43
SIRENIAN MEDICINE

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Contents

Introduction

The order Sirenia is comprised of two families of herbivorous aquatic mammals, Dugongidae (dugong, extinct Steller's sea cow) and Trichechidae (Amazonian manatee, West African manatee, and two subspecies of West Indian manatee [Antillean and Florida; **Table 43.1**]).

Sirenians' closest taxonomic relatives are elephant (Proboscidae) and hyrax (Hyracoidea). All extant species are listed as vulnerable by the International Union for Conservation of Nature (IUCN 2016). Much of this chapter will focus on the Florida (FL) manatee. Detailed information on dugongs is available elsewhere (Marsh, Eros, and Webb 2000; Woods, Ladds, and Blyde 2008).

Natural History

Sirenians are adapted for tropical and subtropical climates, with Florida, USA, being at the northern extreme of their range (Reep and Bonde 2006). FL manatees inhabit coastal areas of the southeastern United States, primarily FL, with their range extending to Texas (USA) and the mid-Atlantic US coast during the summer. Recent population estimates in FL are approximately 6,350 individuals (95% CI: 5,310–7,390; Martin et al. 2015). Florida manatees are currently listed as "threatened" under the US Endangered Species Act and are protected under the US Marine Mammal Protection Act. Manatees inhabit marine, brackish, and freshwater environments typically at depths of 1–4 meters (3–12 feet), coinciding with coastal seagrass beds and rivers (Reep and Bonde 2006). They have no predators, low genetic diversity, low metabolic rates, and life spans of more than 50 years (Reep and Bonde 2006). FL manatees are semisocial, except for cows and calves that form strong bonds for 1–2 years (Hartman 1979; Larkin 2000).

Table 43.1 Family Sirenia

Genus and Species	Common Name	Length, Nose to Tail Tips (m)	Mass (kg)	Distribution	Sources
Dugong dugon	Dugong	A: 2.7 avg., up to 3.3 C: 1–1.3	A: 250–300 avg., up to 400 C: 20–35	Coastal waters of Indo-Pacific	Murphy 2003; Nowak 1999; Odell 2002; Reynolds and Odell 1991
Trichechus senegalensis	West African manatee	A: 3–4	A: <500	Coastal waters, rivers, and lakes of west-central Africa	Domning and Hayek 1986; Murphy 2003; Nowak 1999; Odell 2002; Reynolds and Odell 1991; Walsh and Bossart 1999
Trichechus inunguis	Amazonian manatee	A: 2.8–3	A: 450–480	Freshwater rivers and lakes of Amazonian basin	Domning and Hayek 1986; Murphy 2003; Nowak 1999; Odell 2002; Reynolds and Odell 1991; Walsh and Bossart 1999
Trichechus manatus	West Indian manatee (2 subspecies)			Saltwater, brackish water, and freshwater	Converse et al. 1994; Domning and Hayek 1986; Murphy 2003; Nowak 1999; Odell 2002; Reynolds and Odell 1991; Walsh and Bossart 1999
T.m. manatus	Antillean manatee	A: 1.85–2.7, up to 3.5	A: max 1000	West Indies, Caribbean, coastal waters and rivers of Mexico, Central American, northeastern South America	
T.m. latirostris	Florida manatee	A: 2.7–4, avg. 3 C: 1.2–1.4	A: 400–1,775, avg. 400–600 males, max 1,600 females C: 18–45, avg. 30	Coastal waters and rivers of southeastern United States	

Source: Adapted from Nolan, E. C., and M. T. Walsh, Sirenians (manatees and dugongs), in *Zoo Animal and Wildlife Immobilization and Anesthesia*, 2nd edition, ed. G. West, D. Heard, and N. Caulkett, 693–702, Ames, IA: John Wiley & Sons, Inc., 2014.
Note: A = adults; C = calves at birth.

Rescue and Rehabilitation

An active rescue, rehabilitation, and release program coordinated by the US Fish and Wildlife Service (USFWS) has been in place for FL manatees since 1974 (Reep and Bonde 2006; Adimey et al. 2016). Between 1973 and 2014, 1,619 manatees were rescued (assisted on site and released, or brought into a facility for rehabilitation), and 526 individuals were released after rehabilitation (US Fish and Wildlife Service 2012, 2014). **Table 43.2** lists the numbers and reasons for rescue of FL manatees between 2005 and 2015 with outcomes; data from 2011–2015 are preliminary. Anthropogenic causes were the primary reasons for rescue. This is also true for *T. manatus* in Puerto Rico (Mignucci-Giannoni et al. 2000). Adimey et al. (2016) evaluated postrelease tracking of individuals released from the FL program over a 26-year period and described several variables likely to predict success or failure to acclimate into the wild after release, including age at time of rescue and duration of time in rehabilitation. Similar rescue and rehabilitation programs have been established for West Indian and Amazonian manatees in Central and South America (Negrão et al. 2007; Adimey et al. 2012).

Anatomy and Physiology

Manatees are large and fusiform with a round, dorsoventrally flattened tail fluke or paddle; in contrast, dugongs have a laterally compressed peduncle and forked flukes. FL manatees are the

Table 43.2 Florida Manatee Rescue, Rehabilitation, and Release in the United States between 2005 and 2015* and Outcomes of Rescue Response

	Total	Unsuccessful Capture	Died	Nonreleasable	Conditionally Releasable	Released	Unknown
Watercraft injury	188	1	112	1	5	69	0
Entanglement/entrapment	293	32	6	1	0	254	0
Cold stress syndrome	147	1	51	1	1	93	0
Red tide	36	4	8	0	0	24	0
Unsuitable habitat	14	0	0	0	0	14	0
Poor body condition	19	0	7	0	0	12	0
Orphan calf	99	0	51	0	11	35	2
Buoyancy disturbance	14	0	4	0	0	10	0
Tidally stranded	70	0	0	0	0	70	0
Other	73	2	19	0	0	52	0
Total	953	40	258	3	17	633	2

Source: Adapted from USFWS, *Manatee Rescue, Rehabilitation, and Release Program Database*, US Fish and Wildlife Service Files, www.fws.gov/northflorida/Manatee/Rescue-Rehab/manatee-rescue-rehab.htm [accessed March 24, 2017], 2014.
*Data from 2011 to 2015 are preliminary.

largest of the extant Sirenian species (**Table 43.1**), and females are typically larger than males. Males have a genital opening just caudal to the umbilicus, while female genital openings are just cranial to the anus. Males also often have longer pectoral flippers for grasping females during mating. Gross features described by Reep and Bonde (2006) include densely mineralized bones (pachyosteosclerotic) to aid in buoyancy control, a thin epidermis and very thick dermis, highly tactile lips that contain perioral bristles (modified vibrissae), a flexible and prehensile upper lip, and dorsally located nostrils with valves that close during diving. Manatees (but not dugongs) have only six cervical vertebrae (Buchholtz, Booth, and Webrink 2007).

