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CHAPTER 11

Gaviiformes, Podicipediformes, and Procellariformes (Loons, Grebes, Petrels, and Albatrosses)

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GENERAL BIOLOGY

The three orders included in this chapter comprise a taxonomically diverse group of aquatic birds that are rarely kept in captivity. Despite some similarities in lifestyle and natural history, the three orders are not taxonomically related to each other. The Gaviiformes (loons) share many traits with the Podicipediformes (grebes) and were once believed to be related to each other, but they are considered examples of convergent evolution and not taxonomic relatedness.

Podicipediformes are considered a primitive, distinct lineage of birds with no close relatives, but the Phoenicopteres (flamingoes) may be their nearest taxonomic relatives. The Procellariformes, which includes the albatrosses, petrels, shearwaters, storm petrels, and diving petrels, may be a sister group to the Sheniciformes (penguins). Table 11-1 summarizes the general biologic features of the families in these three orders, and Table 11-2 summarizes select species information.

The Order Podicipediformes is limited to one extant family (Podicipedidae), which includes all the grebes. Approximately 22 species of grebes are recognized worldwide, classified in six genera. Grebes are small- to medium-sized, heavy-bodied birds with long necks and feet set far back on the body. They have an almost exclusive aquatic lifestyle and are limited in mobility when on land. Grebes inhabit freshwater and inland wetland habitats, although some species overwinter in salt water and may be migratory. Some species congregate in flocks of hundreds to thousands of birds and may migrate en masse, but most species are solitary or found in small groups. On average, male grebes are larger than females. Most species exhibit seasonally dichromatic plumage, and molt occurs on nonbreeding grounds. Grebes forage by diving for prey and are highly adapted divers and agile swimmers.

Members of the Order Gaviiformes, commonly known as loons or divers, are limited to one genus (*Gavia*) in one family (Gaviidae). There are five recognized species of loons worldwide. The term "loon" is used in North America and is synonymous with "diver" in the Old World. Loons are geographically limited to the Northern hemisphere (North America and Eurasia). Loons are long and heavy-bodied birds with webbed feet set far back on the body. Like the grebes, their lifestyle is almost exclusively aquatic, and they may have limited mobility on land. Breeding occurs near fresh water, but birds overwinter in marine environments and are migratory.

The Order Procellariformes includes the albatrosses, mollymawks, petrels, storm petrels, shearwaters, and diving petrels. Considerable size diversity exists within this order—from the small storm petrels that weigh 25 grams (g) as adults, to the albatrosses that exceed 10 kg and are among the largest birds capable of flight. The order is composed of four families: (1) Diomedeidea (albatrosses and mollymawks), (2) Procellaridae (petrels and shearwaters), (3) Hydrobatidae (storm petrels), and (4) Pelecanoidea (diving petrels). On the basis of recent molecular data, the Pelecanoidea, which consists of only one genus, should be classified as a subfamily within the Procellaridae.

Procellariformes are oceanic, pelagic species that spend very limited time on land except during nesting or breeding season. They are highly migratory, skilled long-distance fliers who may also be good swimmers. These birds rely on dynamic soaring and slope soaring to cover long distances in flight while conserving energy, and this is particularly true of the larger-bodied albatross species. Long distance migrations, sometimes for hundreds and thousands of miles, are essential for foraging on specialized diets in specific foraging grounds. Procellariformes are present throughout the world, but a distinct predominance of species exists in the Southern Hemisphere.

The Family Diomedeidae, which includes the albatrosses and mollymawks, comprises entirely pelagic oceanic species. Mollymawks are medium-sized albatrosses limited to southern oceans. The taxonomy of this family has undergone frequent revisions and has been the source of ongoing debate. As many as four genera have been proposed, with at least two being widely accepted. The number of distinct species ranges from 13 to 24, depending on taxonomic revisions. The greatest diversity of species occurs in the Southern Hemisphere. It has been hypothesized that the calmer winds found in the doldrums of the equator pose a geographic barrier to the northern dispersal of the albatross species. Many of the albatross species are threatened or at risk of extinction.

The albatrosses have the largest wingspans of any bird and may measure over 11 feet in some species, although the wing profile is only obvious in flight. The majority of flight is energy-efficient gliding, relying on wind speed. During calm wind conditions, albatrosses often choose to sit on the water. The family is extremely colonial, and birds nest in remote, isolated islands, with pairs that remain together for life. Birds feed by floating on the water surface and picking the prey around them.

