Chapter 7

MARINE MAMMAL PROGRAM

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INTRODUCTION

The US Navy Marine Mammal Program (MMP), located in San Diego, California, maintains a large population of military working bottlenose dolphins (*Tursiops truncatus)* and California sea lions (*Zalophus californianus*). This unique group of animals provides rapidly deployable support for mine warfare countermeasures, swimmer defense, and object recovery in support of expeditionary amphibious warfare training missions.[1] Many of the tasks marine mammals perform resemble what military working dogs (MWDs) are trained to do. However, rather than using sense of smell to carry out their missions as canines often do, marine mammals rely on their other senses and unique physiological adaptations (eg, sonar, for dolphins; underwater directional hearing and low-light vision, for both dolphins and sea lions). Trained and certified marine mammals are assigned to a Marine Mammals System (MMS) that includes four to six highly trained animals with a specific set of behaviors, hardware, and personnel.[1]

The MMP veterinary medicine program provides the best possible veterinary care through continued application of advanced knowledge, methods, and equipment, despite the challenges of marine mammal medicine. For example, dolphins and sea lions rely on an evolutionary survival strategy to avoid predation by masking illness or injury. As such, routine physical examinations by skilled veterinarians and daily observations by practiced animal trainers must be employed to rapidly detect subclinical conditions. Additionally, important and routine aspects of terrestrial veterinary medicine such as indwelling catheters, splinting, and casting, along with surgery, are made difficult, if not impossible, because of the animals' aquatic lifestyle. To help advance marine mammal medicine and overcome such challenges, the program continues to perform cutting-edge research of global significance.

This chapter reviews the history of the MMP and highlights different roles that marine mammals fill in the US Navy. It also briefly explains the current use of US Navy marine mammals, including their role in enabling research; outlines the different components of a comprehensive seven-part preventive medicine program; and covers selected marine mammal diseases currently relevant to the population.

HISTORY AND BACKGROUND OF THE MILITARY MARINE MAMMAL PROGRAM

The US military has recognized the value of working animals ever since the 18th century when General Washington directed that a "regiment of horses with a farrier" be raised.[2] War dogs were widely used by the Egyptians, Greeks, Persians, Romans, and other ancient civilizations and are still widely used today by the military for patrol and detection work.[3] Marine mammals represent a unique population of working animals with highly specialized skills that have contributed to US Navy programs for over 50 years.[4] (See Chapter 8, Military Equine Programs, and Chapter 2, Military Working Dog History, for more information about equine and canine military service missions, respectively, throughout US history. See Chapter 1, Military Veterinary Support Before and After 1916, for more historical background on all US military working animals.)

Veterinarians have partnered with the US Navy since the program's inception in 1959. Dr Sam Ridgway, then a veterinary officer in the US Air Force, became involved in marine mammal medicine when Navy scientists approached him about their interest in using dolphins for Navy science. In the mid-1900s, veterinarians occasionally worked on marine mammals in zoos and aquariums, but when he accepted a position in 1962 with the Naval Missile Center at Point Mugu, California, Dr Ridgway became the first person to begin a full-time career in marine mammal medicine (Figure 7-1).[5]

The program has grown significantly since 1962 and has become a world leader in military applications of marine mammals as well as marine mammal health and welfare. These following three sections provide an overview of the history of the program, detail the different roles that marine mammals have filled throughout the years, and explain how US Air Force and Army veterinary personnel have provided support.

The Evolving Marine Mammal Program

Today, the MMP is attached to the Space and Naval Warfare Systems Center Pacific. Over the past 50 years, the Space and Naval Warfare Systems Center Pacific has had several name changes, including the Naval Undersea Center, Naval Ocean Systems Center, and Space and Naval Warfare Systems Center San Diego. However, most of the early marine mammal investigations took place at the facility in Point Mugu, California. In 1960, the US Navy acquired a Pacific white-sided dolphin named Notty to conduct hydrodynamic studies. Navy scientists were primarily interested in studying

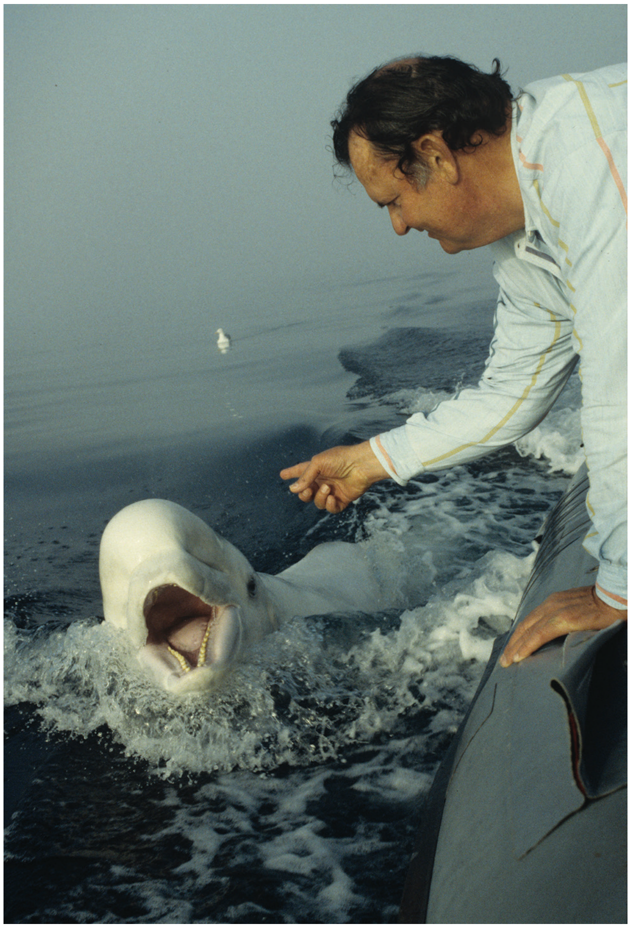

Figure 7-1. Dr Sam Ridgway, now the senior scientist with oversight of the veterinary and research program at the US Navy Marine Mammal Program, gives a visual cue to a beluga whale.
Photo courtesy of the US Navy.

the special characteristics that contributed to dolphins' hydrodynamic efficiency, with the goal of applying these characteristics to design US Navy vessels.[4,5]

These earliest studies proved to be of limited value but soon evolved to include study of the marine mammals' specially developed senses and capabilities (eg, sonar and deep-diving physiology) and how marine mammals might be employed to perform useful underwater tasks. A major accomplishment was the demonstration that trained dolphins and sea lions could work untethered in the open sea with great reliability. In 1965, a Navy dolphin named Tuffy participated in the Sealab II project off La Jolla, California, carrying tools and messages between the surface and aquanauts operating out of the habitat 200 feet below (Figure 7-2).[5]

In l968, some of the animals and personnel were transferred from Point Mugu to a new laboratory in Hawaii at the Marine Corps Air Station on Kaneohe Bay. The research in Hawaii focused on the following topics: (*a*) behavioral studies; (*b*) reproductive physiology; (*c*) further study of the dolphin echolocation system; and (*d*) investigation of the potential of marine mammals for performing underwater tasks more efficiently, safely, and cost effectively than is possible using human divers or submersibles.[4]

The rest of the operation later moved to a new facility on Point Loma. Here, the research and development program continued and included further studies of the following topics: (*a*) capabilities of marine mammals; (*b*) development of improved techniques for diagnosis and treatment of diseases; (*c*) neurophysiologic studies using behavioral and other noninvasive techniques to gain a better understanding of how the large dolphin brain functions; (*d*) development of instrumentation for determining by brain wave activity the hearing range of a cetacean; and (*e*) investigation of how dolphins produce the sounds they make.[4,5]

The Evolving Roles of Marine Mammals in the Program

At Kaneohe Bay, Hawaii, under the Advanced Marine Biological Systems Program, the initial four MMSs were developed.[4] These included the Mark (MK) 4, MK 5, MK 6, and MK 7 systems. Because of the unique capabilities of marine mammals, dolphins and sea lions were trained to perform a variety of tasks, including underwater surveillance for object detection, swimmer defense, and mine countermeasures. The MK 6 swimmer defense system was deployed to

Figure 7-2. Tuffy the dolphin participating in the project Sealab II, in which he repeated dives to 200 feet to deliver mail and tools to the divers below. Tuffy was also trained to guide lost divers to safety.
Photo courtesy of the US Navy.

Vietnam in 1970 to 1971 and successfully protected the US Army ammunition pier at Cam Rahn Bay from all underwater attacks.[1,4] This defense system was again called to duty in Bahrain during Operation Earnest Will in 1987 to 1988 and in San Diego during the 1996 Republican National Convention.[4]

In 1993, because of a Base Closure and Realignment Commission action, the Hawaii laboratory was closed, and the majority of the animals and personnel moved to San Diego (Figure 7-3). The consolidation of support activities was paralleled by a reduction and consolidation of Fleet MMS to San Diego during the same period. The program was also declassified in the early 1990s. The MMP was first accredited by the Association for Assessment and Accreditation of Laboratory Animal Care (now the AAALAC International) in 1995.[4]

In 1996, the MMP was directed to cease further downsizing and pursue the development of new MMSs and enhancements. As a result, the program developed new shipboard forward deployment capabilities and added a fifth type of MMS—MK 8—in October 2001.[1,4]

The terrorist attacks on the USS *Cole* in 2000 and against the US homeland in September 2001 brought dramatic change to the United States and the US Navy, and the MMP responded. The successful and continuous employment of the MK 6 MMS at home during Operation Noble Eagle in 2001 to 2003 was followed immediately by simultaneous deployments of multiple MMSs to Iraq, Kuwait, and Bahrain during Operations Enduring Freedom and Iraqi Freedom.[1,4]

Figure 7-3. The US Navy Marine Mammal Program, located in San Diego Bay, houses marine mammals in open-water netted enclosures. This arrangement provides easy access to the work sites and also offers the animals enrichment and the ability to communicate with each other.
Photo courtesy of the US Navy.

MMP military and civilian personnel, dolphins, and sea lions traveled to the northern Arabian Gulf and served on the front lines of the war on global terrorism. MMSs played a key role in ensuring that the Iraqi ports of Umm Qasr and Az Zubayr were clear of sea mines and other potential hazards, allowing much needed food and medical aid to reach the Iraqi people early in the conflict. MMS dolphins and sea lions also helped to protect coalition forces from the threat of underwater attack and remained in theater and on duty from 2003 to 2005.[4]

These missions were highly successful because of the outstanding performance of MMP dolphins and sea lions and the efforts of many individuals, from those few who themselves ventured into harm's way, to the hundreds of others who supported them. Current tasking for MMSs to provide continuous underwater security at naval installations in Kings Bay, Georgia, and Naval Base Kitsap-Bangor in Washing-

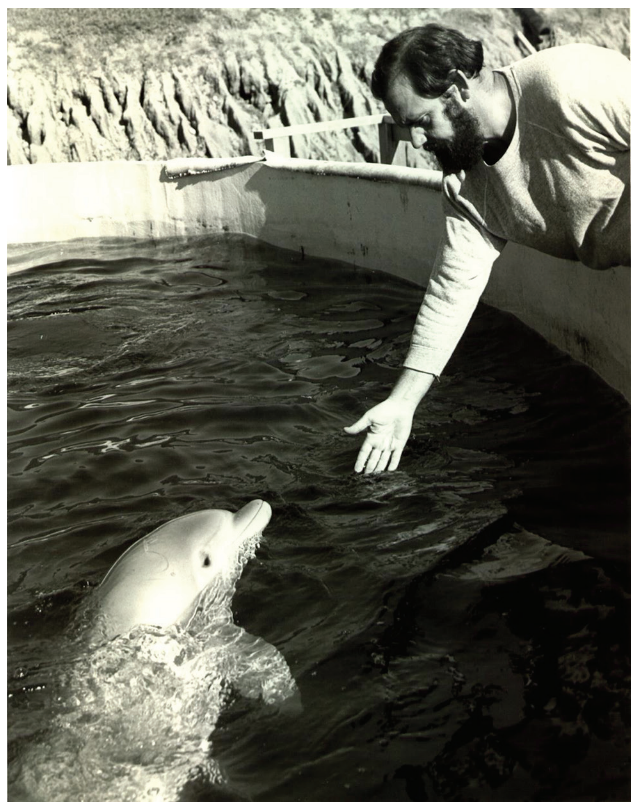

Figure 7-4. A photograph taken earlier than Figure 7-1, featuring Dr Sam Ridgway, who served as the first marine mammal veterinarian for the US Navy Marine Mammal Program. Since he started full-time work in marine mammal medicine in 1962, Ridgway has conducted numerous studies on physiology and neurology, including a study in which he demonstrated right-eye preference in dolphins.
Photo courtesy of the US Navy.

