Common Toxicoses of Wildlife

Terminology:

1. ***Toxicant*** (or poison) – any substance that when introduced into or applied to the body can interfere with homeostasis of the organism or life processes of its cells by its own inherent qualities, without acting mechanically and irrespective of temperature (Osweiler et al 1985)
2. ***Toxic*** – an adjective used to describe the effect of the toxicant(e.g., one toxic effect of lead poisoning is anemia)
3. ***Toxicity*** – the dosage or quantitative amount of a poison that will produce the toxic effect (e.g., the toxicity of lead in raptors is generally considered to be >0.35ppm in whole blood)
4. ***Toxicosis*** – the state of being poisoned by a toxicant (e.g., lead toxicosis)

When to consider toxicants

Toxicants should be considered any time more than one animal is found with similar signs but no evidence or history of disease or trauma, when animals are found in a location likely to have a source of toxicant, when specific species are affected, and when animals present with signs typical of the suspected toxicant.

Locations in which toxicoses commonly occur are agricultural fields and runoffs, urban/suburban lawns, golf courses, roadsides, landfills, and waterways. Treated grain, lawn and garden chemicals, commercial/agricultural use of pesticides, livestock treatment, and prey ingestion by scavengers (secondary poisoning) can all result in poisoning of wildlife. Intentional poisoning of wildlife (intended for ‘pest’ species) may also occur.

All species are susceptible to toxicant exposure and the resulting effects, but fish and birds appear to be most sensitive. Fish are more sensitive largely because all contaminants in their environment pass over their gills. Birds are very sensitive to toxicants for a number of reasons: activation of cytochrome P450 enzymes and limited induction of glutathione-S-transferase are thought to limit their ability to detoxify active metabolites; glomerular filtration, necessary for the kidneys to remove toxicants from the blood, is constant in mammals, but only intermittent in birds; and many migratory birds undergo extreme weight fluctuations associated with migration, resulting in stress to the birds and the release of toxins stored in their body fat (Frazier 1996). Insectivores are obviously at a greater risk of exposure to insecticides; scavengers and predatory species may have a high predilection to toxicoses through ingestion of poisoned food/prey items (secondary poisoning or relay toxicosis); and ‘pest’ species may be exposed through intentional poisonings by humans.

Most toxicants commonly seen in wildlife affect either the central nervous system (CNS) or the gastrointestinal (GI) tract. The respiratory tract, urogenital tract, and skin are affected less commonly and usually secondarily to CNS or GI signs. Common neurological signs include ataxia, torticollis, stargazing, anisocoria, tremors, paresis, paralysis, and seizures. The most common GI signs are diarrhea, vomiting, and anorexia. Animals exposed to toxicants may also have an unusual odor, color, or feel to fur and feathers. Often, sudden death is the only sign.

General Treatment for Suspected Toxicoses (modified from Richardson & Allen, 2006)

1 **Stabilize the patient.** Toxicoses often present as emergencies, and a common reaction is to immediately try to find an antidote. As with any emergency, however, every effort should first be made to stabilize the animal. '**TREAT THE PATIENT, NOT THE POISON!**' is a good rule to follow. Make sure the animal is breathing, has good perfusion (check the mucous membranes and capillary refill time), and is conscious. If the animal is seizuring, act to control the seizures. Provide a dark, quiet area for the animal, provide heat if necessary, and examine the animal for any injuries it may have incurred.

2 **Prevent any more toxicant from being absorbed by the animal.** Perform the appropriate method(s) of decontamination, depending on the type of toxin and the method of exposure (dermal, ocular, ingestion, inhalation, etc.).

External Exposure If the animal has been exposed to a toxicant on the fur or feathers, especially if the skin has become contaminated (*dermal exposure*), the animal should be bathed in a mild hand or dishwashing detergent, then rinsed well with warm water. This should only be done *after* the animal is stable and is strong enough to withstand the washing and rinsing. Only in rare cases where the toxicant is highly irritating to the skin should washing be attempted prior to complete stabilization (e.g., exposure to a caustic substance such as battery acid). Great care should be taken to maintain normal body temperature during this process, and the animal should be placed under radiant heat and/or forced hot air until dry. Protective equipment (nitrile gloves, plastic aprons or Tyvek® clothing [DuPont USA, Wilmington, DE], and protective eyewear) should be worn by personnel working with the animal.

With any *ocular exposure*, the eyes should be flushed repeatedly with warm distilled water or normal saline solutions (0.9 percent NaCl). If inadequate flushing is performed, ophthalmic ointments should *not* be placed in the eyes, as these may actually act to trap the toxicant against the cornea and conjunctivae.