The Family Procellaridae encompasses the petrels, shearwaters, and fulmars and includes a large number of small pelagic birds with drab plumage, which only come to shore during the breeding season. Most species migrate over long distances. Although found in all oceans, species diversity peaks in the Southern Hemisphere. The taxonomy of the Procellaridae is in a constant state of revision, with differences in opinion on numbers of distinct species (70–80) and genera (12–14). The Procellaridae have stout bodies with short tails, webbed feet, and monochromatic plumage that varies on the amount of black, gray-brown, and white coloration. Most species are colonial and nest in remote oceanic islands, primarily in underground burrows.

The Family Pelecanoidea, the diving petrels, consists of four species in a single genus (*Pelecanoides*) and is likely a subgroup of the Procellaridae and not a distinct family. Diving petrels are auk-like species, with geographic ranges limited to the southern oceans, but are some of the most numerous aquatic bird species. Most diving petrels are small, weighing between 100 and 200 g and have a characteristic black-and-white plumage. Diving petrels feed exclusively by underwater pursuit-diving of fish, squid, crustaceans, and other invertebrate prey. Some species of diving petrels may dive distances exceeding depths of 80 meters (m). Their small, stocky wings are also used for paddling and propulsion in the water.

The Family Hydrobatidae includes roughly 20 species of storm petrels, distributed in seven genera, although the taxonomy is being

TABLE 11-1

Basic Biology and Geographic Distribution

Order	Geographic Distribution	Natural Diet	Lifestyle	Unique Features
Order Podicipediformes				
Family Podicipedidae (Grebes)	Worldwide except Oceania, around freshwater wetlands	Fish, amphibians, insects, aquatic invertebrates	Some species migratory Nest on floating platforms built of aquatic vegetation as isolated pairs, but may be semi-colonial in prime habitat	Weak fliers (some species are flightless), clumsy on land Strong swimmers and divers
Order Gaviiformes				
Family Gaviidae (Loons/ divers)	Northern parts of Northern Hemisphere	Fish, insects, crustaceans	Migratory Breed on fresh water, winter on salt water Nest on ground, close to water	Very adept swimmers and divers, strong fliers
Order Procellariformes	Occur in all seas of the world, majority of species in Southern Hemisphere	Fish, marine invertebrates (cephalopods, crustaceans, insects), plankton, carrion		"Tube" extension of the nares, horny plates on bill
Family Diomedeidae (Albatrosses)	Oceans worldwide except North Atlantic, Arctic, and tropical doldrums		Migratory species Colonial species that nest on oceanic islands	Capable of long distance gliding
Family Procellaridae (Shearwaters, petrels)	Oceans, seas worldwide		Migratory species Colonial species that nest in underground burrows or on ledges of sea cliffs	Pelagic species, rely on primarily gliding
Family Hydrobatidae (Storm-Petrels)	Oceans, seas worldwide except Arctic		Most species migratory Colonial species nest in burrows or rock crevices	Flutter over the water
Family Pelecanoididae* (Diving Petrels)	Southern oceans		Nonmigratory Live in small colonies, nest in burrows or under rocks	Weak fliers, excellent swimmers, strong divers

*Recent data suggest that the Family Pelecanoididae should be a subfamily within the Procellaridae.

TABLE 11-2

Information on Selected Species

Family	Species	Common	Weight (kg)	Distribution	Comments
Gaviidae	*Gavia immer*	Common Loon	2.6–3.0	North America, Iceland, Greenland	
Gaviidae	*Gavia stellata*	Red-throated loon	1.6–2.0	Circumpolar	
Podicipedidae	*Podilymbus podiceps*	Pied-billed grebe	0.25–0.57	Americas	Most widespread American grebe species
Podicipedidae	*Podiceps nigricollis*	Eared grebe	0.20–0.74	North and Central Americas	Most abundant grebe in the world
Diomedeidae	*Phoebastria immutabilis*	Laysan Albatross	2.3–3.5	Northern Pacific Ocean to Hawaiian Islands	
Diomedeidae	*Diomedea exulans*	Wandering albatross	6.5–8.5	Southern Hemisphere	
Procellaridae	*Puffinus puffinus*	Manx Shearwater	0.4–0.5	North Atlantic	
Procellaridae	*Fulmarus glacialis*	Northern Fulmar	0.4–1.0	Northern Hemisphere	
Hydrobatidae	*Oceanites oceanicus*	Wilson's Storm Petrel	0.03–0.04	Worldwide except North Pacific and extreme North Atlantic	May be most abundant seabird worldwide

constantly revised and debated. Storm petrels are small, delicate birds with relatively large heads. In most species, the long legs dangle below the body, and the feet patter on the surface of the water when near the surface, giving the impression of the bird walking on the surface of the water. These pelagic species are found in all oceans. These birds may congregate in very large numbers. Storm-petrels feed primarily on phytoplankton and small invertebrates, with fish being consumed occasionally. Storm petrels are often predated by other birds and by introduced mammalian predators.