Ocular structures have been described in detail (Hartman 1979; Harper, Samuelson, and Reep 2005; Mass and Supin 2007; McGee et al. 2009; Samuelson et al. 2009 and 2011). Eyes are small and nearly spherical. Florida and Antillean manatees have vascularized corneas (Harper, Samuelson, and Reep 2005; Ambati et al. 2006; Mass and Supin 2007), whereas dugongs do not. Corneal vascularization does not appear to impact vision (Harper, Samuelson, and Reep 2005; Mass and Supin 2007). *T. manatus* have modified ocular glands (Samuelson et al. 2009) and prominent conjunctival-associated lymphoid tissue (Samuelson et al. 2007, 2011; McGee et al. 2008), and lack a traditional nasolacrimal system (Samuelson et al. 2007). Extraocular muscles are modified and unique; the palpebral fissure closes in a small rounded point similar to a miotic pupil (Samuelson et al. 2009; see **Chapter 23**).

Manatees have molariform teeth and lack canines and incisors, which are replaced by gingival plates (Reep and Bonde 2006). All dugongs have tusks (incisors), but these only erupt at puberty in males and in some very old females. Manatees (but not dugongs) undergo molar progression, whereby the most rostral teeth, as they wear, are slowly replaced by new teeth behind, with an unlimited supply (see **Chapter 22**). Sirenia are hindgut fermenters, and both manatee and dugong gastrointestinal (GI) transit times average 7 days. Detailed descriptions of manatee and dugong GI tracts are available (Lemire 1968; Marsh, Heinson, and Spain 1977; Reynolds 1980; Reynolds and Krause 1982; Snipes 1984; Langer 1988; Colares 1994; Reynolds and Rommel 1996). Notable features include a discrete accessory digestive gland (cardiac gland) in the stomach, unique gastric mucosal histology and glands, large duodenal ampulla and diverticulae, a large cecum with diverticulae (horns), and a prominent colon.

The manatee thoracic system is well detailed by Rommel and Reynolds (2000). Manatees have two single-lobed, elongate lungs that lay dorsally, each within its own horizontal pleural cavity. The diaphragm is uniquely in a horizontal plane, dorsal to the heart, does not attach to the sternum, and extends the entire length of the body cavity, roughly 40% of the total body length. It attaches medially to bony projections extending ventrally from the vertebral bodies forming two distinct hemidiaphragms. The transverse septum is a separate structure oriented in a transverse plane, perpendicular to the diaphragm, which separates the heart from the liver and viscera. The heart of the FL manatee and the dugong is dorsoventrally flattened and has a distinct external separation between the ventricles, often occupied by fat, resulting in a double ventricular apex (Rowlatt and Marsh 1985; Siegal-Willot et al. 2006).

Reproduction

FL and Amazonian manatees and dugongs are seasonal breeders (Larkin 2000; Sheldon et al. 2012). FL manatees have an estrous cycle of 28–42 days (Larkin 2000). Sexual maturity typically occurs at 3–5 years of age but may be related to size rather than age (Walsh and de Wit 2015). Gestation averages 14 months (Larkin et al. 2007), and calves are dependent on their cows for approximately 2 years (Reep and Bonde 2006). Transplacental transfer of immunoglobulins has been documented in *T. manatus* (McGee et al. 2013). Single offspring are usual with a calving interval of 2.5–3 years; twinning is rare (Reep and Bonde 2006). Neonates nurse from axillary teats underwater for 3–5 minutes every 1–2 hours (Reep and Bonde 2006). Manatees are polygynous, and herds of males often pursue females (Larkin 2000), in some cases resulting in mortality of the females from myositis and exhaustion (Harr et al. 2008; Walsh and de Wit 2015). Dugongs become sexually mature at 10 years of age and have a 13-month gestation (Walsh and de Wit 2015). Access these additional references for further information on reproduction (Marsh, Eros and Webb 2000; Rodrigues et al. 2008; Tripp et al. 2008; Chávez-Pérez et al. 2015; see **Chapter 10**).

Husbandry

Minimum housing and care requirements for Sirenia housed in facilities in the United States are listed in the Animal Welfare Act and Animal Welfare Regulations (US Department of Agriculture (USDA) 2013). Manatees have been housed successfully in various pool designs, water volumes, and depths. FL manatees can be housed in freshwater or saltwater, but animals housed in saltwater have thrived when provided a source of freshwater for drinking. Water temperature should be kept between 25 and 30°C (77–86°F). Filtration systems must be able to remove large food and fecal bioloads. Chlorine (<1 part per million) and ozone can be used as for other marine mammal habitats (see **Chapter 31**), though eye damage may occur from excess oxidant use. Facilities should have a medical pool, ideally with a false bottom floor to lift animals out of water for medical access, or with the ability to be drained and filled rapidly.

Sirenia are obligate herbivores that feed on a variety (at least 60 species) of freshwater and marine plants at all depths within the water column. Nutritional content differs between commercially produced lettuce and natural aquatic vegetation (Siegal-Wilott et al. 2010). However, diets of mixed greens (lettuces, spinach, cabbage, kale), commercially produced herbivorous primate pellets (Monkey Diet, PMI International, Inc., Brentwood, MO, USA), and a variety of other fruits, vegetables, grasses, and hays consumed by terrestrial herbivores have been successful in captivity. A manatee-specific pellet diet has been produced and fed to FL manatees (Cardeilhac et al. 2003). Food should be offered at multiple levels within the water column to include submerged feeders, floating food, and partially submerged feeders along enclosure walls. FL manatees spend 4–8 hours per day eating, and adults consume 5–10% of their body weight daily (Reep and Bonde 2006); thus, food should be available 24 hours a day for animals in human care. Appropriate consumption varies based on age and growth. Obesity is common in overfed animals, so weights and body condition need to be monitored regularly to adjust diet as necessary. For a more detailed discussion of manatee diets and feeding strategies in captive settings, see Walsh and Bossart (1999).

Manatees often respond well to the presence of other manatees, which may relieve anxiety as well as encourage anorexic animals to eat (Davis unpubl. data; Walsh and de Wit 2015). Manatees are not territorial or aggressive (Reep and Bonde 2006) and can usually be housed in groups (3–6 animals) pending sufficient pool size, although care must be taken to ensure males have not reached sexual maturity.