Internal Exposure

Oral Ingestion

a. Dilution with water in combination with demulcents is recommended in cases of corrosive ingestion. A demulcent is an agent that coats or soothes the stomach, such as Kaopectate® (Pharmacia Corp., Peapack, NJ), Mylanta® (Johnson & Johnson - Merck Consumer Pharmaceuticals Co. Ft. Washington PA), Pepto-Bismol® (Proctor & Gamble, Cincinnati, OH), or milk of magnesia. Juicy fruits and vegetables may work well for birds and reptiles (Lisa Murphy, VMD, DABT, Assistant Professor of Toxicology, University of Pennsylvania, Kennett Square, PA, personal communication).

b. Emesis (vomiting) is most productive if performed within 2-3 hours of the time the toxicant was ingested. Emesis should *not* be used after ingestion of oil or caustic substances that could be easily aspirated, *nor* should emesis ever be used in rodents, rabbits, ruminants or birds due to the high risk of aspiration. Emetics include 3 %hydrogen peroxide, syrup of ipecac, and apomorphine.

c. Activated charcoal adsorbs a chemical or toxicant and facilitates its excretion via the feces. Activated charcoal has a large surface area (one gram has an average surface area of 1000 square meters!) that adsorbs the toxicant and prevents further absorption by the animal. The sooner activated charcoal is administered after ingestion of the toxicant, the more effective it is.

d. Cathartics increase the speed of the transit time of the toxicant through the GI tract, removing it from the body and theoretically decreasing the amount of toxicant absorbed. When used in conjunction with activated charcoal, cathartics enhance the elimination of the activated charcoal-toxicant moiety, thereby removing the toxicant from the GI tract before it can desorb from the charcoal. To be most effective, the cathartic should be administered within 60 minutes

of toxicant ingestion. Cathartics include sodium sulfate decahydrate (Glauber's salt or mirabilitae), magnesium sulfate (Epsom salt), sorbitol, and psyllium.

e. Enemas may assist in the elimination of toxicants from the lower gastrointestinal tract. A simple and effective enema can be administered using a red-rubber catheter attached to a syringe and gently infusing the cloaca or rectum with plain or soapy warm water.

f. Gastric lavage or the physical flushing of the stomach using warm water should be performed with great care under general anesthesia. Lavage should *not* be used for treating the ingestion of caustic substances or petroleum substances.

g. Endoscopy or Gastrotomy under general anesthesia may be necessary to remove foreign bodies which are also toxicants, such as lead fishing sinkers, coins, etc.

Inhalation

If the animal has been exposed to toxic fumes by means of inhalation, the most important act is to remove the animal from the source of the fumes, taking precautions for human safety (e.g., use of a respirator or self-contained breathing apparatus). If the animal is experiencing respiratory difficulty, oxygen should be administered.

3 **Administer specific antidote to a known toxin, if available.** If the toxin is known and a specific antidote is available, administer it.

4 **Eliminate the absorbed poison, if possible.** In some instances the toxicant that has already been absorbed may not be eliminated naturally by the body. Chelation may be necessary to remove heavy metals that have been absorbed into the blood and various organs.

5 **Provide on-going support while the animal recovers**. Clinical signs should be treated accordingly: if the animal is overheated, it should be cooled; if the animal has ongoing fluid losses (vomiting, diarrhea, etc.), fluids should be provided. Some toxins may take several days for the animal to fully recover, and some may take weeks, with the possibility of permanent damage from which the animal will never recover. During this recovery period, appropriate supportive care (fluids, nutrients, proper caging, physical therapy, etc.) should be provided.

Collection and Submission of Samples for Confirmation of Toxicoses

When a specific agent is not known, it is always best to collect samples for analysis. Samples for toxicology should be placed in the appropriate storage media and refrigerated or frozen at the appropriate temperature until analyses can be run. All samples should be in separate containers (not pooled) and labeled with the date collected, location found, content, and any identifying name or number (Friend and Franson 1999). Shipping of all diagnostic specimens should be done in accordance with the US Department of Transportation Diagnostic Specimens Shipping Regulations available at http://www.epa.gov/fedrgstr/EPA-IMPACT/2001/January/Day-22/i92.htm.

A sample submission form, wildlife diagnostic laboratories in the United States, and sources for collection and shipping supplies can be found at http://www.nwhc.usgs.gov/publications/field_manual/appendices.pdf.

Common samples to submit ante-mortem are whole blood, serum, urine, vomitus, footwash, contaminated feathers, stomach contents, and source materials, if found.

Common samples to submit post-mortem are liver, kidney, brain, GI contents, and fat. Brain and fat are most important with toxicants that are lipid soluble.

Specific Toxicants Commonly Affecting Wildlife

I. PESTICIDES

1. Organochlorine Insecticides (Also known as chlorinated hydrocarbons)
Organochlorines (OCs) were the first insecticides to be widely used, beginning in the 1940s with DDT (dichlorodiphenyltrichloroethane), until their general use was banned in the US in 1972. Despite the ban, DDT and other OCs persist in the environment, are still present in stockpiles of outdated pesticides, and are still used in parts of Central and South America where many raptors and their prey spend the winter, causing them to remain a threat to wildlife in the US.

Most OCs interfere with the transmission of nerve impulses, causing a disruption of normal nervous system functions. The precise mechanism of OCs is not known, with the exception of DDT. DDT inhibits the ion exchange initiated during an action potential, causing muscle fibers to be hyperactive. Acute exposure to OCs may cause excess nervous stimulation and hypersensitivity.