The members of the three orders included in this chapter face similar threats to their continued existence: anthropogenic habitat disturbance and modification, pollution, overharvesting, and (4) predation by introduced species. Some families (e.g., Diomedeidae) contain a large number of species at some risk of extinction. For primarily inland aquatic species (loons and grebes), the threats include the draining of wetland areas, human disturbance, pollution (specifically heavy metals and pesticides), and exposure to coastal oil spills during overwintering in marine environments. Marine seabirds are threatened by overharvesting for food, feathers, and oil; accidental bycatch during fishing operations; habitat disturbance of nesting grounds (including guano harvesting); pollution; and predation by introduced species (rats, cats, pigs, mongoose). Introduced predators may destroy or eat the eggs, the chicks, and the adults sitting on nesting sites, causing a significant impact on the populations in a relatively short timespan. Large-scale harvesting of fish by indiscriminate use of explosives, an illegal practice in many countries, may have a significant impact by affecting large groups of birds during feeding congregations. In addition, long-line fishing operations present a specific risk to many Procellariformes, as the birds get accidentally entangled in lines and die by drowning. Many species are prone to ingesting indigestible pieces of waste and garbage created by humans, specifically plastic, and this has been a threat to albatross species and their chicks. The epidemiology of infectious diseases has not been extensively studied in colonies, but the risk of virulent diseases spreading could be significant to the continued survival of some species, in particular those with limited nesting sites or isolated populations. The introduction and spread of foreign infectious diseases to established, naive colonies could have a significant effect at the population level.

UNIQUE ANATOMY

Members of all three orders have webbed feet. In loons and grebes, the feet are positioned caudally on the body and are the primary form of propulsion when swimming. The caudal positioning of the feet often limits the locomotor capabilities of these birds.

Grebes have specialized, lobated digits, which are specifically used for propulsive locomotion in the water. The tarsi are laterally compressed and the anterior digits (2, 3, and 4) have excess "lobes" of skin capable of contracting or expanding as the bird paddles when swimming. The nails are flat on the foot and do not extend like claws. As the foot is advanced in a cranial direction, the lobes are collapsed to minimize the profile and decrease the friction and drag against the water. The lobes are flared as the foot pushes back to form a paddle effect and propel the bird forward during a stroke. As highly adapted divers with caudally positioned feet, grebes have difficulty launching from the water for flight and often must use the rapid movements of their wings to propel themselves across the surface of the water before becoming airborne. Additional adaptation to swimming and diving in loons and grebes are a predominance of nonpneumatic bones and a decreased air sac system, which allow them better control of buoyancy.

Members of the Procellariformes have a characteristic tubelike extension of the nares extending on the dorsal aspect of the bill, well-developed salt glands, and a good sense of smell that is used for both prey detection and recognition of nesting sites. Some species use the large webs on their feet for maneuvering in flight as well as in swimming. All members have well-developed salt glands, which are located dorsal to the orbit and are used in salt homeostasis by excreting salt in drops over the bill. It is an adaptation that allows the ingestion of saltwater and saltwater prey without the need to drink fresh water. Salt metabolism is also regulated by renal excretion. The sense of smell is well developed in Procellariformes, and many species may detect the smell of certain oils in the water for locating food in the open sea. The sense of smell also serves a purpose in locating nesting sites or burrows, and this function may even be more significant than prey detection in some species of diving feeders, which may rely on few olfactory cues for prey location. Many species are well adapted for nocturnal vision, which may be crucial for the underground nesting species and for predator avoidance when returning to nesting sites at night. In some species, nocturnal vision likely is an adaptation for feeding at night.

Most Procellariform species are highly adapted for long distance flight and gliding, an energy-conserving strategy that allows the larger mass birds to travel long distances. The diving petrels are highly adapted for feeding underwater—including adaptations such as auk-like black-and-white cryptic coloration, a gular pouch, and short wings.

With the exception of the Pelecanoididae, Procellariformes may accumulate gastric oils in their proventriculus. This is an adaptation to concentrate lower-volume, high-caloric meals and occurs both by physiologic regulation and specialized anatomy. The oils are not secretory products but, rather, derived from dietary lipids and concentrated by regulating the amount of lipid emptying. The location of the pylorus is an adaptation to retain lipids while allowing water-soluble ingesta to pass through. Lipid emulsifiers of intestinal origin may be refluxed in a retrograde fashion and may play a role in gradual lipid metabolism without entering the intestines.[15] When handled, all species may regurgitate gastric oils, but some species (e.g., northern fulmar, *Fulmarus glacialis*) are capable of forcefully expelling the gastric oil as a defense mechanism.

Most species of grebes (Podicipediformes) routinely ingest their own feathers. Feather ingestion varies with season and type of ingested prey. Ingested feathers contribute bulk to bind undigested stomach contents and allow the formation of uniform, bound pellets. These pellets, which are excreted regularly, may play a role in gastric parasite control[14] and slowing gastric transit time to maximize digestive efficiency.

