APPENDIX A

NAVY MARINE MAMMAL PROGRAM
SSC SAN DIEGO

SPACE AND NAVAL WARFARE SYSTEMS CENTER
53560 HULL STREET
SAN DIEGO, CALIFORNIA 92152

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AAALAC	Association for Assessment and Accreditation of Laboratory Animal Care International
APHIS	Animal and Plant Health Inspection Services
ASC	Animal Safety Committee
AWA	Animal Welfare Act
BWG	Biotech Working Group
CFR	Code of Federal Regulations
COTS	Commercial off-the-shelf
MHD	Minimum horizontal distance
MMP	Marine Mammal Program
MMPA	Marine Mammal Protection Act
MMS	Marine Mammal System(s)
NATO	North Atlantic Treaty Organization
NMFS	National Marine Fisheries Service
SECNAVINST	Secretary of the Navy Instruction
SISS	Swimmer Interdiction Security System
SOP	Standard operating procedures
SSC San Diego	Space and Naval Warfare Systems Center, San Diego, CA
U.S.	United States
USDA	United States Department of Agriculture

1. HISTORICAL OVERVIEW

The United States (U.S.) Navy's Marine Mammal Program (MMP) began when the Navy acquired a Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) for hydrodynamic studies in 1959. Navy scientists designing torpedoes were aware of the hydrodynamic efficiency of dolphins and were interested in determining whether dolphins did, in fact, have special characteristics that might be applied to the design of underwater ordnance. However, further work with this dolphin indicated that the unique physiological or hydrodynamic capabilities it possessed were limited in applicability to the Navy's hardware systems being developed at that time. Nevertheless, Navy scientists were impressed by the animal's other sensory and physiological capabilities as well as its apparent trainability, and they continued to support studies on how dolphins might be used to perform useful tasks.

In 1963, the Navy began a dolphin research program at Point Mugu, California, to support the studies initiated in the 1950s. Primary interests were in the study of marine mammals' developed senses and capabilities (such as sonar and deep-diving physiology). A major accomplishment was the demonstration showing that trained dolphins and sea lions could reliably work untethered in the open sea. In 1965, a Navy dolphin named Tuffy participated in the Sealab II project off La Jolla, California, carrying tools and messages between the water surface and aquanauts operating 200 feet below on the ocean floor.

In 1967, the Point Mugu facility and its personnel were placed under a newly formed organization, which has since undergone a number of name changes: Naval Undersea Warfare Center; Naval Undersea Research and Development Center; Naval Undersea Center; Naval Ocean Systems Center; Naval Command, Control and Ocean Surveillance Center Research, Development, Test and Evaluation Center; and, finally, the Space and Naval Warfare Systems Center San Diego (SSC San Diego). In 1968, the facility was moved to Point Loma in San Diego, California. Shortly after personnel moved to San Diego, a marine mammal laboratory was established at the Marine Corps Air Station on Kaneohe Bay, Hawaii. Some of the personnel and animals at Point Mugu transferred to the Hawaii laboratory, but over time the complete operation at Point Mugu moved to the new facility at Point Loma, San Diego.

In San Diego, the research and development program that was initiated at Point Mugu continued. This included further studies of marine mammal capabilities; development of improved techniques for diagnosis and treatment of marine mammal health problems; neuro-physiological studies; use of behavioral and other non-invasive techniques to gain a better understanding of how the dolphin brain functions; development of instrumentation for determining, by brain wave activity, the hearing range of cetaceans; and investigations of how dolphins vocalize. These studies were conducted with 10 species of odontocete cetaceans (toothed whales) and 6 species of pinnipeds (seals and sea lions), as well as several species of sharks and marine birds. Presently, only California sea lions (*Zalophus californianus*) and bottlenose dolphins (*Tursiops truncatus*) reside at SSC San Diego.

Marine mammal work at the Hawaii laboratory consisted of behavioral studies, reproductive physiology, further research on dolphin echolocation, and investigation of marine mammal potential for performing useful tasks more efficiently, safely, and cost-effectively than using human divers or deep submersibles. Four of the five current Navy operational marine mammal systems were developed in Hawaii, including a dolphin-based swimmer defense system. In

1993, as a result of the U.S. Military Base Closure and Realignment Commission action, the Hawaii laboratory was closed, and the animals, personnel, and selected facilities were moved to San Diego. The consolidation of military support activities was paralleled by a reduction and consolidation of the program at San Diego during the same period. Currently, the MMP focuses on the use of marine mammals (dolphins and sea lions) for protecting ports and Navy assets from swimmer attack, locating and assisting in the recovery of expensive exercise and training targets, and locating potentially dangerous sea mines. Research into animal care, health, physiology, behavior, and management of these marine mammals is also conducted.

2. MMP USE OF DOLPHINS AND SEA LIONS

The marine mammals within the MMP provide unique capabilities for Navy undersea missions, particularly in finding and locating intruders and mines, which are capabilities that cannot be matched by existing technology. Although recent efforts in modernizing and upgrading the Navy's capability in detecting underwater mines and human intruders have been significant, there remain technological challenges associated with the detection, location, marking, and neutralization of underwater objects in harbors, rivers, and complex nearshore environments. To address these challenges, and until technological advances provide for use of underwater detection hardware in these types of environments, Navy marine mammals continue to perform required operational missions as assigned by the Chief of Naval Operations. All MMS underwent independent testing and evaluation when developed at SSC San Diego. The tests were administered by the Commander, Operational Test and Evaluation Force or assigned Independent Test and Evaluation Agents. To date, marine mammals have consistently out-performed other technology-based systems (such as remotely operated vehicles), demonstrating a high probability of completing their tasks while being efficient, reliable, and cost-effective.

Under the MMP at SSC San Diego, research and development continues in exploring the capabilities of marine mammals to conduct Navy tasks. During the 1970s and 1980s, the major components of the MMP were developed under the Advanced Marine Biological Systems Program. This program maintained the care, health, and management of the animals; pursued research that supported marine mammals in the Navy; and initiated the Navy's current operational Marine Mammal Systems (MMS) component. An MMS refers to a collection of personnel, equipment, operational processes, logistics procedures, and documentation that come together to perform a specific operation for the Navy's undersea mission. The key components of the MMP MMS are the mammals and their human teammates. (MMS is used in this document as both a singular and plural acronym.)

The MMP developed five unique MMS referred to as MK 4 to MK 8. The MMS fulfill requirements where Navy hardware is determined to be inadequate or human capability is an issue. The following five MMS are currently in operation.

- MK 4 is a dolphin searching system that detects and marks locations of deep water mines moored off the ocean floor.

- MK 5 is a sea lion mine recovery system that locates pingered training mines for retrieval. The sea lions can dive to mines placed at depths over 500 feet and then attach a grabber device for recovery by a vessel on the surface.

- MK 6 is a dolphin and sea lion swimmer and diver detection system that can detect and mark the location of an intruder in areas such as harbors, ship channels, and anchorages.

- MK 7 is a dolphin mine searching system that detects and marks the location of mines placed on the ocean bottom and buried under the sea floor.

- MK 8 is a dolphin system where dolphins are trained to swiftly identify safe corridors for the initial landing of troops ashore. MK 8 operates in very shallow water (10 to 40 feet sea level).

The typical MMS operation is for dolphins, sea lions, and the necessary equipment to be transported by small boat to an area where the animals are to search for an object/intruder. The animal enters the water as directed by the trainer and follows the boat while searching the area using its detection senses (either vision and hearing for sea lions or sonar and hearing for dolphins). If a target is identified, the animal returns to the boat, alerts the trainer, and is then given instruction by the trainer as to how to proceed (e.g., whether to mark or attach to the object). Usually, the animal is given marking hardware to facilitate retrieval and examination of the target by other security personnel. The MMP marine mammals are generally trained for a particular operational capability; however, animals may be cross-trained to better serve the program.

Dolphins were selected for the MMS because of their exceptional biological sonar that is unmatched by hardware sonar in detecting objects in the water column and on the ocean bottom in shallow water. Sea lions were selected because of their sensitive underwater directional hearing and low light level vision. In addition, dolphins and sea lions dive more quickly and easily than humans. They are capable of diving more than 1,000 feet in a matter of minutes. The primary advantage that dolphins and sea lions have over human divers is their ability to make repeated dives quickly without the threat of decompression sickness.

The MMS accomplish tasks that could not readily be accomplished by human divers. It takes several years for the bottlenose dolphins and California sea lions in the MMP to certify for a specific MMS. The animals are trained at SSC San Diego for operations elsewhere in the U.S. or around the world when needed.

The MMS have been successfully deployed by ship, aircraft, helicopter, and land vehicles to regional conflicts or staging areas around the world. In addition to participating in exercises and deployments worldwide, the current use of marine mammals at the Naval Submarine Base Kings Bay, Georgia, has demonstrated that the MMS is the most capable option for successfully interdicting appropriate targets.

SSC San Diego provides engineering, equipment, maintenance, veterinary care, marine mammals, and training for military personnel. The military and civilian personnel are trained as marine mammal handlers under the supervision of experienced civilian trainers. A senior civilian technical representative is assigned to each MMS to support the training of personnel and marine mammals.

3. MMP LOCATIONS

The MMP is headquartered at SSC San Diego. Most research, development, operations, maintenance, and daily marine mammal care and training occur in and around San Diego Bay and in the adjacent nearshore waters. Marine mammals are then deployed from SSC San Diego when needed elsewhere in the United States and around the world.

Training and operation of the MMS have occurred throughout the world. Training exercises have included waters in the vicinity of Asia, Australia, Canada, and Europe, and along the coast of the United States, including Alaska and Hawaii. Notable training exercises (full-scale rehearsal of military maneuvers) where the MMP participated include the following cold weather locations:

- Maritime Coordinated Operational Training—North Atlantic Treaty Organization (NATO) amphibious exercise off the coast of Newfoundland in 1998;
- Blue Game—NATO exercise in Europe (North Sea, Skagerrak, Kattegat, and Western Baltic area) during 2000, 2001, 2002, and 2004; and
- Northern Edge—Alaska training exercise during 2000 and 2001.

The MMP marine mammals performed well and were effective while participating in these exercises.

Military operations where the MMP participated include the following:

- Dolphins were used in Vietnam from 1970 to 1971 to protect harbor installations and ships against unauthorized human swimmers (Viet Cong) attempting to detonate Army munitions at Cam Ranh Bay. They were then deployed to Guam until 1972.
- Dolphins were used in the Persian Gulf (Bahrain) from 1986 to 1987 during the Iran-Iraq War to perform as sentries and protect the USS LaSalle.
- Dolphins patrolled San Diego Bay in 1996 when the Republican National Convention was held in San Diego.
- Operation Noble Eagle employed dolphins to perform security missions on U.S. military installations and at other potential terrorist targets from 2001 to 2003.
- For Operations Enduring Freedom and Iraqi Freedom, MMP military and civilian personnel, dolphins, and sea lions traveled and worked in the Northern Arabian Gulf including Iraq, Kuwait, and Bahrain beginning in 2003. In particular, the MK 6 MMS provided security for U.S. and coalition ships berthed at the Mina Salman pier in Bahrain until September 2005. During this time, the dolphins and sea lions were available for work assignments continuously every day for more than 2.5 years.
- A swimmer interdiction security system (SISS) utilizing MMP marine mammals was implemented at Naval Submarine Base Kings Bay, Georgia, in early 2005 and is currently in continuous operation at that facility.

4. MMP FACILITIES

MMP facilities at SSC San Diego include a veterinary clinic, fish houses and freezers, storage facilities, above-ground holding pools (20 feet in diameter and 20 feet by 40 feet) for deployment training, staff offices, laboratory and testing equipment, boats and piers, and marine enclosures.

The dolphin enclosures at SSC San Diego were constructed as open-air enclosures without above-water nets or fences. The enclosures have above-water decking and underwater netting separating the individual enclosures, which are each 30 by 30 feet square. The floating portion of the enclosures was constructed from commercial off-the-shelf (COTS) decking material and floats. Some enclosures were constructed from EZ-Dock, a COTS interlocking dock system. The underwater portion of the dolphin enclosures was constructed with stretch, box-shaped nets with 1.5- to 6-inch size openings that attach to the floating walkways. The mesh netting includes underwater gates that allow for dolphins to move between enclosures and socially interact.

The sea lion enclosures at SSC San Diego are closed both above and below water. Each enclosure has outside dimensions of 30 by 30 feet square with above-water fencing 6 feet high surrounding the outer enclosure perimeter. Deck space is available above-water for sea lion haul-outs. The underwater netted enclosures are constructed in the same way as the dolphin enclosures. Half of the open-water enclosure is designed as a common area with water access. The other half of the enclosure is designed as an area to separate the sea lions for health inspections and preparation for open-water excursions.

MMP enclosures for dolphins and sea lions exceed requirements for minimum size and depth as specified by the Animal Welfare Act (AWA) (9 Code of Federal Regulations [CFR] 3.104). For housing up to two bottlenose dolphins, the regulations specify enclosure minimum depth (6 feet), minimum horizontal distance (MHD) (24 feet), and minimum surface area (117.75 square feet). The MMP houses dolphins in socially compatible groups and assembles interconnected groups of enclosures such that one enclosure is available for each dolphin in the group. Each MMP dolphin enclosure has a minimum depth of 8 feet, MHD of 24 feet, and a surface area of at least 576 square feet. Incorporating additional requirements for minimum volume when housing more than two animals, each MMP dolphin enclosure meets the requirements to house up to four bottlenose dolphins. The result is that a group of MMP dolphins typically share a group of interconnected enclosures that, in total, are four times larger than the minimum federal standard.

