed or damaged cords must not be used. All circuits in damp locations must have ground fault interrupters,[4,5] nonmetallic conduits should be used, and lighting fixtures should be watertight. Operational procedures such as the use of lockout or tag out procedures should be implemented to control energy sources during repair and maintenance.[6]

A common occupational hazard noted in aquatic facilities is the extensive use of extension cords. All electric cords and wires should be fixed away from water and personnel traffic to prevent falls and electrocution. Electrical equipment should be placed away from splash zones and not under water pipes or tanks. Extra care must be taken if seawater is used (either natural or synthetic) due to the extreme corrosiveness and high electrical conductivity of salt water.[1]

Sharps

Tanks made of polycarbonate are used for high-density housing of zebrafish; however, many smaller populations of fish, amphibians, and reptiles are often housed in glass tanks. While the transparency of glass permits easy observations, daily handling of the tanks can lead to contact with sharp surfaces from broken glass or glass without rounded corners. Dried salt crusts that form along the edges of aquariums and lids from splash and evaporation of salt water cause an abrasive surface. When working in research facilities, regardless of species, care must always be taken when handling needles and scalpels.

Light

Artificial lighting commonly used in aquariums generates ultraviolet light (both UV-A and UV-B). If the light is suspended above the aquaria it should be shielded. Unshielded lights can lead to the development of acute erythema and be a long-term potential for photocarcinogenesis and other UV-induced skin changes in personnel.[3] Ultraviolet sterilizers are the most frequently used method to disinfect water in zebrafish housing systems.[7] Sterilizers must be encased in a protective shield during operation to protect personnel from UV exposure that can damage their eyes and skin.

Chemicals

Disinfectant footbaths are commonly used in aquatic facilities.[8,9] Appropriate PPE should be worn during the preparation of the footbaths as the disinfectant may cause acute inhalation toxicity, skin corrosion, and eye damage during preparation.[10]

Water chemistry test kits are frequently used in aquatic facilities to test ammonia and nitrate levels in water tanks. Sodium hydroxide and sodium hypochlorite may be present in ammonia testing kits; these substances can cause chemical burns and irritation, while nitrate test kits may contain hydrazine, a contact sensitizer.[3,11]

One of the most widely used anesthetic agents in aquatic species is tricaine methane sulfonate. In its powdered form, it can easily be airborne.[12] The compound has been reported to be retinotoxic as well as a mucous membrane irritator.[13,14] The powder should be used only in a well-ventilated area such as outdoors or in a fume hood.

Large Enclosures

Research may necessitate the use of large enclosures to either mimic industry production, such as aquaculture, or to promote species-specific behavior such as flight for songbirds or shoaling and schooling behavior for fish. While these enclosures offer a clear benefit to meet both research and/or animal welfare needs, they present distinct physical hazards.

Approximately 1% of occupational fatalities in the United States result from working with animals, with the majority (67%) related to large animal work.[15] Aquaculture fatalities include drowning, electrocutions, crushing-related injuries, and fatal head injuries. Nonfatal injuries are associated with slips, falls from heights, falls overboard, strains, sprains, and chemicals.[2] Flight cages and tanks for large aquatic species present hazards associated with the potential for falls from high ladders and scaffolding.

Allergens

Allergy to laboratory animals is a well-published occupational hazard; the reported incident rate varies between 10% and 56% of exposed individuals.[16–19] While most of the clinical symptoms reported are from personnel handling rabbit and rodent cages, approximately 10% of individuals exhibit animal-induced asthma to dander, scales, fur, saliva, and body waste.[17,18]

Birds

Bird allergens are an important cause of occupational allergic disease. Reports of Farmer's Lung, Pigeon Breeder's Lung, and Breeder's Lung describe severe respiratory symptoms associated with inhaled antigens and date back to the mid-twentieth century.[20] Allergic symptoms have been described in individuals with exposure to parrots, pheasants, canaries, geese, and owls.[21] The principal causative agents are avian proteins from serum and feathers.[22,23] The incidence rate was reported to be 8% among pigeon breeders and zookeepers with exposure to birds.[24,25] In the zoo study, clinical symptoms included rhinitis, asthma, conjunctivitis, and some dermatitis; exposure to canary serum and/or feathers was found to be most allergenic, followed by parrots and then pigeons.