SPECIAL HOUSING REQUIREMENTS

With the exception of wild birds being temporarily housed for rehabilitation purposes, the birds in this chapter are not routinely housed in captivity. The caudal positioning of the feet of these birds renders them almost incapable of ambulating on land, so they need special accommodations. Birds should be given access to large pools of water, if possible. Providing proper padding to avoid ulcers and pressure sores on the keel and the ventrum is essential. In addition, vigilance to detect the development of pododermatitis and provision of clean, padded substrates to avoid it are essential, since a lot of aquatic or pelagic species are not adapted to spend significant amounts of time weight bearing on their feet.

Salt water should be used when housing marine species, but many species adapt well to housing in fresh water. Holding pools should be designed for ease of cleaning and draining. The large amount of oils in the diets of aquatic birds often soil the water quickly. In temporary housing arrangements, draining and refilling pools at regular intervals help keep the water fresh, but more elaborate filtration systems capable of handling the oils and organic matter produced by these species may be necessary for long-term holding. Attention should be given to concrete or flooring substrates surrounding the pools, as the porous surfaces may be difficult to

disinfect properly. The use of rubber mats may provide surfaces that facilitate cleaning and also provide additional traction and padding. Excessively smooth surfaces may predispose the birds to tendon or joint injuries.

Monitoring ambient temperature is an important factor in the holding environments. Birds that are highly adapted to life in the oceans may not thermoregulate as well in limited spaces or when housed indoors. Stressed birds may generate endogenous heat from muscle activity or continuous attempts to escape, and their bodies may overheat. Birds with compromised feather function may suffer from hypothermia. Social species may be particularly stressed when the birds are held in isolation. If conspecifics are not available, mirrors may be used judiciously.

The propensity of many aquatic birds to regurgitate or expel gastric oils when handled (as in the Procellariformes) warrants special consideration. A bird that gets soiled by its own regurgitant should be properly washed, as the oils may compromise feather function and thermoregulation.

The translocation of hand-reared chicks has been advocated as a tool for establishing safety populations of endangered *Procellariform* species. Between 1997 and 2008, a large-scale trial of relocating chicks of eight petrel species was done in New Zealand with burrow-nesting birds of four genera.[10] The birds were placed in artificial burrows and hand reared until fledged by feeding a pureed diet of canned sardines and water into the crop. This diet worked well for all species regardless of their natural diet, and a majority of birds fledged near the expected natural fledging weight. Some translocation attempts to historical colony sites have been supplemented by continuously playing recorded vocalizations, which attract conspecifics to the site. Likewise, short-tailed albatross (*Phoebastria albatrus*) chicks have been successfully translocated between islands and hand reared to fledging.[2]

FEEDING AND DIET

The birds in these orders feed primarily on other aquatic animals: fish, invertebrates (squid, krill, crustaceans, shellfish, plankton, insects, etc.), or carrion. In general, most rely on calorically dense diets rich in fat, protein, or both. The diversity of species makes a summary of specific diets beyond the scope of this chapter, and readers are encouraged to consult the natural history of particular species of interest. Emaciation and cachexia from malnourishment is the most common cause of morbidity in aquatic birds in captivity.

Loons feed primarily on live fish but will also eat aquatic invertebrate prey. Grebes have diets that may vary seasonally and include fish, amphibians, and aquatic invertebrates. The taxonomic diversity in Procellariformes groups also includes a large variety of feeding preferences. Albatross species differ in the percentage of squid, fish, or carrion that they normally take as part of their diet, and in some instances, the species of squid and fish prey is important. Giant petrels are opportunistic feeders, taking carrion when available (and often relying on the carcasses of marine mammals) but catching live invertebrate or fish prey. The prions (family Procellaridae) are specialized filter-feeders, relying on highly adapted beaks with lamellae along the mandible to eat small food particles from the water.

Artificial diets should be supplemented with thiamine if frozen fish are being fed. Vitamin E is often added as a supplement to aquatic animal diets, but attention should be given to dosage to avoid antagonism of other vitamins. The addition of 25 to 30 milligrams (mg) of thiamine and 100 mg of vitamin E per kilogram of fish is a recommended amount when feeding most species. The addition of salt supplements has been advocated to prevent atrophy of the salt gland in marine birds fed freshwater fish or maintained in freshwater systems for prolonged periods. Diets containing deboned fish, which may be given to sick individuals or chicks, should be supplemented with calcium to avoid metabolic bone disease.