Enclosures housing California sea lions must incorporate both a water or pool area and a dry resting area. For housing up to four California sea lions, the regulations specify enclosure minimum water depth (3.65 feet), MHD of water area (10.95 feet), minimum water surface area (213.16 square feet), and minimum dry resting area (213.16 square feet). The MMP houses sea lions in socially compatible groups of four animals. Each MMP sea lion enclosure has a minimum depth (6 feet), MHD (11.69 feet), minimum water surface area (278.57 square feet), and dry resting area (440.54 square feet). Incorporating additional requirements for minimum volume when housing more than four sea lions, each MMP sea lion enclosure meets the federal standard to house up to six animals.

5. ANIMAL MANAGEMENT PROGRAM

The MMP reviews, monitors, and adjusts the program based on best available science and program expectations and performance. The management concept for the MMP was developed to meet the Navy's internal policy guidelines requiring that Navy marine mammals be provided the highest quality of humane care and treatment. The MMP manages through committee policy direction; review of ongoing operations, research, and best available science when implementing this direction; and adjusting MMP practices when necessary to ensure that the MMP marine mammals receive the highest quality health and humane care and treatment according to the most recently available information. The MMP is continuously reviewed by several MMP committees and work groups. These committees and their functions include:

- *Institutional Animal Care and Use Committee.* The MMP is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International and adheres to the national standards of the United States Public Health Service Policy on the Humane Care and Use of Laboratory Animals and the Animal Welfare Act. As required by the Department of Defense, the MMP's animal care and use program is routinely reviewed by an Institutional Animal Care and Use Committee and the Department of Defense Bureau of Medicine.

- *Biological Technician (BioTech) Working Group.* The purpose of the Biotech Working Group (BWG) is to continuously assess training methodologies, facilities design, and husbandry procedures; to optimize the use of the animal program resources to support mission accomplishment; and to insure the animals receive the highest quality care. The Biotech Working Group is comprised of civil servant biological technicians who are assigned direct oversight for the operation of the Navy's marine mammal population. The BWG meets on a bi-weekly basis with attending veterinarians, contract supervisory staff and In Service Engineering Agent representatives. The BWG makes policy recommendations to the Division Head for the MMP with respect to animal training procedures and husbandry of marine mammals. The BWG reviews and makes recommendations on future animal facilities and hardware designs for use with Navy marine mammals.

- *Animal Safety Committee.* The purpose of the Animal Safety Committee (ASC) is to review animal safety issues and in particular, changes to hardware, methodologies and applications of training employed with the military assigned working animals. Committee emphasis is to insure that the safest hardware and equipment designs and methodologies practical are being employed. New hardware applications are reviewed prior to implementation. Existing hardware to be utilized in new areas or greatly expanded in application, such as transfer from use at SSC San Diego to Fleet systems are also reviewed. The ASC includes personnel with experience from animal training, veterinary service, military systems technical representatives, MMS hardware engineering and marine mammal research.

- *Safety Working Group.* The MMP has a personnel safety committee consisting of key personnel involved in MMP operations. The committee meets as required to review all personnel safety procedures, equipment use, training certifications, and other pertinent areas and to recommend updates/changes.

6. DOLPHIN AND SEA LION FOOD

Frozen fish obtained from outside vendors are used to feed the MMP marine mammals. Examples of fish species fed to the mammals include capelin, herring, mackerel, and squid. The fish are initially stored in a large freezer room and are individually inspected, thawed, and cleaned in a fish house (sanitary kitchen) prior to feeding the dolphins and sea lions. The fish house is cleaned following each daily fish inspection, thawing, and fish cleaning. The MMP quality assurance program is equivalent to that required for restaurant-quality fish, including onsite inspections conducted at vendors' facilities by qualified personnel (e.g., Army Veterinary Corps inspectors) as fish are caught, frozen, and shipped. Fish are tested for histamine levels as an indicator of bacterial activity. Analyses are also conducted on the fish for caloric, fat, and protein content, which is needed to calculate daily intake for individual marine mammals. The fish houses are inspected monthly by an Army Veterinary Corps inspector and semi-annual inspections are conducted by an Institutional Animal Care and Use Committee. Per requirements set forth by the Secretary of the Navy Instruction (SECNAVINST) 3900.38C, the amount of fish fed to each animal is recorded daily by animal trainers. The dolphins and sea lions are also provided nutritional supplements.

7. DOLPHIN AND SEA LION TRAINING AT MMP

Operant conditioning is the training technique the MMP uses to train dolphins and sea lions, whereby the consequences of a behavior affect the frequency of that behavior happening again. The MMP uses successive approximation and positive reinforcement as the standard method to establish system behaviors. Successive approximation refers to a behavior-shaping progression in which behavior comes closer and closer to a preset goal, and the marine mammals are rewarded for advances toward the goal. To maintain the desired behavior once it is established, an intermittent reinforcer (such as food) is used to ensure long-term responses. Positive reinforcement for the MMP is not limited to food. Tactile reinforcement and praise are used to reinforce the animals for correct behaviors. A behavior is broken down into small steps and trained one step at a time until the total goal behavior is complete. The key is to teach the animals without causing frustration. Positive relationships are developed between trainers and the MMP marine mammals.

Marine mammal training at the MMP affects the dolphins' and sea lions' natural behavior. The longer an animal has been in the care of humans, the more the animal relies on humans for food, sustenance, and protection. However, MMP marine mammals retain their ability to forage and evade danger when in the open-water environment because they are continuously exposed to the open-water environment during training and on exercises and deployments. MMP dolphins and sea lions are released to the open water on an almost daily basis and typically stay close to the boat and trainer. One of the most difficult steps in open-water training is building an animal's confidence to leave the home enclosures and enter open-water conditions. The MMP enclosures provide the animal's social bonds with other animals and security from the outside environment. The animals are not tasked in open water outside their enclosures until they have displayed precise responses to basic behaviors within enclosures. Once released to open water, trainers continuously evaluate an animal's responses to cues when working in these conditions. Also, the animals are outfitted with tracking equipment to aide a quick recovery should they become separated from the work boat (e.g., rough seas).

The MMP dolphins and sea lions are congregated into compatible social groups, as the animals have the opportunity to move about within the enclosures at the end of daily training. Both male and female dolphins reside in the MMP. The MMP also has a dolphin breeding program to produce replacements for aging MMP dolphins. Sea lions are procured from public display and other marine animal facilities, are all male, and are neutered or not sexually viable.

8. DOLPHIN AND SEA LION VETERINARY CARE

Per SECNAVINST 3900.41E, the MMP is tasked to ensure that "all Navy marine mammals receive the highest quality of humane care and maintenance in accordance with all applicable laws and regulations." Veterinary care, including emergency response, is available 24 hours a day, 7 days a week (including holidays) at all locations housing MMP marine mammals. Abnormal observations noted by an animal's trainer regarding the health or behavior of an animal are reported to the attending or on-call veterinarian. Veterinary care plans include administration of supportive care or medications, diagnostic tests, enhanced observations of animal behavior and appetite, and/or changes in environment or social structure.

Direct veterinary care of marine mammals within the MMP is provided by a team of Navy and civilian veterinarians, Army Veterinary Corps officers, and enlisted veterinary technicians; and all are supported by animal trainers. The veterinary care program is currently overseen by the Head of the Scientific and Veterinary Support Branch and the Senior Scientist for Animal Care. A total of ten veterinarians serve the MMP animal population, including eight clinical veterinarians, a veterinary epidemiologist, and a senior scientist. At least one veterinarian and/or one veterinary technician accompany animals during all deployments outside SSC San Diego. For long-term deployment of animals, at least one veterinarian and veterinary technician are assigned to that location for the duration of the deployment. For deployments, all animals receive pre- and post-transport health examinations conducted by veterinarians.

The MMP preventative medicine program includes daily supplements, monthly or quarterly antiparasitics, and vigilant monitoring of animal health through routine examinations by veterinarians and daily assessments by trainers. The MMP marine mammals receive complete comprehensive physical examinations semiannually or annually unless otherwise directed by the attending veterinarian (e.g., during late-term pregnancy or early lactation). The physical may include an assessment of the animal's vital signs (temperature, blood pressure, pulse, and respiratory rate), length, weight, and general physical appearance (eyes, abdomen, genitalia, musculoskeletal system, head and neck, skin, and extremities). Diagnostic testing may also occur including tissue sampling on feces, urine, and blood. An in-house clinical laboratory is used to process, archive, and ship animal samples to reference laboratories. Mobile clinical laboratories are used during animal deployments.

Diagnostic tests can include complete blood counts, serum chemistries, bacterial and fungal cultures, fecal examinations, antibody enzyme-linked immunosorbent assays validated specifically for bottlenose dolphins or California sea lions, and testing for marine toxins.

9. ENVIRONMENTAL HEALTH AND DISEASE POTENTIAL FOR MMP MARINE MAMMALS

To assess the aquatic environment where marine mammals are housed in San Diego Bay, the Navy employs the same water quality tests and diagnostics required by San Diego County and California State Health departments for recreational water deemed fit for human use. Routine water quality tests of animal enclosures include temperature, salinity, and weekly coliform counts. If coliform counts exceed the county threshold, a veterinarian is notified, samples are retested and, if necessary, mitigation strategies are implemented (e.g., movement of marine mammals to other locations), and the water is retested until levels return to normal.

Routine reports by local and state agencies regarding water contamination events, including sewage spills, oil spills, and harmful algal blooms, are provided to MMP management and the veterinary staff. Animal health concerns associated with water quality are addressed by the attending veterinarian and Senior Scientist for Animal Care. Specific and routine responses to water contamination events have been developed by the MMP to ensure immediate responsive actions particularly related to emergencies, adverse weather conditions, or other catastrophic events. To date, the MMP has had no reports of animal illness associated with harmful algal blooms. This includes the algal blooms occurring in 2007, as well as toxic blooms in 2002 and 2003. Wild sea lions that appear to be affected by these toxic blooms have been observed in San Diego Bay (Associated Press 2007) and within the vicinity of the MMP. It is believed that the Navy’s animals are not affected by toxic blooms in southern California because their food is procured from vendors supplying fish from outside California and areas with toxic blooms. Navy marine mammal samples were routinely tested for marine toxins during 2004.

Communicable diseases, including bacterial and viral infections, have been reported among wild marine mammals, particularly several types of virus of the genus *Morbillivirus*. These include dolphin morbillivirus, which killed several thousand striped dolphins (*Stenella coeruleoalba*) in the Mediterranean Sea during the early 1990s (Aguilar and Borrell 1994) and unknown numbers of bottlenose dolphins in the western Atlantic during the late 1980s and Gulf of Mexico in the mid-1990s (review in Kennedy 1999); phocine distemper virus, which produced large die-offs of harbor seals and gray seals in Europe in the late 1980s and 2002 (review in Kennedy 1999; Jensen et al. 2002; Wohlsein et al. 2007); and canine distemper virus, which caused mass mortalities among Baikal seals (*Phoca sibirica*) in the late 1980s and Caspian seals (*P. caspica*) in 2000 (review in Kennedy 1999; Kennedy et al. 2000). Morbillivirus may have been the causative agent in an epidemic which killed approximately 50 percent of the largest colony of endangered Mediterranean monk seals along the Mauritanian coast of Africa in1997 (Di Guardo et al. 2005).

Morbillivirus infections may occur in marine mammals without overt clinical signs of disease or causing death, and no marine or terrestrial reservoirs have been identified since the epidemics in the 1980s and 1990s (Wohlsein et al. 2007). A recent test of eleven individuals from four different odontocete species sampled in the northeast Pacific, along the coast of British Columbia, found that none had dolphin morbillivirus antibodies (Van Bressem et al. 2001). Antibodies to dolphin morbillivirus have been detected in common dolphins (*Delphinus delphis*) from southern California (Reidarson et al. 1998), placing the virus inside the range of the MMP marine mammals. To date, MMP animal populations remain immunologically naïve (unexposed) to known marine morbilliviruses.

Because of the species-jumping history of morbilliviruses, there is a possibility that these forms could infect MMP marine mammals. To date, the MMP marine mammals have not demonstrated population exposure to morbilliviruses. Aside from morbilliviruses, there are limited tests available for disease known to be communicable to bottlenose dolphins and sea lions. The Navy has quarantine facilities at all MMP deployed locations for those animals that could be found to harbor a communicable disease of population health concern.

There are no reported incidents in which the presence of MMP marine mammals has led to disease introduction from an MMP animal to the wild marine mammal population. Although the MMP marine mammals socialize with other marine mammals within the MMP, they are not encouraged to socialize with wild marine mammals. While training and working outside of their enclosures, the trainers attempt to avoid areas where other wild marine mammals are observed. However, this is not always possible because some marine mammals may be underwater and not observable by the trainers when the MMS boat initially enters an area. Thus, a Navy marine mammal may encounter a wild marine mammal while training or working. When this has occurred in the past, trainers have rarely observed interactions between the animals. Although the animals were aware of each other, they were observed by the trainers to avoid contact.