Chronic exposure to OCs may result in quite a wide range of effects, the best known being eggshell thinning. Other effects of long-term exposure include male infertility, bone marrow suppression, hepatic damage, immunosuppression, hyperestrogenism, changes in hepatic steroid metabolism, and cutaneous hypersensitivity (Raisbeck 2001).

Signs: DDE, one of the main metabolites of DDT, causes eggshell thinning and reproductive failure in a wide variety of avian species. 'Acute' organochlorine toxicity is seen in emaciated birds, especially great horned owls (*Bubo virginianus*) (Porter, 1990). They exhibit tonic-clonicconvulsions, particularly when stimulated. Their pupils may respond to light, but also constrict and dilate independently, and these birds often appear to be blind. Affected animals exhibit abnormal posture and are unable to stand. All are extremely anemic (packed cell volume [PCV] <15 percent) and have low total blood solids (<1.0 g/dl).

Diagnosis: Clinical signs in conjunction with anemia and/or any history of exposure. The definitive diagnosis of organochlorine toxicity is usually made post-mortem, though whole blood may be submitted for detection of OC residues. Due to the chronic, persistent nature of this toxicant in the environment, blood and tissue samples may show OC residues at a nontoxic level.

Treatment: There are no specific antidotes for OCs, so treatment is supportive.

2. Carbamates and Organophosphates (**Anticholinesterase Insecticides)**
These substances competitively inhibit acetylcholinesterase (AChE), an enzyme that inactivates acetylcholine, a neurotransmitter found at certain synapses within the body. When acetylcholine (ACh) is not broken down by AChE, it accumulates and causes excessive synaptic transmission or 'firing' of neurons in the autonomic nervous system, smooth and cardiac muscle, endocrine glands, the somatic nervous system, and the CNS (Blodgett 2001). This constant depolarization of the postsynaptic neurons may lead to paralysis of the target muscles.

Diagnosis: Usually based on history of exposure and clinical signs, followed by response to treatment. Exposure can be confirmed by ante-mortem blood tests or post-mortem tissue analysis.

Treatment: Provide general supportive care (supplemental heat, fluids, and diazepam to control seizures). Atropine is indicated for cholinergic signs, with one-fourth of the dose given intravenously (IV), and the remainder given intramuscularly (IM) or subcutaneously (SQ). Response to atropine is often dramatic, and treatment can be repeated every three to four hours as needed (Porter 1990).

3. Neonicotinoid Insecticides (Synthetic nicotine)
These pesticides were introduced in the early 1990's, and are now the most widely used insecticides in the world. They are used to treat a number of insects, including termites, and are applied to soils, plants, structures, seeds, and pets (e.g., Advantage™ for flea control). They are effective by both contact & ingestion, and can be absorbed thru the skin or digestive tract of vertebrate species. Neonicotinoids bind irreversibly to the post-synaptic nicotinic acetylcholine receptors, causing the nerve impulse to discharge spontaneously. They are not broken down by acetylcholinesterase, so activation of the receptor is sustained (NPIC 2010).

Signs: Similar to OP/Carbamates: salivation, lethargy, vomiting, diarrhea, salivation, muscle weakness and ataxia. At high doses, tremors, seizures and/or death may be seen. Immunosuppression, testicular changes and egg-shell thinning have also been reported (Gibbons 2015).

Diagnosis: Clinical signs in conjunction with history of exposure. The definitive diagnosis is usually made post-mortem via toxicology on liver samples. Whole blood may be submitted for detection of these chemicals, but results are not always reliable.

Treatment: Supportive care and treatment of symptoms. Supplemental oxygen and fluids are important aspects of treatment in human cases of toxic exposure.

Rodenticides
Most rodenticides are placed in baits of seeds, grain, or pelleted feed designed to be highly palatable for rats and mice; consequently, most rodenticide poisoning in wildlife occurs as a result of squirrels, chipmunks, birds and other seed-eating animals inadvertently ingesting the bait. Intentional poisonings (in the case of 'nuisance' wildlife) may occur, and secondary toxicities may result when predators, such as raptors, ingest prey species that still contain unmetabolized toxicant in their bodies.

1. Anticoagulants
Anticoagulant rodenticides are coumarin-derived compounds that interfere with the normal blood coagulation pathways by preventing the conversion of vitamin K1 epoxide to active vitamin K1. Active vitamin K1 is necessary for the production of clotting factors II, VII IX, and X. Therefore, the lack of active vitamin K1 leads to a depletion of these clotting factors, resulting in hemorrhage and anemia.

Signs: Anticoagulants often cause minimal external clinical signs other than depression or dyspnea (caused by pulmonary or intrathoracic hemorrhages) (Murphy 1994). Toxicity may result in internal hemorrhages, bruising, hemorrhage within the eyes, and profuse bleeding when cut or injected.

Diagnosis: Usually based on clinical signs, and a prolonged clotting time or complete failure to clot.