When hand-rearing or giving supplements to chicks, a general approach has been to duplicate adult diets and puree them into liquid forms that may be fed by tube to most altricial species. As discussed earlier, feeding Procellariform chicks these slurries, with canned whole sardines as the base, suggests that this may be a practical and suitable strategy for some species.[3] Precocial species (grebes) may be fed small-sized prey items, including live fish, that are supplemented with insects (crickets, mealworms) to stimulate self-feeding behaviors. Prey size is an important consideration in the bird's acceptance of offered prey.

RESTRAINT AND HANDLING

Birds in these taxa may be handled using basic precautions appropriate for their size, powerful beaks, and sharp nails. The wings must be protected, as even seemingly minor injuries could affect their ability to forage and migrate. Handlers should take precautions to avoid injury to their eyes, hands, and face caused by the birds' powerful beaks. Light gloves and eye protection are sufficient for handling most species, and towels may be used for safe restraint.

The foul-smelling oily secretions regurgitated or expelled when the birds are handled require special consideration. Besides the unpleasant effects on the handlers, the tenacious nature of these oils may cause damage to feather function and thermoregulation if the substance adheres to a bird's own plumage. Beaks should not be held shut without close monitoring, as it may lead to accidental ingestion of regurgitated oils and may restrict respiration. The excretion of salt in marine birds may be impaired by holding a bird's mouth tightly shut.[19]

No specific anesthetic techniques unique to this group of birds exist, although the same considerations as for handling—attention to body temperature, feather function, regurgitation and possible aspiration—are applicable.

SURGERY (COMMON AND SPECIAL CONSIDERATIONS)

Surgical interventions may be necessary for injured birds in rehabilitation settings, and in these cases, basic avian surgical techniques should be followed. Surgical placement of internal telemetry devices, which has found applications for monitoring bird populations and objectively assessing the success of rehabilitation-and-release efforts, is also applicable to the species in these orders. Species-specific differences in surgery-related morbidity and mortality have been suggested, and caution should be used when extrapolating between species. Surgical technique and surgeon's skill, size of device, anesthesia management, species' physiology, temperament, and underlying health or social conditions may all affect the outcome of the surgical placement of these devices. Descriptions of specific surgical techniques in Procellariformes, Gaviiformes, or Podicipediformes have been limited at the time of writing this chapter. In a short (9 day) study in wild western grebes (*Aechmophorus occidentalis*),[4] postoperative survival improved when the surgical techniques improved waterproofing, decreased communication into the coelom, and improved the seal around a protruding antenna. These general considerations are likely applicable to successful outcomes in all aquatic taxa. The specific measures taken in this study included offsetting the body wall incision from the skin incision, applying tissue adhesive glue to the subcutaneous space between the two incisions, applying a waterproof sealant to the skin incision after closure, and using porcine small intestine submucosa at the site of the antenna egress.

PHYSICAL EXAMINATION AND DIAGNOSTICS

Physical examination of these birds should follow general principles of avian medicine. Expediency is essential to minimize handling time and associated stress. Scoring body condition may be difficult until a veterinarian has reached enough familiarity with the anatomy of the pectoral musculature of some of these species. Many healthy birds will feel lighter than their body size and wing span would

TABLE 11-3

Representative Hematology and Biochemistry Parameters

	Laysan Albatross (*Phoebastria immutabilis*)[21]	Waved Albatross (*Phoebastria irrorata*)[13]	Hawaiian Dark Rump Petrel (*Pterodroma phaeopygia*)[21]	Southern Giant Petrel (*Macronectes giganteus*)[20]	Common Loon (*Gavia immer*)[5]
White blood cells ($\times 10^9$ /μL)	19.52 +/– 4.49	5.9 +/– 2.4	10.94 +/– 3.46	4.0 +/– 1.2	17 +/– 6.2
Heterophils ($\times 10^9$ /μL)	10.21 +/– 3.31	3.9 +/– 1.77	3.39 +/– 1.50	2.1 +/– 0.7	See below
Lymphocytes ($\times 10^9$ /μL)	3.80 +/– 1.19	1.8 +/– 0.89	4.36 +/– 2.59	1.2 +/– 0.5	See below
Monocytes ($\times 10^9$ /μL)	0.02 +/– 0.04	0.1 +/– 0.1	0.10 +/– 0.11	0.2 +/– 0.1	See below
Eosinophils ($\times 10^9$ /μL)	4.40 +/– 2.28	0.1 +/– 0.1	1.99 +/– 1.24	0.4 +/– 0.2	See below
Basophils ($\times 10^9$ /μL)	1.09 +/– 0.46	0.0 +/– 0.0	1.11 +/– 0.53	0.006 +/– 0.023	See below
PCV (%)	39 +/– 3	38.2 +/– 5.1	49 +/– 4	47.4 +/– 4.0	47 +/– 4.7
Total Protein (g/dL)		4.5 +/– 0.6	3.1 +/– 0.5	6.2 +/– 1.1	3.9 +/– 0.5
Calcium (mg/dL)	11.5 +/– 4.0	9.8 +/– 1.1	7.0 +/– 1.6	9.1 +/– 1.2	
Phosphorous (mg/dL)	4.3 +/– 1.7	3.4 +/– 0.8	0.8 +/– 0.3	2.4 +/– 2.0	
Glucose (mg/dL)	162 +/– 34	229.4 +/– 35.4	329 +/– 43	285 +/– 39	189.2 +/– 45
Uric Acid (IU/L)	2.5 +/– 0.7	4.4 +/– 2.7	7.3 +/– 4.4	8.9 +/– 2.3	
AST (IU/L)	139 +/– 18	117.6 +/– 46.9	212 +/– 116	93.1 +/– 29.6	
Sodium (mEq/L)		152.7 +/– 6.2		154.5 +/– 15.5	
Chloride (mEq/L)		118.0 +/– 7.7		121.3 +/– 5.8	
Albumin (g/dL)	1.9 +/– 0.2	1.8 +/– 0.2	1.5 +/– 0.2	1.5 +/– 0.3	
Globulin (g/dL)	3.1 +/– 0.3	2.8 +/– 0.5	1.7 +/– 0.4	2.3 +/– 0.86	