MMP strategies to prevent disease transmission among Navy and wild marine mammals are based upon discussions with local and state wildlife agencies; review of marine mammal diseases documented in the area of interest; and a population risk assessment involving the likelihood of novel introduction of a disease to an unexposed and susceptible population, documented mortality rates, and potentially negative impacts on reproduction. The risk assessment approach used by the MMP is based upon the U.S. Department of Agriculture's (USDA) generic non-indigenous risk assessment process and has been used for other species to assess the risk of introducing new diseases to various locations (Orr et al. 1993). If a communicable disease present in the area has been identified as a potentially high risk to either the MMP or wild marine mammals, a plan is implemented by the attending veterinarian, in concert with local and state wildlife agencies, to prevent disease transmission between the two populations. In addition to routine, transport-associated physical examinations, veterinarians also implement pre- and post-transport quarantine periods as required to monitor animals for illness and to conduct diagnostic tests for previous exposure, active shedding, and/or active infection. Due to the relatively high risk potential of morbillivirus infections compared to other marine mammal communicable diseases, paired morbillivirus antibody tests and viral cultures are always conducted before deployments outside southern California. These animals are also tested upon their return to check that they were not infected during deployment.

The Navy follows strict guidelines to avoid transfer of diseases between humans and marine mammals. These guidelines follow recommendations from Geraci and Ridgway (1991) and the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC) guidelines. Safety measures can include wearing gloves and other protective gear when handling animals; avoiding contact with animals when trainers are ill or immuno-compromised; using additional safety equipment when risks of acquiring an infection are high; use of necropsy, husbandry, and laboratory procedures that minimize the risk of cuts and injuries; and washing hands thoroughly after contact with animals and specimens. Most injuries reported by marine mammal workers are cuts and scrapes followed in frequency by bites (Mazet et al. 2004). There have been no incidences of disease transfer between humans and MMP animals.

The MMP marine mammals have high survival rates. While the average life expectancy for wild bottlenose dolphins is 25 years (as calculated by van der Toorn 1997 from data in Wells and Scott 1990), the MMP has numerous dolphins aged 40 to 50 years. For bottlenose dolphins, life expectancy was not shown to be significantly different between wild and captive dolphins (Small and DeMaster 1995; DeMaster and Drevenak 1988). However, recent data have shown that dolphin life expectancy in captivity has been increasing, presumably from increased knowledge of raising dolphins in captivity (Woodley et al. 1997). Wild male sea lions have considerably lower maximum longevity (17 years) but this is primarily due to mortality inflicted among competing breeding males. More than a third of the Navy's sea lions are more than 20 years old.

10. DOLPHIN AND SEA LION TRANSPORT

When it is necessary to transport the MMP dolphins and sea lions for deployment outside of San Diego Bay, they are trucked, placed aboard ships, and/or flown in cargo aircraft equipped for the transport of animal transport containers. Dolphins at SSC San Diego have been transported outside of their facility for over 35 years. Marine mammal transportation procedures exceed relevant regulatory and accreditation guidelines including 9 CFR Chapter 1, USDA Regulation Subpart E, Specification for the Humane Handling, Care, Treatment, and Transportation of Marine Mammals. All transports are planned in advance to ensure that the necessary equipment and personnel are available for the transport, as well as at the location of deployment. Transport staff include a transport coordinator and planner, trainer, safety officer, veterinarian, and other support staff. The MMP staff are also responsible for providing guidance regarding liaison with outside agencies with respect to marine mammal transport, care, and maintenance when animals are transported outside of San Diego Bay.

For any transport over 2 hours in duration, the attending veterinarian will accompany the animals. The veterinarian works cooperatively with the transport coordinator and safety officer to ensure that the animal's comfort and health are maintained during the transport. Pre-transport briefings are held in advance of the transport to address logistics and assign responsibilities. One of the responsibilities of the transport coordinator is to ensure that an adequate number of trained personnel are available to monitor and/or attend to the dolphins and sea lions during transport at all times. At the pre-transport briefing, all involved parties receive guidelines and procedures along with specifics particular to the transport. A final transport briefing is held at least one day prior to the transport to ensure that requirements necessary for personnel and animal safety have been met. As previously described under Section 7, Dolphin and Sea Lion Care, if any animal is to be transported for more than 2 hours, a veterinarian assesses its health prior to transport. At least 48 hours is allowed for laboratory results, thus requiring the health assessment to occur no less than 2 days and no more than 10 days before the transport. During the week prior to the transport, equipment needed for the transfer and deployment is cleaned and assembled to ensure all parts are available and functioning properly.

For land transports, flatbed or enclosed trucks are normally used in transporting the MMP marine mammals. In addition, at least one safety vehicle accompanies the transport truck(s). Specific procedures have been developed for use of the dolphin and sea lion transporters to ensure the safety and comfort of the animals. The animals are kept wet, cool, and shaded at all times. Animals are cleaned and their waste removed as needed during transport. Procedures are followed to ensure that additional clean water is available for use and exchange when needed. Animal respiration rates, ambient temperature readings, and animal activity levels are monitored throughout the transport. Each animal's trainer is required to be near the transport carrier at all times to ensure that he/she is aware of the animal's safety and comfort during movement. The driver is required to take slower speeds and avoid rough areas that might lead to bumps and vibrations. The trainer has direct contact with the driver via radio to immediately inform the driver of any animal behavior that may indicate discomfort or if there are changes in the animal's position that may need more secure cushioning. A refrigerated food supply is also provided with transport.

Each transport animal is under constant surveillance. The attending veterinarian is notified immediately if rapid respiration rates or any other health concerns are observed. After arrival at the deployment site, the attending veterinarian assesses the animal's health. At the new site, a 24-hour watch is conducted to monitor the transported animal. A post-transport review is conducted by the transport coordinator or attending veterinarian after each transport.

Air transport of the MMP marine mammals is similar to that described for land transport. Generally, the air transports are planned with at least a 30-day advance notice. Cabin pressure and ambient temperatures are controlled and recorded throughout flight to ensure appropriate conditions. Animals are continuously monitored for body temperature variations. Shallow angled ascent and descent of the aircraft are necessary to prevent water from spilling out of the animal's transport carrier and to ensure that the animals are entirely moist and/or wet at all times. Flight operations personnel are informed of required cabin pressures, temperatures, and flight take-off and landing angles well in advance of the transport to ensure that the plane and pilot can meet these conditions continuously during the transport. Transport from the plane to the operations site follows the truck procedures described above.

Ship transport also occurs with similar procedures as described above for truck and air transport. On ships, however, dolphins are housed in specially designed pools. Water depth is monitored continuously and water quality is tested on a daily basis. If animals are housed on ships during deployment, they are given regular exercise in open water, and compatibility between animals is required prior to placing MMP marine mammals together in a pool. At the transport location, all required equipment and facilities are in place prior to the transport. Pools are cleaned when animals are employed for open-water exercises. Pool watches are required at all times (24 hours) to monitor animal safety and security. All watch personnel must be trained by SSC San Diego staff on pool operation and emergency procedures. The watch personnel may not conduct any other activity when watching the dolphins. Specific pool conditions must be written in a log throughout pool watches, including animal pool conditions such as water flow, depth, and quality.

11. MINIMIZING OPEN-WATER RISKS

MMP marine mammals working under care of their trainers are released into the open ocean on an almost daily basis. The animals are not tasked in open water outside their enclosures until they have displayed precise responses to basic behaviors within their enclosures. Once released to open water, trainers continuously evaluate an animal's responses to cues when working in these conditions; however, MMP marine mammals have occasionally become separated from their workboats. This can happen for a variety of reasons, including inclement weather or mechanical problems with the boat. When an MMP marine mammal becomes separated from its workboat, trainers recall the animal with an acoustic recall pinger. The pinger is a low-power, sound generator that is lowered by hand into the water from the side of a boat. The pinger is omni-directional, and the sound is transmitted into the water. This pinger is a commercial device that has been used for many years by the MMP. The marine mammals are trained to respond to the sound from the pinger as an emergency recall.

Each animal is also outfitted with radio and satellite transmitters that can be used to locate an animal when it is out of range of the acoustic pinger recall. Program personnel are well trained in the use of these tracking devices and can quickly ascertain a marine mammal's location. When the MMP marine mammal is located, the trainers travel to the animal and then use pingers and positive reinforcement behaviors to retrieve the marine mammal.

Whenever an animal does not return to its workboat or respond to a pinger, the trainer immediately contacts the MMP to report a missing animal. Information on the location of the boat and most recent location of the animal is reported. This would occur if an animal does not respond within 5 minutes. If neither a pinger nor a transmitter can locate the marine mammal, the first location physically searched is the MMP home enclosure. This is the most likely location where animals are found. If the animal is not found at the MMP enclosures, satellite telemetry system tracking for the animal commences. Additional MMP staff become involved in the search, and telemetry is used to find the animal. Harbor police and the U.S. Coast Guard may be notified, along with the Navy public affairs officer for SSC San Diego and/or the cognizant Navy commanding officer.

To ensure that any equipment placed on an animal does not injure it; all equipment has been approved by the MMP Animal Safety Committee and is attached with breakaway materials (dissolvable links, suction cups, and adhesive and/or magnetic rubber band connectors). Animals wearing equipment are closely monitored at all times and are never left unattended. The animals wear the equipment only when working with trainers, and not when they are within their enclosures. If the animals behave abnormally when the equipment is placed on them, an indication of a potential equipment malfunction or incorrect placement, the equipment is immediately removed.

12. REGULATORY OVERVIEW AND COMPLIANCE

The MMP complies with all laws and regulations applicable to the use of animals in government defense programs, and to marine mammals specifically, as described below.

SECNAVINST 3900.41E, Acquisition, Transport, Care and Maintenance of Marine Mammals, prescribes the policies and procedures governing the care and maintenance of Navy marine mammals. The policy states that Navy marine mammals will be provided the highest quality of humane care and treatment and will be maintained in accordance with federal law and regulations. The MMP at SSC San Diego is designated the lead laboratory for all Navy-sponsored programs for marine mammals, responsible for ensuring the Navy adheres to the provisions of the instruction, while serving as the principal liaison with other federal, state, and international agencies. The MMP has designated a Senior Scientist for Animal Care who directs and supervises a program of animal husbandry and veterinary care for all mammals within Navy responsibility.

As directed by Department of Defense Directive 3216.1, the MMP is also accredited by AAALAC, a private nonprofit organization that promotes the humane treatment of animals in science through a voluntary accreditation program. AAALAC evaluates organizations using animals in research, teaching, or testing and accredits those organizations that exhibit excellence in animal care. Accreditation implies quality, scientific validity, accountability, and commitment to humane animal care. The accreditation process begins with a comprehensive internal audit conducted by the institution applying for accreditation. Members of the AAALAC International Council on Accreditation, which include animal care and use professionals and researchers, then review the institution's internal reports and conduct their own comprehensive assessment. Institutions are reevaluated every 3 years to maintain their accredited status.

The AWA is the law establishing minimum care, maintenance, and operating standards for captive animals, including marine mammals. Regulations enforcing the AWA are administered by the USDA, Animal and Plant Health Inspection Service (APHIS). These regulations specify facility licensing, permitting, animal registration, and inventory and medical records requirements; and the establishment and operation of an Institutional Animal Care and Utilization Committee at institutions holding marine mammals. Veterinary care requirements for facilities, personnel, equipment, drugs, and pathology and necropsy procedures are established. Operations and transport standards are delineated for animal enclosure construction, materials, dimensions, maintenance, and sanitization; food preparation and handling; animal feeding, observation, and training; water quality; security; and personnel qualification and instruction. The MMP maintains a program of animal care that meets or exceeds APHIS regulations but, as a U.S. government organization, does not require a license from APHIS and is not subject to inspections. However, APHIS personnel with nationwide inspection responsibility have regularly visited the MMP facilities, and MMP staff annually submits the APHIS form associated with annual inspections.

The Marine Mammal Protection Act (MMPA) of 1972, as amended, establishes a national policy designated to protect and conserve wild marine mammals and their habitats. This policy is established so as to not diminish such species or population stocks beyond the point at which they cease to be a significant functioning element in the ecosystem, nor to diminish such species below their optimum sustainable population. The Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service (NMFS) is responsible for reviewing federal actions for compliance with the MMPA. In addition, NMFS is tasked with maintaining an inventory of all marine mammals in U.S. facilities. MMP staff regularly submit inventory reports and updates to NMFS, specifically the Office of Protected Resources, so that the Navy's animals can be included in the inventory, and they notify the agency prior to acquiring animals from or transferring marine mammals to other facilities.

13. REFERENCES CITED

Aguilar, A. and Borrell, A. 1994 Abnormally high polychlorinated biphenyl levels in striped dolphins (*Stenella coeruleoalba*) affected by the 1990–1992 Mediterranean epizootic. *Science of the Total Environment* 154: 237–47.

Associated Press. 2007. Algae bloom blamed for killing California birds, sea lions, dolphins. *San Diego Union-Tribune*. http://www.signonsandiego.com/news/state/20070427-0157-ca-deadlyacid.html (Accessed August 10, 2007).

DeMaster, D.P. and J.K. Drevenak. 1988. Survivorship patterns in three species of captive cetaceans. *Marine Mammal Science*. 4(4): 297-311.

Di Guardo, G., Marruchella, G., Agrimi, U., and Kennedy, S. 2005. Morbillivirus infections in aquatic mammals: A brief overview. *Journal of Veterinary Medicine Series A* 52(2): 88-93.