Figure 7-5. Brigadier General Michael Cates (now retired), previously assigned as an Army captain to support the marine mammal facility in Hawaii, visits with one of the US Navy Marine Mammal Program sea lions.
Photo courtesy of the US Navy.

ton State suggest that the MMP will be called on to continue a period of unprecedented activity through the Future Years Defense Plan.[4]

The Evolving Roles of Military Veterinarians in the Program

In addition to Dr Sam Ridgway, who holds the distinction of being one of the pioneers of marine mammal physiology and medicine (Figure 7-4), many other US military veterinarians have played key roles throughout MMP's history.[5] One of the earliest Air Force veterinarians, Major Donald Van Dyke, contributed significantly to the study of diet formulations and rations for marine mammals.[6] Many other Air Force veterinarians continued to assist the MMP mission, contributing to the understanding of marine mammal nutrition, physiology, and medicine and supporting deployments and exercises. For example, Air Force veterinarians supported Operation Earnest Will in the Persian Gulf from 1986 to 1988, deploying with several dolphins on mine-hunting and swimmer defense missions.[4]

In 1980, when the Air Force Veterinary Corps was disestablished, the US Army became the service branch that provided all DoD veterinary services.[2] In the late 1980s, the MMP program began receiving support from the Army Veterinary Corps. Captain Michael Cates, who was assigned to the Hawaii laboratory in the 1980s, contributed to understanding blastomycoses in bottlenose dolphins.[7] Cates would later be promoted to Brigadier General and serve as Chief of the US Army Veterinary Corps from 2005 to 2008 (Figure 7-5).[8]

Army Captain Richard Linnehan was assigned to the program in 1989, contributing to research in the areas of cetacean and pinniped anesthesia, orthopedics, drug pharmacokinetics, and reproduction.[9,10] Toward the end of his tour, he was selected by NASA to attend astronaut candidate training and went on to participate in four space flights, including a mission to the Hubble Space Telescope.[11]

When the Hawaii laboratory closed in 1993, the mission of the US Army veterinarians shifted back to San Diego. Army veterinarians again supported marine mammals deployed to Bahrain in Operations Enduring Freedom and Iraqi Freedom. With the establishment of two satellite facilities, Army veterinarians played a critical role in providing veterinary support at remote sites.[4]

Because of its broad mission, the MMP also has benefited from the wide range of experience and knowledge that other US Army veterinarians have contributed over the years. Alumni include experts in virology, pathology, laboratory animal medicine, public health, nutrition, physiology, and many fields. These Army veterinarians contributed to research, publishing articles that cover a wide range of topics from nutrition, infectious disease, anesthesia, pharmacology, physiology, internal medicine, and radiology. They participated in numerous deployments and exercises, forged relationships with other military medical personnel, and established policies and standard operating procedures. US Army veterinarians also manage the fish procurement program and maintain regulatory requirements needed for the MMP research program. The value that Army Veterinary Service personnel add to the MMP is substantial and will continue for as long as the need is present (Figure 7-6).

Figure 7-6. Group photograph of a unit of US Army veterinary personnel, typical of the Army personnel that provide daily, round-the-clock support to the US Navy Marine Mammal Program.
Photo courtesy of the US Navy.

CURRENT MILITARY OBJECTIVES AND MISSIONS OF THE MARINE MAMMAL PROGRAM

The primary objective of the MMP is to operate and maintain in-service MMS readiness. In support of this mission, the Biosciences Division of the Space and Naval Warfare Systems Center Pacific is designated as the lead laboratory for all US Navy-sponsored programs that involve the acquisition, transport, care, and maintenance of marine mammals.[12] This laboratory is charged with the duty to "ensure that all naval marine mammals receive the highest quality of humane care and maintenance per all applicable laws and regulations."[12(p3)] As a supporting objective, the laboratory also participates in a variety of research focus areas that contribute to the understanding of marine mammals.[13]

Currently, the unique capabilities of marine mammals that contribute to the US Navy mine and undersea warfare missions cannot be matched by existing technology, despite significant efforts and upgrades. Often, the varied underwater terrain present in harbors, rivers, and shallow water provides significant challenges to the marine mammals' technological counterparts. Until technology advances further, marine mammals will continue to perform required operational capabilities.[13]

Marine Mammal Systems Using Bottlenose Dolphins

Each MMS consists of animals that have been trained and certified to performance specifications for that particular task, dedicated personnel, and equipment needed to perform the mission and operate forward deployed from shore or aboard ship. Three MMSs are currently operational to perform tasks that cannot be accomplished by hardware or human divers, including two systems that operate at satellite facilities. All but one system includes bottlenose dolphins.

Bottlenose Dolphin Physiology

The common bottlenose dolphin (*Tursiops truncatus*) is classified in the infraorder Cetacea (carnivorous, finned, aquatic marine mammals) and belongs to the family Delphinidae, which includes over 30 species of toothed whales.[14(p298)] They are characterized by a medium-sized, robust body, moderately falcate dorsal fin, and dark coloration, with sharp demarcation between the melon and short rostrum.[14(p250)] They are typically colored light gray to black, dorsally and laterally, with a light belly. Many scientists recognize several subspecies, including the Atlantic bottlenose dolphin (*Tursiops truncatus*) and the Pacific bottlenose dolphin (*Tursiops truncatus gilli)*, which tend to be slightly larger and with darker pigment.[14(p250)] Most dolphins from the MMP are Atlantic bottlenose dolphins, but the program does maintain some *T. gilli* hybrids.

One of the most unique and well-known adaptations of dolphins involves their sophisticated echolocation abilities. Dolphins have evolved the ability to produce focused high-frequency clicks and listen for echoes that bounce off small objects to locate obstacles and prey. A 1980 study demonstrated that dolphins can detect a 2.5 cm metal target about 72 m away.[15] The dolphin brain has subsequently evolved for rapid auditory processing and can integrate this high-frequency energy over an interval of about 0.25 ms.[16]

Dolphins are also especially adapted for exceptional aquatic locomotion and diving. They have replaced long limbs and small feet characteristic of terrestrial mammals with a markedly reduced appendicular skeleton, streamlined bodies, and enlarged propulsive appendages.[17(pp73-76)] In addition, they have evolved the ability for prolonged breath holding and thus submerged swimming, where drag forces have least impact. They routinely swim at 2 to 4 meters per second, with sprint speeds reaching 10 meters per second.[14(p1143)]

In order to dive, marine mammals have also developed some unique methods for dealing with lack of oxygen and increased pressure underwater. Total oxygen stores of marine mammals often exceed two to three times that of terrestrial mammals.[14(p328),18] Dolphins and other deep diving marine mammals use skeletal muscles and blood, rather than lungs, as the primary oxygen storage site to support aerobic metabolism during diving.[14(p328)] They also have increased myoglobin concentrations in the muscles, in addition to changes in blood volume, hemoglobin concentration, and respiratory volumes.[14(pp328-329),17(pp79-86)] Their unique "dive response" includes breath-holding, bradycardia, and peripheral vasoconstriction in order to decrease oxygen demand to peripheral tissues.[17(p83)] During the dive, the lungs and airways collapse in response to the hydrostatic pressure, enabling them to avoid buildup of nitrogen and subsequent decompression sickness when resurfacing.[18]

Bottlenose Dolphin Operational Systems

US Navy dolphins participate in two out of three operational systems, focusing on two main areas of interest: mine countermeasures and force protection operations. All systems can be ready to deploy within

72 hours of notice, at any time, to virtually any location in the world. Teams of animals and personnel, including all their equipment and supplies, must be rapidly transported by aircraft, helicopter, land vehicles, or ships to the work site, get set up, and get to work quickly. MMSs have the ability to deploy to extreme environments, from areas as warm as Bahrain in the summer and as cold as Alaska in the winter. Once they arrive to their destination, dolphins are housed at shore facilities in floating enclosures or aboard amphibious assault ships or other ships of opportunity in specially designed inflatable shipboard dolphin pools.

Mine Countermeasures Operations. One operational system, MK 7, employs dolphins to search for, detect, mark, and neutralize mines. Using their sensitive biosonar, they operate in water depths up to 1,000 feet. The dolphins are particularly suited for precision mine hunting in difficult, highly cluttered acoustic environments of the near shore zone. They play an important role in securing ports and harbors for the US Navy and currently provide the Navy's only capability for detecting, marking, and neutralizing buried mines (Figure 7-7).[4]

MK 7 utilizes dolphins to detect and neutralize proud and buried bottom mines in shallow water. This system has been enhanced to include moored mine capabilities and minefield mapping, and to expand its operational area into very shallow water.

Force Protection Operations. Both dolphins and sea lions are trained in force protection operations and operate as the "patrol dogs of the sea." They have helped to mitigate threats of underwater attack for 40 years, beginning with the defense of the ammunition pier at Cam Rahn Bay, Vietnam, in the early 1970s.[4] US Navy dolphins and sea lions also play an essential role as an operational underwater security component at US submarine bases in Georgia and the state of Washington.

Force protection operations are carried out day or night and in all environmental conditions. Using its superior biological sonar, the dolphin can search off the bow of the patrol craft for intruders. Once detected, the dolphin reports the presence of a swimmer or diver and localizes the position of the threat. Dolphins also can detect and localize intruders in and around piers, ships, and pilings and on various diving modes such as re-breather, scuba, or breath hold.

Bottlenose Dolphin Fleet Support

Animals not assigned to a MMS Service Unit or designated as a certified replenishment animal are given the designation of fleet support. These animals include breeding female dolphins; dependent and weaned dolphin calves; young animals working toward MMS certification (Figure 7-8); and animals involved in enabling research related to deployment, clinical research, biosonar, and environmental compliance. The MMP acquires new dolphins from the in-house breeding program as well as from loans with other institutions or participants in the National Oceanic and Atmospheric Association Marine Mammal Stranding Network, a nationwide network consisting of members that respond to marine mammal strandings.

Figure 7-7. A US Navy dolphin, trained to detect sea mines and other submerged, unexploded munitions, leaps into the air in Montenegro's Strait of Verige during Operation Dolphin 2012. Photo courtesy of the US Navy.

Figure 7-8. A female bottlenose dolphin guides her new calf. The US Navy Marine Mammal Program manages a successful breeding program to provide replacement dolphins for the Navy's Marine Mammal Systems.
Photo courtesy of the US Navy.

Marine Mammal Systems Using California Sea Lions

California Sea Lion Physiology

The California sea lion (*Zalophorus californianus*) belongs to the family Otariidae, which includes fur seals and sea lions.[14(pp861-862)] Otariids are distinguished from other pinnipeds (seals and walrus) by their external ear flaps, large hind flippers that can be rotated under their body to support weight, and long, sparsely haired foreflippers with vestigial nails.[17(p14)] Their flipper structure allows them more mobility on land. California sea lions, like other otariids, are sexually dimorphic. The males are longer and up to three times heavier than females and develop a raised forehead with prominent sagittal crest on the skull.[14(p170),17(pp14-15)] Like other marine mammals, sea lions are adapted for exceptional aquatic locomotion. Their body and appendages are streamlined to reduce drag forces during swimming. They have also adapted a dive response and have been shown to hold their breath for up to 16 minutes.[13]

Unlike dolphins, sea lions do not use a sonar system to locate objects. Instead, they rely on their exceptional ability to see underwater in low-light situations. They also use directional hearing, though their ability to determine the sound source is not as sensitive as that of dolphins. Finally, as an adaptation to cold temperatures in aquatic environments, sea lions rely on a combination of an external fur layer and an underlying blubber layer to keep warm.[17(p84)]

Sea lions have a good disposition and are very trainable for tasks such as object detection, location, marking, and recovery. The MMP currently uses male castrated sea lions. Castration may improve health with regard to certain disease conditions, reduces aggressive behaviors, and reduces development of secondary sexual characteristics. Sea lions are highly food-motivated, and fish serve as the primary positive reinforcement for most behaviors.