Hypersensitivity pneumonitis, also known as the Bird's Fancier Lungs, mimics pneumonia and usually occurs several hours after exposure. Occupational hypersensitivity pneumonitis can be acute for those with intermittent high level of exposure to antigens such as when cleaning pens. Chronic disease can occur with daily low level of exposure, such as with bird breeders, and can lead to fibrosis and emphysema.[22]

As with all allergens, exposure must be minimized. Staff should be provided with appropriate respiratory PPE during periods of exposure to high levels of antigens such as when cleaning out pens or when birds molt and shed feathers. For those with clinical symptoms, it is important to be aware that avian antigens can persist in the environment. Despite extensive environmental controls, high levels of antigens can be still detected after 18 months.[22]

Fish

Fish allergies are most often associated with ingestion; however, occupational allergies have been documented in fishermen and seafood-processing workers. The first report involved a fisherman who handled codfish.[26] The processing of seafood has been associated with respiratory allergic symptoms due to aerosolization of fish antigens.[27] Occupational prevalence rates are estimated to be between 7% and 8% for asthma and between 3% and 11% for contact dermatitis.[28–32] As these occupational allergies involve both contact dermatitis and inhalation of antigens, their consideration in laboratory settings should not be dismissed. In research settings, the processing of fish tissue, particularly at the end of large studies, may lead to the aerosolization of fish antigens.

Reptiles

As the prevalence of reptiles as pets has increased over the last several years, so has the documentation of allergic reactions from exposures. While few research facilities house reptiles, exposure of personnel during field studies may be an occupational hazard consideration.

The first report of an allergic reaction to snake venom was published in 1930. The case involved an individual with a history of a bite from a copperhead and subsequently, he was injected with experimental intradermal injections of a variety of venoms including *Crotalus*. He then developed allergic symptoms when handling dried venom, confirmed through a positive skin test to *Crotalus* venom.[33] Respiratory allergic reactions occurred in a snake handler, with no history of bites, when exposed to rinkhals (*Hemachatus haemachatus*) venom. It was suspected that the sensitivity developed from inhalation or contact with venom present on the snake's skin and mucus membranes.[34] Other reports involve anaphylactic shock secondary to snake bites from a rattlesnake (species not identified) and a king cobra (*Ophiophagus hannah*).[35,36]

A few reports have been documented on allergies to iguanas. One patient complained that respiratory symptoms were accentuated when handling his pet iguana; IgE antibody to protein from scale extracts from both his iguana and a local zoo's iguanas were identified.[37] Other allergic respiratory symptoms have been reported from exposure to iguanas.[38] Symptoms are reported to be more intense when exposed to male iguanas, who have larger femoral pores/glands. The pores' secretions are primarily made of proteins and used to mark their territories. It was presumed that some material shed by lizards become airborne and caused sensitization.[39] Additional reports involved reactions to bites; one involved a dermal hypersensitivity consistent with the pattern seen in arthropod-bite reaction,[40] and a second was an anaphylactic reaction to a Gila monster bite.[41]

Amphibians

There are limited reports of allergy to amphibians in the literature. As with fish, the majority involves food allergies. The earliest publication concerning research animals involved a laboratory technician who experienced asthmatic attacks when handling frogs (*Rana esculenta*).[42] Another report involved asthmatic symptoms and contact dermatitis in a laboratory technician from handling bullfrogs (*Lithobates catesbeianus*) and extracting brain tissue. Years later, that same individual accidentally injected herself with extracts from frog brain tissue, and she developed swelling in her right hand, stridor, and dyspnea; IgE antibody to frog extracts were identified.[43] A third patient developed allergic symptoms two years after he began handling frogs. Specific IgE antibody to frog venom was demonstrated, and his symptoms remitted after he changed occupation.[44]

Feed (crickets, mealworms)

Cricket (Gryllidae) and mealworm beetle (*Tenebrio molitor*) colonies are often maintained in animal facilities to produce feed for frogs, reptiles, and birds; they can also be used as a source of environmental enrichment for nonhuman primates. These animals are not usually considered as part of an occupational hazard program; however, they can be a cause of occupational allergy based on the following reports.