Handling and Restraint

Sirenians are powerful and can cause injury to personnel if not handled appropriately. Manatees can thrust their paddles dorsoventrally or side to side. In-water captures should only be attempted by experienced individuals. Handling for medical or husbandry procedures needs to be done with the animals out of water. Place animals on thick closed-cell foam in sternal recumbency. Place a large piece of closed-cell foam across the animal's caudal body and paddle, and have several people lean on the foam for added restraint. Attempts should not be made to restrain an animal that is on its back, due to a high risk of handler injury from the paddle. Many manatees are calm when removed from the water; basic diagnostic and husbandry procedures can often be performed with mild restraint. Anesthesia and sedation of Sirenia are discussed in **Chapter 26**.

Physical Examination

A complete history should be obtained (when available) and a physical exam performed. Observe the animal in the water, noting any abnormalities in buoyancy, attitude, activity level, positioning in the water column, swimming and diving abilities, and respiratory rate and character. A manatee can hold its breath for long periods, and the normal respiratory rate is variable according to activity level, but 3–5 breaths per 5 minutes is typical.

While dry-docked, the clinician should assess body condition, both dorsally and ventrally. Straps can be placed under the axilla and cranial to the peduncle to facilitate rolling the animal to determine sex and examine the ventrum (see **Chapter 38**); care should be taken with animals that have fractured ribs. Malnourished animals have a distinct neck due to loss of nuchal fat ("peanut-head"), as well as prominent scapulae, hips, and spine (**Figure 43.1**), and a flat (thin) or concave (very thin) ventrum with the occasional presence of longitudinal skin folds (emaciated).

The physical exam also needs to include a thorough oral exam with digital palpation of the molars, and thoracic and abdominal auscultation. Healthy FL manatees have a normal sinus rhythm. Calm adults have heart rates of 40–60 beats per minute (bpm), while calf heart rates are 60–75 bpm (Siegal-Willmot et al. 2006; Wong et al. 2012). Percussion can be useful in evaluating the GI tract. Hindgut fermentation produces large volumes of colonic gas; gas and peristaltic intestinal sounds are normal findings in a healthy manatee. The absence of these findings is abnormal. Fecal character should be assessed; normal stool is formed, but not dry. If no feces are available for evaluation, perform digital rectal palpation.

Figure 43.1 Emaciated FL manatee (left) and the same manatee after rehabilitation and in good body condition (right). (Photo courtesy of Dr. Ray Ball, Tampa's Lowry Park Zoo.)

Diagnostic Techniques

Blood Collection

Veins used for blood sampling are illustrated in **Figure 43.2**. Blood is collected from the brachial vascular bundle, accessed via the interosseous space between the radius and ulna. The vasculature can be accessed from a medial or lateral approach to the pectoral flipper. Blood vessels are not visible, and anatomical landmarks are used as follows: the flipper is firmly restrained, and the elbow and carpal joints are identified; the radius and ulna are palpated, and the space between them located; the middle portion of the flipper midway between the elbow and carpus is thoroughly surgically scrubbed with alcohol and an antiseptic. Insert an 18- to 20-gauge, 1- to 2-inch needle, attached to an extension line and syringe (or vacutainer), between the radius and ulna (**Figure 43.3**).

A 25- to 21-gauge butterfly set with a 3/4-inch needle can be used for calves, with the lateral aspect being easier to access, due to minimal abduction of the pectoral flipper. Manatee calf blood can clot quickly, and it is sometimes necessary to heparinize the needle prior to collection. Blood samples can also be collected from the caudal vascular bundle that runs just ventral to the vertebral column in the paddle. In an awake juvenile or adult animal, this location is difficult to access safely due to manatees' propensities for thrusting their paddles ventrally when positioned on their backs, so it is more commonly used in anesthetized or very ill animals.

Fecal Sampling

Freshly passed fecal samples can be collected for cytology, occult blood testing, and parasitology screening. If culture for enteric pathogens is warranted (or no fresh sample is available), an uncontaminated sample can be collected by passing a lubricated small flexible tube a short distance into the rectum. Gastric samples can be collected for cytology and culture by passing a standard soft plastic foal or small equine gastric tube through the nares or oral cavity into the stomach. Urethral catheterization for urine collection is difficult due to anatomical configuration and is not routinely performed. Opportunistic urine samples can be collected by placing a small, flat, collection receptacle (such as a clean Frisbee) under the urogenital opening of a dry-docked manatee during the exam, and waiting (see **Chapter 38**). The application of pressure on the abdomen cranial to the vulva in females, or caudal to the genital opening in males, may be useful to stimulate urination.

Radiography and Ultrasonography

Radiographs can aid in diagnosis of fractures, pneumothorax, pneumonia, and GI disorders. Most manatees will rarely lie still when placed on their backs; thus, dorsoventral (DV) views are easier to obtain than ventrodorsal (VD) views. In adult manatees, size can pose challenges for obtaining orthogonal views, and often, only DV views are feasible. Lateral views in smaller animals are usually feasible. Ultrasonography can be useful for pregnancy diagnosis; evaluation of subcutaneous abscesses, kidneys, and urinary bladders; and echocardiography. It can also aid in guiding thoracocentesis in cases of pneumothorax or pleural fluid accumulation. Advanced imaging (MRI or CT) can be considered for smaller individuals and may or may not require sedation, depending on the disposition of the animal (see **Chapters 24 and 26**).

Endoscopy

Flexible endoscopy has been used successfully for gastric, colonic, and reproductive tract evaluation, and hysteroscopy has been described (Hall et al. 2012). Slow GI transit time limits GI tract visualization, though gastric ulcers may be detected with preprocedural fasting. Rigid thoracoscopy has been successfully performed to confirm pyothorax or evaluate pleural and lung surfaces. Dopplers (2 MHz) can be used to monitor heart rate during health assessments. Electrocardiography has been described in both subspecies of *T. manatus* (Siegal-Willmot et al. 2006) with techniques similar to those for domestic animals. Compared with other large terrestrial and aquatic vertebrates, manatees have prolonged PR and QT intervals, and differences in some parameters are seen when comparing adults and calves (Siegal-Willmot