California Sea Lion Operational Systems

US Navy sea lions participate in tasks involving both force protection and hardware recovery. Just like the dolphin systems, sea lion systems must be ready to deploy within 72 hours. During deployments and exercises, they may be housed at shore facilities, in land-based enclosures, or aboard ships in specially designed sea lion pens.

Force Protection Operations. Like their dolphin counterparts, US Navy sea lions provide port security operations. Sea lions naturally inhabit open water; areas under wharfs and piers; and along shorelines, rock walls, and quarry walls, and other places that limit the use of hardware systems. They have excellent low-light vision, passive acoustic detection, and agile mobility that allow them to detect and mark an intruder in total darkness. Sea lions may work autonomously, searching specified areas for intruders, or may be directed to specific locations to pinpoint and classify targets acquired with other assets such as anti-swimmer sonar systems.

Object Recovery Operations. Sea lions also participate in the MK 5 system to locate and attach recovery hardware to underwater objects (eg, practice mines or instrumented hardware) that the US Navy has fired or dropped into the ocean.[19] Although human divers may recover these items, they are limited by depth; poor visibility; currents; and the requirements for medical personnel, a recompression chamber, and other surface support. In contrast, the sea lion recovery system consists of a small rubber boat, a sea lion, and two or three handlers.

When the boat arrives at the approximate position of the object, the sea lion begins searching the area. If the sea lion searches and then reports the presence of an object, it is given a bite plate to which an attachment device is mounted (Figure 7-9). A strong line tied to this device is payed out from the boat as the sea lion

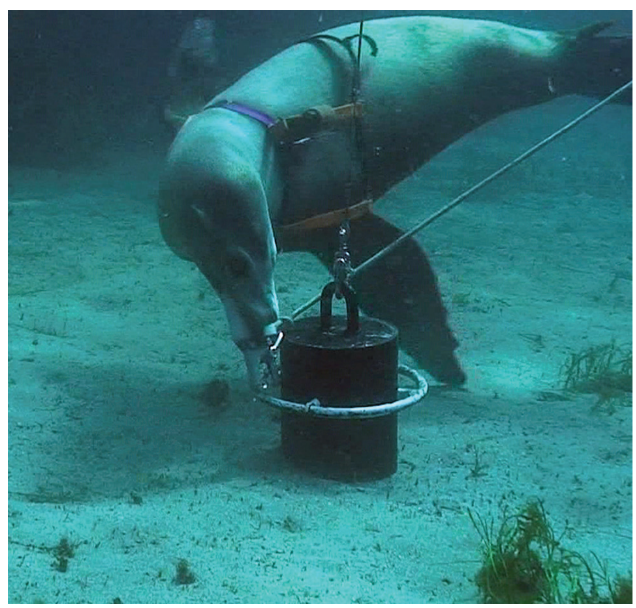

Figure 7-9. A California sea lion assigned to the MK 5 system attaches recovery hardware to an underwater target. Once the hardware is attached, the sea lion returns to the boat and a crane is used to pull the object to the surface.
Photo courtesy of the US Navy.

swims down and attaches the device to the object. To be sure the connection is good, the sea lion tests it by pulling back on the line a few times. The sea lion then returns to the boat, and a crane is used to pull the object off the bottom. The sea lions can also carry a tethered underwater video camera down to the object, providing surface personnel a real-time view of unknown targets reported by the mammals.

MK 5 became operational in 1975 and has been in use since that time. It boasts a recovery success rate in excess of 95% for objects in water depths up to and exceeding 1,000 feet.[4]

California Sea Lion Fleet Support

Similar to the dolphins, sea lions that are not assigned to a MMS Service Unit or designated as a certified replenishment animal are given the designation of fleet support. This category includes sea lion pups, young animals working toward certification, and animals involved in enabling research.[20]

The US Navy is committed to providing care to all of its marine mammals for the duration of their natural lives. Similar to MWDs or military police dogs and the dolphins in the MMP, US Navy sea lions are cared for by a professional staff, including at least one veterinarian and veterinary technician who are on call at all times. When not deployed, US Navy sea lions live in social groups of four to five animals, and are housed in floating enclosures that provide natural bay water and a combination of shade and sunshine. When not on patrol or recovery operations with their trainers or handlers, their days are filled with training and enrichment activities, as well as ample opportunity to rest. They swim and dive in the open ocean every day.

US Navy sea lions typically live into their late 20s, three times as long as their wild counterparts. Very few animals retire from service in the MMP. As expeditionary animals grow older, and the rigors of deployment become more difficult for them, the US Navy considers assigning them to duty at submarine bases where they can continue to serve without traveling. The oldest sea lions live out their last years in familiar surroundings at the MMP's facility in San Diego and spend time socializing with the programs' youngest pups. US Navy animals are only euthanized in the face of debilitating terminal illness when, in the judgment of the attending veterinarian, the animal's quality of life can no longer be maintained. The MMP uses only castrated male sea lions that are acquired from zoos and stranding network participants or collection from the wild in accordance with 10 US Code 7524.[1,20,21]

Healthcare Research Furthering Marine Mammal Understanding

The MMP has pioneered much of the research responsible for the current knowledge about marine mammals and their healthcare, and the program's spirit of commitment to advancing marine mammal wellness continues today. With over 1,000 publications, the MMP is the single largest contributor to open scientific literature on marine mammals.[4] The MMP, which is accredited by the AAALAC International in accordance with DoD regulations, was the first DoD nonbiomedical animal use program to be accredited and continues to receive exemplary evaluations from AAALAC International and DoD program reviews and facility inspections.[22]

Clinical research is essential for maintaining the readiness of the MMP's various marine mammal systems. Clinicians are continuously seeking to improve the ability to detect, diagnose, treat, and prevent marine mammal illnesses. Most recently, the MMP's research program has focused on several topics of high priority, including improved geriatric care, common infectious and metabolic diseases, advanced medical technologies, protection against disease, and applying the One Health concept to benefit both animals and humans.[19]

Aging Research

Dolphins and sea lions at the MMP benefit from a lifespan that, on average, exceeds that of their wild counterparts by more than 10 years.[23] Thus, the goal of research on aging is to increase the quality and duration of life for working geriatric animals. Aging research with US Navy dolphins has demonstrated that dolphins are more likely to have hypercholesterolemia and chronic inflammation as they aged past 30 years, which resembles changes that are seen in aging humans.[24] By comparing with research in human aging, the US Navy hopes to understand the cause of chronic inflammation and dyslipidemia in older animals and develop means to prevent and treat these conditions.

Pneumonia

In general, dolphins are especially susceptible to pneumonia.[25] For Navy dolphins, advanced age is a significant risk factor for pneumonia.[26] Thanks to routinely implemented molecular diagnostics and use of ultrasound-guided sampling of lesions, rapid and accurate detection methods for viral, bacterial, and fungal infections in marine mammals are rapidly improving.

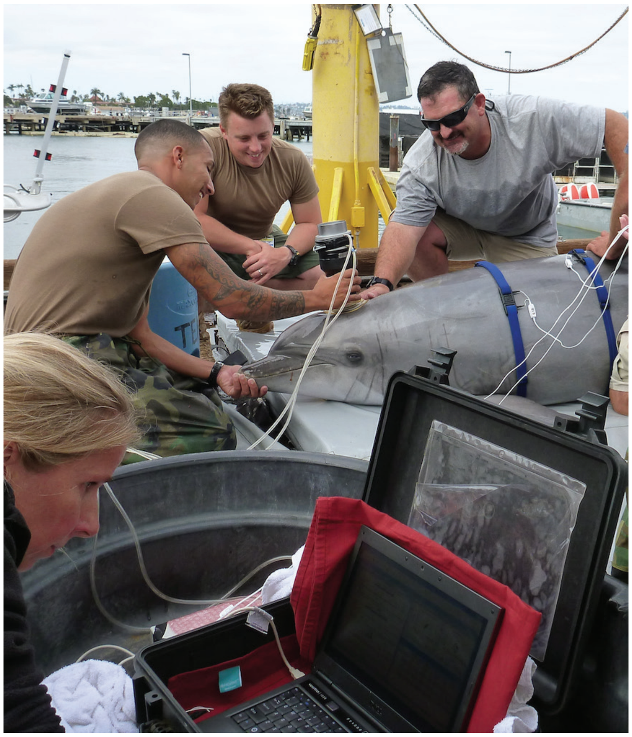

Figure 7-10. To better understand pulmonary function, this dolphin is participating in a noninvasive pulmonary function evaluation. The elastic resistance bands are loosely placed around the dolphin's chest to measure the expansion of the ribs and diaphragm during respiration.
Photo courtesy of the US Navy.

Limitations of pathogen detection that are present in traditional domestic animal and human medicine, however, also exist for marine mammals. Current methods being investigated to improve disease diagnosis include advancements in digital imaging, characterization of noninvasive breath condensate metabolites, and predictive models for disease onset and outcomes.[13] Some dolphins and sea lions have participated in pulmonary function tests, with the goal of improving understanding of pulmonary diseases and anesthesia (Figure 7-10).

Metabolic Conditions

Health data from US Navy dolphins has demonstrated that dolphins can develop a subclinical condition similar to metabolic syndrome in humans, including elevated insulin, glucose, and triglycerides and associated iron overload and fatty liver disease.[27-30] In addition, dolphins can develop ammonium acid urate kidney stones, a condition present in an estimated quarter of the US Navy's dolphin population.[31] Current research, including genomics, proteomics, and metabolomics, is focusing on potential dietary, genetic, and environmental factors that may influence these metabolic conditions in dolphins.[28]

Advanced Medical Technologies

The most significant challenge associated with providing clinical care to marine mammals concerns their unique in-water environment and the specialized anatomy and physiology developed by these animals to cope with living in the ocean. For example, major surgery such as exploratory laparotomy has been limited due to challenges the marine environment creates for postoperative care and proper wound healing. Currently, several institutions are working with the MMP to evaluate the use of minimally invasive surgery in marine mammals. Advanced medical technologies that are currently being incorporated into clinical care include computed tomography scans or CT, magnetic resonance imaging or MRI, renal scintigraphies, interventional radiology, and laparoscopy. Safe and successful use of general anesthesia, including techniques for invasive and noninvasive blood pressure monitoring and blood gas monitoring, are also high clinical priorities. The program has performed successful anesthesia for several dolphin cases and has developed the expertise to place arterial catheters in both dolphins and sea lions to monitor blood pressure and other parameters.

Disease Prevention Research

Since US Navy marine mammals deploy worldwide, generalized protection against the various diseases they may encounter is critical. In collaboration with Stanford University and Baylor College of Medicine, a dolphin probiotic candidate has been identified that may protect the dolphin gastrointestinal system against infections.[13] Additionally, adipose stem cells successfully isolated from the nuchal fat pad in dolphins have been shown to effectively speed up wound healing (Figure 7-11).[32] In sea lions, stem cells have been isolated from adipose tissue and used to treat ocular disease and for joint care. Stem cell therapy shows promise in treating or preventing many other disorders.