A research facility produced two hundred thousand crickets (*Acheta domesticus*) per week as a feed source for amphibians. Allergy symptoms of ocular pruritis, rhinitis, and bronchial asthma were reported in two animal care personnel. Specific IgE antibodies to cricket extract were isolated. Three of the eleven other workers in the facility also had a positive skin prick test to the cricket extract.[45] Another occupational exposure also described respiratory symptoms. The employee had direct contact with three different species of crickets (*Gryllus campestris*, *G. bimaculatus*, and *A. domesticus*), and specific IgE for each species of crickets was identified.[46] A third report included contact urticaria in addition to respiratory symptoms in an employee where crickets were bred.[47] A subacute hypersensitivity pneumonitis was also reported in a man who previously owned an avian pet shop.[48]

Finally, sensitivity to mealworm beetles (*Tenebrio molitor*) was reported in workers at a specialty insect breeding facility and among personnel in an entomology laboratory.[49,50]

Hazards Associated with Handling Nontraditional Species

Trauma

Knowledge and practice in proper restraint techniques along with well-designed holding facilities that facilitate safe access to the animals are the mainstays of avoiding animal-inflicted trauma. Relevant literature is available about restraint and immobilization approaches.[51–53] Well-developed restraint techniques take advantage of knowing which defensive/offensive attributes of the animal are most likely to inflict injury and working the animal in ways that neutralize those threats. In many species bites or damage from hard bills or beaks are the most probable cause of trauma, making restraint of or avoidance of the head a primary objective. However, in many species other appendages, either armed with claws, talons, venomous spines, or simply just massive and powerful, can be even more dangerous than the head.

Bites, particularly from larger species, can be dangerous. Clearly this is well recognized for the crocodilians and their many-toothed jaws. It is relatively uncommon to find these species in research facilities, but they do occur. Similarly, snapping turtles and sea turtles can inflict very painful and debilitating bites if not handled properly, taking care to keep hands away from their mouths and respecting their considerable rapid reach with their long flexible neck. Their jaw closing pressures are less than those of a human using molars when scaled for head size, but their mouth anatomy and tendency to bite and hold make their bites a formidable risk to avoid.[54,55]

Considerable literature is written about the risks of various nonvenomous snake and lizard bites, though concerns are generally related to avoiding damage to the teeth of the animal and preventing sepsis from the bite would. It is incumbent on facility managers to recognize the potential hazards and to solicit input from experts experienced working with these species to help develop safe husbandry and handling SOPs. The recognition of potential for harm from smaller creatures with less obviously powerful oral armament is equally important. Lizards and larger amphibians can inflict sometimes painful bites on unwary husbandry or restraint personnel. Much of the challenge with these situations is avoiding being mistaken for food. Washing hands and avoiding hand movements that mimic prey are key preventative measures that can help in this regard.

Overall, with few exceptions such as large amphiumas, amphibian bites are generally considered inconsequential. The lack of dentition on the lower jaw, relatively small weakly affixed teeth, and lack of jaw manipulation after the bite for most species means bites usually barely break the skin if that. There is more concern for injuring the mouth of these species than the risk of damage to the bitten human. This is true even for the large African bullfrogs (*Pixicephalus spp*) that are occasionally found in research settings. Their bite can be quite painful because of their powerful jaw and grip. The key is avoid pulling the hand away. To break the grip of an African Bullfrog, it is suggested that the frog be held under cold running water until it voluntarily releases its grip.

There is one important exception among the amphibians with regard to bites. Members of the genus *Ceratophrys*, sometimes referred to as the Pac Man Frogs, have a combination of unusually short, relatively highly ossified jaws with an ossified mandibular symphysis.[56] Those jaws provide greater leverage than most amphibian jaws. This, combined with a very unusual recurving tooth structure where teeth are also strongly attached to the jaws, allows the horned frogs to inflict serious bites on unsuspecting handlers.[57,58] Recent research has shown that one of these species, *Ceratophrys cranwelli*, has a bite force similar to those of mammalian predators and approaching that of crocodilians when scaled for head width.[57] This work has led to speculation that ancient giant amphibians (*Beelzebufo spp*) may have preyed upon dinosaurs.