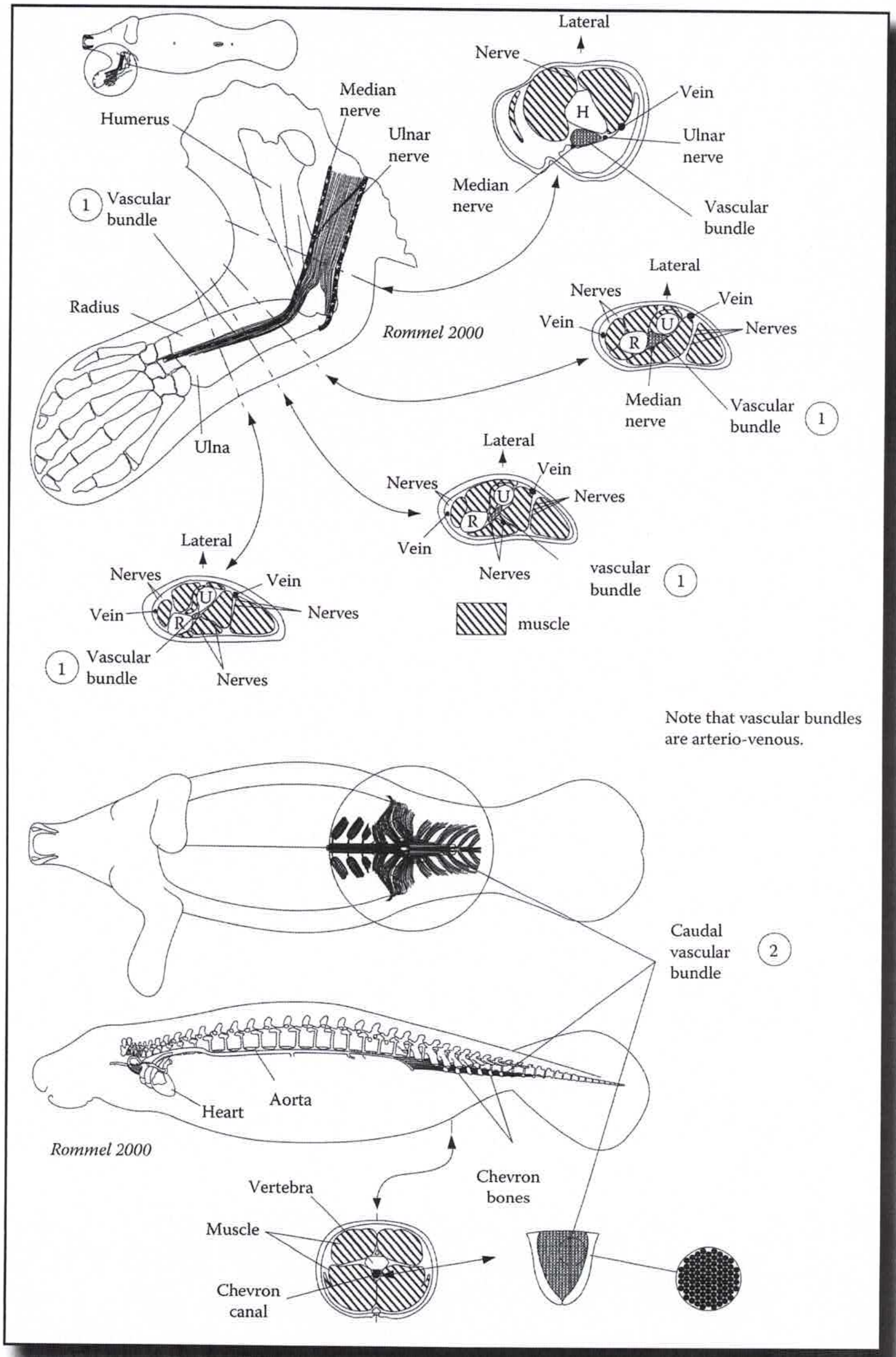

Figure 43.2 Veins used for blood collection in the manatee. (Courtesy of S. A. Rommel.)

Figure 43.3 Blood collection from the interosseous space between the radius and ulna in a FL manatee. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

et al. 2006). Parameters for echocardiography have been established (Gerlach et al. 2013). See **Chapter 25** for additional information.

Clinical Pathology

Standard processing of blood samples in manatees should include a complete blood count (CBC), serum chemistry panel, fibrinogen, erythrocyte sedimentation rate (ESR), and, when possible, D-dimers and serum amyloid A (SAA). In neonates and calves, cold-stressed animals, and critically ill patients, blood glucose should be assessed upon presentation with a portable glucometer. A portable blood gas analyzer such as an i-STAT or Element POC (Abbott, Princeton, NJ, or Heska Corp., Fort Collins, CO, USA) may aid in evaluating critical patients, or as part of monitoring during general anesthesia or health assessments (Fauquier et al. 2004; Meegan et al. 2009).

Detailed descriptions of manatee hematology and serum chemistry analytes can be found elsewhere (see **Appendices 1, 2, and 3**; see **Chapter 38**). A few important features of manatee hematology include larger erythrocytes and lower erythrocyte counts than most domestic mammals, heterophils (rather than neutrophils) that stain positive for myeloperoxidase, and total leukocyte counts that are slightly lower than in most domestic mammals, with approximately equal numbers of heterophils and lymphocytes (Keil and Schiller 1994; Harvey et al. 2009). There are statistical differences in analyte levels among age classes, free-ranging and captive individuals, and genders (Harvey et al. 2007, 2009). Total leukocyte counts may only increase modestly in the face of illness and are not sensitive indicators of inflammation. Serum amyloid A is a highly sensitive indicator of inflammation in FL manatees (Harr et al. 2006; Cray et al. 2013), and a reference interval has been established using an automated assay (Cray et al. 2013). Recent research has characterized coagulation profiles and utilized thromboelastography to determine coagulation factors in healthy free-ranging FL manatees (**Table 43.3**) and individuals with various disease states (Gerlach et al. 2015; Barratclough et al. 2016a and 2016b). Thromboembolic disease (Ball 2013) and disseminated intravascular coagulation (DIC) have been described in FL manatees, with DIC being most common in cases of trauma and cold stress syndrome (Barratclough et al. 2017).

Table 43.3 Coagulation Factors of Healthy Florida Manatees (*Trichechus manatus latirostris*)

	D-Dimer (ng/ml)	Fibrinogen (mg/dl)	PT (seconds)	PTT (seconds)	Platelets ($\times 10^3/\mu l$)
	Healthy FL Manatees Released (after Rehabilitation; n = 29 unless otherwise stated)[a]				
Mean	134	350 (*n* = 22)	9.5	15.9	333 (*n* = 15)
SD	211.29	53	1.9	16	267
95% CI	23–103	322–359	8.7–9.5	11.2–12.7	166–451
	Healthy Free-Ranging FL Manatees (n = 40)[b]				
Mean	142	369	10.7	9.5	
SD	122	78.8	0.5	1.5	
90% CI	110–174	348–390	10.6–10.8	9.1–9.9	

[a] Gerlach et al. 2015.
[b] Barratclough et al. 2016a.

Urinalysis

Urinalyses and urine chemistry panel reference ranges have been reported in FL manatees living in freshwater and saltwater (Manire et al. 2003).

Other Clinical Pathology

The immune system has been characterized in detail (Bossart 1999; Smith et al. 2006; McGee et al. 2011; Ferrante et al. 2015; Ferrante and Wellehan 2015; see **Chapter 11**). A variety of other health investigations are available for reference (Ortiz, Worthy, and Byers 1999; Ortiz, MacKenzie, and Worthy 2000; Varela and Bossart 2005; Ortiz and Worthy 2006; Stavros, Bonde, and Fair 2008; Takeuchi et al. 2009; Tripp et al. 2011; de Wit et al. 2013, 2016; Siegal-Willmott et al. 2013).