Other Research

Aside from research that directly supports MMS requirements, operation and maintenance, and care, the MMP also provides a unique opportunity for scientists to conduct research in support of other US Navy and

Figure 7-11. An Army Veterinary Corps officer assigned to the Marine Mammal Program injects a topical anesthetic in preparation for a procedure to measure the effects of stem cells on wound healing.
Photo courtesy of the US Navy.

government activities. The federal government does not maintain marine mammal inventories to support research and development efforts outside the MMP; rather, Navy mammals may be used opportunistically when requested by other activities in support of efforts for which the Navy and research sponsors see the potential for enhanced scientific knowledge. Many of these efforts offer direct and indirect benefits to the MMSs, and no efforts are undertaken that might adversely affect any aspect of supporting MMSs. Sponsors for these efforts generally fund costs associated with the research, along with any unique maintenance and support costs that emerge as a result of these efforts.[13]

Since the late 1960s, behavioral conditioning techniques have been used at the MMP to evaluate hearing sensitivity and auditory function in a variety of marine mammal species (Figure 7-12).[33-41] More recently, electrophysiological techniques have been developed to allow audiometric assessment in animals not specifically trained for behavioral hearing tests or to whom access is limited, including stranded and rehabilitating marine mammals. Electrophysiological methods rely on the measurement of auditory evoked potentials (AEPs), which are small changes in the electrical activity in the brain produced when an animal hears a sound.[40-42] A rugged, portable system for AEP measurements, developed by the MMP, is used for hearing assessment in a variety of marine mammals. The unique capabilities of the MMP to conduct both behavioral and AEP tests with the same animal allow the AEP results to be validated with more universally accepted behavioral data.

Procedures have also been developed to conduct periodic auditory screening of MMS dolphins and sea lions via AEP measurements. Many US Navy dolphins and sea lions have been tested, revealing potential effects of age, gender, and certain health conditions on their hearing abilities. These data form an important complement to clinical physical examinations and provide key information for MMP animal management decisions.

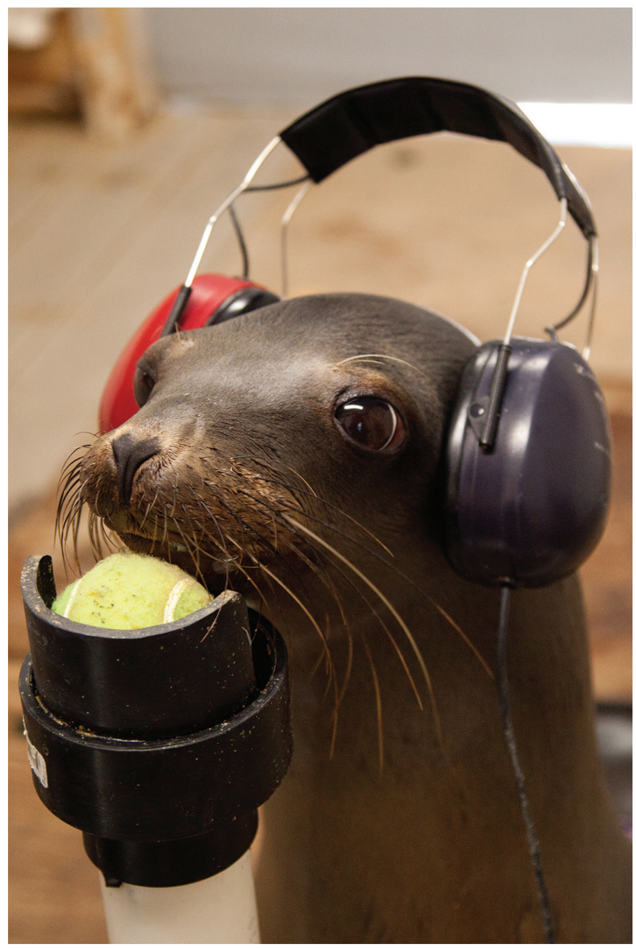

Figure 7-12. A California sea lion participates in a hearing study.
Photo courtesy of the US Navy.

Over the last decade, concerns that high-intensity Navy underwater sound sources may adversely affect the health and behavior of marine mammals in the wild have steadily increased. To address these concerns, MMP scientists have applied both behavioral and AEP methods to directly measure the effects of intense sound on marine mammal hearing.[35,36] These studies compare marine mammal hearing thresholds measured before and after exposure to intense sound to determine the amount, if any, of temporary hearing loss, called temporary threshold shift.[34,37] The resulting data have been used to predict and mitigate the effects of underwater noise on wild marine mammals and develop deconfliction guidelines for US Navy dolphins and sea lions operating near active acoustic sources. At present, the data collected by MMP scientists form the cornerstone of the Navy's criteria to assess the effects of midfrequency sonar and explosives on marine mammals.

MMP scientists are also combining psychophysical approaches, acoustic measurements, AEP measurements, and functional medical imaging modalities to learn how dolphins detect and use various echo features to identify targets and to improve the performance of man-made sonars.[33,43,44] Although some progress has been made in understanding the characteristics of dolphin biosonar emissions, the operation of the biosonar receiving system, particularly the signal processing stage, is still not well understood, and dolphin biosonar capabilities currently exceed those of man-made sonars, particularly in shallow, cluttered environments.

Finally, the MMP recognizes the unique adaptations of marine mammals that make them especially well suited for military purposes. They can dive deeper, longer, and safer than any human diver and have demonstrated the ability to locate targets with exceptional accuracy. For several years, the US Navy has been developing unmanned underwater vehicles that also use sonar to locate objects, with the goal of replacing the marine mammal. However, until technology can accurately replace the natural skills and trainable tasks that make the marine mammal systems successful, the MMP will continue to provide an invaluable service to the US Navy.

PREVENTIVE MEDICINE FOCUS FOR MILITARY MARINE MAMMAL HEALTH

The cornerstone of the MMP healthcare practice is the extensive preventive medicine program established by veterinary personnel within the MMP. This program, which is essential to protecting, promoting, and maintaining optimal health as well as preventing disease, disability, and death, consists of seven components: (1) physical examinations and health monitoring, (2) sanitation and nutrition oversight, (3) data and tissue collection and management, (4) deployment support, (5) development of advanced clinical technology, (6) environmental health monitoring, and (7) education. Historically, US Army personnel have contributed significantly to the preventive medicine program and continue to provide support in areas vital to maintaining good health.[45]

Physical Examinations and Health Monitoring

Similar to the standards set for the MWDs, US Navy marine mammals receive a comprehensive physical examination at least once a year. These examinations include a thorough history and observation; visual examination; palpation; auscultation; blowhole and stool sample collection to screen for parasites and inflammation; gastric fluid analysis; and blood sample collection for complete blood count and serum chemistry. Because of their unique anatomy and housing requirements, ultrasound examination is extremely valuable for dolphins and is often included as part of the physical examination. Additional imaging may include radiology, CT, and MRI as needed. In some animals, endoscopic procedures are indicated to monitor health. The veterinarian performing the physical examination may add any additional diagnostics depending on the animal and its current health status. From these results, veterinarians can often detect the early stages of illness and prescribe effective treatment.

Deployability guidelines for military marine mammals differ from that of MWDs. Although there are four categories that determine MWD deployability, marine mammals assigned to a fleet system or certified as a spare animal are designated as either (1) "fit" or (2) "unfit" for duty. The US Navy deploys only healthy animals that are fit for duty.

Animal trainers teach husbandry and medical behaviors so that dolphins and sea lions will allow voluntary examinations. Dolphins start this training as soon as they are born, interacting with trainers and learning to accept fish. By the time they are 6 to 8 months old, dolphins learn to follow the trainer's hand as a guide and lay out for medical body checks. Young dolphins are also taught to present their flukes and keep them raised for up to 3 minutes for venipuncture.

New sea lions are taught to line up, leave the water when called, and climb onto a dressing stand for examination. Many will voluntarily present their hind end for venipuncture. Sea lions also learn to open their

Figure 7-13. With the help of a marine mammal trainer, a US Army Veterinary Corps officer performs a voluntary physical exam on a California sea lion.
Photo courtesy of the US Navy.

mouths on command, hold up their flippers when asked, and hold still for auscultation and palpation (Figure 7-13).

Training for additional medical procedures, such as ultrasound examination and radiographs, is accomplished by the training staff when the need arises (Figure 7-14 and Figure 7-15). The emphasis on training solid medical behaviors—essential for ensuring good health—is critical when illness arises and animals need medical treatment.

Figure 7-14. Ultrasound examination of animals such as this California sea lion provides valuable information to ensure marine mammal health.
Photo courtesy of the US Navy.

Given that animals are maintained in close proximity to the veterinary hospital, veterinary personnel are in close communication with the training staff and can observe the animals on a daily basis. In addition to the annual examination, animals are examined frequently for other reasons, including illness or a change in health status, pre- or post-deployments, pregnancy, neonatal care, and geriatric care. For example, since all nondeployed animals are housed in open-ocean enclosures with access to wild fish and other wildlife, a parasite control plan is essential to ensure good health. Dolphins and sea lions are dewormed every 6 months and as needed. Sea lions are susceptible to canine heartworm, so they also receive monthly prophylactic parasiticide (eg, ivermectin). Currently, vaccinations are not considered part of the MMPs preventive medicine plan and are rarely administered because of the potential for side effects and limited research demonstrating efficacy (Dr Eric Jenson, Attending Veterinarian, Navy Marine Mammal Program, personal communication, February 2013).

Sanitation and Nutrition Oversight

Each year, the US Navy purchases over 800,000 pounds of fish to feed its marine mammals (Dr Mark Xitco, Head of Navy Marine Mammal Program Biosciences Division, personal communication, February 2013). US Army personnel are largely responsible for overseeing the sanitation and nutritional aspects of

Figure 7-15. A bottlenose dolphin presents her ventrum so that a veterinarian can place a urinary catheter to collect a urine sample. Marine mammal trainers shape behaviors that allow animals to voluntarily participate in medical procedures.
Photo courtesy of the US Navy.

Figure 7-16. Veterinary Corps personnel inspect the fish production facilities that supply all fish fed to the US Navy marine mammals.
Photo courtesy of the US Navy.

marine mammal care, and this oversight is the second key component of the MMP's preventive medicine program.

All fish fed to the Navy's animals are purchased from production facilities that are individually inspected by US Army veterinary personnel (Figure 7-16). These personnel reference military sanitation requirements for food establishments, including the Military Standard 3006C[46] and Military Handbook 3006C.[47]

In addition to general sanitation guidelines, Army veterinary personnel rely on more specialized references for fish and fisheries products.[48] A variety of fish may be fed, including capelin (*Mallotus villosus*), herring (*Culpidae* spp), mackerel (*Scromber* spp), croaker (*Micropogonias* spp), pin fish (*Lagodon rhomboids)*, and mullet (*Mugilidae* spp). Additionally, squid (*Loligo* spp) is frequently fed. All fish are caught, packaged, shipped, and stored using the same standards as for human food. Each new lot of fish is subject to organoleptic sensory evaluation, chemical proximate analysis, heavy metals, and pathogenic bacteria screening upon procurement.[48]

Food service sanitation principles are also applied to all aspects of the ration preparation and feeding. The US Army maintains a hazard analysis critical control point plan with critical control points and potential significant hazards associated with fish transport, storage, and handling on-site. The San Diego facility is equipped with two fish preparation areas designed to meet or exceed the standards set forth in MIL STD 3006C, *Sanitation Requirements for Food Establishments*. Frozen fish are stored at 0° F at a large off-site facility and delivered to on-site freezers and fleet support freezers at satellite facilities. US Army Veterinary personnel inspect the fish preparation facilities and freezers monthly. Microbiological testing is routinely conducted on food-contact surfaces and includes frequent use of an adenosine triphosphatase (ATPase) system to detect biological contamination.[46,49,50]

All animals are weighed monthly, and their body condition is evaluated regularly to ensure maintenance within individually established guidelines. Each individual goal weight is based on historical morphometrics, individual animal health needs, statistical analyses of free-ranging animals, and US Navy animal's morphometrics. A customized ration is formulated for each animal based on the caloric and nutritional content of the fish being fed and the animals' requirements.