There is a wide array of bite risk across the broad range of bony fishes, elasmobranchs, and invertebrates. Most individuals are aware that the incredibly sharp edges of the modified placoid scales that serve as teeth for many sharks can inflict major trauma in a very short encounter. Less well known perhaps are the painful bites that may be inflicted by beaks of large cephalopods. For the most part the larger species will not be found in research facilities, but the bite of the giant Pacific octopus (*Octopus doefleini*) can cause significant tissue damage and is painful.[59] Bites of smaller species of octopus may be complicated by secondary bacterial infections and development of nonhealing granulomatous wounds.[60]

The beaks of many birds are capable of inflicting pain and damage to unwary people. The bite force and beak strength of many parrots can inflict severe wounds, and physical head restraint is a key to safe handling. Secondary infections including those caused by introduction of rickettsial and mycobacterial organisms should be considered in the management of parrot bites.[61] Many raptors can inflict serious wounds with their beaks, particularly the scavenging birds that are adapted to working large carcasses and crushing bones with their beaks. Again, management of secondary infections should be a component of the trauma management.

Trauma from other than bite wounds can and does occur across the spectrum of species considered in this large taxonomic group. Long-billed birds, including herons, egrets, cranes, etc., will stab out quickly with their bill, aiming for eyes. Head control is critical when handling these species and some institutions require wearing eye protection. This can be a good thing so long as it does not confer a false sense of security to the bird handlers. Talons of the feet are the most damaging weapon of many of the raptors. In handling these species, it is critical to contain foot movement even prioritized over complete control of the head. The tail of crocodilians is a particularly challenging weapon used to suddenly knock prey or a predator to the ground where the head and mouth can be better brought into play. For larger specimens it is critical that the tail be managed simultaneously with efforts to restrain the head. Larger lizards can similarly inflict damage, including lacerations with their tails. The tails of iguanas, varanid lizards, and other large lizards should be restrained during handling. Large constrictor snakes will use their bodies to wrap and crush prey. Care should be taken to avoid allowing even relatively small constrictors to be in a position to wrap the neck. For larger snakes, multiple handlers will be necessary to avoid the risk of the handler holding the head being wrapped and suffocated by the snake.

Aquatic species come equipped with a variety of spines that may be venomous in addition to well designed for inflicting trauma. Stingrays and other batoids are equipped with rather apparent spines on the dorsum near the base of their tails. If their presence is not required for the research it is common for the spines to be routinely removed to reduce the risk of trauma/envenomation. Smaller fish have a variety of spines, often associated with dorsal or pectoral fins. The channel catfish is a good example. The spines can cause a painful wound. Assumption of spines existing until proven otherwise is a very good policy when handling fish species that have not been maintained previously in a facility.

Similarly, some extant species of *Coleoids* (octopus, squid, cuttlefish) have hooks or hooked suckers that can come as a rude surprise to handlers unaware of the extra armament. Species of octopus and squid more often maintained in research facilities tend to not have hooks, but hooks are found in many members of the *Onychoteuthidae*, *Enoploteuthidae*, *Octopoteuthidae*, *Gonatidae*, and *Cranchiidae*, and when a new species is proposed for management it will be useful to establish whether or not it has hooks or hooked suckers.

Electric Shock (Electric Fish)

Electric shock is a hazard peculiar to fishes. Though many people become very concerned when they learn they may be dealing with an electric fish, actually the vast majority of the 348 known species of electric fishes generate very small fields with their dedicated electric organ, usually 1 volt or less. These fields are not used for immobilizing prey or defense but rather for navigating and exploring their environment, exploring objects, or even communication. Most fishes capable of generating an electric field of this nature also have the ability to sense electric fields.[62] Species of weakly electric fish found commonly in research settings would include several different species of freshwater knife fish from genera in several families and freshwater elephant fish or mormyrids from various genera in the family *Mormyridae*. They pose no electrical hazard to personnel.