Neonatology and Hand-Rearing

Orphaned calves often present to critical care facilities dehydrated and hypoglycemic, and occasionally hypothermic (**Figure 43.4**). Initial assessment involves, at minimum, blood glucose, physical exam, and rectal temperature. Hypoglycemia and dehydration should be corrected with fluid and dextrose supplementation. Glucose levels less than 40 mg/dl require dextrose supplementation. Gastric intubation with dextrose and oral electrolyte fluid supplements can be used when the condition is mild, while intravenous (IV) administration may be indicated in severe cases (≤30 mg/dl; **Figure 43.5**).

However, due to the blood vessel anatomy, IV infusion into a single vessel, particularly in a calf, is challenging. Nonetheless, attempts should be made to administer IV dextrose in clinically affected animals. Manatee immunoglobulin G may be given via gastric intubation and IV administration (both are given to orphans upon arrival at SeaWorld Orlando), as levels may be low in calves in rehabilitation (McGee et al. 2013). When possible, collect a blood sample upon admission during standard processing. Within the first 24–48 hours of arrival, perform whole body radiographs and fecal sampling (cytology and occult blood testing). Broad-spectrum antibiotics are commonly used prophylactically.

Once hydration and hypoglycemia have been addressed, institute nutritional support. See **Chapter 30** for a detailed discussion on hand-rearing and artificial milk formulas for FL manatees. Historically, survival rates have been poor in orphaned calves, particularly if weights are <30 kg (66 lb) on admission (Campbell et al. 1990; Croft and Tollefson 2014); GI complications associated with artificial milk formulas have been implicated as part of the reason for poor success (Croft and Tollefson 2014). GI disorders frequently seen in orphaned calves include diarrhea, constipation, decreased appetite, leukocytes in fecal cytology, fecal occult blood (Croft and Tollefson 2014), and less commonly, necrotic enterocolitis. The most severe complication

Figure 43.4 Emaciated, hypothermic, hypoglycemic FL manatee calf upon arrival at a rehabilitation facility. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

Figure 43.5 (Left) Orogastric intubation of a FL manatee calf with fluids, dextrose, and electrolytes. (Right) Intubation of a subadult manatee with gruel. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

is *pneumatosis intestinalis* (PI; gas within the wall of the GI tract; **Figure 43.6**; Walsh, Murphy, and Innis 1999; Croft and Tollefson 2014; Neto et al. 2016), which can occur secondarily to conditions such as necrotic enterocolitis, GI obstruction, GI ischemia, or sepsis (Pear 1998).

Interactions among mucosal integrity, intraluminal pressure, bacterial flora, and intraluminal gas play a role in the development of PI (St. Peter, Abbas, and Kelly 2003). In manatees, successful treatment has consisted of oral aminoglycosides, metronidazole, Pepto-Bismol, and changing the diet to an elemental human infant formula (EleCare, Abbott Nutrition, Columbus, OH, USA, or Nutramigen, Mead Johnson and Co., Evansville, IN, USA; Walsh, Murphy, and Innis 1999; Croft and Tollefson 2014). Several years ago, SeaWorld began using new milk formula recipes (see **Chapter 30**). Several calves have been successfully raised and released with each of the listed formulas, and fewer GI complications have been seen. Often after a calf recovers from PI or any other condition warranting oral antibiotics, the GI tract benefits from being seeded with feces from a healthy adult manatee via gastric intubation of a fecal slurry. Occasionally, this treatment is employed even in calves that have not been on oral antimicrobials but have persistent diarrhea. Other illnesses seen in neonates are pneumonia, bacterial infections, and sepsis. The first 3–4 weeks in rehabilitation is the most critical period for orphans.

Therapeutics

The most common therapies provided to ill FL manatees are fluid support, nutritional support, antibiotics, GI medications, analgesics, sedatives, enemas, and wound care.

In calves and extremely ill individuals, IV fluid support can be provided, typically using normal saline or a balanced replacement solution. IV catheterization is difficult, and often, fluids are provided via a needle inserted into the brachial vascular plexus or the ventral tail complex and attached to an extension set and fluid line. In stable animals, gastric intubation of fluids is the more common route. Gastric intubation is via the oral or nasal route using a lubricated foal or small equine soft plastic stomach tube inserted to the depth of the distal tip of the pectoral flipper when it is folded against the body. Usually, a conservative volume is given initially (1–2 l for adults; 30–100 ml for calves; 0.5–1.5 l for subadults) two to three times per day (more frequently in calves). Volume can be increased as indicated and tolerated.

Once hydration status is addressed, nutritional support should be provided to anorectic or partially anorectic animals. For subadults and adults, gruel is made of mixed lettuces and spinach, water, ± an herbivorous or omnivorous primate pelleted diet (monkey chow). Many animals needing nutritional support have some degree of GI stasis, necessitating a gradual introduction of food. Initial treatments are with a very dilute gruel (25% strength); thickness and gruel concentration are gradually increased over several days once feces and flatulence are being produced. Provide manatees needing nutritional support access to solid food at all times, because they will begin grazing as GI function improves. Continue nutritional supplementation via gastric intubation (**Figure 43.5**) until the animal is eating normal amounts regularly for several days and producing normal stool. Many ill manatees may require long-term nutritional support (weeks to months).

Oral medication can only be administered effectively via gastric intubation. Due to sirenians' hindgut fermentation,