Data and Tissue Collection and Management

The third key component of the preventive medicine program includes data management and tissue collection and archiving. In addition to maintaining hard copy healthcare records, the MMP maintains an extensive electronic medical records database that was specifically designed for the program. All data, including observations; diagnostic sample submissions and test results; treatment records; medication history; body weight and length measurements; daily diet rations; and transport history are entered into the database by a dedicated staff, which includes a veterinary epidemiologist. The database is capable of gathering the input information and performing sophisticated statistical analyses on this information to guide future clinical decisions. Using the database, epidemiologists also can analyze past and current trends in order to track an epizootic event and predict the future course and impacts of that event.

In addition to the database, the records department manages an extensive collection of archived tissue samples (Figure 7-17). Just like MWDs, every deceased marine mammal undergoes a comprehensive and complete necropsy procedure not only to characterize disease and determine cause of death, but also to collect and archive as much tissue as possible. These tissue samples may be used for future research purposes such as characterizing fatty liver disease in dolphins, a recently discovered disease state. Other biological samples archived include serum, plasma, buffy coats, feces, milk, urine, and fluid aspirates. These samples also support future retrospective studies.

To ensure MMP animals are ready to deploy, the records department researches requirements for animal transports and prepares all required documentation and permits for imports and exports. The regulations governing transport of marine mammals are extensive

Figure 7-17. The US Navy Marine Mammal Program manages an extensive collection of archived tissue samples dating back to the origins of the program in the 1960s. These tissue samples can provide valuable insight into pathology that may not have been recognized in the past due to recent advances in technology.
Photo courtesy of the US Navy.

and vary based upon the destination. The records department maintains relationships with host nation, state, and federal regulatory agencies such as the National Oceanic and Atmospheric Administration, US Fish and Wildlife Service, and US Customs and Border Protection.[51-53]

Deployment Support

The fourth component of the preventive medicine program is deployment support. The MMP supports, on average, 12 deployments per year, ranging from local exercises lasting a week to full-scale overseas deployments lasting several months (Dr Mark Xitco, Head, Navy Marine Mammal Program Biosciences Division, personal communication, February 2013). The US Army veterinary element participates heavily in supporting these deployments. Prior to deployment to a new location, an extensive site survey is conducted to gather information on the location and support available. A veterinarian usually accompanies the team to identify local medical and veterinary resources and perform an environmental assessment.

Animals scheduled for deployment undergo a pretransport health assessment using risk assessment-based principles. The goal of these health assessments are to identify any emerging health problems or reasons the animal should not be transported or participate in an exercise. A veterinarian or veterinary technician accompanies all animals while on deployment. Usually local exercises require a veterinary technician, but larger exercises involving aircraft, long-distance travel, longer duration, or deployment to more remote areas require at least one veterinarian to be present.

A mobile marine mammal clinic, fully stocked with appropriate diagnostic and treatment supplies, is also available for large-scale deployments. During transport, veterinary personnel are responsible for monitoring animal health, establishing health parameters, and diagnosing and treating any medical issues that arise. Once the animals arrive at the destination, the veterinary personnel monitor animal health and provide treatments if necessary, liaise with local medical support when needed, and perform water quality assessments (Figure 7-18).

Upon return, animals are usually quarantined to protect the population. Each animal receives a full post-transport physical examination, and depending on location, diagnostic testing specific to infectious risks associated with the deployment location.

Figure 7-18. A Navy dolphin slides into a beaching mat in preparation for work. Dolphins are housed in special inflatable shipboard pools when transporting and working off ships.
Photo courtesy of the US Navy.

Development of Advanced Clinical Technology

The MMP prides itself in striving to be the best marine mammal facility in the world, and the fifth component of the preventive medicine program emphasizes the goal to continually improve knowledge, equipment, and methodology. Clinical research includes kidney disease pathophysiology, hormonal stress markers, intestinal microbiota, breath analysis, stem cell therapy, and metabolic syndrome. The program has published over 1,000 papers in peer-reviewed scientific journals.[4]

The concept of "One Medicine," which is often credited to the veterinarian Calvin W. Schwabe, is thoroughly embraced by the MMP veterinary team.[54,55] (See Chapter 13, Global Zoonotic Disease Surveillance and Control, for more information about the One Medicine concept and its proponents, including Rudolf Virchow and Sir William Osler.)

The MMP has developed and expanded collaborations between veterinarians, physicians, public health officials, and environmental scientists, with the goal of providing the finest care to the marine mammals and obtaining a better understanding of the link between multiple disciplines. For example, specialists in human medicine fields have recently assisted veterinarians with CT, MRI, and positron emission tomography scans (Figure 7-19); CT-guided biopsies (Figure 7-20); advanced wound management; and laparoscopic procedures, and these specialists also have helped develop and refine the technique for ultrasound-guided hepatic vein catheterization in dolphins.

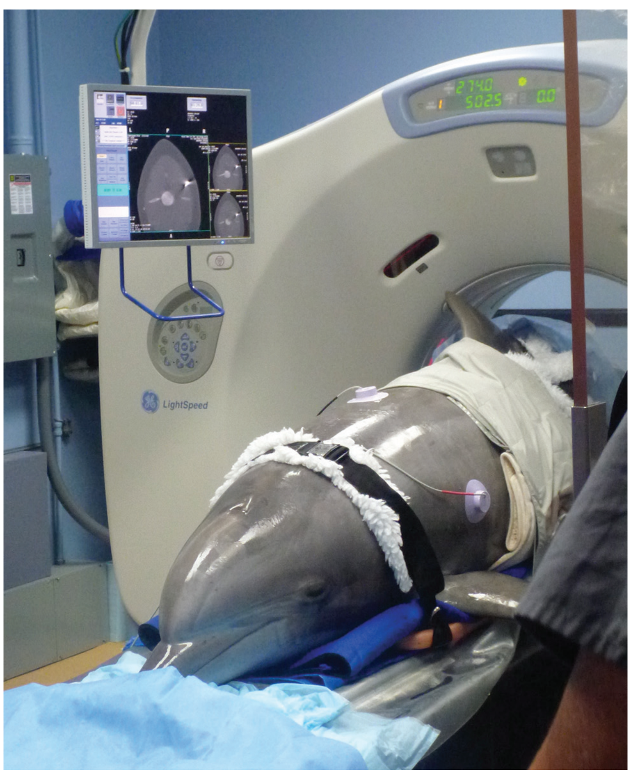

Figure 7-19. Army Veterinary Corps personnel assist in performing a positron emission tomography scan on a bottlenose dolphin.
Photo courtesy of the US Navy.

Figure 7-20. A bottlenose dolphin undergoes a computerized tomography scan in preparation for a guided bone marrow biopsy. US Navy and other military healthcare facilities provide valuable medical support.
Photo courtesy of the US Navy.

Since the MMP values the care and welfare of each animal, the program provides resources for procuring and testing new, high-quality equipment that will benefit marine mammal health. Researchers and clinicians have recently developed a breath condensate collection technique that measures certain compounds in breath, which may be useful in detecting early indicators of inflammation or infection. The program also opened a 2,500-square-foot, newly renovated, state-of-the-art marine mammal hospital in 2012. This facility included creation of a surgery suite, laboratory, pharmacy, and pathology room. Mechanical, electrical, and information technology improvements support new diagnostic-imaging and patient-monitoring capabilities.[53]

A final area of technological development focuses on the marine mammal's special medical needs. Because of the unique physiology and housing requirements of marine mammals, standard veterinary procedures are not always possible or practical. For example, even though exploratory laparotomy may be indicated, it may not be possible because large surgical incisions may not heal well in a marine environment. The MMP veterinary team is currently working on developing an abdominal laparoscopy technique and refining anesthesia in cetaceans. Development of these techniques will allow clinicians to greatly improve the level of care available to marine mammals and increase cetacean lifespan.

Figure 7-21. An Army animal care specialist collects plankton for domoic acid testing. Environmental testing is critical to preventing marine mammal disease.
Photo courtesy of the US Navy.

Environmental Health Monitoring

The effect environmental health likely contributes to animal disease processes is not a new concept for marine mammal medicine or the MMP. Recently the program increased its efforts to better understand the area of marine biotoxins and how they may affect US Navy marine mammals.

At the MMP, all nondeployed animals are housed in open ocean enclosures and frequently train untethered in open water. The MMP meets and often exceeds policies and procedures consistent with the Animal Welfare Act and Regulations in regard to animal housing and water quality monitoring.[56] Marine mammal enclosures and work sites are tested weekly for total coliforms. The program also has expanded on the recommended guidance to better understand the potential presence of other environmental contaminants. Environmental monitoring includes testing fish, mussels, and plankton for domoic acid (Figure 7-21); testing water for heavy metals and toxins; and testing native wildlife and excrement for various infectious agents.

Emphasis on Education

The final concept of the preventive medicine program, the education of MMP personnel, is arguably the most important for two reasons. First, because the Army element of the US Navy staff is constantly rotating, the requirements of marine mammal care are new to most incoming soldiers. All veterinary staff—civilian, contractor, and Army—must embrace the challenge of training new animal care staff on the state-of-art medicine practiced by the MMP.

Second, a good preventive medicine program is essential in any field of medicine but is especially critical for marine mammals because of their tendency to mask disease. To meet this challenge, the MMP strives to provide the most complete educational training possible, focusing, as aforementioned, on the preventive medicine components of marine mammal care: physical examinations and health monitoring, sanitation and nutrition, data and tissue collection and management, development of advanced clinical technology, deployment support, and environmental health monitoring.

CURRENT RELEVANT MARINE MAMMAL DISEASES

Marine mammals are susceptible to a variety of diseases, including infectious diseases and metabolic conditions. The following section on current relevant marine mammal diseases briefly covers a few disease processes that are of particular interest to the US Navy MMP, namely respiratory disease, ocular disease, metabolic conditions, and gastritis.

Respiratory Disease in Dolphins

Just like terrestrial mammals, marine mammals are susceptible to respiratory disease. However, as mentioned previously in this chapter, because of the unique anatomy and behavior of cetaceans in particular, they are vulnerable to developing both primary and secondary pneumonia. In order to dive, bottlenose dolphins rely on long periods of breath-holding with periods of brief surfacing to take breaths, and, therefore, have developed specialized respiratory anatomy that enables rapid exchange of large volumes of air.[57] The nasal passage, located on the dorsal aspect of the head, lacks the intricate nasal turbinates and sinuses of other mammals that perform the important function of warming and filtering air. While humans exchange about 20% of their lung capacity with each breath, dolphins take short and deep breaths, with an exchange of 75% to 90% of air in one-third of a second.[58-60] These breathing adaptations put them at increased risk of respiratory infections by enabling deep lung exposure to airborne threats at the marine surface.

A retrospective study conducted at the MMP indicated that *Staphylococcus aureus* was the most common confirmed pathogen in US Navy dolphins with pneumonia, it being present in 19% of cases.[25] Other pathogens confirmed in this study include *Cryptococcus neoformans*, *Erysipelothrix rhusiopathiae, Histoplasma capsulatum,* parainfluenza virus, *Proteus* spp, *Pseudomonas aeruginosa,* and *Streptococcus zooepidemic*.[25] Other known infectious causes of pneumonia in dolphins include *Aeromonas hydrophilia*, *Aspergillus fumigatus*, *Coccidioides immitus*, *Halocercus* sp. (lungworm), morbillivirus, *Streptococcus* Group D, and *Toxoplasma gondii*.[25]

Histiocytic pneumonia is also reported as common in dolphins. Potential causes of histiocytic pneumonia may include eosinophilic pneumonia, drug reactions, chronic infections, and metabolic or iron storage diseases.[25]

Clinical Signs

Pneumonia in cetaceans often presents with subtle clinical signs, if any signs at all. Clinicians must remember that cetaceans are extremely good at masking signs of illness. Declining appetite or anorexia may be the only clinical sign; therefore, clinicians should not dismiss this important finding nor hesitate to obtain additional diagnostics.