Reported reference parameters: Heterophils: 32 +/– 11%, mononuclear cells: 37 +/– 13.7%, eosinophils: 31+/– 11.5%, and basophils: 0%.
g/dL, Gram per deciliter; *IU/L*, international unit per liter; *mEq/L*, milliequivalent per liter; *mg/dL*, milligram per deciliter; *μL*, microliter

suggest on first impression, and objective monitoring of body weight should be used as a baseline. Special attention should be given to plumage (for parasites, waterproofing, flight feather quality); to the tubular structures of the nares (for patency), and to the feet (for evidence of pododermatitis). The open oral cavity should be visualized, and the coelomic cavity should be palpated carefully for evidence of foreign bodies (specifically, ingested pieces of plastic).

Venipuncture may be accomplished using the same landmarks and anatomic sites as in other bird species. Reference ranges are available for very few species, and even these should be used with caution in interpreting health status, as differences in sampling techniques, sample handling, analytic techniques, and laboratory equipment may not be applicable. Table 11-3[5,13,20,21] summarizes relevant blood work parameters for representative species.

DISEASE

General

Reports of diseases affecting members of the orders in this chapter come from distinctly different sources, introducing a sampling bias not unique to these birds. The bulk of the health-specific literature derives from the study of free-ranging populations, data collected during mass mortality or morbidity events, and from rehabilitation efforts. Many pelagic species are not even available for examination until breeding season, and carcasses may not be retrievable, representing only a portion of these birds' life history. The diseases discussed in the following sections of this chapter represent unique diseases of significance, and this is not a comprehensive list of avian diseases that may affect these birds.

Infectious Disease

The dynamics of infectious diseases in colonial nesting pelagic species have not been well studied and are areas of specific interest for the conservation of species and protecting them against the introduction of novel pathogens.

Viral Diseases

A novel herpesvirus (Gaviid herpesvirus-1) was recently described from two stranded common loons suffering from ulcerative tracheitis and showing lesions similar to those caused by infectious laryngotracheitis virus in chickens.[16] As a newly identified virus, its significance in loon populations is currently unknown.

Avian poxviruses have been reported in different species of Procellariformes. Although mosquitoes are the primary vectors of transmission of poxviruses, transmission by contact may also occur during feeding of chicks by infected parents. Manx shearwaters (*Puffinus puffinus*) are affected by cutaneous, self-limiting pox lesions on the feet, which may be confused with the lesions caused by puffinosis virus. Cutaneous pox lesions are common in Laysan albatross (*Phoebastria immutabilis*) chicks during high rainfall but do not have an effect on fledgling success at the population level.[22] Since 2004, cutaneous and diphtheritic pox lesions have been identified in giant petrels (*Macronectes giganteus*) from Antarctica,[17] although the overall impact at the population level and the reasons for the apparent emergence of this disease are not currently known.

Puffinosis is an epizootic viral disease of Manx shearwaters (*Puffinus puffinus*),[19] presumbed to be caused by a coronavirus. Regular epizootics affect general juveniles near fledging, causing high mortality after a period of blisters on the web of the feet and, sometimes, conjunctivitis. It is thought that the virus overwinters in other species such as fulmars and gulls, suggesting that other Procellariformes are susceptible. In one instance, it was suspected that the black-browed albatross served as an intermediate host between shearwaters and penguins.[5]

Serological evidence of adenoviral infections is common during health surveys of aquatic birds,[5] but the significance is often not clear, since links to clinical disease are missing and because most serologic testing has some limitations. Antibodies to avian influenza viruses and evidence of viral presence are common in seabird colonies. Some strains of avian influenza may be present at enzootic levels and circulate in seabird colonies, often being shared between species, but documentation of the dynamics and epidemiology of

these viruses is limited. The globalization of trade and travel and related agricultural practices carry the potential to increase contact between domestic animal strains (poultry, swine, human) of influenza and those present in seabird colonies, warranting special vigilance.