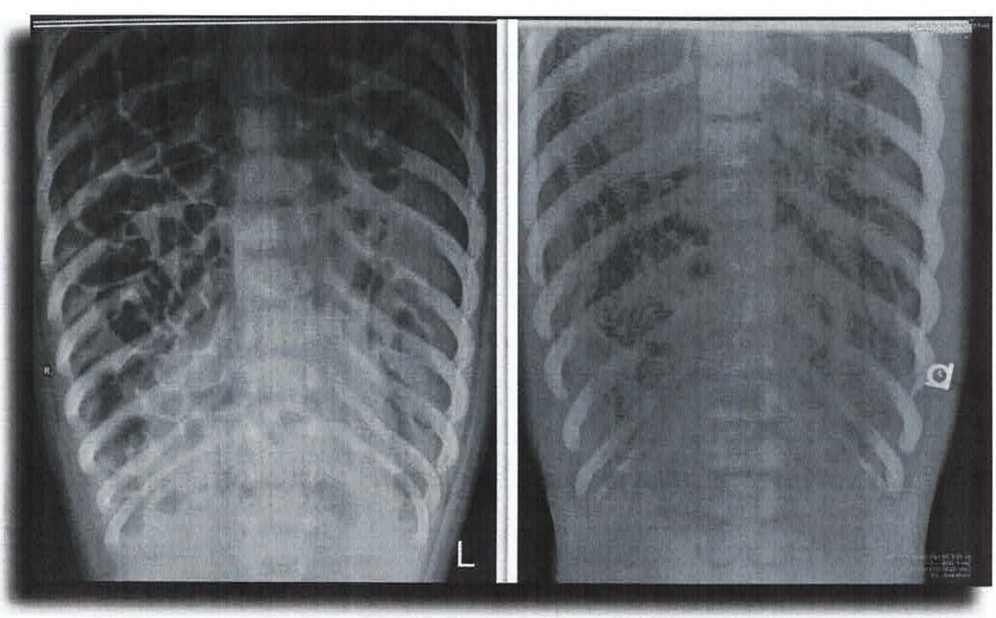

Figure 43.6 (Left) Dorsoventral radiograph of a FL manatee calf demonstrating large amount of gastrointestinal gas. (Right) Dorsoventral radiograph of a FL manatee calf with pneumatosis intestinalis. Note intramural gas within the wall of the gastrointestinal tract in multiple locations. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

only use oral antibiotics conservatively to avoid intestinal dysbiosis. Parenteral antibiotics are typically selected over oral antibiotics unless specific medical reasons warrant otherwise. IM or subcutaneous (SC) routes of administration are most common, with the caudal epaxial muscles the preferred sites for IM injections, and the shoulder or caudal epaxial areas appropriate for SC use. Shoulder muscles are small, and placement of irritating drugs into fascial planes should be avoided when possible. In adults, 1.5- to 3.5-inch, 18- to 20-gauge needles are used (1.5–2 for SC; 3.5 for IM in most large animals), and in calves, 1-inch 20- to 22-gauge needles can be used. As for blood collection, a thorough surgical scrub is necessary. Duration of injection therapy should be limited when possible, as injection-site abscesses, pain, and muscle necrosis can occur secondary to chronic IM/SC injections.

Pharmacokinetic data are lacking for most medications in Sirenia. Dosing regimens used for related species or other hindgut fermenters, such as domestic horses, are often used as guidelines. Long-acting antibiotic formulations manufactured for domestic large animals have recently been used to minimize injection frequencies. To provide four-quadrant coverage, antibiotic combinations are often used. See **Chapter 27** for doses of the most commonly used medications. Culture and antibiotic sensitivity should be used to guide antibiotic selection and avoid inducing antibiotic resistance (Sidrim et al. 2016).

Other Disorders

GI disorders such as constipation, diarrhea, dysbiosis, enterocolitis, and colic-type clinical signs (excessive rolling, abdominal crunching) are periodically encountered in adults and frequently in calves. Attempts should be made to determine the underlying cause (radiography with or without contrast, fecal cytology, fecal occult blood, and cultures for enteric pathogens), but supportive GI medications can be helpful. Treatment with antigas medication (simethicone) is recommended for animals showing colic-type signs; metronidazole can aid in cases of clostridial enteritis/colitis. For animals in which dysbiosis is suspected (long-term oral antibiotic use, lack of microbial diversity in fecal cultures, diarrhea), transfaunation can be employed as described for calves. Equine probiotics have also been used. For cases of constipation (minimal amounts of feces, hard/dry feces), enemas, metoclopramide, and gastric intubation of mineral oil in water two to three times a day for the first few days can be useful for restoring motility.

Consider administering analgesics and anti-inflammatories for conditions considered painful in other taxa. A number of medications have been used in manatees with pain or inflammation, including nonsteroidal anti-inflammatory medications (NSAIDs) such as flunixin meglumine, ketoprofen, aspirin, and opioids such as butorphanol and tramadol. As with other medications, pharmacokinetic data are lacking. A recent behavioral ethogram in one FL manatee suggested that oral tramadol at a dose of 1 mg/kg SID reduced behaviors associated with pain (resting on the bottom, crunching; Komarnicki, Rodriquez, and Richardson 2012). In most instances, employ conservative doses used in related taxa.

Animals with poor buoyancy control (pneumothorax, collapsed lung, excessive localized GI gas, neurologic, emaciated, or weak) may require support within the water column to improve appetite, lower stress during respirations, avoid chronic musculoskeletal complications, and prevent drowning. Neoprene material from human wetsuits can be modified to wrap around a manatee's body and be secured with Velcro straps (**Figure 43.7**; Walsh et al. 1995).

Human floatation devices can also be used (Murphy 2003). The addition of foam or other floatation devices to the "down" side may be necessary to achieve symmetry within the water. Individual variation exists in regard to acceptance of these

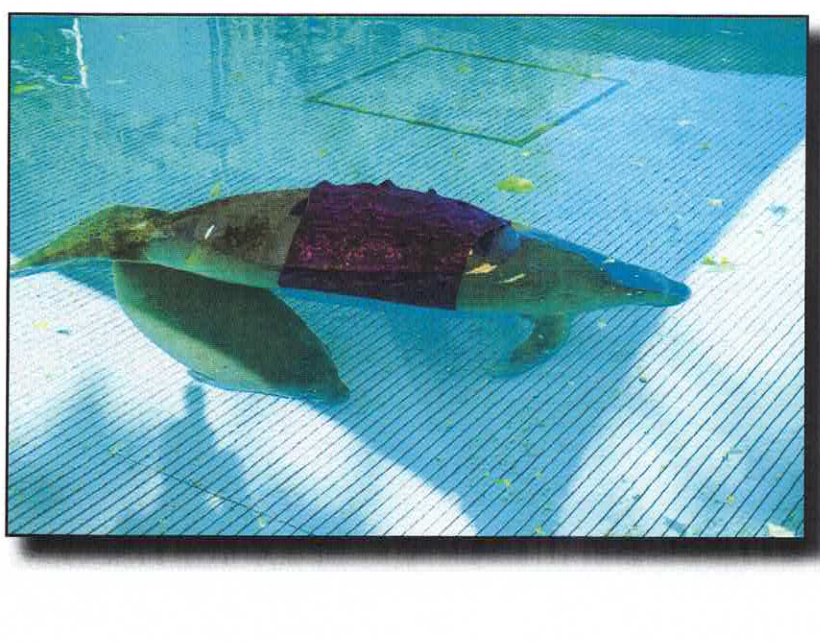

Figure 43.7 FL manatee with a neoprene floatation device in place to aid in buoyancy. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

Figure 43.8 (Left) Traumatic paddle wound in a FL manatee. (Center) Propeller wounds on the dorsum of a FL manatee. (Right) Entanglement of the pectoral flipper of a FL manatee. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

devices; some animals will not tolerate them or eat with them on. Oral diazepam may be helpful with acclimation to the device. In severely ill cases, animals may need to be kept in very shallow water to facilitate ease of respiration. When possible, larger animals should be propped on foam but remain afloat rather than be dry-docked for long periods of time to prevent gravity-dependent injury to tissues and lungs. Food can be affixed to the side of the pool or weighted at the bottom to assist in feeding in accordance with buoyancy abnormalities.