Treatment: Vitamin K1 should be given subcutaneously (SQ) or orally to any patient with known hemorrhaging and suspected exposure; however, synthesis of new clotting factors may take 6 to 12 hours (Murphy and Talcott 2001). If the animal is actively bleeding, whole blood or plasma transfusions are the only treatment that can immediately replace clotting factors.

2. Cholecalciferol (vitamin D toxicosis) Rodenticides containing 0.075 percent cholecalciferol (vitamin D3) are the main source of vitamin D toxicosis in wildlife. Once ingested, cholecalciferol is metabolized in the liver to calcifediol, which is further metabolized to calcitriol in the kidneys. The result is a marked hypercalcemia as calcitriol promotes the movement of calcium from the bone (Bahri 1990). The hypercalcemia, in turn, leads to dystrophic calcification, electrolyte imbalances, and renal failure.

Signs: Common early signs include depression, anorexia, polyruria and polydipsia, followed by hypertension, anorexia, vomiting, constipation, weakness, and seizures. Blood may be seen in the feces or vomitus in some cases.

Diagnosis: History of exposure, clinical signs, and elevated serum calcium and depressed serum phosphorus levels should lead to a tentative diagnosis in the live animal. Post-mortem exam may reveal mucosal hemorrhages in the gastrointestinal tract, calcification of the kidneys, myocardial necrosis, and calcification of the myocardium and other soft tissues (e.g., aorta, stomach, and kidneys) (Carothers and Chew 1991; Murphy 1994).

Treatment: If ingestion has been recent, especially prior to the appearance of clinical signs, emetics or activated charcoal may be helpful in removing any cholecalciferol remaining in the gastrointestinal tract. Saline diuresis is necessary to remove the excess calcium from the blood. (Murphy 1994). Cholecalciferol is lipid soluble and may be stored in fat, liver, and muscle prior to being metabolized, so complete clearance may take several weeks. Patients should be kept out of direct sunlight to discourage natural synthesis of vitamin D3 during this time, and should be fed a diet low in calcium.

3. Strychnine

Strychnine is an alkaloid derived from the seeds of the tree nux vomica (*Strychnos nux vomica*), and is commonly used as a rodenticide (Talcott 2001). Strychnine inhibits the glycine receptor (GlyR) in the spinal cord and medulla, interfering with postsynaptic inhibition at these sites (Murphy 1994). Secondary poisonings may occur in predators ingesting affected prey species.

Signs: The inhibition of the GlyR receptor leads to unchecked neuronal activity, causing paralysis and may lead to violent tetanic seizures in response to external stimuli. Paralysis begins with the face, neck, and limb muscles and may be accompanied by anxiety and excessive salivation. Signs usually occur within ten minutes to two hours of ingestion (Murphy 1994).

Diagnosis: History of exposure, rigid ‘sawhorse’ posture, and ‘sardonic grin’ seen with the seizures are usually sufficient for diagnosis. Definitive diagnosis can be made by GC/MS of the vomitus, serum, or urine. Stomach content, liver, bile, and kidney should be collected for analysis.

Treatment: No specific antidote exists for strychnine, but it is metabolized and cleared normally by the body. Gastric lavage or activated charcoal to clear the gastrointestinal tract, and IV fluid therapy to help clear the circulatory system, will decrease the recovery time.

4. Bromethalin

This compound is rapidly absorbed and metabolized by the liver to the more toxic compound, desmethylbromethalin. Desmethylbromethalin causes uncoupling of oxidative phosphorylation and decreased adenosine triphosphate, leading to edema in the central nervous system (Dorman 2001).

Signs: Muscle tremors, hyperthermia, excitability, hyperesthesia, and focal or generalized seizures occur within 2 to 24 hours of ingestion of high doses. Hindlimb ataxia, paresis, and decreased proprioception and pain response develop 10 to 24 hours after ingestion of lower doses. Vomiting, anorexia, anisocoria, positional nystagmus, abnormal postures, opisthotonus, extensor rigidity, and fine muscle tremors may also be seen (Dorman 2001).

Diagnosis: History of exposure and clinical signs are the only means of diagnosis in the live animal. Diffuse vacuolization of the myelin sheath may be seen on histology, and bromethalin *may* be detected in fat, liver, kidney, and brain tissues on post-mortem (Means 2003; Dorman 2001).

Treatment: Efforts should be made to reduce the cerebral edema, including the use of mannitol in a 20 to 25 percent solution, and glucocorticoids (Murphy 1994). Other supportive care involves the removal of toxicant from the gastrointestinal tract and sedation to control seizures.

Avicides
These toxicants are manufactured specifically for the control or eradication of 'nuisance' birds. Most are available as a pelleted product, a powder intended to be mixed with seeds, or as pre-treated seed or grain mixes. They are generally licensed only for use against specific species, but ingestion by non-target species and secondary poisonings of predatory species is common.