Geraci, J.R. and Ridgway, S.H. 1991. On disease transmission between cetaceans and humans. *Marine Mammal Science*. 7(2): 191-194.

Jensen, T., M. Van de Bildt, H.H. Dietz, T.H. Andersen, A.S. Hammer, T. Kuiken, and A. Osterhaus. 2002. Another phocine distemper outbreak in Europe. *Science*. 297:209.

Kennedy, S. 1999. Morbilliviral infections in marine mammals. *Journal of Cetacean Research and Management, Special Issue*. 1:267-273.

Kennedy, S., T. Kuiken, P.D. Jepson, R. Deaville, M. Forsyth, T. Barrett, M.W.G. van de Bildt, A.D.M.E. Osterhaus, T. Eybatov, C. Duck, A. Kydyrmanov, I. Mitrofanov, and S. Wilson. 2000. Mass die-off of Caspian seals caused by canine distemper virus. *Emerging Infectious Diseases*. 6:637-639.

Mazet, J.A.K, Hunt, T.D., and M.H. Ziccardi. 2004. Assessment of the risk of zoonotic disease transmission to marine mammal workers and the public: Survey of occupational risks. University of California, Davis, Wildlife Health Center, School of Veterinarian Medicine.

Orr, R.L., S.D. Cohen, and R.L. Griffin. 1993. Generic Non-indigenous species pest risk assessment process (for estimating pest risk associated with the introduction of non-indigenous organisms). Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Beltsville, MD.

Reidarson, T.H., J. McBain, C. House, D.P. King, J.L. Stott, A. Krafft, J.K. Taubenberger, J. Heyning, and T.P. Lipscomb. 1998. Morbillivirus infection in stranded common dolphins from the Pacific Ocean. *Journal of Wildlife Diseases*. 34:771-776.

Small, R.J. and D.P. DeMaster. 1995. Survival of five species of captive marine mammals. *Marine Mammal Science*. 11(2): 209-226.

Van Bressem, M.F., K. Van Waerebeek, P.D. Jepson, J.A. Raga, P.J. Duignan, O. Nielsen, A.P. Di Beneditto, S. Siciliano, R. Ramos, W. Kant, V. Peddemors, R. Kinoshita, P.S. Ross, A. López-Fernandez, K. Evans, E. Crespo, and T. Barrett. 2001. An insight into the epidemiology of dolphin morbillivirus worldwide. *Veterinary Microbiology*. 81:287-304.

van der Toorn, J. 1997. A survival guide to survival rates. *Marine Mammals: Public Display and Research.* 3(1): 27-38. (updated in 2000)

Wells, R. S. and M. D. Scott. 1990. Estimating bottlenose dolphin population parameters from individual identification and capture-release techniques. In: *Individual Recognition of Cetaceans: Use of Photo- Identification and Other Techniques to Estimate Population Parameters*. Eds. P. S. Hammond, S. A. Mizroch and G. P. Donovan. Report of the International Whaling Commission, Special Issue 12, U. K., pp.:407-415.

Wohlsein P, Puff C, Kreutzer M, Siebert U, Baumgärtner W. Distemper in a dolphin [letter]. *Emerging Infectious Diseases* [serial on the Internet]. 2007 Dec [July 11, 2008]. Available from http://www.cdc.gov/EID/content/13/12/1959.htm

Woodley, T.H., Hannah, J.L. and D.M. Lavigne. 1997. A comparison of survival rates for captive and free-ranging bottlenose dolphins (*Tursiops truncatus*), killer whales (*Orcinus orca*) and beluga whales (*Delphinapterus leucas*). International Marine Mammal Association, Inc. Technical Report 97-02.

APPENDIX B

SUPPLEMENTAL INFORMATION TO APPENDIX A ON DISEASE TRANSMISSION PREVENTION AND COLD STRESS AVOIDANCE

SPACE AND NAVAL WARFARE SYSTEMS CENTER
53560 HULL STREET
SAN DIEGO, CALIFORNIA 92152

U.S. NAVY
MARINE MAMMAL
PROGRAM

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
AAALAC	Association for Assessment and Accreditation of Laboratory Animal Care
APHIS	Animal Plant and Health Inspection Service
CBC	complete blood count
CDC	Centers for Disease Control and Prevention
CDV	canine distemper virus
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
DMV	dolphin morbillivirus
EIS	environmental impact statement
ELISA	Enzyme-Linked Immunosorbent Assays
ESR	Erythrocyte sedimentation rate
LCT	lower critical temperature
MMP	Marine Mammal Program
NBK–Bangor	Naval Base Kitsap at Bangor
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
PDV	phocine distemper virus
PMV	porpoise morbillivirus
SECNAVINST	Secretary of the Navy Instruction
SISS	Swimmer Interdiction Security System
SSC San Diego	Space and Naval Warfare Systems Center, San Diego, CA
USDA	United States Department of Agriculture

1.0 INTRODUCTION

The potential long-term deployment to NBK–Bangor has raised public concern regarding the potential for these marine mammals to come into contact with or transfer new diseases, as well as the ability of Navy Marine Mammal Program (MMP) marine mammals to remain healthy in the cooler water and air conditions at NBK–Bangor. This Appendix provides additional details on how the MMP manages disease transmission prevention and cold stress avoidance.

1.1 ANIMAL MANAGEMENT AND NBK-BANGOR WORKING GROUP

The MMP Animal Management Program is described in Appendix A Section 5. An NBK-Bangor Working Group would be established to oversee the health monitoring program and ensure consistency in animal health and welfare decisions. The NBK-Bangor Working Group would include senior personnel with experience in animal training, veterinary service, and region-specific expertise. The NBK-Bangor Working Group would be represented in all the standing meetings of the committees listed in Appendix A Section 5, Animal Management Program. The Working Group would provide recommendations to the Senior Scientist for Animal Care and the Head of the Biosciences Division, who would be responsible for approving changes to indicators, thresholds, monitoring programs, and management actions. This management approach is consistent with current processes in place throughout the MMP.

1.2 SCOPE

The following sections describe: (1) the indicators and thresholds developed for monitoring communicable disease and cold stress, (2) the monitoring programs that would be used to assess if the MMP marine mammal indicators are outside of thresholds, and (3) management actions that would be taken if thresholds are exceeded.

2.0 INDICATORS AND THRESHOLDS

2.1 DISEASE TRANSMISSION PREVENTION

Like all natural animal populations, communicable diseases (including bacterial and viral infections) can occur in marine mammal populations. Morbillivirus is perhaps the most widely known marine mammal communicable disease due to its ability to cause illness, increased susceptibility to other diseases, and/or mortality. Morbilliviruses, including dolphin morbillivirus (DMV), porpoise morbillivirus (PMV), phocine distemper virus (PDV), and canine distemper virus (CDV), can be highly communicable among marine mammal populations and have been shown to cross over species (Osterhaus et al. 1995; Cowan 2002). Antibodies to morbilliviruses and morbilliviral ribonucleic acid (commonly referred to as RNA) have been detected in many wild marine mammals throughout the world, including common dolphins (*Delphinus delphis*) from southern California (Reidarson et al. 1998). There is a validated blood test for antibodies to all four morbilliviruses of interest (DMV, PMV, PDV, and CDV), and active morbillivirus infections can be detected using this test (see discussion of serology below). There is no indication that the current MMP marine mammal population has been exposed to and actively infected with morbilliviruses.

Because there are validated blood tests for only two marine mammal communicable diseases, serology is not a comprehensive health screening tool. As such, the MMP relies on a health surveillance system that constantly evaluates many factors (Figure B-1). Similar surveillance systems (called syndromic surveillance systems) have been recommended and established by the Centers for Disease Control and Prevention (CDC) to monitor human populations for existing and emerging communicable diseases (CDC 2004). This Appendix incorporates the MMP's long-standing health surveillance program to avoid, detect, and respond to potential communicable diseases, including morbilliviruses.

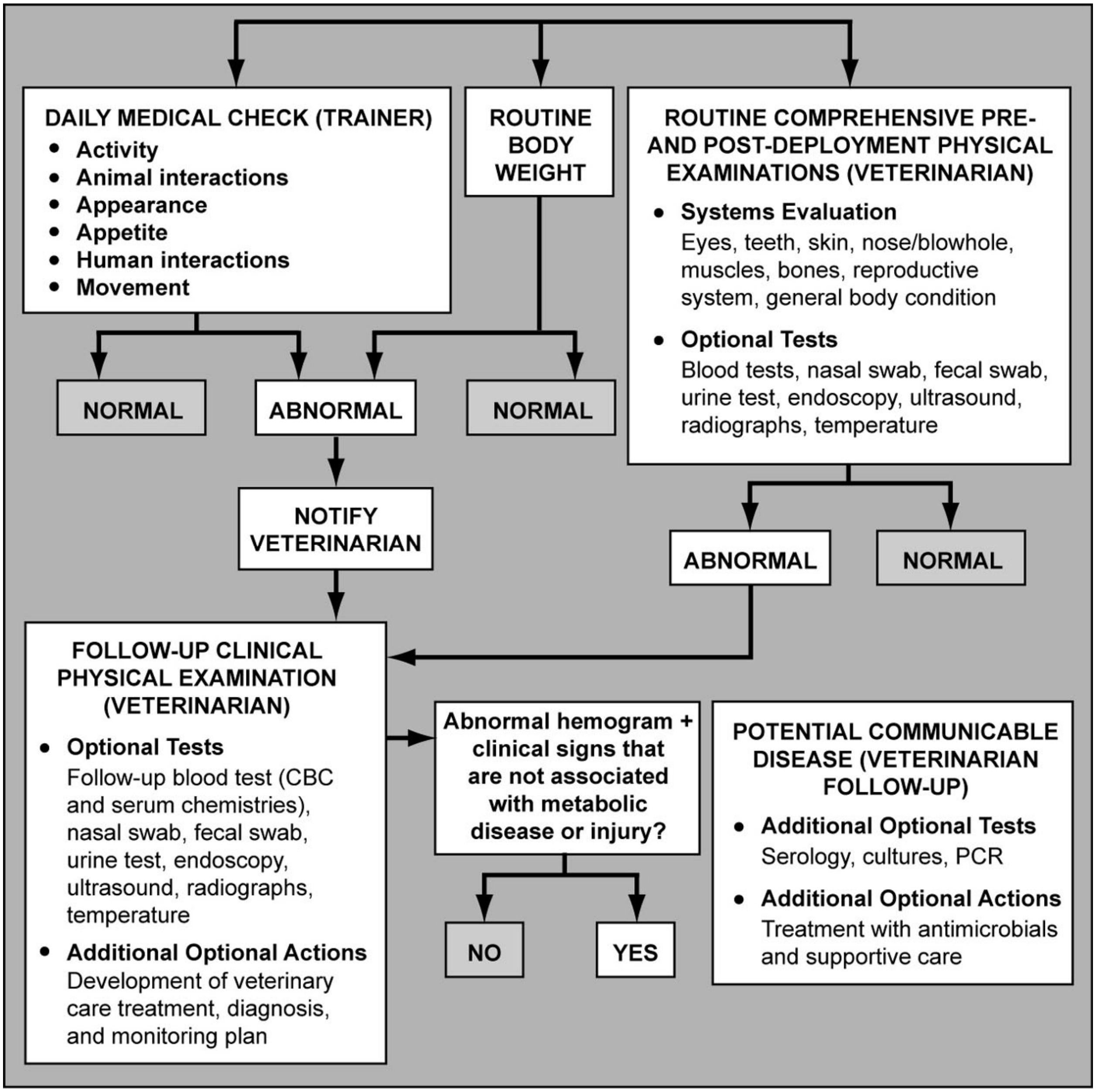

Figure B–1. Navy Marine Mammal Program Health Surveillance System: Communicable Disease Detection

Communicable disease in the marine mammals may include the following indicators. Thresholds for these indicators are defined in Table B-1.

- **Positive Serology Test.** Detection of rising antibodies to specific communicable pathogens in paired blood samples using a validated enzyme linked immunosorbent assay (ELISA).
- **Viral, Bacterial, and Fungal Isolation.** Clinically relevant, cultured (grown) viruses, bacteria, or fungi from animal samples submitted to reference laboratories.
- **Weight Loss.** Unexplained rapid weight loss that is not attributable to changes in diet prescribed by the veterinarian.
- **Behavioral Changes.** Abnormal behaviors such as not eating, listlessness, failure to respond to trainer commands, which are indicative of poor health.
- **Abnormal Hemogram.** Abnormal complete blood counts (CBCs) and erythrocyte sedimentation rates (ESR) consistent with potential communicable disease processes (infection and inflammation) in marine mammals.
- **Abnormal Physical Examination Finding.** Abnormalities may include laboratory results (e.g., urine, feces, gastric fluid), and physiological parameters (e.g., heart rates, respiratory rates, body temperature).

Paired serology is used to assess whether an animal has been exposed to a given infectious agent. These tests are used to detect exposure to bacterial, viral, and fungal infections by measuring the animal's antibody response, usually in serum or blood. Antibodies are produced by the immune system in response to the presence of a foreign agent (e.g., a virus) and would only be detected if the animal had previously been exposed to the virus (Guyton and Hall 2006). Previous exposure, however, does not indicate whether an animal is actively infected with an agent. Therefore, paired serology is required to detect active infections in animals. Two blood samples from the same animal, taken approximately 4 to 6 weeks apart, are tested for antibodies. If the second blood sample has at least four times the amount of antibodies than the first sample, this result strongly suggests active infection by the agent. Currently, only five serological tests have been validated for marine mammal species at the MMP (DMV, PMV, PDV, CDV – bottlenose dolphins and California sea lions; *Brucella* species – dolphins only). While research studies may involve unvalidated serological tests in marine mammals, the MMP limits routine, clinical evaluations to species-specific, validated serologic tests.