Traumatic wounds are common in Sirenia rescued from the wild and brought to rehabilitation settings (**Figure 43.8**). Wound management is challenging given the aquatic environment in which the animals are swimming and with water containing fecal contaminants. Bandaging is not typically effective, because when submerged in pool water, the bandage traps more bacteria and tissue necrosis may ensue. Traumatic wounds with necrotic bone involvement require regular debridement to avoid trapping of necrotic debris by wound granulation. Abscesses often need to be lanced and a large opening left to facilitate flushing with dilute antiseptics and daily drainage. Antimicrobials mixed with water-resistant diaper creams and honey can be applied. Abscesses with relatively small orifices can be maintained with umbilical tape through two orifices to prevent closure and allow flushing.

Environmental Health Concerns

Brevetoxicosis

For a thorough discussion on brevetoxicosis, see **Chapter 16**. Mass mortality events have been reported in FL manatees from both the west and east coasts of FL, with a higher incidence from the west coast (Bossart et al. 1998; Ball et al. 2014; Fire et al. 2015). Transmission is via inhalation (Bossart et al. 1998) or ingestion (Flewelling et al. 2005; de Wit et al. 2007; Capper, Flewelling, and Arthur 2013). Toxins remain stable in the environment and within seagrass, and mass mortalities can be seen long after and/or remotely located from a known algal bloom (Flewelling et al. 2005; de Wit et al. 2007; Capper, Flewelling, and Arthur 2013). Clinical signs are neurologic and either respiratory or GI, based on route of transmission (Bossart et al. 1998; Ball et al. 2014; Walsh and de Wit 2015). Clinical pathologic abnormalities include heterophilic and eosinophilic leukocytosis; hemoconcentration; increased partial thromboplastin time (PTT); electrolyte abnormalities; elevated serum creatine kinase; hyperglobulinemia; hypocalcemia; decreased blood urea nitrogen, gamma glutamine transaminase, and amylase (Ball et al. 2014); and thrombocytopenia (Murphy 2003). Necropsy findings usually include congestion of nasopharynx, airways, and meninges; hemorrhage in liver, kidney, and lungs; and variably, intestinal hemorrhage (Bossart et al. 1998; de Wit et al. 2007; Ball et al. 2014).

Many animals are found dead prior to intervention (de Wit et al. 2007), but if found in time, even severely affected animals can survive (Ball et al. 2014). Treatment includes prevention of drowning (floatation devices or propping on foam) and supportive care (fluid therapy, anti-inflammatories, parenteral antibiotics, atropine). Animals presenting with neurological signs generally recover within 24 hours (Ball et al. 2014; Walsh and de Wit 2015).

Cold Stress Syndrome

Manatees are not tolerant of cold water temperatures, and FL manatees with prolonged exposure to temperatures below 20°C (68°F) become subject to a disease process known as cold stress syndrome (CSS). Recent investigations suggest dugongs also succumb to CSS (Owen et al. 2013). Mortality from CSS is one of the major threats to free-ranging FL manatee populations. All age classes are susceptible, but subadults are more commonly affected (likely due to their higher surface area-to-volume ratio) than adults, also because they may lack maternal care (guidance to warm water, constant source of nutrition), as mothers provide to calves (Bossart et al. 2004). However, orphan calves may be particularly susceptible, due to relatively lower body fat mass (Ortiz and Worthy 2004). Acute exposure can lead to lethargy and fatal hypothermia (Buergelt et al. 1984; de Wit et al. 2012). Chronic exposure results in a complex cascade of pathophysiologic events resulting in emaciation, depletion of fat stores, serous fat atrophy, lymphoid depletion, epidermal hyperplasia, pustular dermatitis, enterocolitis, and myocardial degeneration (Bossart et al. 2002b). Compromised metabolism and immune systems, and malnutrition, make way for opportunistic infections and secondary diseases (Bossart et al. 2002b). Bacteremia, dehydration, hypoglycemia, and renal failure are potential sequelae (Murphy 2003). Recent research supports the role of thromboembolic disease by demonstrating that cold-stressed manatees demonstrate hypercoagulability and have statistically prolonged prothrombin time (PT) and PTT, increased D-dimer and fibrinogen, and thrombocytopenia, consistent with Barratclough et al. (2016b). Severe acidemia, metabolic acidosis, and abnormal electrolyte findings can be present on blood gas analysis (Murphy 2003). Leukocytosis and elevated LDH, CK, creatinine, and serum amyloid A are common findings.

The most notable outward clinical signs of CSS are skin lesions and poor body condition (**Figure 43.9**). Early skin lesions present as epidermal bleaching of the extremities and muzzle. Chronic lesions include hyperkeratosis, diffuse pustules, and ulcerative lesions. The muzzle, head, and extremities are most severely affected. Gastrointestinal stasis, constipation, the absence of gut sounds or flatulence, and pneumonia can be observed. Other sequelae can include necrotic enteritis, PI, pyothorax, septic arthritis (Murphy 2003), and sloughing of the large portions of the flippers (Davis unpubl. data). Treatment is aimed at correcting dehydration, acidosis, and electrolyte abnormalities, and treating underlying infections. In severe cases, IV fluids can be administered, but in most cases, gastric intubation with water two to three times per day over 24–48 hours is sufficient, followed by introduction of a dilute gruel. Food should be offered immediately and be available at all times. Gruel or water should be provided until normal food consumption and fecal production is seen. In some cases, prolonged nutritional support is necessary. Constipation is treated with mineral oil and water gastric intubation, and warm water or saline enemas. Broad-spectrum parenteral antibiotics are typically selected, but culture and sensitivity of lesions should be used to guide therapy. Secondary fungal infections of the skin and lungs have also been seen, and fungal cultures should be included in diagnostics.