Bacterial Diseases

Chlamydophila psittaci is a common zoonotic concern cited in aquatic bird populations and a concern in colonial nesting species. Between 1930 and 1938, 174 cases of human infection with *C. psittaci* were reported in the Faroe Islands.[6] These cases were characterized by high human mortality, prompting an investigation that linked human infections to the preparation of wild-caught juvenile fulmars for cooking and a ban on fulmar consumption until 1954. A recent survey has shown that *C. psittaci* is still endemic in the Faroe Island fulmar population at a relatively high (10%) prevalence, but human infections are not common despite the resumed harvesting of fulmars for human consumption at high numbers (estimated at 50,000 to 100,000 juvenile fulmars per year).[6] *C. psittaci* should be considered a zoonotic concern in working with seabirds of unknown status and of specific concern in Procellariformes.

Avian cholera (*Pasteurella multocida*) has been reported in a southern Giant petrel[9] and has been isolated from grebes,[19] in which it may occur concurrently with other diseases. *Salmonella* bacteria are often isolated from carnivorous and piscivorous birds. *Salmonella* spp. (multiple serotypes) have been documented in overwintering loons in Florida and in eared grebes. Chronic salmonellosis has been documented in an eared grebe (*Podiceps nigricollis*),[3] and morbidity and mortality likely occur with certain strains in all species.

Fibrinous airsacculitis caused by infections with *Nocardia asteroides* has been reported in albatrosses. Air sac lesions are tightly adherent fibrinous plaques or exudates adhering to the wall of the air sacs. Nocardial airsacculitis may be seen as incidental pathologic findings in Laysan albatross chicks.[18]

Fungal Diseases

Respiratory infections with aspergillus have been commonly reported in overwintering loons. In addition, many aquatic birds are susceptible to aspergillus infections during periods of stress and during rehabilitation. Fatal fungal nephritis was documented in a gray headed albatross.[19]

Parasitic Diseases

Most reports of parasites of the aquatic birds in these orders are mentioned as incidental findings or reported in the ecologic or evolutionary science literature. The clinical significance of parasite infestations is not often clear, but special attention should be paid to birds with concurrent disease, as the parasites may impose an additional physiologic burden for recovery. A listing of parasites or an in-depth discussion of parasite diversity are beyond the scope of this chapter. Ectoparasites (lice and mites) are common findings, and specialized parasites of feathers, nares, and respiratory tract exist, often adapted and co-evolved with their host species. Some topical ectoparasite treatments may affect a bird's waterproofing ability, and caution is warranted when selecting products.

In grebes, intestinal, ventricular, and proventricular nematodes are commonly reported. The parasites of notable clinical relevance are *Eustrongylides tubifex* and *Contracaecum* spp., including *C. ovale*,[19] which shows high specificity for Podicipediformes. *E. tubifex* may cause verminous coelomitis in many bird species, including grebes and loons, and has an indirect life cycle that requires two intermediate hosts. Cestodes are very common in grebes. For instance, in the western grebe, 11 species of cestodes have been documented, but no obvious clinical disease.

Intestinal trematodes are a common finding in debilitated wild loons or in birds affected by concurrent disease, including toxicities. *Cryptocotyle* spp. is often seen in common loons in the maritime provinces of Canada.[1] Renal coccidiosis, caused by *Eimeria gaviae*, has been reported in a common loon.[19]

Few clinically significant parasites have been documented in Procellariformes, which is likely a function of their pelagic lifestyle and not of absence of helminthes. A case report of *Anisakis* sp. causing proventricular perforation in a greater shearwater (*Puffinus gravis)* showed that this common parasite of marine mammals may be a lethal aberrant host in this species.[12]

Limey disease is caused by a renal coccidian (*Eimeria* spp.) that affects the flightless chicks of the Tasmanian mutton bird (also known as short-tailed shearwater; *Puffinus tenuirostris*). Affected birds have "limey" staining and pasting of the vent and poor body condition.[19] These clinical signs are neither unique nor specific to coccidian nephritis, and other diseases may be lumped with the common name of this disease if gross signs are the only basis for a diagnosis.