Infectious agents may be isolated (cultured) from marine mammal samples by reference laboratories. If the microbe is determined to be neither an environmental contaminant nor a commensal (a naturally occurring microbe co-existing in a healthy animal), then it may be a clinically relevant infectious agent; this likelihood increases if the microbe was isolated from a clinically relevant sample from an animal with relevant clinical signs (e.g., isolation of a known gastrointestinal pathogen from the feces of an animal with diarrhea).

Table B–1. Thresholds for Indicators of Communicable Disease in MMP Marine Mammals

PARAMETER	QUALIFIERS	STANDARD	THRESHOLD	INDICATOR TYPE
Paired Serology	Validated, species-specific test	No indication of pathogen or significant rise (four-fold or greater) in antibodies to the pathogen	Four-fold rise in antibodies to the pathogen	Primary[1]
Viral, bacterial and fungal isolation	1. Isolate has been ruled out as a contaminant or commensal 2. Microbe was isolated from clinically relevant samples 3. (+/-) Animal has clinical signs consistent with infection by the microbe	No indication of clinically relevant viral, bacterial, or fungal infection	Isolation of virus, bacterium, or fungus that is clinically relevant	Primary
Weight-dolphins	Weight loss is unexpected (i.e., not due to natural, healthy seasonal changes) and not due to non-infectious causes	Minimum weights for individuals would be consistent with Ridgway and Fenner 1982; goal weights would be established by the attending veterinarian in consultation with the program manager or cognizant technical representative	Weight below the minimum weight or unexpected weight loss as determined by veterinarian	Secondary[2]
Weight- sea lions	Weight loss is unexpected (i.e., not due to natural, healthy seasonal changes) and not due to non-infectious causes	Minimum weights for individuals would be established by the attending veterinarian; goal weights would be established by the attending veterinarian with approval of the Senior Scientist for Animal Care	Weight below the minimum weight or unexpected weight loss as determined by veterinarian	Secondary
Behavior	Behavior changes are unexpected and are not due to non-infectious causes (e.g., reproductive status)	Normal behavior for each individual animal would assessed and determined by the trainers	Animal exhibits abnormal behavior indicative of illness such as listlessness, non-responsiveness to trainers, or loss of appetite	Secondary
Abnormal Hemogram (blood values)	Abnormal CBC and ESR are not due to non-infectious causes, such as metabolic disease or injury	Normal CBC count and ESR	CBC is abnormal by in-house reference ranges for age and sex of animal. CBC and ESR are abnormal for individual animal	Secondary
Abnormal physical examination findings	Not due to non-infectious causes, such as metabolic disease or injury	Physiological and laboratory findings within normal limits	Physical examination findings are outside normal for population and for individual animal.	Secondary

1 Primary indicators- exceedance of threshold for a primary indicator would elicit an immediate management action or response.
2 Secondary indicators- elicitation of a management action for a secondary indicator may require exceedance of thresholds for more than one secondary indicator.

Each MMP marine mammal's individual goal weight is set by the attending veterinarian based on that animal's age, length, gender, activity level, and seasonal temperatures. Goal weights are maintained by feeding each animal a specific diet determined to provide sufficient energy for the animal's activity level. Weight loss in an animal that cannot be explained by changes in diet ordered by the veterinarian or by increases in energy expenditure by that animal could indicate a change in health status.

Changes in normal marine mammal behaviors can be indicative of health status or potential affliction with disease. Animal trainers assess each animal's activity, animal interactions, appearance, appetite, human interactions, and movement on a daily basis.

CBC and serum chemistry profiles provide the veterinarian with information regarding the health of the animal. In general, the most common blood profile abnormalities in animals with infectious diseases are an abnormal white blood cell count and an increased ESR. Normal, in-house reference ranges for bottlenose dolphins have been determined and published by the MMP (Venn-Watson et al. 2007). The same methodology used to determine the dolphin reference ranges has been applied to determine in-house California sea lion reference ranges; publication of these reference ranges are pending.

Abnormal findings during physical examinations that are not due to non-infectious causes (e.g., metabolic disease or injury) could indicate presence of a communicable disease. Such abnormalities may include laboratory results from tests on urine or feces and changes in physiological parameters such as heart rate, respiratory rate, and body temperature.

2.2 COLD STRESS AVOIDANCE

The goal of cold stress avoidance is to minimize the impacts of cold and maintain the health and well-being of the marine mammals in the program. Marine mammals deployed to NBK–Bangor would experience water and air temperatures that are cooler than conditions at SSC San Diego. Potential indicators of cold stress in bottlenose dolphins and California sea lions are listed below. Thresholds for these indicators are defined in Table B-2.

- **Body Temperature.** Decreases in body temperature below the normal range.
- **Respiration Rate.** Increases in respiration rate might indicate the animal has increased its metabolism to generate heat.
- **Shivering.** Marine mammals can shiver to generate heat.
- **Skin Conditions.** Discolorations of the skin can occur during prolonged exposure to cold water and air.
- **Behavioral Changes.** Changes in some normal behaviors can indicate an animal is stressed by exposure to the cold.
- **Weight Loss.** Rapid weight loss can indicate increased metabolism of fat stores to generate heat.

Table B–2. Thresholds for Indicators of Thermal Stress in MMP Marine Mammals

Parameter	Standard	Threshold	Indicator Type
Body temperature	96.8-98.6 degrees Fahrenheit (°F) is the range of core body temperature for dolphins (Hampton et al. 1971; Pabst et al. 2002; MMP unpublished data), 97.7-99.5°F has been reported for California sea lions (South et al. 1976; Whittow et al. 1975)	Hypothermia (decrease in internal temperature by 2°F) for more than 30 minutes-94.8°F for dolphins; 95.7°F for sea lions	Primary[1]
Respiration rate	Maximal resting respiratory rate will vary by individual and taken into account when calculating the threshold	Increase the maximal resting respiratory rate to a level twice the maximal respiratory rate for a period greater than 2 hours (not attributable to exercise or other factors)	Secondary[2]
Shivering	Not shivering	Shivering for greater than 30 minutes	Secondary
Skin Discoloration	Skin appears uniform with no discoloration	Changes in skin appearance to include discoloration	Secondary
Weight-dolphins	Minimum weights for individuals would be consistent with Ridgway and Fenner 1982; goal weights would be established by the attending veterinarian in consultation with the program manager or cognizant technical representative	Weight below the minimum weight or unexpected weight loss as determined by veterinarian	Secondary
Weight- sea lions	Minimum weights for individuals would be established by the attending veterinarian; goal weights would be established by the attending veterinarian with approval of the Senior Scientist for Animal Care	Weight below the minimum weight or unexpected weight loss as determined by veterinarian	Secondary
Behavior	Normal behavior for each individual animal would assessed and determined by the trainers	Animal exhibits abnormal behavior such as listlessness, refusal to perform, and/or poor appetite, indicative of cold stress	Secondary

Footnotes: [1] Primary indicators- exceedance of threshold for a primary indicator would elicit an immediate management action or response.
[2] Secondary indicators- elicitation of a management action for a secondary indicator may require exceedance of thresholds for more than one secondary indicator.

The maximum cold water temperature that causes an animal's metabolic rate to increase is known as the Lower Critical Temperature (LCT). This temperature defines the lower limit of the thermal neutral zone, which is the range of environmental temperatures over which a mammal's metabolic rate remains stable. Below the LCT, an animal compensates for heat loss by increasing its metabolic rate. At some temperature below the LCT, heat loss is greater than can be compensated for by increases in metabolism. At this point, the body temperature begins to fall and a condition that is commonly termed hypothermia will eventually occur. The LCT (water) calculated for bottlenose dolphins is between 41.9° and 51.1°F. The LCT (water) derived for California sea lions is 42.6°F. See SISS EIS Section 6.2.1.2.2, Water and Air Temperature, for a complete discussion of the derivation of these values.

Normal range of body temperatures for bottlenose dolphins is approximately 96.8° to 98.6°F in thermally neutral environments (Hampton et al. 1971; Pabst et al. 2002). A core body temperature of 94.8°F would be used to delineate the onset of hypothermia in bottlenose dolphins. Normal range of body temperatures for California sea lions is approximately 97.7° to

99.5°F in thermally neutral environments (Whittow et al. 1975; South et al. 1976). For California sea lions, a core body temperature of 95.7°F would be used to delineate the onset of hypothermia. Core body temperatures would be monitored through the use of a rectal thermometer. Measurements would be taken based on veterinary assessment during work periods where the water temperature is equal to or less than the LCT for the animal.

Respiration rate, how often an animal takes a breath within a given period of time, is often used as an indicator of increased metabolism in mammals (see SISS EIS Section 6.2.1.2.2., Water and Air Temperature). Observance of increased respiration rates of the MMP marine mammals might be a useful indicator that the animals are increasing their metabolism to compensate for colder temperatures. However, respiration rates vary by individual depending upon that individual's activity and metabolic level, and there is a large amount of individual variability in respiration rates across bottlenose dolphins and California sea lions. Utilizing respiration rate as a potential indicator of increased metabolism would require determining the maximal resting respiratory rate of the individual animal for baseline comparisons.

Shivering is an unconscious response of the body to cold and can increase the internal heat production of an animal for short time periods. Cold signals from the skin and spinal cord initiate the process of increased heat production as a means to prevent a fall in internal body temperature (Guyton and Hall 2006). Therefore, observation of shivering in the marine mammals is potentially a good indicator for cold stress because it will begin before an animal's core body temperature decreases, and it generally occurs at temperatures colder than that at which metabolism increases.

There are multiple reasons for skin discoloration in marine mammals, including disease, injury, and aging. Various skin conditions have been observed in marine mammals when exposed to water temperatures near or below their LCT. Such conditions include discoloration, lesions, and bumps (Chun and Harris 1978; Scronce and Bowers 1985). Shunting of the blood supply, where blood is directed away from appendages and in toward the body core as a way to conserve heat, can cause darkening of the skin (Chun and Harris 1978). However, in the studies by Chun and Harris (1978) and Scronce and Bowers (1985), skin discoloration did not appear until 1 to 4 days after the onset of increased respiration. Skin lesions are indicators of cold stress in marine animals because they can occur as a direct result of prolonged exposure to cold, although other indicators (such as increased respiration rate) are likely to be observed before onset of skin discoloration occurs. Thus, skin discoloration would be considered as a secondary indicator of cold water stress, and more than one secondary indicator would be needed to ensure that skin discoloration is representative of cold water stress for any specific individual.

Blubber layer thickness varies seasonally and with age, nutritional status, and reproductive status (Iverson 2002). During times of cold stress, marine mammals can use the energy stored in the blubber layer to produce internal body heat. Without an increase in daily caloric intake, the increased mobilization of blubber lipid will result in a reduced blubber layer and a decrease in the insulative value of the blubber (Iverson 2002). Weight loss, which can correspond to decreases in the blubber layer, might indicate that an animal is utilizing energy stores at a higher than normal rate in order to produce more body heat. However, weight loss can occur for many different reasons, thus requiring increased monitoring and investigation by veterinary staff.

Captive bottlenose dolphins have been observed to alter their normal behavior when exposed to extreme cold water and air temperatures. For example, when air temperatures fell below freezing and surface water temperatures fell below those of deeper water, bottlenose dolphins were observed spending more of their time in deeper waters (Scronce and Bowers 1985). Trained marine mammals may also fail to obey simple commands from their trainers when exposed to colder temperatures, particularly with respect to behaviors that require exposing skin to air temperatures below freezing (Scronce and Bowers 1985). Deviations from normal behavior, such as altered swimming behavior and refusal to beach, might be good indicators of cold stress because they can indicate that the animal is trying to minimize exposure to cold temperatures. However, to date, variation in behavior has not been observed in MMP California sea lions as a function of cold water or air exposure when deployed in areas with colder water temperatures than those that occur at SSC San Diego.

3.0 MONITORING

3.1 DISEASE TRANSMISSION PREVENTION

3.1.1 Health Monitoring Program

A schedule for monitoring of health status of the MMP marine mammals is provided in Table B-3. The table also provides the procedures that would be performed during pre- and post-transport processes (which are the same as those undertaken during an annual or semiannual comprehensive physical exam), the measures recorded daily, and the minimum intervals for the recording of other health and disease screenings.

The transport health screen, daily observation, and routine comprehensive exams and their components relevant to disease transmission are provided in Table B-3 and are described in more detail below.

Marine mammal transportation procedures are in alignment with and exceed applicable Federal regulations. The MMP has a program in place for screening the health of animals before and after they are deployed. This includes physical examinations performed by a veterinarian no less than 2 days and no more than 10 days before departure for any animal planned to be transported for more than 2 hours. Health screen procedures that would be used before and after the transport of marine mammals from SSC San Diego to NBK–Bangor are described below.

MMP animal trainers observe each marine mammal daily. Each animal’s appearance, activity, appetite, movement, and interactions with humans and animals are assessed as normal or abnormal, and observations are recorded. Abnormal findings are reported to an attending veterinarian who responds as appropriate.