4-aminopyradine (4-AP)
This substance has 'flock-alarming properties' (product label), designed to cause birds to seizure and frighten away other birds. This compound is a cholinergic agent that blocks potassium ion channels and increases synaptic acetylcholine release. Off the market in 2010; available in 2011….

Signs: The most common sign is tonic-clonic seizuring; weakness, hypersalivation, vomiting, dyspnea, tachycardia, ataxia, and tremors may also be seen in as little as 5 to 15 minutes after ingestion.

Diagnosis: History of exposure and clinical signs. Multiple birds in one area are usually affected. Definitive diagnosis may be made on examination of stomach content or possibly urine (Beasley 1999). Liver analysis can confirm the presence of 4-AP.

Treatment: Supportive care and general toxicant treatment should be provided (emetics, gastric lavage, and/or activated charcoal, if recent ingestion).

DRC-1399 (Starlicide) (3-chloro-4-methylbenzenamine hydrochloride)
The only lethal toxicant currently registered in the U.S. for managing blackbird damage in sunflower during both the spring and fall migrations. Nephrotoxicity occurs 3-24 hrs after ingestion, resulting in uric acid deposits in kidney and blood vessels, leading to necrosis and circulatory impairment. Sensitivity varies among species; most non-target species (like doves and meadowlarks) are fortunately not sensitive; most raptors not sensitive (Eisemann et al 2001).

Signs: Weakness, lethargy, acute death.

Diagnosis: Location found (known use), multiple deaths, renal necrosis seen on necropsy/histopathology. DRC-1399 is metabolized quickly (usually within 4hrs) and is rarely found in tissues/toxicology.

Treatment: Supportive consisting largely of fluids.

II. HEAVY METALS

1. Lead

This is the most common toxicosis of wildlife seen by the author. Lead exposure usually occurs by the ingestion of spent lead ammunition, lead fishing weights, disposed lead terminals in batteries, lead paint, and environmental contamination from lead smelters or sewage sludge. It is particularly a problem in waterfowl because they often ingest lead pellets while dabbling. The muscular gizzard grinds the pellets into smaller particles, allowing lead to be systemically absorbed from the gastrointestinal (GI) tract. Seabirds are also frequently affected as a result of ingesting fish containing lead sinkers or jigs. Raptors are often exposed by ingesting hunter-shot prey but are usually less vulnerable to the toxic effects because they often cast the lead with undigested portions of their meals within 12–24 hours of ingestion.

Although lead exposure adversely affects all body systems through inhibition of enzyme activity and protein synthesis, it is primarily the nervous, digestive, renal, and hematopoetic systems that are most affected (Casteel 2001). Lead inhibits heme synthesis, resulting in profound anemia. Competitive inhibition of calcium at the presynaptic level and demyelination of the vagus nerve may result in peripheral neuropathies (Dumonceaux 1994).

Signs: *Chronic lead poisoning* is suspected when waterfowl present with a combination of gastrointestinal and neurological signs. Affected birds may be emaciated, with pasty vents and characteristic green feces. Head and neck carriage may be crooked or bent, crops are often distended with forage material, subcutaneous edema of the head and neck is common, and a change in voice is often noted. Unsteady gait, inability to fly, and altered wing carriage is common in raptors. Serous nasal discharges and moderate anemia are commonly seen. *Acute lead poisoning* presents primarily with CNS signs including lethargy, weakness, ataxia, paralysis, torticollis, circling, blindness, and seizures.

Diagnosis: Definitive diagnosis is usually made on the basis of blood lead levels, although the activity levels of specific enzymes may be more reliable (blood protoporphyrin levels, porphobilinogen synthetase, etc.) (Dumonceaux 1994). Erythroid hyperplasia and basophilic stippling may sometimes be seen on a peripheral blood smear. Radiographs may reveal metallic densities in the GI tract, joints, or bone marrow, but are not considered definitively diagnostic, as the source of lead may no longer be radiographically visible. Fresh or frozen liver samples may be submitted for post-mortem confirmation. (Sileo 1992).

Treatment: Prolonged supportive care is often required, including assisted alimentation and intravenous fluids, iron dextran and B complex vitamins, prophylactic treatment for aspergillosis, chelation therapy, and elimination of the source of exposure. Ingested lead may be removed using endoscopy, ventriculotomy, or copious lavage (Degernes 1989). Tiny pieces of lead and flakes of lead paint are sometimes successfully removed with oral administration of a 1 percent psyllium solution.

2. Zinc

Zinc toxicosis has the same mechanism of action as lead poisoning, resulting in the same clinical signs and responding to the same treatment. Pennies minted in the US after 1982 contain up to 98 percent zinc, coated with copper. Ingestion of these pennies is the primary cause of zinc toxicosis in wildlife. Chewing on galvanized wire, ingesting galvanized hardware, and drinking water from galvanized pans may also lead to zinc poisoning.

Diagnosis: Whole blood samples for zinc testing should be carefully collected in vials containing an anti-coagulant. The vials must have non-rubber tops; most rubber contains zinc oxide and contact with the rubber top may contaminate the sample. (Lloyd 1992).