Fishes that generate dangerous electrical fields are also found in research settings. These include the well-known freshwater electric eel (*Electriphorus electricus*), electric catfishes, and the marine electric rays. The freshwater species generate high-voltage, low-amperage discharges to overcome the high impedance of freshwater and have been well studied.[63] Electric eels have been documented to generate up to 600-volt discharges[64] but also generate low-voltage signals used similarly to those of the weak signal generators. The electrogenic marine rays (*Torpedo spp.*) and a group of marine perciform fish known as stargazers produce low-voltage but high-amperage discharges well designed for propagation in their highly conductive environment. Torpedo rays if completely rested have been reported to produce charges as high as 220 volts,[65] but many researchers question this measurement and field measurements are more in the rage of 45 to 60 volts.[66,67] Though these stronger electrical discharges are unlikely to kill a healthy human that has no underlying medical problems, they could easily incapacitate a person sufficiently to cause them to fall or long enough for them to drown.[64,68,69] Caution in handling and working around these species is well advised. Generation of high voltage or current rapidly depletes adenosine triphosphate (ATP) levels in the generating organs of these animals over time. Some individuals advocate stimulating the animal prior to handling to reduce their ability to discharge during manipulation.[69] However, this technique should not be relied upon, and electrical insulating gloves should be used by staff when handling the animal.

Toxins and Venoms

The toxicology of venomous snakes and the relatively few venomous lizards is a well-studied field, and considerable information on the safety procedures appropriate to managing them in captive situations is available.[51,70] It is beyond the scope of this brief review to go into detail. The keys to safe management of venomous snakes in captivity include (1) cage security with cages always locked, (2) handling and husbandry by personnel trained in all SOPs in tandem, (3) emergency security communications and alarms, (4) practiced routine, escape, and bite SOPs that include rapid access to trained health care professionals and a rigorously maintained availability of appropriate antivenin.

Other reptiles and birds generally do not pose toxin or venom risks. However, several amphibians and fishes produce toxic skin secretions of various forms that can be problematic or even lethal for humans not aware of them. Similarly, many invertebrate species produce potent venoms and toxins. Many of these species can be found useful in research and may be maintained in research facilities.

The poison dart frogs of the genus *Dendrobates* are colorful neotropical frogs that produce neuromuscular blocking compounds that have been exploited by natives for creating rapidly acting darts for immobilization of small prey. These curare-like substances are actually generated by the frogs through metabolizing precursors ingested in their native diet, primarily specific species of ants. This explains why captive-bred animals may be relatively if not completely devoid of the toxins. Wild dendrobatid frogs retain metabolites and can produce the skin toxins for years in captivity. Also, these animals are very sensitive to absorbing toxins such as nicotine or disinfectants that might be on the hands of a human. Because of this and the difficulty of being certain of the origin of the animal or how long they have been in captivity, these animals are best not handled directly. Instead, it is best to “handle” these species with clear containers that allow close observation, imaging, and such diagnostic activities as well as facilitate transfer between habitats etc.

In contrast to the dendrobatid frogs, the cardioactive steroids referred to as bufdienolides are synthesized by toads such as the cane toad (*Rhinella marina*, formerly *Bufo marinus*) without dependence on specific precursors from dietary items. The toad bufdienolides are derived from cholesterol and have similar activity to plant cardenolides, being inhibitors of membrane-bound Na+/K+ ATPase.[71] They are referred to as cardiac glycosides though, unlike plant bufdienolides, those from toads do not conjugate with a carbohydrate.[72] The bufdienolides are secreted by skin glands and particularly the parotoid glands of many toads. There is a strong ontogenic relationship to toxicity in amphibians excreting bufdienolides, both in relation to the amount and number of toxin species in tissues. The eggs of cane toads contain at least 28 varieties of bufdienolides in larger quantities than the two to eight compounds found in larvae, with the quantity decreasing throughout development. Juvenile toads generally secrete at most five bufdienolide toxins.[73] Therefore, the greatest care should be placed on avoiding skin contact with eggs and early toad larvae. However, adult toads continue to secrete a limited number of but clinically impactful cardioactive bufdienolides in their parotoid and skin secretions throughout their lives. Handling with disposable gloves is a necessary precaution in laboratory settings.

Recently, two species of South American frogs, Greening’s frog (*Corythomantis greening*) and Bruno’s casque-headed frog (*Aparasphenodon brunoi*), have been reported as venomous frogs.[74] This is a bit of a stretch because their relatively unique adaptation is the presence of bony spikes on their heads, which they use to abrade the skin of predators to open access for their quite toxic mucous skin secretions. Those secretions are indeed quite toxic, but the claim as venomous stretches the delineation between toxins and venoms.