3.1.2 Daily Observation

As described above in Section 3.1.1, Health Monitoring Program, MMP marine animals deployed to NBK–Bangor would be observed daily by their trainers. Each animal’s appearance, activity, appetite, movement, and interactions with humans and animals would be recorded daily.

Table B–3. Schedule for Health and Disease Monitoring for MMP Marine Mammals

Parameter	Daily	Monthly	Semiannual or Annual	Pre-Transport	Post-Transport
Paired Serology			X	X	X
Weight[1]		X	X	X	X
Blood Counts		X	X	X	X
Serum Chemistry		X	X	X	X
Medical Check (activity, animal interactions, appearance, appetite, human interactions, and movement)	X	X	X	X	X
Routine comprehensive physical examination			X	X	X

[1] Weights would be taken monthly or more often at the direction of the attending veterinarian when ambient water temperatures fall below 50°F.

3.1.3 Monthly Health Screening

Monthly health screening would include, at a minimum, animal weights and examination of physical appearance.

3.1.4 Routine Comprehensive Physical Exams

As described in Section 2.1, Disease Transmission Prevention, changes in animal health can be useful secondary indicators of communicable disease. The marine mammals at the MMP receive comprehensive semiannual or annual physical examinations and also when an animal’s behavior or physical appearance warrants a health review by a veterinarian or a secondary threshold is surpassed during daily monitoring. The physical involves an assessment of the animal’s general physical appearance (including eyes, abdomen, genitalia, musculoskeletal system, head and neck, skin, extremities) by a qualified marine mammal veterinarian and may also include assessment of vital signs (temperature, pulse, and respiratory rate), length, and weight. Diagnostic testing may include laboratory examination of feces, urine, and blood, as well as endoscopy, ultrasound, or radiographs. A clinical laboratory is used to process, archive, and ship animal samples to reference laboratories. Mobile clinical laboratories are used during animal deployments.

3.1.5 Transport Health Screen

For the deployment to NBK–Bangor, a pre-transport health screen would occur 4 weeks prior to transport and would include quarantine of the deployment animals from the MMP marine mammals at SSC San Diego. Procedures would include, but are not limited to:

1. Paired serology for communicable diseases – Serum samples would be collected 4 and 2 weeks prior to transport and within 7 days after transport. With paired serology, a second sample is taken some time after the first sample for comparison. A validated ELISA is used at a reference laboratory to assess increases in antibody response over time and would indicate if the animal had active infection with a specific pathogen. Paired serological tests are limited to ELISAs that have been validated for bottlenose dolphins and/or California sea lions. To date, species-specific validated ELISAs are limited to morbillivirus (bottlenose dolphins and California sea lions) and *Brucella* bacteria (bottlenose dolphins only).

2. CBCs and serum chemistries – 2 to 10 days prior to transport and 2 to 10 days after transport. Blood constituents measured in a CBC and serum chemistry panel include: white blood cell count, hematocrit, platelets, absolute neutrophils, absolute lymphocytes, absolute monocytes, absolute eosinophils, absolute basophils; and serum glucose, blood urea nitrogen, creatinine, uric acid, sodium, potassium, chlorine, carbon dioxide, total protein, albumin, globulins, cholesterol, bilirubin, triglycerides, calcium, inorganic phosphate, alkaline phosphatase, lactate dehydrogenase, aspartate aminotransferase, alanine aminotranferase, gamma-glutamyl transpeptidase, iron, and creatine kinase. Actual values are compared with in-house reference ranges (Venn-Watson et al. 2007, bottlenose dolphins; MMP unpublished data, California sea lions) as well as expected ranges for individual animals. Communicable diseases are most often associated with abnormal white blood cell counts and increased ESR, although non-infectious conditions may also be associated with abnormal CBC and serum chemistry values.

3. Fecal/Oral/Blowhole viral, bacterial, and fungal cultures and examination – 4 weeks prior to transport and within 7 days after transport. Fecal/oral/blowhole microbial (viral, bacterial, parasitic, and fungal) screening would test the marine mammals for exposure to viruses, bacteria, parasites, and fungi that may be associated with disease in bottlenose dolphins or California sea lions. A microbe is most likely to be considered disease-associated if it has been ruled out as a contaminant or commensal, was isolated from a clinically relevant sample, and the animal has clinical signs consistent with infection by the microbe (e.g., isolation of a known gastrointestinal pathogen from feces of an animal with diarrhea).

3.2 COLD STRESS AVOIDANCE

3.2.1 Health Monitoring Program

As described in Section 3.1.1, Health Monitoring Program, the MMP has a program in place for the screening of animal health before and after they are deployed (for the schedule, see Table B-3). Water temperatures would be maintained above the dolphin LCT within the enclosures. Although trainers and handlers monitor marine mammals constantly during open-water work, special care would be taken for cold-stress indicators when animals are working in water temperatures approaching the LCT of the animal. The animals would be continuously monitored for increased respiration rate, behavior change, and shivering. Other secondary indicators (skin discoloration, weight loss) would not be evident during individual sessions because these conditions occur over a longer period of time, and thus would be considered as part of the longer term monitoring program. When during a session the thresholds for the secondary indicators of increased respiration rate, shivering, and behavior changes are exceeded, the core body temperature of the animal would be measured. Measurements would be repeated at 30-minute increments until the end of the session. The method of core body temperature measurement would be one of several approved for use in MMP animals by the veterinary staff (e.g., rectal temperature probe, stomach temperature pill, implantable temperature sensor, etc.).

3.2.2 Daily Observation

As described in Section 3.1.2, Daily Observation, MMP marine mammals deployed to NBK–Bangor would be observed daily by their trainers. Each animal's appearance, activity, appetite, movement, and interactions with humans and animals would be recorded. Any abnormalities that could indicate stress due to cold, such as shivering, altered behavior, or abnormal skin conditions, would be reported to the veterinary staff.

3.2.3 Monthly Health Screening

As described in Section 3.1.3, Monthly Health Screening, monthly health screening for MMP marine mammals deployed to NBK–Bangor would include, at a minimum, animal weights and an examination of physical appearance.

3.2.4 Routine Comprehensive Physical Exams

As described in Section 3.1.4, Routine Comprehensive Physical Exams, marine mammals at the MMP receive annual or semiannual comprehensive physical examinations. Elements of the physical that are relevant to monitoring temperature acclimation in marine mammals include:

- vital signs (temperature, pulse, and respiratory rate);
- general physical appearance;
- weight;
- blubber thickness; and
- blood counts and serum chemistries.

3.2.5 Transport Health Screen

The transport health screening for the transport from SSC San Diego to NBK–Bangor is described in Section 3.1.5, Transport Health Screen. The following screening aspects relevant to monitoring cold stress for MMP marine mammals include:

- vital signs (temperature, pulse, respiratory rate, and general physical appearance);
- weight;
- behavior; and
- blood counts and serum chemistries.

While stationed at NBK–Bangor, MMP marine mammals would be transported from their enclosures to the NBK–Bangor waterfront area when working. Typically, they would be in the water accompanying the boat, or in an appropriate carrier on the boat. Whenever any marine mammal is out of the water for transport during cold temperatures, the animal would be transported in a closed, tri-fold mat to minimize exposure to the cold air.

4.0 MANAGEMENT ACTIONS

4.1 DISEASE TRANSMISSION AVOIDANCE

4.1.1 Primary Thresholds

4.1.1.1 Paired Serology

If paired serological monitoring revealed that an MMP marine mammal had evidence of active infection with morbillivirus, MMP staff would quarantine the animal in a separate enclosure. The animal would not be allowed to perform work in the open water environment. The veterinarian would take actions to stabilize the health of the animal and ensure its comfort. A complete health assessment would be performed by the veterinarian. The veterinarian would make recommendations as to the course of action to maintain the health of the animal. Actions may include supportive care and treatment with medication.

Detection of active infections by other pathogens would lead to supportive care and treatment as needed for the individual animal. Decisions to quarantine animals for any communicable disease other than morbillivirus would be dependent upon the severity of the disease; the potential of transmission among animals; the novelty of the pathogen to either the MMP animal population or to local, wild marine mammal populations; and the direction of the attending veterinarian. By analogy to human populations, a person with a dangerous and rare strain of tuberculosis may be quarantined, but a person with a common influenza virus (flu) would not be quarantined.

4.1.1.2 Viral, Bacterial, and Fungal Isolation

Management actions initiated would be the same as described for Section 4.1.1.1, Paired Serology, if fecal, oral, or blowhole viral, and bacterial and fungal screening revealed that any MMP marine mammal had a clinically relevant, active infection with morbillivirus or another communicable virus or bacteria. The attending veterinarian may prescribe appropriate antibiotics in the case of bacterial infection.

4.1.2 Secondary Thresholds

4.1.2.1 Weight

If an animal is determined to be below its minimum weight, the attending veterinarian would be notified, and the animal would not work in open water until it gains weight and is determined to be healthy. The veterinarian would perform a health assessment to determine possible causes of weight loss. Feeding records would be examined for possible trends in the animal's decrease in food consumption. The attending veterinarian may decide to increase the frequency of blood draws to assess the presence of an adverse health condition. Upon completion of the health assessment, the veterinarian would make recommendations for increasing caloric content of the animal's diet. Should a communicable disease (viral or bacteriological) be identified during the health assessment, management actions would continue as described in Section 4.1.1.1, Paired Serology.

If an animal is determined to be below its goal weight, the attending veterinarian would be notified. The animal would only be removed from open water work upon a veterinarian's recommendation. Feeding records may be examined, frequency of blood draws may be increased, and consultation with work group members may occur to determine further actions.

In the event of two or more animals failing to maintain minimum or goal weight, records of all the animals of the same species would be examined to determine if there are any trends indicating a possible need for changes in the MMP diet or feeding regimen for all animals. For example, after review of data for all program animals by the Senior Scientist it may be determined that some animals are having difficulty maintaining their goal weights. This would initiate collaboration of the NBK–Bangor MMP Work Group to determine the best course of action.

4.1.2.2 Behavior

Diagnosis of abnormal behavior is dependent on daily interactions between the MMP marine mammals and their trainers. Any behaviors observed in the MMP marine mammals that are clearly indicative of conditions immediately threatening the animal's health (e.g., refusal to eat for multiple days) or indicating presence of disease would initiate an immediate response as if a disease had been detected in the animal. The management response would follow the same course as for Section 4.1.1.1, Paired Serology, with the exception that notification of disease to the appropriate agency would not occur without further confirmation of the presence of morbillivirus or a disease associated with an unusual mortality event.

Abnormal behaviors not clearly associated with communicable disease or environmental temperature changes may not necessarily be cause for animal health concerns. For example, during part of the reproduction cycle in healthy female bottlenose dolphins, behavioral changes may be seen, including a short-term decrease in appetite. In such cases, the Senior Scientist may meet with the animal's trainers and the attending veterinarian to assess the animal's overall health and determine the most appropriate course of action.

4.1.2.3 Abnormal Hemogram

As described above, CBC and ESR are used in assessment of health, specifically inflammatory and potential communicable disease. Deviations from defined ranges of various blood constituents can indicate an animal is actively infected with a disease. One example is white blood cell count, which may increase or decrease in response to various disease conditions. If monitoring of any MMP marine mammal indicates that animal has an abnormal CBC and elevated ESR, several management actions might follow notification of the attending veterinarian and performance of a health evaluation. Should the health evaluation reveal presence of a communicable disease, the management response would follow the same course as if a positive serology test had been made, as described in Section 4.1.1.1, Paired Serology.

If the health evaluation does not implicate communicable disease as the cause for the variation in CBC and elevated ESR, further testing may be ordered by the attending veterinarian. The attending veterinarian may consult with the Senior Scientist and trainers to determine the most appropriate course of action to return the animal to optimal health.

4.1.2.4 Abnormal Physical Examination Findings

If an abnormality was noted during routine physical examination of any animal, the attending veterinarian would perform a health evaluation for that animal. If the health evaluation reveals presence of a communicable disease, the management response would follow the same course as if a positive serology test had been made, as described in Section 4.1.1.1, Paired Serology.

If the health evaluation does not implicate communicable disease as the cause for the observed abnormality, further testing may be ordered by the attending veterinarian. The attending veterinarian may consult with the Senior Scientist and trainers to determine the most appropriate course of action to return the animal to optimal health.

4.2 COLD STRESS AVOIDANCE

4.2.1 Primary Thresholds

The bottlenose dolphin enclosures would be operated in closed-circuit mode and maintained at a water temperature within the LCT of bottlenose dolphins. Ambient temperatures in the natural environment are unlikely to be below the LCT of the bottlenose dolphins for extended periods. Therefore, keeping temperatures within the enclosures approximately 6° to 10°F above the LCT would minimize temperature differences between the enclosures and the work environment.

As discussed in SISS EIS Section 6.2.1.2.2, Water and Air Temperature, bottlenose dolphins have been observed spending up to 7 hours at temperatures below their LCT without demonstrating effects from the cold exposure beyond an increase in their metabolic rate (Yeates and Houser 2008). The amount of time bottlenose dolphins and California sea lions are working outside of their enclosures may be limited at the discretion of the attending veterinarian when water temperatures drop below their respective LCTs. In the event that monitoring of an MMP marine mammal indicates the threshold for the primary indicator has been exceeded, that animal would be immediately returned to its enclosure for further observation by the attending veterinarian. If one or more of the secondary thresholds are exceeded, the animal may undergo increased testing and observation by the veterinary staff.