Treatment: Therapy for zinc poisoning is very similar to that for lead. Ingested zinc should be removed as soon as the animal is stable, using endoscopy, ventriculotomy, or copious lavage. Supportive care should be provided as needed. Once the source has been removed, zinc is naturally eliminated from the body rapidly, so additional chelation may not be required.

3. Mercury

Industrial effluents (especially from early pulp and paper production and chlor-alkali plants), fungicides (organic mercury), improper disposal of mercury containing items (batteries, paints thermometers, medications, etc.), and biotransformation of inorganic (elemental) mercury in the environment can all contribute to the presence of mercury in the environment. Waterfowl and other seed-eating species have become directly intoxicated through the ingestion of seed grain treated with fungicides containing mercury. Biomagnification of mercury in the food chain can lead to secondary toxicoses in predatory species.

Signs: Mercury has an affinity for the CNS tissues, so toxicosis is most often exhibited as neurological signs, including ataxia, lethargy, weakness, abnormal vocalization, blindness, circling, tremors, seizures, and/or paralysis. (Osweiler et al 1985).

Diagnosis: Diagnosis is usually based on clinical signs. Normal values for blood mercury vary widely from one species to another and are not known for most wildlife species. Kidney is the best tissue to submit for post-mortem determination of mercury levels (Franson 1999). Postmortem lesions include interstitial nephritis, enlarged splenic follicles, general petechiation in the heart and other organs, and focal hepatic necrosis (Osweiler et al 1985).

Treatment: No specific treatment exists for mercury toxicosis. Supportive therapy should be provided, including appropriate fluid therapy to compensate for any renal damage.

4. PCBs (Polychlorinated Biphenyls)
These and other aroclors were used in a variety of materials to enhance insulative properties, improve physical and chemical resistance, and act as plasticizers, coolants, and lubricants. They were first produced in 1929; EPA banned their use in 1979, but they are still prevalent in the environment. Exposure is most likely to occur via ingestion of contaminated fish or benthic invertebrates.

Signs: Acute toxicity is not likely to be seen today, but usually results in contact dermatitis. Chronic exposure most often results in birth deformities, neoplasia and probable immunosuppression.

Diagnosis: Whole blood or tissue samples submitted for toxicology can confirm elevated levels.

III. NATURAL TOXINS
1. Botulism
Botulism is caused by a toxin produced by the Gram-positive bacterium, *Clostridium botulinum*. Primarily seen in waterbirds, botulism has been documented in wading birds, shore birds, waterfowl, and diving birds. Some species, such as vultures, are extremely resistant to intoxication (Bennett 1994). Outbreaks rarely involve only one bird and may affect thousands of birds. There are several strains of botulism toxin (types A through F); types C and E are most commonly responsible for outbreaks in wildlife. This bacterium is very hardy because it is normally in an inactive spore form that allows it to survive extreme conditions, and it only grows in areas without oxygen. When conditions are favorable, the spore is activated, grows, and produces toxin. The bacteria producing type C botulism does not have the genetic material for toxin production and must first be infected by a bacteriophage (a virus that infects bacteria) in order to receive the genetic material necessary to produce the toxin (Rocke and Friend 1999). The toxin is only produced by active *Clostridium* (i.e., in the growth or vegetative stage), but the toxin remains functional even if the bacterium is destroyed. Maggots feeding on a carcass containing either types C or E may accumulate the toxin, resulting in acute toxicity in another animal feeding on the maggots or carcass; thus, carcass collection is key to controlling any botulism outbreak.

Signs: The endotoxin interferes with the release of acetylcholine at motor end plates, resulting in signs of peripheral neuropathy. The classic sign, 'limber neck', results from paralysis of the cervical musculature. Mildly affected waterfowl (stage one) cannot fly but may 'wing-walk'. These birds are alert but cannot escape predators; as a result, their level of stress may be very high. Birds in stage one are generally self-feeding and will recover with minimal supportive care. More seriously affected birds (stage two) cannot fly or walk and are not self-feeding. These birds can hold their heads up weakly and possess a slow nictitans response. Critically ill birds (stage three) are almost completely paralyzed. These birds cannot hold up their heads; consequently, death frequently results from drowning. Paralysis of respiratory muscles may result in suffocation in birds in stage three.

Diagnosis: Characteristic clinical signs may be seen in multiple animals from the same location. Diagnosis can be confirmed with an *in vitro* enzyme-linked immunosorbent assay (ELISA) test for type C botulism toxin, but the mouse-protection test is still considered the 'gold standard'. For the mouse test, serum from the affected animal is inoculated into two sets of mice, one of which has been given type-specific antitoxin. Only the mice that receive no antitoxin will become sick (or die) if the toxin is present in the sample (Rocke and Friend 1999).

Treatment: Botulism is treated by gavaging the bird with activated charcoal (AC) and numerous fluid boluses. If available, antitoxin can be given for type E botulism to inactivate toxin that was previously absorbed into the blood; however, it is often limited in availability and may be costly. With prompt and intensive treatment, many animals recover completely.