While bacterial respiratory disease often makes other animals cough, cetacean coughing occurs mainly with upper respiratory disease; however, frequently, tachypnea is not observed until a significant portion of the lung field is damaged. Unilateral pneumonia or large abscesses in the lungs can sometimes cause animals to list to the side of the damaged lung.[61(p326)]

The animal care staff is the most significant source of information regarding history and early clinical signs. At the MMP, clinical signs that have preceded pneumonia include reluctance to perform trained behaviors, blepharospasm, abnormal odor from the blowhole, increased discharge from blowhole, lethargy, and partial to complete anorexia. Progressive clinical signs can include abnormal respiratory character, tachypnea, shallow breaths, dull eyes, anorexia, skin desquamation, lethargy, halitosis, disorientation, abortion, difficulty maintaining buoyancy, and dyspnea.[61]

Diagnosis

As previously mentioned in this chapter, history and visual examinations often give little indication that cetaceans have pneumonia. Auscultation is rarely useful because of the cetacean's thick blubber layer, rapid expiratory-inspiratory cycle, and ability to emit loud transmitted sounds that can obliterate subtle rales.[61(p901)] When faced with equivocal clinical signs, veterinarians turn next to hematology and serum chemistry. Blood results may show signs of inflammation (described subsequently in the clinical pathology section) in varying degrees. It is helpful if the clinician has access to previous blood values in order to appreciate subtle changes or deviations from normal.

Ultrasound examination is another valuable tool in diagnosing and assessing progression of pneumonia (Figure 7-22, a–d). Findings can include pleural effusion detected between parietal and visceral pleura (see Figure 7-22b). If a pulmonary mass is present on the periphery of lungs, it can sometimes be visualized, allowing for fine needle aspiration or biopsy (see Figure 7-22d). Rockets or ring-down artifacts (B-lines) can indicate alveolar interstitial syndrome (AIS), especially if clustered or seen with higher frequency than expected (see Figure 7-22c).[62]

AIS is an increase of fluid or cellular infiltrate in the interstitium and reduced air in the alveolar spaces, with or without interlobular septal thickening.[62] Visual observation of AIS is a nonspecific finding that indicates acute disease (ie, pulmonary edema, respiratory distress, or interstitial pneumonia) or chronic disease (ie, pulmonary fibrosis or interstitial

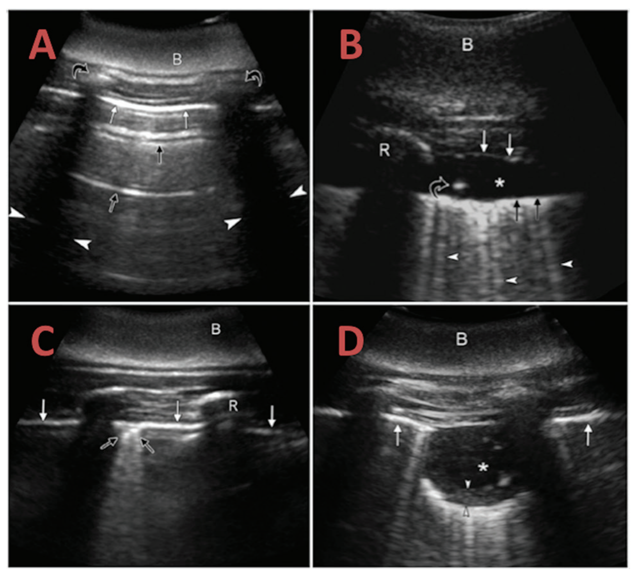

Figure 7-22 a–d. A. Normal sonogram of thorax of a bottlenose dolphin, including blubber (B) layer, ribs (curved arrows) with acoustic shadowing (white arrowheads), visceral pleura (white arrows), and reverberation pattern (black arrows). **B.** Example of pleural effusion (*) between the visceral (black arrows) and parietal pleura (white arrows). Comet-tail and ring-down artifacts are present (arrowheads). **C**. Example of a pleural lesion creating a ring-down artifact (black arrows). **D.** Pulmonary abscess with hypoechoic center (*) and concentric echogenic outer layer (arrowheads). Photo courtesy of the US Navy.

lung disease). If pulmonary consolidation is present, the lung may have an appearance similar to liver. Lymphadenopathy may be noted if the marginal lymph node is visualized.

Radiography is also a valuable tool in evaluating cetacean lungs for pneumonia; this tool often allows more complete visualizations of lesions, especially deep lesions that are not noted on ultrasound. Fine needle aspirates and bronchiolar lavage, currently the most successful means of isolating sole bacterial pathogens antemortem, are invasive techniques and can be technically difficult. Additional diagnostics can include cytology of nasal or blowhole swabs, in addition to culture and sensitivity and molecular diagnostics if organisms are present.[25]

Clinical Pathology

Complete blood cell count and serum chemistry often yield important indicators of inflammation. These indicators are not specific for pneumonia, but in the absence of clinical signs that suggest otherwise, the clinician should assume and treat for pneumonia. The tests that are most useful for indicating inflammation include white blood cell count, differential count, erythrocyte sedimentation rate, plasma fibrinogen, serum albumin, alkaline phosphatase, and serum iron.[63]

Fibrinogen is a very reliable indicator of inflammatory disease in cetaceans and should be measured with the photo-optical test, as the heat precipitation test is prone to inaccuracy. Fibrinogen elevation of 20% or more above the animal's normal value is significant, but it can "be elevated by 50% or more with significant inflammation."[61(p902)]

Erythrocyte sedimentation rate (ESR) is a traditional tool for inflammation that measures the distance erythrocytes fall through a vertical suspension of anticoagulant over time. The magnitude of inflammation is directly related to the rate with which erythrocytes fall in a standard vertically positioned tube. ESR is associated with increases in plasma fibrinogen, and although it is prone to fluctuations, ESR is commonly used in cetacean medicine because it is easily run with inexpensive equipment.

Alkaline phosphatase (ALP) will typically decrease dramatically during illness. ALP may function in endotoxin detoxification, as observed in rats and humans, causing depletion of serum ALP that returns to normal with resolution.[64] Although the level of ALP is considered a very reliable prognostic indicator, it is a poor prognostic indicator if serum levels remain low, despite clinical therapy. ALP will also normally decline with age and decrease in food uptake[61(p409)] and can indicate other things such as hemolysis, certain drugs, and anticoagulants.[61(p902)]

Total white blood cell count (WBC) is a reliable indicator of an inflammatory response and is interpreted similarly as in terrestrial animals. However, life-threatening pneumonia can be associated with unremarkable total WBCs. Cetacean differential counts are also interpreted the same way as terrestrial animal differential counts. WBCs and the differential may fluctuate unpredictably over a very short interval, which may affect interpretation.[63]

Serum iron decreases acutely in animals with bacterial infection or acute inflammation. The body sequesters iron in the liver in a form that is not available to pathogenic bacteria, which can readily use transferrin-bound iron in the serum.[65] The change can be profound, decreasing to levels 20% of normal or less in 24 hours.[61(p902)] A low serum iron indicates infection or inflammation but not necessarily the severity; thus, clinicians should not automatically begin supplementing with iron in cases of potential inflammation. Serum iron, along with WBC and ALP, are often the most sensitive parameters to monitor when assessing treatment and response to therapy. Fibrinogen and ESR are also useful, but improvements tend to occur later in the time course of therapy.

Therapy

Treatment of pneumonia in dolphins usually consists of antibiotic therapy, with selection that follows routine culture and sensitivity. Since treatment often begins before diagnostic results are available, broad-spectrum antibiotics are a good choice.[61(p326)] At the MMP, daily intravenous antibiotics, along with supportive care, have produced good results, especially if an animal presents with anorexia. Supportive care often consists of fluid support, gastrointestinal protectants, pain medications, and appetite stimulants. Antifungal therapy is often considered because of the likelihood of fungal overgrowth during antibiotic treatment.

Since pneumonia is common in cetaceans, clinicians must be knowledgeable of the subtle clinical signs and be prepared to consider diagnostics and treatment, even when the animal does not appear to be sick. Although this condition can be rapidly fatal, it can be treated very successfully if diagnosed early.

Ocular Disease in Sea Lions

While ocular disease affects many marine mammals, diseases affecting the cornea and lens are especially common in sea lions. This section focuses on five topics: (1) background information concerning the sea lion's innate proclivity to ocular disease; (2) the challenges of conducting sea lion ocular examinations;

(3) the potential causes and risk factors of sea lion ocular disease; (4) specific information concerning certain diseases common to sea lions (ie, otariid keratitis, cataracts, and lens luxation); and (5) the treatment and prevention methods for these typical diseases.

Anatomy and Physiology

Pinnipeds, such as sea lions, have evolved some unique characteristics that allow them to achieve visual function both above and below water. The cornea and aqueous humor have roughly the same refractive index as sea water, essentially making them optically inefficient when underwater.[66] The refractive power of the submerged eye depends on the function of the lens, which is large and spherical, with a high refractive power.[17(pp128-132),66,67] This spherical lens would tend to cause severe myopia on land, but sea lions have adapted to overcome this obstacle as well.

The surface of the cornea contains an obvious round, flattened area approximately 6.5 mm in diameter at the midnasal region, which helps achieve a negative refractive power that counteracts myopia in air.[17(p131),66] Additionally, sea lions have a teardrop-shaped pupil and possess the ability to constrict this pupil to a pinpoint shape that aligns with the flat surface. This provides a window that allows refraction to remain almost constant in both air and water (Figure 7-23).[61(pp920-921)66,67]

Figure 7-23. The normal appearance of a sea lion's globe. Photo courtesy of the US Navy.

Several adaptations have evolved that allow for great vision in low light, including a highly developed tapetum lucidum that encompasses almost the entire fundus, large ganglion cells, and a predominance of rods in the retina.[61(pp921),66,67]

Eye Examination

Performing an ophthalmologic examination in sea lions can be challenging, especially if the clinician suspects ocular disease that may be interfering with normal vision. Visually impaired animals accommodate rapidly to their surroundings using tactile and visual cues; therefore, it is not always obvious from observation that the animal is having difficulties seeing. The menace response (the reflex blinking that occurs in response to the rapid approach of an object) is difficult to evaluate because sea lions have sensitive vibrissae (whiskers), which can cause a blinking response even if the animal cannot see the object.

Further complicating the examination, sea lions have a prominent nictitating membrane, strong eyelids, and ability to retract the globe into the ocular cavity.[61(p921)] The narrow pupils can limit visualization of the internal eye structures such as lens and retina. Pharmacologic dilation is not generally used as topical parasympatholytic agents do not adequately dilate pinniped pupils.[66] Thus, voluntary ocular examination is best performed in low-light settings. Visually impaired sea lions tend to thrust their vibrissae forward for prolonged periods to investigate new surroundings and may have short or broken vibrissae.[61(p921)] This may provide an addition clue that the animal is visually impaired.

Pathogenesis

Both wild and managed sea lions appear to be susceptible to numerous corneal lesions; however, the epidemiology and pathogenesis varies significantly between the two groups.[61(pp920),67-70] Among the most common lesions found in captivity are keratitis, cataracts, and lens luxations.[66] A 6-year study of managed pinnipeds showed keratitis or keratopathy present in 62.8% of sea lion eyes examined.[68] In a separate study, 42.4% of California sea lion eyes were found to have cataracts, lens luxations, or both. While populations of wild sea lions appear to be affected by keratopathy and cataracts, the incidence appears greatly reduced compared to the managed populations studied. Several theories have emerged as to why managed sea lions seem more susceptible to these ocular lesions, and the cause appears to be multifactoral. Risk factors that have been identified in development of cataracts include age, history of eye problems, and history of fighting.[66]

Increased ultraviolet (UV) exposure has been suggested as another likely contributing factor to developing ocular lesions.[66,71] Pinnipeds with no access to shade may be 10 times more likely to develop cataracts or lens luxations.[66] Spatial characteristics of the animal enclosures that may contribute to UV exposure include the orientation of the sun on wet and dry areas, depth of enclosures, and surface color.[66] Also, hand-feeding of fish causes the captive sea lions to look upward toward the sky much more often than they would in the wild.