Most if not all salamanders secrete toxins from skin glands. Several species of salamander produce some very potent toxins, including tetrodotoxin. Tetrodotoxin, also referred to as tarichatoxin, is an amino perhydroquinazoline derivative that is among the most toxic nonprotein substances known.[75] Ironically, this toxin is also found in species of marine pufferfish, suggesting some very interesting convergent evolution. Tetrodotoxin is only found in the true newts in the family Salamandridae. Concentrations are highest in newt species found in western North America followed by newts of eastern North America, Asia, and lowest in European newts. It is in highest concentrations in skin, ovaries, and ova of females and skin and blood of male newts. Weak alkalinity destroys tetrodotoxin. Interestingly, tetrodotoxin content of tissues increases over time in captivity (1 year) in females, suggesting exogenous factors are not involved in the toxin synthesis.[76]

Toxins and venoms of marine animals are well covered in some admittedly hard-to-find reference books that span thousands of pages.[77,78] The complexity of the topic is compounded by the vast diversity of marine vertebrates and invertebrates. The interest in marine toxins for basic and applied investigation means many species may be maintained in laboratory animal facilities, including species whose toxicology is not well characterized. Some species of interest are reasonably well known, including venomous fishes such as the stone fishes and lion fishes, the infamously toxic cone shells, and the blue ringed octopus. The best approach to any marine species being held for research is to investigate the literature for any indication of associated toxins and then, if finding none, assume that it may not yet be reported.

Zoonoses Associated with Nontraditional Species

Bacterial Zoonoses

Bacterial pathogens are the most commonly described zoonotic agents associated with nontraditional research species. *Chlamydia* (*Chlamydiophila*) *psittaci* is a bacterium most commonly found in birds; however, horses, pigs, and dogs have been identified as occasional hosts.[79] In 2014, several cases of human psittacosis in a veterinary school in Australia were linked to exposure to equine fetal tissues.[80,81] It was concluded that the horse was most likely infected by wild birds.[80] Avian species most commonly infected with *Chlamydia psittaci* are parrots, cockatiels, budgerigars, and other psittacines. Pigeons are also an important reservoir. Outbreaks in turkeys, ducks, and chickens have been described, and infections have been documented in songbirds, sea birds, and over 460 avian species worldwide.[82] Transmission occurs by inhalation of infected nasal discharge or aerosolized dried feces. Disease in birds is variable and can range from acute systemic illness to mild conjunctivitis. Inapparent carriers have also been documented.[83] In humans, *Chlamydia psittaci* symptoms can include fever, chills, headache, and pneumonia. Psittacosis is treated with antibiotics. Proper quarantine, diagnostic testing, and appropriate PPE will help minimize personnel risk.

Mycobacterium marinum and related species (*M. fortuitum*, *M. ulcerans*, *M. chelonae*, and other "atypical mycobacteria") are zoonotic bacteria associated with aquatic species.[84] Mycobacteria are found in both fresh and salt water environments. Fish infected with *M. marinum* can develop visceral granulomas and skin ulceration.[85] Humans typically contract the disease through contamination of a preexisting wound when they are conducting activities such as handling fish or cleaning tanks.[86,87] Disease in humans usually manifests as self-limiting granulomas on extremities and has been called fish tank granulomas, fish handlers' disease, and fish fanciers' finger. Infection can progress and become more invasive, particularly in immunocompromised patients.[86,88,89] Recently, a novel clinical presentation of eczema-like scaling and crusting was described in three patients.[90] Mycobacteriosis is treated with combination antibiotic therapy for a prolonged duration. Surgical excision may also be indicated.[86] Effective colony management and use of PPE will mitigate risk of transmission of atypical mycobacteriosis.

Salmonella is a gram-negative bacterium with two species and thousands of serovars. This organism may be present as part of the normal gut flora in some species. Crowding, stress, and poor husbandry can be contributing factors in disease outbreaks. *Salmonella* has long been associated with reptiles, particularly turtles. Bearded dragons, iguanas, corn snakes, boa constrictors, frogs, and salamanders have also been implicated in transmission of *Salmonella* to humans.[91,92] Birds are susceptible to *Salmonella* infections, with poultry, pigeons, and even psittacines linked to human cases.[93] Animals that are positive for *Salmonella* may be asymptomatic or may exhibit a variety of signs, ranging from diarrhea and dehydration to visceral granulomas, arthritis, and sepsis. Animal-to-human transmission occurs primarily through contact with feces or contaminated surfaces. In humans, *Salmonella* typically causes headache, fever, and gastrointestinal signs. Frequent hand-washing, good sanitation and husbandry practices, and use of appropriate PPE will diminish likelihood of transmission of *Salmonella*.