2. Harmful Algal Blooms / Red tides
Several toxins are known to be produced by dinoflagellates, diatoms, and other algaes during 'red tides'. These pigmented blooms of phytoplankton occur under specific environmental conditions and appear to be more frequent in recent years (Creekmore 1999).

a. Domoic Acid (amnesic shellfish poisoning [ASP]) Primarily known to affect pelicans, cormorants, dolphins, sea lions, sea otters, and whales, the toxidrome is termed amnesic shellfish poisoning (ASP) because it often causes memory loss in affected humans. One genus of diatoms, *Pseudonitschia,* is thought to be the main source of domoic acid, the toxicant responsible for ASP. This genus may be increasing in abundance due to eutrophication from increased nutrients in coastal areas (NOAA 2006). Domoic acid binds to glutamate receptors on nerve endings, resulting in excessive activation of the receptors and may result in permanent loss of neurological function.

Signs: Early or mild intoxication causes vomiting and diarrhea. Neurological signs usually occur two or more hours after ingestion of larger quantities of domoic acid. Signs include ataxia, tremors, side-to-side head movement (pelicans), abnormal aggression, weakness, lethargy, dyspnea, seizures, coma, and death (Glavin 1990; Creekmore 1999).

Diagnosis: Clinical signs in combination with a die-off or large morbidity in an area known to be high in domoic acid is sufficient for a presumptive diagnosis. Gastric content, blood, urine, and feces can be tested with the same mouse assay used for paralytic shellfish poisoning, and HPLC can be used to quantify the domoic acid in food sources from the region (Nantel 1996).

Treatment: No specific treatment is available at this time, so efforts should be made to provide supportive care and control seizures with diazepam or phenobarbital as indicated.

b. Brevetoxin (neurotoxic shellfish poisoning [NSP]) Brevetoxin is a neurotoxin produced by the dinoflagellate *Karenia brevis* (formerly *Gymnodinium* sp.). The production of this toxicant during red tides has resulted in large fish dieoffs, as well as the poisonings of whales, manatees, lesser scaup, and humans, through the ingestion of the algae and contaminated shellfish. Once ingested and absorbed, brevetoxin binds to sodium channels on nerve and muscle cell membranes, causing an influx of sodium ions across the membranes, leading to cell death.

Signs: Lethargy, weakness, reluctance to fly, head droop, oculonasal discharges, and excessive salivation were observed in the lesser scaup (Creekmore 1999).

Diagnosis: Clinical signs in animals in an area known to have had a recent red tide incident is sufficient for a presumptive diagnosis. A definitive diagnosis can be made by confirming the presence of brevetoxin in stomach content, blood, urine, and/or environmental samples using a competitive ELISA or mouse bioassay.

Treatment: No specific treatment is available, so efforts should be made to provide supportive care.

c. Saxitoxins (paralytic shellfish poisoning [PSP])This potent neurotoxin is one of the most toxic non-protein substances known. It is produced by algal blooms of *Alexandrium catenella,* (formerly *Gonyaulax catenella*), *A. tamarenseexcavatum* (formerly *G. tamarensis*.), and the dinoflagellate *Pyrodinium bahamense*. It is also produced by some cyanobacteria. Saxitoxins bioaccumulate in shellfish filter-feeding on the algae, consequently causing intoxication in seabirds feeding on the shellfish. The ingested saxitoxin binds to sodium channels of nerve and muscle cell membranes, preventing the passage of sodium ions and therefore blocking the passage of nerve impulses.

Signs: Seabirds and turtles suspected of poisoning by saxitoxin are usually found dead. Birds found still alive exhibit paralysis and vomiting prior to death (Creekmore 1999). Death fromrespiratory failure usually occurs within 2 to 12 hours after exposure.

Diagnosis: Clinical signs in animals in an area known to have had a recent red tide incident is sufficient for a presumptive diagnosis. Mouse bioassays, HPLC, radioimmunoassays, and indirect ELISAs can all be used to detect saxitoxin in the urine or blood.

Treatment: No specific treatment is available at this time, so efforts should be made to provide supportive care if saxitoxin exposure is expected.

d. Aetokthonos hydrillocola (cause of AVM) Epiphytic cyanobacteria causing avian vacuolar myelinopathy in bald eagles and coots. Grows on the aquatic plant hydrilla. Primary death in American coots feeding on the hydrilla and secondary deaths in eagles eating affected coots.

Signs: Neurologic signs and death; seen in inland lakes in the SE US, in association with the plant hydrilla. On post-mortem histopathology: an intramyelinic edema, most pronounced in the optic tectum and cerebellar tracts in the myelin sheath of the brain (Wilde et al 2014).

Diagnosis: Clinical signs and AVM lesions in brain on histopathology.

Treatment: Supportive care, though no successful treatment has been reported.