Water quality issues have also been implicated, including the effects of disinfectants such as chlorine, bromine, and ozone, as well as total coliform levels.[66,71] Additionally, freshwater or environments with low salinity are thought to increase the frequency of eye lesions and have been directly linked to development of corneal edema.[61(p920),69] Further studies are needed to enhance understanding of the causes and specific risk factors in order to further improve prevention and husbandry practices.

Otariid Keratitis. Corneal disease, common in both managed and wild sea lions, can cause impaired vision and significant pain. Otariid keratitis (ie, inflammation of a sea lion's cornea) has been described and characterized, including progression and risk factors. Subadults and adults may be affected by mild to moderate ulcerative corneal disease, and it has been theorized that keratitis can cause uveitis and, therefore, contribute to cataract formation. More specifically, the disease has been categorized into three stages, ranging from mild focal corneal opacities with superficial ulcers to severe diffuse corneal lesions with recurrent ulcers and secondary infection.[66]

In a study involving captive otariids, predominantly California sea lions, most presented with bilateral disease, and animals over 5 years of age were found to have a 50% chance of presenting with keratitis lesions. Animals typically presented with signs of eye pain such as epiphora, periocular brown debris caked on the eyelid fur, and blepharospasm. Other clinical findings present in varying degrees include perilimbal or diffuse edema, pigmentation that crosses the limbus, vascularization, and conjunctival hyperemia (Figure 7-24). In severe cases, the epithelium sloughs easily, and some cases present with stromal abscess formation.[66]

Potential causes identified include viral infections, underlying uveitis, trauma, excessive sunlight, and changes in water quality. For example, severe cases are characterized by chronic recurrence, typically two to four flare-ups per year that seem to coincide with increased daylight duration and more intense UV exposure (eg, flare-ups occur in colder climates on days that coincide with snow on the ground and sunny skies).[66] At the MMP, sea lions are housed in shaded structures. Although they could be exposed to increased sunlight during work sessions, water quality seems to play an important role. Flare-ups are often associated with increase in total coliforms, which can occur in the winter because of increased rainfall and runoff.

When keratitis presents with superficial ulcers, it should be treated aggressively to prevent secondary infection. If infection is suspected, aggressive use of antibiotic and anti-inflammatory therapy is recommended to avoid progression. While waiting for culture and sensitivity results, an antibiotic should be selected that targets pathogens present in the water (eg, coliforms, *Pseudomonas* spp, and *Aspergillus*). Oral doxycycline has been suggested for its role in stabilizing the corneal stroma and speeding epithelialization and for general anti-inflammatory effects.[66]

Topical nonsteroidal anti-inflammatory drugs such as nepafenac may reduce eye pain; however, oral nonsteroidal anti-inflammatory drugs should be considered for more severe pain and secondary uveitis. Cyclosporine (2%) or tacrolimus (0.03%) can be helpful to reduce recurrence of active disease.[66] Hypertonic saline applied several times per day is useful in reducing corneal edema.[61(p921)] In addition to drug therapy, animals should have access to shade in order to accelerate resolution.

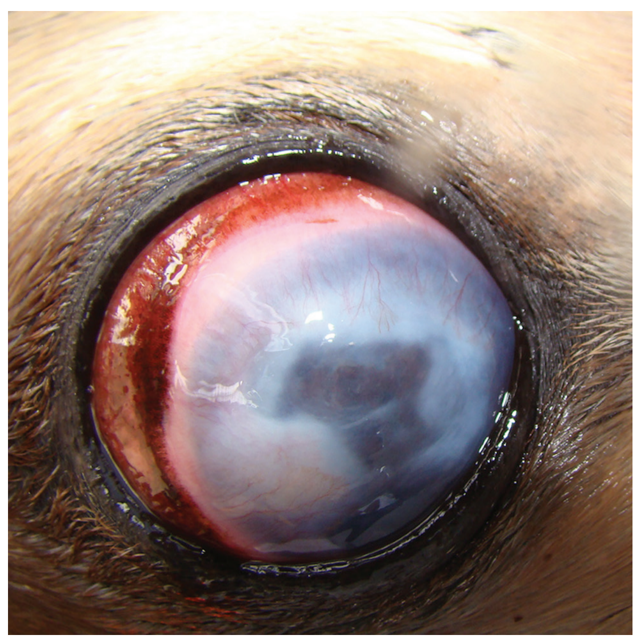

Figure 7-24. Severe keratitis in a sea lion's eye, characterized by diffuse corneal edema, fibrosis, and vascularization. Photo courtesy of the US Navy.

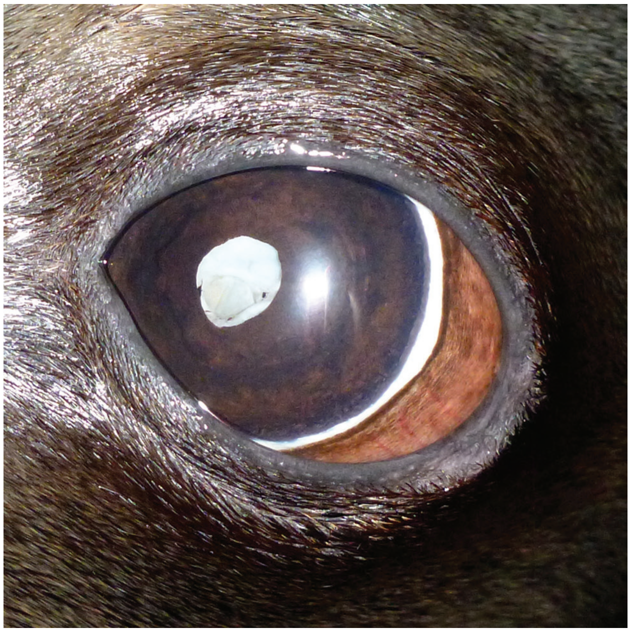

Figure 7-25. A mature cataract in a sea lion's eye.
Photo courtesy of the US Navy.

Cataracts and Lens Luxations. Cataracts, commonly defined as opacity of the lens or capsule, have been documented as a common cause of visual impairment in both wild and managed pinnipeds (Figure 7-25). However, cataract formation appears to be much more prevalent in managed populations, which could be attributed principally to the increased lifespan of managed sea lions.[68] Suspected causes of cataracts in the wild population include congenital anomalies, nutrition, trauma, and age.[72]

Cataracts should be distinguished from nuclear or lenticular sclerosis, an aging change in which the nucleus of the lens becomes compressed over time and is seen as a bluish haze that typically does not affect vision.[68] The pathogenesis of age-related cataract formation may be similar to that of human cataracts, which are thought to develop as a result of long-term exposure to solar radiation and subsequent oxidation, protein cross-linking, and denaturation of soluble lens proteins.[68,73] However, cataract changes were detected in all age groups over 5 years old, suggesting that other factors besides age may play a role in development of cataracts, including, as previously mentioned, history of fighting, history of ocular disease, and no access to shade.[66]

The clinical appearance of cataracts in sea lions is similar to that of other species and is often initially detected as increase in light refraction with punctuate to linear opacification in the adult nucleus of the lens. A unique component of this disease in pinnipeds is the tendency for them to develop lens instability and luxations, often in association with cataract formation (Figure 7-26). It has been suggested that chronic or prolonged exposure to UV radiation could cause degradation of zonular-like, fibrillin-rich structures that adhere the ciliary processes to the lens, resulting in lens instability and luxation. The onset for lens luxation is variable but typically involves anterior luxation, causing uveitis with blepharospasm and epiphora. Lens luxation can progress to secondary glaucoma and severe keratitis and bullous keratopathy.[68]

Sea lions at the MMP that present with lens luxations are usually treated with intracapsular lens extraction, a procedure which has been shown to dramatically decrease pain and improve vision but requires intensive perioperative and postoperative medical management. Such management typically consists of frequent application of topical antibiotics, antifungals, anti-inflammatories, and analgesics.

Until the pathogenesis of sea lion cataract formation is fully understood, prevention is currently targeted at reducing some of the risk factors that have been identified. Lutein, a carotenoid that protects ocular tissue against photooxidative stress, may be useful in improving ocular health.[68] Pinnipeds have been shown capable of absorbing orally ingested lutein, and, therefore, may be capable of accumulating this antioxidant in their lenses.[74]

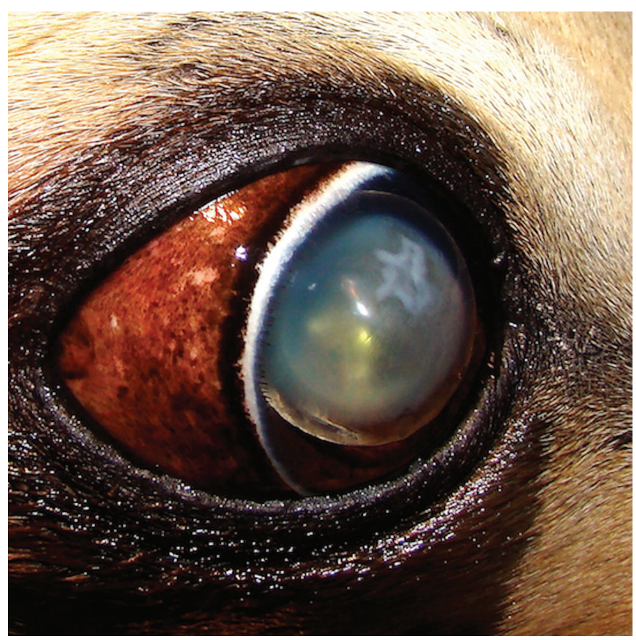

Figure 7-26. Acute lens luxation in a sea lion's eye.
Photo courtesy of the US Navy.

Early detection and treatment of sea lion ocular disease is essential for preventing future disease or progression. However, because diseases such as otariid keratitis, cataracts, and lens luxations are highly prevalent in pinnipeds, and these diseases appear to be related at least in part to management and husbandry, further study is needed to determine the best methods of prevention. Current recommendations to reduce UV radiation exposure include providing shade structure, avoiding activities that encourage animals to look at the sun, and reducing the amount of reflection from the environment. Marine mammal facilities should also undergo frequent water quality evaluations to mitigate factors such as high chemical levels or coliform counts.

Metabolic Conditions in Dolphins

Metabolic Syndrome

Dolphins can develop metabolic syndrome, a subclinical condition similar to that seen in humans.[28,30] Metabolic syndrome in dolphins includes a combination of the following blood abnormalities: elevated ferritin, iron, insulin, glucose, or triglycerides as well as lower adiponectin (an insulin-sensitizing protein).[29] Dolphins with metabolic syndrome may also have hepatic iron deposition or fatty liver disease.[27] The MMP has been on the forefront of research investigating metabolic syndrome and exploring the parallels between humans and dolphins.

Cetaceans and primates share some unique traits that support a shared drive for common glucose metabolism. Compared to other terrestrial animals, primates have high encephalization quotients (a measurement of actual brain size compared to expected brain size given body mass); cetaceans possess similar high quotients.[75] Primates and cetaceans also share the trait of having red blood cells that are extremely permeable to glucose, theoretically for the purpose of supplying the high amounts of glucose a larger brain requires.[76] Because cetaceans consume a high-protein, low-carbohydrate diet, an insulin-resistant state may be evolutionarily advantageous to ensuring that glucose is always available for the brain. Humans may have also benefited from this evolutionary trait during the ice age, when they consumed a high-protein diet.[77] With the return to high-carbohydrate diets, insulin resistance became pathologic, leading to type 2 diabetes.[28] In the past few years, clinicians and researchers have begun to link together several metabolic diseases seen in dolphins, potentially associating them with this common metabolic trait shared by large-brained mammals.

Two components of a metabolic syndrome seen in Navy and other dolphins—namely, (1) iron overload and (2) fatty liver disease—and nephrolithiasis, a different condition, are briefly highlighted in subsequent sections. All of these conditions are common problems found in cetaceans in managed populations and to lesser degrees in wild populations.