Vibrio vulnificus is a bacterium found in marine environments and has an affinity for warmer temperature and lower salinity. The organism can cause hemorrhagic and ulcerative disease in fish, including species such as eels and pompano. In humans, infection of a preexisting skin wound can result in painful necrotizing infections and even septicemia.[94–96]

Streptococcus iniae is a gram-positive bacterium that infects fish, including tilapia, catfish, and hybrid striped bass. Infected fish demonstrate clinical signs and lesions of the central nervous system. In humans, the organism can infect wounds and cause cellulitis. Endocarditis and meningitis can occur with systemic infections.[88,96,97]

Erysipelothrix rhusiopathiae is a gram-positive bacterium that is found worldwide in a wide variety of species, including birds, reptiles, fresh and salt water fish, and cephalopods.[98] Turkeys are especially sensitive and develop skin discoloration, diarrhea, depression, and septicemia.[99] The organism can also be found in the protective mucous layer of fish. Recent reports of fish disease include hemorrhagic septicemia in eels and cutaneous hemorrhage and necrosis in ornamental tropical fish.[100,101] Wound contamination during handling infected animals is the primary means of transmission to humans. The disease in humans manifests as a localized cutaneous infection ("erysipeloid"), which can be quite painful; a generalized cutaneous cellulitis; and septicemia, which may have accompanying endocarditis.[102]

Dermatophilus congolensis is a filamentous bacterium that causes exudative skin lesions and has been described in a variety of species, including crocodilians. Humans contract the disease through contact with infected animals. In humans, the disease typically manifests as self-limiting pustules, furuncles, or eczematous lesions.[98]

Viral Zoonoses

The primary zoonotic viral diseases in birds are Newcastle Disease, avian influenza, and West Nile Virus. Newcastle Disease is caused by a paramyxovirus and is of most concern in poultry. Disease in birds is characterized by gastrointestinal, respiratory, and neurologic signs. Humans can be infected by direct contact with infected birds, especially chickens. Newcastle Disease can cause conjunctivitis, headaches, and fever in humans.[98,103]

Avian influenza is an orthomyxovirus that infects birds and can be transmissible to humans. Virus is shed in droppings and respiratory secretions. Free-ranging and migratory waterfowl frequently act as carriers. Clinical signs in affected chickens and turkeys are variable and can include respiratory disease, comb and wattle edema, and neurologic disease.[99] Avian influenza can cause severe respiratory disease in humans.[98]

West Nile Virus is transmitted by mosquitoes and has affected over three hundred bird species in the United States. Crows, hawks, and owls are especially susceptible. Affected birds show various neurologic signs, including ataxia, paresis, and seizures. Infected humans may be asymptomatic or show signs of encephalitis.[104] Treatment is supportive. Practices to prevent avian viral diseases include limiting exposure of captive animals to wild carriers, having effective quarantine and management practices, and proper use of PPE.

Fungal Zoonoses

Histoplasma capsulatum is a fungus commonly associated with dove and pigeon feces and can cause respiratory disease in humans. Good sanitation and husbandry practices will diminish potential transmission to humans.[93]

Microsporum gallinae, a dermatophyte of poultry, causes scaly cutaneous lesions. This disease can be transmitted to humans by direct contact with infected birds.[99] Proper use of PPE will prevent bird to human transmission.

Conclusions

Ensuring personnel safety in animal facilities housing nontraditional species can pose unique challenges. Enlisting help from construction and safety experts well-versed in the design of aquatic and avian facilities can ensure provision of safe and functional housing units. Understanding basic biology and behavior of the particular species and consultation with specialists in the field to assist with development of current best practices will address concerns related to handling, restraint, and housing. Review of literature regarding zoonoses, particularly recent case reports and population studies, will help in determining proper PPE and other precautions when dealing with unfamiliar species. Attention to these details in the planning stages will result in optimal and safe environments for nontraditional research animals and the personnel caring for them.

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