4.2.1.1 Body Temperature

If monitoring of any individual marine mammal indicates a drop in body temperature of more than 2°F for more than 30 minutes, that animal would be immediately removed from the work or training session and returned to its enclosure for further observation by the attending veterinarian. The veterinarian would take actions to ensure the health of the animal and ensure its comfort. The attending veterinarian would perform a health assessment to determine if the animal is exhibiting any other symptoms of cold stress. If the core body temperature of the bottlenose dolphin does not return to normal within 24 hours of being returned to its enclosure, the attending veterinarian would have the water temperature of its enclosure raised or would have the animal moved to a warmer enclosure. California sea lions exhibiting hypothermia would either have pens modified to reduce cold exposure or would be moved to another location where temperature can be controlled or elevated, depending upon an assessment of the attending veterinarian.

4.2.2 Secondary Thresholds

4.2.2.1 Respiration Rate

Increased respiration rate, above that observed at rest, is expected in working animals. Furthermore, an increase in respiration rate as a result of an increase in metabolism is not a sufficient reason for removing an MMP animal from open-water work. However, if respiration rate is observed to increase above twice the maximal resting respiration rate over the duration of a work session, the air and water temperature would be noted, and the attending veterinarian would determine if an increase in caloric intake is warranted. If the animal's respiration does not return to normal levels within 4 hours of being returned to its enclosure, the attending veterinarian would perform a health assessment to determine if the animal is exhibiting any other symptoms of cold stress and whether the animal is hypothermic. Further testing may be implemented, at the discretion of the attending veterinarian, to rule out other potential causes of increased respiration rate.

4.2.2.2 Shivering

If monitoring of any individual marine mammal indicates prolonged shivering (lasting more than 30 minutes), the air and water temperature would be noted, and the attending veterinarian would determine if an increase in caloric intake is warranted. If shivering continues within 30 minutes of being returned to the enclosure, the attending veterinarian would perform a health assessment to determine if the animal is exhibiting any other symptoms of cold stress and whether the animal is hypothermic. Further testing may be implemented, at the discretion of the attending veterinarian, to rule out other potential causes of shivering.

4.2.2.3 Skin Discoloration

If any new skin discoloration is observed on a working MMP marine mammal that cannot be attributed to a cause other than exposure to cold temperatures, the air and water temperature would be noted, and the attending veterinarian would perform a health assessment to determine if the animal is exhibiting any other symptoms of cold stress and whether the animal is hypothermic. Further testing may be implemented, at the discretion of the attending veterinarian, to rule out other potential causes of skin discoloration.

4.2.2.4 Weight

In the event any marine mammal is determined to be losing weight in the absence of seasonally warming temperatures or dietary changes made by the attending veterinarian, management actions would be the same as for the disease portion of the animal management plan, Section 4.1.2.1, Weight.

4.2.2.5 Behavior

As described in Section 4.1.2.2, Behavior, diagnosis of abnormal behavior may be subjective and is highly dependent on the daily interactions between the MMP marine mammals and their trainers. Any behaviors observed in the MMP marine mammals that may indicate conditions immediately threatening the animal's health (e.g., refusal to eat for multiple days) would initiate an immediate assessment of health by the attending veterinarian to determine if the animal is exhibiting any symptoms of cold stress. The veterinarian would take actions to stabilize the health of the animal and ensure its comfort, and the animal would be removed from duty.

5.0 REGULATORY COMPLIANCE

The Animal and Plant Health Inspection Service (APHIS) of the USDA is responsible for setting standards for care and maintenance of marine animals under the Animal Welfare Act. The MMP maintains a program of animal care that meets or exceeds APHIS regulations but, as a United States government organization, does not require a license from APHIS and is not subject to inspections. NBK–Bangor facility reports would be provided to APHIS. The NBK–Bangor MMP and facilities would be inspected semiannually by the Navy MMP Institutional Animal Care and Use Committee. The MMP is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC), which is a nonprofit organization that promotes the humane treatment of animals in science through voluntary accreditation and assessment programs. Annual reports on the NBK–Bangor MMP facilities would be provided to AAALAC by the MMP.

6.0 REFERENCES

Centers for Disease Control and Prevention (CDC). 2004. Syndromic Surveillance: Reports from a National Conference 2003, Morbidity and Mortality Weekly Report, September 24, 2004. 53:Suppl. http://www.cdc.gov/mmwr/preview/su5301toc.htm.

Chun, N.K.W., and M.G. Harris. 1978. Cold water temperature tolerance test of three Atlantic bottlenose dolphins (*Tursiops truncatus*). Technical Report 206. Naval Ocean Systems Center, San Diego, CA.

Cowan, D.F. 2002. Pathology. In *Encyclopedia of Marine Mammals*. W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. New York: Academic Press. 883-890.

Guyton, A.C. and J.E. Hall. 2006. *Textbook of Medical Physiology*. Eleventh Edition. Philadelphia: W.B. Saunders Company.

Hampton, I.F.G., G.C. Whittow, J. Szekerczes, and S. Rutherford. 1971. Heat transfer and body temperature in the Atlantic bottlenose dolphin, Tursiops truncatus. *International Journal of Biometeorology* 15(2-4): 247-253.

Iverson, S.J. 2002. Blubber. In *Encyclopedia of Marine Mammals*. W.F. Perrin, B. Wursig, and J.G.M. Thewissen, eds. New York: Academic Press. 107-112.

Osterhaus, A.D.M.E., R.L. de Swart, H.W. Vos, P.S. Ross, M.J.H. Kenter, and T. Barrett. 1995. Morbillivirus infections of aquatic mammals: Newly identified members of the genus. *Veterinary Microbiology* 44:219-227.

Pabst, D.A., W.A. McLellan, E.M. Meagher, and A.J. Westgate. 2002. Measuring temperatures and heat flux from dolphins in the eastern tropical Pacific: is thermal stress associated with chase and capture in the ETP-tuna purse seine fishery? Southwest Fisheries Science Center, NMFS, La Jolla, CA. Administrative Report LJ-02-34C.

Reidarson, T.H., J. McBain, C. House, D.P. King, J.L. Stott, A.Krafft, J.K. Taubenberger, J. Heyning, and T.P. Lipscomb. 1998. Morbillivirus infection in stranded common dolphins from the Pacific Ocean. *Journal of Wildlife Diseases* 34(4):771-776.

Ridgway, S.H., and C.A. Fenner. 1982. Weight-length relationships of wild-caught and captive Atlantic bottlenosed dolphins. *Journal of the American Veterinary Medical Association* 181 (11):1310-1315.

Scronce, B.L., and C.A. Bowers. 1985. Effects of a cold environment on Atlantic bottlenose dolphins (*Tursiops truncatus*). Technical Report 1028. Naval Ocean Systems Center, San Diego, CA.

South, F.E., R.H. Leucke, J.L. Zatzman, and M.D. Shanklin. 1976. Air temperature and direct partitional calorimetry of the California sea lion (*Zalophus californianus*). *Comp. Biochem. Physiol*. 54A: 27-30.

Venn-Watson, S., E.D. Jensen, and S.H. Ridgway. 2007. Effects of age and sex on clinicopathologic reference ranges in a healthy managed Atlantic bottlenose dolphin population. *Journal of the American Veterinary Medical Association* 231(4): 596-601.

Whittow, G.C., D. T. Matsuura, and G.A. Ohata. 1975. Physiological and behavioral temperature regulation in the California sea lion (*Zalophus californianus*). *Rapp. P.-v. Réun. Cons. Int. Explor. Mer* 169: 479-480.

Yeates, L.C., and D.S. Houser. 2008. Thermal tolerance in bottlenose dolphins (*Tursiops truncatusa*). *The Journal of Experimental Biology*. 211: 3249-3257.

APPENDIX C

COMBAT SWIMMERS BACKGROUND

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

CB	construction battalions (SeaBees)
DA	direct action
EOD	Explosive Ordnance Disposal
fsw	feet of seawater (depth)
IED	improvised explosive devices
NCDU	Navy Combat Demolition Units
SCUBA	Self-Contained Underwater Breathing Apparatus
SEAL	Sea, Air, And Land (Navy Special Warfare personnel)
SOF	Special Operations Force
SR	special reconnaissance
U.S.	United States
UDT	Underwater Demolition Team

1.0 HISTORICAL OVERVIEW

Man has ventured into the sea for thousands of years, seeking food, items for commerce, treasure, and the remains of shipwrecks and other disasters. Since it is not his natural environment, he must adapt himself to it, using his own available physiological resources or developing equipment that will allow greater adaptation. This equipment helped to assist humans to breathe underwater, to fight the cold, to withstand underwater pressure, and to resist the diseases associated with deep water depths. As in many other areas of life, humans have developed much of this equipment to aid in the conduct of war.

The Navy, Marines, Army, Air Force, and Coast Guard maintain units of divers specially trained to support national needs related to operating effectively in the oceans. Scores of tasks are performed on and under the water's surface, but can be generalized into a handful of categories—salvage/object recovery, rescue, equipment and platform maintenance, handling of underwater ordnance, and special warfare. It is possible to generalize further and characterize these various tasks and categories into two main categories, combat diving and non-combat diving, although clearly there are tasks in which the distinctions are hazy. For the sake of this discussion, combat swimmer or combat diver are generic titles for an individual trained to perform military missions involving confrontation with an enemy on, under, or near the water. Thus, Navy Special Forces personnel who move from a ship at sea to smaller craft and come ashore to make a precision strike or initiate a larger beach landing are combat swimmers. Explosive Ordnance Disposal (EOD) divers who hunt for and disarm or destroy enemy mines guarding a narrow expanse of water such as a strait or a harbor entrance are combat divers. Divers who clear obstructions to navigation and check ship hulls underwater for marine growth or collision damage are non-combat divers.

Clearly, however, there are very obvious connections between these sets of divers: both use similar suits and equipment that are the result of centuries of scientific experimentation and engineering development. Both benefit from scientific study into the causes of and remedies for physiological disease generally affecting only divers—nitrogen narcosis and decompression sickness. And both participate in a profession that is fairly dangerous whether or not combat is involved.

1.1 DIVING PIONEERS

A brief history is useful in providing background to the current state of diving in the U.S. military. As is usual in histories like this, a number of individuals stand out as pioneers in their field, either through personal exploits or by their contributions to the advancement of that field. Some of those in the diving (both combat and non-combat) arena include the following:

- A Greek in the 5th Century BCE (Before Christian Era) named Scyllis, according to an account of Herodotus (Father of History), was captured by the enemy and taken aboard one of its ships as a prisoner. Learning the Persian King Xerxes intended to attack the Greek fleet, he jumped overboard armed with a knife. Subsequent searching by the Persians failed to find him, and he was presumed drowned. Under cover of night, and using a hollow reed as a snorkel to avoid detection, he reportedly swam from ship to ship of the Persian fleet, cutting their mooring lines and setting the ships adrift. He then swam nine miles to the island of Euboea to rejoin the Greek forces. By his actions, he may be regarded as one of the very first combat swimmers.

- Two millennia later, in the 15th/16th Century, Leonardo da Vinci, ahead of his time in so many areas, briefly mentions the concept of air tanks to allow a swimmer to breathe underwater. As with a number of his inventions, he kept the description sketchy because he foresaw such a device as an aid to hostile actions such as sinking ships. Some of his drawings feature snorkels and a sort of diving suit including a face mask and a small container for air.

- In the early 1700s, Englishman John Lethbridge invented a diving suit that was actually a watertight barrel with a viewing port and watertight arm holes, which enabled him to conduct useful work underwater in a more mobile fashion for about half an hour.

- In 1828, a suit originally designed five years earlier by brothers John and Charles Deane for firefighters to breathe in heavy smoke had evolved into a diving dress, with insulation against the cold, a helmet featuring viewing ports, and connections for air coming from the surface.

- Augustus Siebe modified the Deane design, which had critical flaws if the diver did not remain upright (if, for example, he tripped and fell), and developed Siebe's Improved Diving Dress, which was viewed as a direct early relation to the Navy's standard Mark V deep-diving dress.

- More sophisticated diving hardware began appearing around the time of the Civil War, when Frenchmen Benoit Rouquayrol and Auguste Denayrouze developed an air tank with the first known air regulator. The diver carried his air supply on his back, rather than having it supplied from the surface, and used a device to regulate the flow of high-pressure air so he could breathe effectively and comfortably, even at depths previously considered prohibitive due to the significant pressure. Captain Nemo discusses this equipment in Jules Vernes' *20,000 Leagues Under the Sea*, with highly improbable claims of bottom-time capability of 9 to 10 hours (Verne 1870).

- At about the same time, U.S. Army Brevet Major General John G. Foster, a West Point graduate and decorated veteran of the Battle of Fort Sumter and other Civil War engagements, wrote a paper titled *Submarine Blasting in Boston Harbor* in 1869. The techniques described for underwater diving became the standard reference for divers conducting underwater demolition for almost 50 years.

- J.S. Haldane, a British physiologist, is credited with early 20th Century studies related to diving diseases, such as decompression sickness. He developed a rate of air flow to counter carbon dioxide build-up in diving helmets, and invented a set of diving tables for safe decompression in stages.