Iron Overload. Hemochromatosis or iron overload is characterized by high serum iron (>300 ug/dl), high transferrin saturation (83%–85%), high serum aminotransferases, hyperglobulinemia, hypercholesterolemia, hypertriglyceridemia, and hyperferritinemia.[31,78,79] Hemosiderosis refers to a form of iron overload resulting in the accumulation of hemosiderin, which is often observed in the liver of affected dolphins. Like dolphins, increased levels of iron in the serum and liver of humans also has been associated with hyperinsulinemia and insulin resistance.[80,81]

In dolphins, hemochromatosis can be initially treated using phlebotomy. Three dolphins diagnosed with hepatopathy and hemosiderosis at the MMP were treated with phlebotomy and monitored for changes in their blood values. In all three cases, phlebotomy treatment successfully resolved the clinicopathologic abnormalities, supporting the diagnosis of iron overload in these dolphins.[78] Treatment involved weekly removal of 7% to 17% of estimated blood volume (1–3 L) for 22 to 30 weeks (Figure 7-27).[78] During treatment, red blood cell indices were closely monitored, including hematocrit and hemoglobin, and no adverse effects were noted in the three dolphins.

A trace dietary saturated fatty acid, called heptadecanoic acid or C17:0, recently discovered in fish, may help prevent or treat high ferritin and associated metabolic syndrome.[81] Studies with MMP and free-ranging dolphins demonstrated that higher C17:0 blood levels independently predicted lower ferritin and insulin. When six dolphins were fed a diet of fish higher in C17:0, ferritin decreased within 3 weeks, and metabolic syndrome improved within 24 weeks. While encouraging, this nutrition research is still in its early stages, and recommendations for dolphin diets are pending.

The exact cause of hemochromatosis in dolphins remains unknown, but it has been suggested to be multifactoral, including genetic, nutritional, and infectious disease processes.[82] While dolphins from managed populations have demonstrated significantly higher serum iron, ferritin, and transferrin saturation than free-ranging animals, hepatic hemosiderosis was also present in approximately 25% of the wild dolphins studied after being stranded along US coastlines.[79,83]

Fatty Liver Disease. A study involving histological examination of postmortem liver samples from US Navy bottlenose dolphins showed that 39% had

Figure 7-27. A US Army Veterinary Corps captain performs a phlebotomy procedure to correct hemochromatosis in a bottlenose dolphin.
Photo courtesy of the US Navy.

morphological change suggestive of fatty liver disease, similar to nonalcoholic fatty liver disease in humans.[27] The fatty liver disease observed in humans and dolphins should be differentiated from hepatic lipidosis seen in cattle and cats, which is associated with obesity, negative energy balance, and hypoglycemia.[84,85]

Evidence of fatty liver disease was observed in 18% of wild, stranded dolphins along US coastlines.[83] These dolphins were more likely to have postprandial hyperglycemia than dolphins that did not demonstrate fatty liver disease. They also were more likely to have leukocytosis and hyperglobulinemia throughout the last year of life, suggesting that chronic inflammation was also present in dolphins with fatty liver disease.[27]

Fatty liver disease is seen in humans as a component of metabolic syndrome, which is associated with fasting hyperglycemia and insulin resistance.[85] The evidence from wild dolphins suggests that the potential link between insulin resistance, type 2 diabetes, chronic inflammation, and fatty liver disease seen in humans may also apply to dolphin metabolism.[27]

The US Navy is actively conducting research to better understand the link between the insulin-resistant-like syndrome in dolphins and other metabolic diseases such as iron overload, fatty liver disease, and chronic inflammation. The goal is to learn how to better detect, treat, and prevent these changes. Another value of the current research is the potential to apply what is learned to human metabolic diseases, including metabolic syndrome and type 2 diabetes.

Nephrolithiasis

Nephrolithiasis (the process of forming renal calculi or kidney stones) has been identified in bottlenose dolphins from the MMP population and has been reported in other managed dolphin populations.[27,86] Archived nephroliths from the MMP were determined to be composed of 100% ammonium acid urate (Figure 7-28).[27] The analysis of archived samples and record review of cases at the MMP revealed that 50% of mild nephrolithiasis cases and 100% of advanced cases involved both kidneys. Advanced cases also

Figure 7-28. Ammonium acid urate nephroliths (kidney stones) recovered during necropsy of a bottlenose dolphin.
Photo courtesy of the US Navy.

demonstrated increased likelihood of visible collecting ducts and hydronephrosis, diagnosed on ultrasound. One case presented with ureteral obstruction, confirmed by CT.[27] If large enough, nephroliths can be visualized on ultrasound examination as a hyperechoic structure with acoustic shadowing.[27]

Like iron overload disease, urate nephrolithiasis appears to be a disease of managed populations.[86] The direct cause is under investigation but is thought to be linked to the finding that dolphins from the MMP and other managed collections demonstrated significantly lower levels of urine citrate compared to free-ranging wild dolphins. Potential therapy being investigated include lower protein diets (more squid, less mackerel) and use of potassium citrate.[86] Researchers are also investigating the potential benefit of altered feeding schedules that more closely mimic what wild dolphins experience.[27]

At the MMP, dolphins that are diagnosed with kidney stones are closely monitored to assess progression of the disease. Ultrasound examination of kidneys can be used to subjectively assess the extent and progression of disease. Signs of ureteral obstruction visible on ultrasound include visibly enlarged collecting ducts and hydronephrosis. Routine blood is collected and monitored for increasing renal values that could indicate obstruction. CT scan is valuable for quantitative assessment of stone burden and documenting the location of ureteral obstruction. In cases of acute bilateral ureteral obstruction, anesthesia and surgery may be necessary to relieve obstruction. The MMP is working towards developing a laparoscopic technique to remove stones in life -threatening cases.

Gastritis in Dolphins and Sea Lions

Etiology

In wild and managed populations of marine mammals, gastroenteritis has been attributed to parasites, bacterial infection, stress, or foreign bodies.[61(p533),87] As in other mammals, severe lesions can progress to perforations and peritonitis. Gastritis in US Navy marine mammals and other managed populations can develop secondary to pica,[87] a craving for unnatural articles such as food, which can include organic material (eg, sea grass and kelp) or inorganic material (eg, plastics). While the cause for this unusual craving is unknown, several theories exist, including motivation by hunger; response to gastrointestinal pain or discomfort; behavioral problems; vitamin and mineral deficiencies; and other reasons.[87] A complete and thorough management plan is required to treat this complex and multifactorial problem.

Since animals at the MMP are housed in free-floating enclosures in the San Diego Bay, US Navy marine mammals may have access to naturally occurring marine animals and vegetation that grows on the ocean floor and the nets. Specifically, this includes kelp (*Macrocystis* spp), eel grass (*Zoster marina)*, and surf grass (*Phyllospadix* spp).[87] Most animals consume little to no plant material, but some animals are known to consume substantial amounts of plant material. Since this material is poorly digested, it can remain in the forestomach of dolphins or stomach of sea lions, potentially causing local irritation and gastric ulceration.

Clinical Signs and Diagnosis

Animals with pica and secondary gastritis typically present with subtle signs such as inappetence and behavioral changes such as reluctance to participate in daily routines. If the condition progresses, animal care personnel may observe the animal vomiting plant material or note the presence of vomited material in the enclosure. They may also directly observe the animal eating vegetation that is present in the enclosures or open water.

Signs of gastric ulceration may be present on routine complete blood count and serum chemistry, especially if the animal has a progressive anemia. A gastric sample can be a valuable diagnostic tool when suspecting gastritis in dolphins. Normal gastric samples from a fasting dolphin should appear clear to light pink in color, produce a pH of 1.5 to 2.0, and emit a light fishy odor.[61(p444)] Abnormal samples can show evidence of hemorrhagic ulceration, including a dark pink-red coloration and the presence of coffee-ground appearing material and a foul coppery smell.

Gastroscopy is the diagnostic tool of choice to confirm the presence of a phytobezoar (a trapped mass made up of indigestible plant matter) and evidence of secondary gastric ulceration and hemorrhage. Often, ultrasound evaluation will also reveal a distended forestomach (in dolphins) or stomach (in sea lions). Use of an endoscope is often helpful, and dolphins and sea lions can be trained to voluntarily accept an endoscope for examination (Figure 7-29a and Figure 7-29b).

Cetaceans have a three-chambered stomach, consisting of the forestomach, fundic chamber, and pyloric region.[61(p632)] Few foreign bodies pass beyond the forestomach because of the small opening leading into the fundic chamber. The normal forestomach has peristaltic contractions that occur at a rate of 3 to 4 cycles per minute; reduced peristalsis can indicate a digestive disturbance such as delayed gastric emptying.[61(p632)]

Figure 7-29 a. A US Army Veterinary Corps captain performs a voluntary gastroscope exam on a bottlenose dolphin with the help of an animal trainer and a veterinary technician.
Photo courtesy of the US Navy.

Figure 7-29b. Endoscopic image obtained from an animal that consumed a significant amount of vegetation.
Photo courtesy of the US Navy.

Typically, only the cetacean's forestomach is visualized during gastroscopy. A small amount of cloudy gray fluid is usually present and considered normal. In dolphins with pica and gastritis, the large mass of plant material is easily visualized. If gastritis is present, the clinician may observe gastric lesions on the mucosal surface of the forestomach. However, gastric lesions can easily be missed as much of the mucosa can be obstructed by plant material or fluid.

Sea lions have a simple stomach, similar to dogs. Sea lions can also be trained to voluntarily accept an endoscope for examination of the esophagus and stomach mucosa. If the voluntary behavior is not yet trained, sea lions are typically anesthetized (using procedures similar to other small animals) in order to perform the evaluation.

Treatment and Prevention

Treatment consists of removing the source of mucosal irritation. Dolphins with plant material in their forestomach will often spontaneously vomit this material over several days, especially when they are placed in an enclosure that limits further access to vegetation such as an open- or closed-system pool. This placement not only prevents further ingestion of material, but also allows for evaluation of the animal and visualization or collection of the vomited material.

Other treatment methods for dolphins include oral administration of hydrogen peroxide, which may result in vomiting of the material. As with other animals, care should be taken when attempting this treatment because of the risk for entrapment in the esophagus and asphyxiation. Foreign material can also be extracted either manually or with an instrument.[87]

Treatment of sea lions consists of removal of the plant material with gastroscopic instruments, as hydrogen peroxide administration has not been very effective in this species. Once the source of irritation is removed, animals may be treated symptomatically with gastric protectants, proton-pump inhibitors, or H2-receptor antagonists, and healing progresses quickly.

Prevention involves development of a long-term management plan to reduce or eliminate the behavior. The management plan should be tailored to each case, taking into consideration the potential causes for the behavior. For example, nets on the enclosures should be kept relatively clean and free of vegetation. Feeding schedules and types of fish given can be modified in an attempt to limit the behavior, and animals may be provided with additional items to provide enrichment.

SUMMARY

Marine mammals represent a vital asset to the US Navy because they currently possess the ability to complete underwater detection tasks easier, safer, and with better accuracy than any other technology or human team. Maintaining the health of the US Navy's marine mammals is a vital part of the MMP's mission and focus. The marine mammals at the MMP are susceptible to a variety of disease processes, many of which are found in other managed populations. Some diseases, such as pneumonia in dolphins, have been well documented in both managed and wild populations. Others, such as metabolic syndrome, are still being actively researched in order to obtain a better understanding of the pathophysiology in order to develop effective treatment plans. The MMP continues to be at the forefront of marine mammal medicine and research, with the goal of better understanding the issues that affect the US Navy animals as well as other managed and wild populations.

The veterinary care team provides health care to keep all MMP animals well and fit for duty, incorporating cutting-edge techniques and technologies and supporting research programs focused on constantly improving animal health. The continued success of the veterinary care program depends on several key MMP elements: a strong preventive medicine program, continued support of US Army veterinary personnel, employment of expert civilian veterinary staff, and positive relationships with the training and husbandry staff. With so many people and endeavors invested in the health of the US Navy marine mammals, the program will continue to thrive and provide a valuable service for years to come.

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