Noninfectious Disease

Large-scale mortality events of eastern grebes have been periodically reported in North America, and the cause is often undetermined, as in a 1992 mass mortality event involving over 150,000 eared grebes (*Podiceps nigricollis)* in the Salton Sea in California.[7] It has been theorized that weather conditions during migration may play a role in these events, but the grebes' tendency to congregate in large numbers prior to migration, limited agility in flight, and flying at night lead to interspecific collisions and crashes of large groups of birds at once.

During their coastal migration, loons and grebes may become victims of oil spill events. Procellariformes are also susceptible to damage by oil, but their choice of offshore feeding sites may protect them. The success of operations that rescue, stabilize, treat, and rehabilitate oiled grebes and loons for return to the wild depends on many factors, and results may be variable. Besides the physical damage caused to the feathers and the integument, oil negates the thermoregulatory and waterproofing capabilities of an aquatic bird's plumage, leading to energy lost through loss of body heat. Accidental ingestion of oil may have toxic systemic effects. A mass stranding of 14 species of birds, including loons and grebes, was attributed to surfactant-like proteins produced on the water surface by organic matter associated with a red-tide event caused by the dinoflagellate *Akashima sanguinea*.[8]

Albatrosses, petrels, and other marine fish-eating animals are susceptible to accidental death by drowning caused by fishing operations. Line fishing is particularly dangerous to birds that follow ships in their search of fish and may get caught and dragged by the fishing line, eventually dying by drowning. The impact at the population level is difficult to quantify.

Accidental ingestion of plastic has long been recognized as a problem in Laysan albatrosses in the Hawaiian Islands but has now been recognized as a worldwide concern that may affect many seabird species. Direct morbidity or mortality from mechanical obstruction may occur, but ingested plastic can also cause chronic physiologic stress as a result of malnourishment.

Nutritional Diseases

Emaciation and cachexia are common signs in many aquatic bird species, specifically loons, presenting for rehabilitation. The underlying cause is often not found.

Metabolic bone disease was documented in two northern royal albatross chicks (*Diomedea sanfordi)* that were being hand reared shortly after hatching and fed an unsupplemented diet of primarily (deboned) fish filets and gastric oil harvested from sooty shearwaters.[11] After these cases, chicks have been successfully hand reared on a diet of whole fish and no gastric oil and have showed no evidence of fibrous osteodystrophy.

Toxicities

Mercury has been identified as a concern for the survival of common loon populations in northern United States and the Great Lakes region. After entering a water source, elemental mercury is converted into a biologically active form by bacteria. This biologically active

TABLE 11-4

Reproductive Parameters of Select Species

	Common Loon	Least Grebe	Wandering Albatross	Wilson's Storm Petrel	Northern Fulmar
Latin name	*Gavia immer*	*Tachybaptus dominicus*	*Diomedea exulans*	*Oceanites oceanicus*	*Fulmarus glacialis*
Family	Gaviidae	Podicipedidae	Diomedidae	Hydrobatidae	Procellaridae
Sexual maturity	1 year	1 year	8–9 years	Unknown	8–10 years
Eggs per clutch	1–3	4–6	1	1	1
Incubation period	28 days	21 days	75–82 days	39–48 days	52–53 days
Fledging age	56 days	Unknown	278 days	70–75 days	46–51 days
Nest	Mound of plant material around lakeshore	Floating nest made of vegetation in shallow water	Mound of mud and vegetation on ridge	Underground burrows	Grass ledge or ground vegetation

form, methylmercury, enters the food chain and accumulates in fish. Inland piscivorous birds such as loons and grebes, are at high risk of mercury exposure. Exposure varies according to local concentrations in the water as well as lake conditions. Although overt signs of mercury toxicity have been difficult to demonstrate, mercury may have reproductive effects at the population level, and some evidence suggests effects on eggs, chicks, and hatchability.

Lead poisoning has been documented in common loons and Pacific loons. Birds ingest toxic levels of lead derived from fishing sink weights or from spent lead shot. Clinical signs are primarily neurologic but may be limited to subtle paresis or partial paralysis.

Birds of all three orders are susceptible to the biotoxins produced by algal blooms and by domoic acid toxicity and have been affected in mass mortality events affecting multiple species. Avian botulism type E has been reported in grebes and in loons. Botulism type C has been seen in grebes.

REPRODUCTION

Most knowledge on the reproductive biology of the birds in these orders comes from observations and studies of free-ranging species. Table 11-4 summarizes biologic data on some common species.[19]

PREVENTIVE MEDICINE

Because many grebes and loons are prone to aspergillosis during periods of stress or during prolonged captivity, the use of antifungals has been advocated as a prophylactic treatment when working with these species. It is reasonable to assume that this practice is also applicable to Procellariformes. Pharmacokinetic data are extrapolated from other species, and the Sphenisciformes may be the best available model for Procellariformes.

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