Watercraft Injuries

Trauma from watercraft is a common cause of death of FL manatees and *T. manatus* in Puerto Rico (Mignucci-Giannoni et al. 2000; Bossart et al. 2004), accounting for an average of 22% (8–31%) of reported carcasses annually over the past 20 years (FWC 2016) and a substantial number of rescues (**Table 43.2**). Injuries, usually on the dorsum, are due to blunt trauma from the hull, sharp/shearing trauma from the propeller blades and lower motor units (**Figure 43.8**), or both. Deaths from blunt force trauma are more common than from sharp trauma and are frequently accompanied by severe internal hemorrhage and trauma with minimal external wounds visible (Lightsey et al. 2006). The most common injuries are skin, diaphragm, and lung lacerations; skeletal damage (rib or spinal fractures); hemothorax; pyothorax; pneumothorax; hemoabdomen; and kidney damage (Lightsey et al. 2006). Wounds are managed as discussed below. Supportive care, analgesia, and antibiotics are usually indicated. Pneumothorax may be suspected, based on clinical signs (increased respiratory rate and effort, listing, excessive buoyancy) and confirmed with radiographs/ultrasonography or the presence of air on thoracocentesis. Floatation devices may be necessary to keep the animal symmetrical and able to eat and breathe. Thoracocentesis can be both diagnostic and therapeutic, but the air may return; serial thoracocentesis has been successful in achieving resolution. Removing smaller amounts of air over multiple procedures is frequently more effective than

Figure 43.9 (Left and center) Multifocal dermatitis secondary to cold stress syndrome in a FL manatee. (Right) Severe ulcerative dermatitis with loss of epidermis and emaciation secondary to cold stress syndrome (CSS) in a FL manatee. (Courtesy of SeaWorld Parks & Entertainment, Inc.)

trying to remove all the air at once, due to immediate refilling of that potential space. Chest tubes have been used successfully (Murphy 2003) but can be challenging to maintain in the aquatic environment. Many cases will resolve with supportive care and time, and thoracocentesis may not be indicated if the animal is still able to eat and breathe normally and shows no signs of respiratory distress. Recently, following conservative management, pneumothorax and pneumoperitoneum in two calves resolved (Gerlach, Sadler, and Ball 2013).

Entanglements

Entanglements in fishing line, netting material, crab pots, and other anthropogenic sources are very common reasons for rescues of FL manatees (**Table 43.2**; **Figure 43.8**). In some cases, no treatment is necessary after removal of the entanglement, but in other cases, wounds are severe and may require medical care or amputation of severely damaged appendages, particularly if osteomyelitis is present.

Other Environmental Health Concerns

FL manatees have died due to entrapment in floodgates, canal locks, drainage pipes, and other locations. Fishhook foreign bodies have also been seen. In 2013, an unusual mortality event (UME) of FL manatees (and bottlenose dolphins and brown pelicans) occurred in the Indian River Lagoon. The mortalities followed a dramatic reduction of seagrass in the area, due to long-term, nontoxic phytoplankton blooms, with the cause of the latter still unknown. Impacts of natural disasters (Flint et al. 2012) and ecotourism (King and Heinen 2004; Solomon, Corey-Luse, and Halvorsen 2004) have also been explored (see Working Group on Unusual Mortality Events [WGUME] website).

Infectious Diseases

Bacteria and Viruses

Dermal and subcutaneous abscesses are not uncommon in manatees and are often infected with a variety of bacteria. Septic metritis secondary to dystocia and fetal maceration (Davis unpubl. data), enteritis/enterocolitis and pneumonia (Bossart et al. 2004), pyelonephritis (Keller et al. 2008), omphalitis and septicemia (Walsh et al. 1987; de Wit et al. 2006), mycotic dermatitis, pleuritis, and lung abscessation have all been described. A case of fatal salmonellosis was reported in a dugong (Elliott et al. 1981). Fatal atypical mycobacterial infections have been infrequently reported in manatees (Boever, Thoen, and Wallach 1976; Morales, Madin, and Hunter 1985; Sato et al. 2003).

Trichechus manatus papillomavirus type 1 (TmPV1; Rector et al. 2004) has been associated with cutaneous papillomas in captive and free-ranging FL manatees (Bossart et al. 2002a; Woodruff et al. 2005). Free-ranging animals can be infected but rarely show lesions (Dona et al. 2011). Recently, two new papillomaviruses were associated with genital papillomas in a FL manatee (Ghim et al. 2014). Trichechid herpesvirus 1 (TrHV1) has been isolated from the skin and whole blood of free-ranging manatees with and without skin lesions (Wellehan et al. 2008). Polymerase chain reaction (PCR)–positive animals without skin lesions were pregnant or lactating, or had severe, chronic disease, suggesting immunosuppression (Wellehan et al. 2008).

Serologic surveys for exposure to morbillivirus (Duignan et al. 1995; Sulzner 2012), leptospirosis (Erlacher-Reid et al. 2011; Mathews 2012; Sulzner et al. 2012; Aragón-Martinez, Olivera-Gómez, and Jiménez 2014; Delgado et al. 2015), brucellosis, pseudorabies, San Miguel sea lion virus type 1, and Eastern, Western, and Venezuelan equine encephalitis virus (Geraci et al. 1999) in several manatee species showed seropositive animals, but clinical disease has not been reported. A serosurvey for West Nile virus in FL manatees yielded no positive samples (Keller et al. 2004).

Parasites

Parasitic infections are rarely of clinical significance in Sirenia, and detailed reviews are available (Beck and Forrester 1988; Dailey, Vogelbein, and Forrester 1988; Upton et al. 1989; Forrester 1992; Colon-Llavina et al. 2009). *Cochleotrema cochleotrema*, a nasopharyngeal trematode, can cause rhinitis. Enteritis in FL manatees has been described secondary to the small intestinal trematodes *Moniligerum blairi* and *Nudacotyle undicola* (Bando et al. 2014). *Cryptosporidium* spp. have caused weight loss, diarrhea, abdominal discomfort, and lethargy in Antillean and Amazonian manatees and dugongs (Hill, Fraser, and Prior 1997; Morgan et al. 2000; Borges et al. 2009, 2011), and death in a dugong (Morgan et al. 2000). While disease associated with *Toxoplasma gondii* is uncommon in manatees (Buergelt et al. 1984; Dubey et al. 2003; Bossart et al. 2004), toxoplasma encephalitis (Buergelt and Bonde 1983), myocarditis, and, more recently, disseminated toxoplasmosis have been reported (Bossart et al. 2012). Serologic investigations show exposure to toxoplasmosis in Amazonian and West Indian manatees (Alvarado-Esquivel, Sánchez-Okrucky, and Dubey 2012; Mathews et al. 2012; Sulzner et al. 2012; Attademo et al. 2016; see **Chapter 20**).

Miscellaneous Conditions

Cardiac diseases are rare, but cardiomyopathy (Bossart et al. 2004) and atrioventricular valve myxomatous transformation (Buergelt et al. 1984) have been reported. Early reports suggested dugongs were susceptible to capture myopathy

(Anderson 1981; Marsh and Anderson 1983); however, more recent data do not support this (Lanyon, Sneath, and Long 2012). Nephrolithiasis with pyelonephritis was described in two manatees (Keller et al. 2008), and polycystic kidneys were described in one FL manatee (Rember et al. 2005). Neoplasia has been infrequently reported in manatees (Bossart et al. 2004; Hammer et al. 2005; Smith et al. 2015). However, reproductive neoplasia was recently described in eight FL manatees (Smith et al. 2015).

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