3. Over-ripe berries

Berries from several sources have been documented as the source for ethanol toxicity in songbirds. Known sources include *Ampeloposis brevipedunculata* in the Vitaceae (Grape Family), Juniper berries (*Juniperus spp.*), and Brazilian Pepper Tree (*Schinus terebinthifolius*) in which ethanol levels can reach 260–1,000 ppm. Heavenly Bamboo (*Nandina domestica*)*,* is a documented source of cyanide toxicity (Woldemeskel and Styer 2010).

Signs: Birds often present with ataxia, reports of poor flight, and secondary head trauma from collision with windows or other structures close to berry bushes (ethanol toxicity). Large flocks of birds often affected at once or received from same area. In cases of cyanide toxicity, birds are usually found dead with congestion and hemorrhage in lungs and other organs.

Diagnosis: Usually based on location found and clinical signs, or the presence of berry seeds in the ventriculus on post mortem exam. Liver, brain and stomach content can be submitted for toxicology.

Treatment: Supportive care, including oral fluids and NSAIDs for secondary head trauma.

IV. POLLUTANTS/MISCELLANEOUS

1. Petroleum

Toxicity of any oil varies considerably with the source of the oil, weathering, and degree of refinement. Many oils (sour crudes) contain hydrogen sulfide, while many refined fuels contain naphthalene, and polyaromatic hydrocarbons of differing toxicities may be present in any petroleum oils.

Signs: External contamination and contact dermatitis; components may be irritating to the eyes, fumes may cause congestion or hemorrhage of the lungs, ingestion may cause ulcerative damage to the GIT, and absorption via all routes may lead to damage of the brain, liver, kidneys, hematopoetic system and reproductive organs and subsequent offspring, depending on the composition of the oil.

Diagnosis: Evidence of external contamination and proximity to known oil source. Many of the toxic components are metabolized quickly and may not be found on toxicology screens. Organ changes are often evident on histopathology; congestion and hemorrhages may be found on necropsy.

Treatment: Supportive care including fluid therapy; removal of external contaminant; administration of an adsorbent such as sucralfate may be beneficial to reduce oral absorption (Miller and Welte 1999).

2. Barbiturates

Depending on environmental conditions, pentobarbital-containing euthanasia solutions may persist in dead carcasses for several weeks, if not longer. Improper disposal of euthanized carcasses may result in secondary intoxication of predatory species that subsequently feed on the carcasses (Thomas 1999).

Signs: Affected animals exhibit signs of sedation: depression, lethargy, hypothermia, slow corneal reflex, depressed heart and respiratory rates, and coma.

Diagnosis: Field diagnosis is often based on proximity of affected animals to a euthanized carcass; however, since poisoning may take several hours to develop, affected animals may travel some distance from the source of the toxicant. Whole blood from live animals and liver or upper GI contents may be submitted for the detection of pentobarbital.

Treatment: Removing the toxicant is of primary importance and may be done by manually emptying or lavaging the crop and/or the stomach. Emetics may be helpful in removing GI contents from mammals. Activated charcoal should be administered to prevent further absorption of toxicant, and supportive care should be provided through heat, fluids, and supplemental oxygen.

3. Salt

Sodium and chloride may result in toxicosis, either through excess ingestion of salt or as a secondary consequence of dehydration/water deprivation. Most wildlife ingest excess salt when they are forced to drink saline water (e.g., when fresh water sources are frozen or desiccated) or when they feed along roads in the winter and consume road salt. The resulting electrolyte imbalance leads to renal failure, fluid imbalances and, consequently, cerebral edema, ascites, gout, heart failure, and death.

Signs: Polydypsia and polyuria are the most common signs as of salt toxicosis. Chronic and/or severe salt toxicosis will eventually lead to renal failure, ascites, weakness, ataxia, convulsions, heart failure, and death. Affected birds may also have crop impactions.

Diagnosis: Clinical signs and history suggestive of exposure (location and/or time of year) are usually sufficient for a presumptive diagnosis. Postmortem findings include hemorrhages and congestion in the liver, GI tract, lungs, brain, kidneys and muscles; visceral gout and ureters impacted with urates; and ascites and subcutaneous edema. Refrigerated blood and frozen brain may be analyzed for salt concentration and formalin-fixed brain may be examined for changes consistent with salt toxicity (Kahn 2006).

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WEB RESOURCES

Extension Toxicology Network Pesticide Information Profiles
http://extoxnet.orst.edu/ghindex.html

ASPCA Animal Poison Control Center
http://www.aspca.org/site/PageServer?pagename=apcc

EPA Pesticides Information
http://www.epa.gov/pesticides/

Field Manual of Wildlife Diseases
http://www.nwhc.usgs.gov/pub_metadata/field_manual/field_manual.html

National Coalition Against the Misuse of Pesticides
http://www.beyondpesticides.org/index.html

USGS Contaminants Exposure and Effects
http://www.pwrc.usgs.gov/contaminants-online/pages/CEETV/CEETVintro.htm

Endocrine Disruptors
http://www.endocrinedisruption.com/endocrine.TEDXList.overview.php

American Bird Conservancy: Toxins
http://www.abcbirds.org/abcprograms/policy/toxins/index.html