- One of the diving's most critical developments occurred during World War II in German-occupied France, as Frenchmen Jacques-Yves Cousteau and Emile Gagnan experimented with and perfected high-pressure air tanks and an improved demand regulator, creating the Aqua-Lung, the first efficient and safe Self-Contained Underwater Breathing Apparatus (SCUBA). With the end of the war, it became a phenomenal commercial success, with obvious applications for military divers in both combat and non-combat roles.

1.2 U.S. Navy Diving History

The U.S. Naval Historical Center website (Navy 2007) presents a fairly detailed history of diving worldwide, which is a copy of its original description in the *Navy Diving Manual* (Navy 2005). A summary of the diving portions of this description follows.

The U.S. Navy began employing divers for various tasks beginning about the middle of the 19th Century. In 1898, Navy divers from Key West, Florida, were sent to Havana harbor, Cuba, to investigate the explosion that sank the battleship USS Maine. A series of sinkings accompanying the rapid growth of the Navy submarine force led to a similar growth in numbers of Navy divers and in diving technology and capability, including diving tables to ensure safe decompression following dives. Of particular note was the March 25, 1915, sinking of the submarine USS F-4 near Honolulu, Hawaii, after a battery explosion which killed 21 crew members. According to the Naval Historical Center account (Navy 2007): "Navy divers salvaged the submarine and recovered the bodies of the crew. The salvage effort incorporated many new techniques, such as the use of lifting pontoons, but what was most remarkable was that the divers completed a major salvage effort working at the extreme depth of 304 fsw [feet of seawater], using air as a breathing mixture. These dives remain the record for the use of standard deep-sea diving dress. Because of the depth and the necessary decompression, each diver could remain on the bottom for only ten minutes. Even for such a limited time, the men found it hard to concentrate on the job at hand. They were unknowingly affected by nitrogen narcosis."

Important long-term results of this incredible effort were the publication of the first U.S. Navy Diving Manual and the establishment of a Navy Diving School at Newport, Rhode Island. It also led, a decade later, to experiments in the use of helium-oxygen mixtures, which were found to shorten decompression time and eliminate the mental effects of breathing air at great depths. This testing supported development of improved equipment and more reliable decompression tables. A nearly year-long salvage effort for the USS S-51 (SS-162), which sank off Block Island, Massachusetts, highlighted inadequacies of training and numbers of divers, resulting in re-establishment of the Naval School, Diving and Salvage at the Washington Navy Yard in 1927. Shortly afterward, the Navy Experimental Diving Unit was also moved to the Navy Yard, consolidating the dive training and technology development efforts in one location.

Navy divers were substantially involved in World War II less than two hours after it began when dive teams worked to cut through the hull of the overturned USS Oklahoma (BB-37) in Pearl Harbor to rescue sailors trapped inside. Other dive teams recovered ammunition from sunken ships to be used in case of resumption of the attack. Over the next year and a half, Navy divers made 4,000 dives totaling more than 16,000 hours to salvage the battleships and other surface ships that littered Pearl Harbor and to help the naval station and shipyard prepare for active war support. An ocean and a continent away, Navy divers were salvaging the former French passenger ship Normandie, converted into a U.S. Navy ship, which caught fire and sank in a New York harbor, obstructing access to a pier badly needed for the war. As part of the effort, the Navy established the Naval Training School, which primarily supported salvage efforts, on site.

Although the majority of the publicized Navy dive efforts up to this point were to salvage sunken ships, divers had previously conducted underwater reconnaissance missions to gather intelligence and remove obstacles to beach landings. An early group of Navy divers, referred to as the Scouts and Raiders, were assigned to identify and come ashore on beaches designated for landing and to guide assault forces ashore. Commissioned in October 1942, the group supported landings in North Africa, Sicily, Salerno, Anzio, and Normandy. Other Scouts and Raiders units operated in New Guinea and China.

Navy Combat Demolition Units (NCDU) were formed to eliminate obstacles on enemy-held beaches prior to an invasion. A training unit was established on June 6, 1943, and one year later on Omaha Beach at Normandy NCDU divers, working under intensive enemy fire, blew eight complete gaps and two partial gaps in the German defenses as the landing craft came ashore. At Utah Beach, divers of another NCDU cleared 700 yards of beach in two hours and another 900 yards by the afternoon.

In the Pacific, following the November 1943 battle of Tarawa, 30 officers and 150 enlisted men formed the nucleus of a demolition training program, becoming Underwater Demolition Teams (UDT) One and Two. The teams combined bomb disposal experts and Navy combat engineers in construction battalions (CBs), also known as SeaBees. Their mission was to remove hazardous material from shallow water to provide access for landing craft. Originally set up to remove German barricades off French beaches, they saw their first combat in January 1944 in the Marshall Islands, and conducted a day-time demolition and reconnaissance effort off Saipan in June 1944. In March 1945, UDT personnel off Okinawa removed 1,200 underwater obstacles in two days under heavy fire, preparing for the invasion of the island, amazingly without a single casualty.

Regarding the UDT teams, the Navy Special Warfare Command (2007) states: “Eventually, 34 UDT teams were established. Wearing swim suits, fins, and facemasks on combat operations, these ‘Naked Warriors’ saw action across the Pacific in every major amphibious landing including: Eniwetok, Saipan, Guam, Tinian, Angaur, Ulithi, Pelilui, Leyte, Lingayen Gulf, Zambales, Iwo Jima, Okinawa, Labuan, Brunei Bay, and on 4 July 1945 at Balikpapan on Borneo which was the last UDT demolition operation of the war.”

According to the Navy Diving Manual (Navy 2005): “Fleet diving has become increasingly important and diversified since World War II. A major part of the diving mission is the inspection and repair of naval vessels to minimize downtime and the need for day-docking. Other aspects of fleet diving include the recovery of practice and research torpedoes, installation and repair of underwater electronic arrays, underwater construction, and location and recovery of downed aircraft. Ship sinkings and beachings caused by storm damage and human error continue to demand the fleet’s salvage and harbor clearance capabilities in peacetime as well as in times of hostilities.”

As indicated earlier, the loss of submarines prompted major efforts to increase the number of Navy divers and improve the equipment needed to perform their missions. The April 1963 loss of the new nuclear attack submarine USS Thresher (SSN-593) had a similar result. The ship sank in 8,400 fsw, far beyond hull crush depth and even farther beyond a rescue capability. In addition to the standard Court of Inquiry to investigate causes of the sinking, a second significant group was formed, called the Deep Submergence Review Group, to assess the Navy's undersea capabilities. Among important achievements of this group were the design, development, and fielding of the Deep Submergence Rescue Vehicle, which became operational in 1972, providing a 5,000 fsw rescue capability for submarine crews stranded on the bottom, and the series of Man-in-the-Sea saturation diving experiments known as SeaLab.

In subsequent years, saturation diving became a standard for long-term, deep-water projects, a majority of which require salvage, either to recover valuable platforms and equipment or to clear areas needed for transit or docking of ships.

The Navy's Sea, Air, And Land (SEAL) force originated with President Kennedy's stated desire for the U.S. Armed Forces to develop an unconventional warfare capability. In response, the Navy established SEAL Teams One and Two in January 1962. Formed entirely with personnel from Navy Underwater Demolition Teams, the SEAL's mission was to conduct counter guerilla warfare and clandestine operations in maritime and riverine environments. SEALs served in Vietnam in an advisory capacity; among other responsibilities, they instructed a training course for South Vietnamese UDT commandos. In February 1966, a small detachment of SEAL Team One began direct-action missions over the next five years. Before departing the country in December 1971, eight SEAL platoons operated in Vietnam on a continuing basis.

UDTs also experienced combat in Vietnam, supporting Navy Amphibious Ready Groups, conducting operations with river patrol boats and patrolling beaches, riverbanks, and even into the countryside to destroy bunkers and other hazards.

On May 1, 1983, all UDTs were re-designated as SEAL Teams or Swimmer Delivery Vehicle Teams, which have since been re-designated SEAL Delivery Vehicle Teams. The current organizational structure for SEALs, Naval Special Warfare Command, was commissioned April 16, 1987, in Coronado, California.

SEAL post-Vietnam War operations included combat missions in Grenada, the Persian Gulf, Panama, Somalia, Bosnia, Haiti, and Liberia. In response to the attacks on America September 11, 2001, Naval Special Warfare forces were in Afghanistan in October, and a senior Navy SEAL officer was there shortly afterward commanding a joint task force of Navy, Army, Air Force, and Coalition Special Forces. SEALs executed more than 75 special reconnaissance and direct action missions during Operation Enduring Freedom. For Operation Iraqi Freedom, the military had the largest number of SEALs and special warfare craft operators in its history.

Navy EOD units also were active in Vietnam, providing mine clearance capabilities both at sea and in Vietnam river systems, ensuring shipping and maritime operations safety. Also tracing their history to World War II units, initial EOD efforts began with a group of volunteers who trained with British unexploded ordnance teams in 1940, before the U.S. entered the war. When they returned to the U.S., they attended the first class of the Mine Recovery School. In all, 19 classes graduated from the school between 1941 and 1945, and then they deployed throughout the Pacific and Mediterranean areas assigned to Mobile Explosive Investigative Units. They cleared explosive hazards both at sea and on land. During the Korean conflict, now titled EOD units, they served on minesweepers but also participated in in-country intelligence operations.

After Vietnam, the deteriorating world situation and increased tasking stimulated substantial increases in EOD units. During the Persian Gulf War, EOD personnel cleared more than 500 sea mines. Navy EOD personnel were also involved in joint operations in Bosnia, Haiti, Kosovo, and Somalia, and they are serving today in Afghanistan and Iraq, forward deployed and heavily involved in dealing with the improvised explosive devices (IED) threat.

Today, in addition to the highly specialized Special Warfare and EOD communities, Navy divers rotate regularly through shipyards, research and development commands, dive lockers aboard ships and submarines, and mobile salvage and diving units (Daubon 2007, personal communication). One Navy diver commented on this capability, saying all personnel attending Navy dive schools are trained in all diving gear they will use during their careers, except for special purpose equipment (Bagley 2007, personal communication).

2.0 CURRENT MILITARY DIVER/COMBAT SWIMMER UNITS AND MISSIONS

The Navy, Marines, Army, Air Force, and Coast Guard maintain units of divers, with the Navy providing the lead and much of the training for all military divers. The Navy separates its diving billets into eight major categories—fleet maintenance, salvage, SEALs, EOD, submarine support, research and development, aviation support, and training billets. The Navy currently has more than 5,000 divers. The U.S. Navy Assistant Supervisor of Diving, who is also the program manager of a major new Navy saturation diving capability, states that most of the Navy’s current non-combat divers are assigned to mobile salvage and diving units (Daubon 2007, personal communication). Statistical data provided by his office indicate there are currently about 1,225 non-combat Navy divers, with about 240 divers assigned to salvage billets and another 275 divers to fleet maintenance duties. Additionally, approximately 160 divers support the submarine force and 80 divers are assigned to various Navy research and development commands. Over the next six years, the total number of these divers is expected to increase to 1,300 personnel.

The largest number of Navy combat divers is assigned to the Special Warfare community, which maintains a current force of 2,450 SEALs and another 325 reservists. They are supported by more than 700 Special Warfare Combatant-craft Crewmen and another 700 support personnel (Navy Special Warfare Command 2007). They are also supported by another 150 regular Navy divers (of the 1,225 stated above), who maintain their diving equipment and assist in maintaining SEAL diving proficiency. It is anticipated the largest increase in the regular Navy diving community over the next six years will be in this role of Special Warfare requirements support. The EOD community has about half the number of divers assigned to the Navy Special Warfare Command, including 100 regular Navy divers who provide the same equipment and training maintenance support.

Divers with the U.S. Marine Corps are members of reconnaissance units, with the no-nonsense nickname of "swift, silent, and deadly" units and with diving only one of several critical skills. They are trained in a variety of disciplines, including basic and advanced reconnaissance, close quarters combat, urban warfare, rappelling, and parachuting, in addition to survival, evasion, and escape training. They receive their dive training (the Marine Combatant Diver Course) at the Naval Dive Training Center at Panama City Beach, Florida (Pomykal 2001). Typical of Marine units to which these personnel are assigned is the 24th Marine Expeditionary Unit (Special Operations Capable), Maritime Special Purpose Force, 2nd Force Reconnaissance Battalion, operating recently in the Central Command Theater of Operation, where the unit participated in underwater dive and aerial free fall/static line training to enhance their capabilities in those areas. They also conducted training with the Diver Propulsion Device, a commercial product rigorously tested by the National Aeronautics and Space Administration and U.S. Navy SEALs prior to its release to Recon Marines. This torpedo-shaped device weighs less than 200 pounds and provides a means for rapid underwater insertion and extraction of Marine divers. The two-man device tows Marines from a water insertion site over the horizon (and thus out of enemy sight) into the beach in a short amount of time (Walker 2004), eliminating what one Marine Corps veteran described as 10,000 meters of "finning," just to get to the beach for the start of the reconnaissance operation.

Like the Navy, the U.S. Army has a corps of engineer divers tracing its roots back to World War II. Several hundred enlisted personnel and 17 officers made up the Port Construction and Repair Groups trained at Fort Screven, Georgia. Of these, 16 personnel became deep sea divers trained by the Navy. The Army divers of the 1056th Port Construction and Repair Group landed on Utah Beach shortly after the D-Day invasion and within three weeks had moved to Cherbourg, France, and cleared the port of sunken ships and other underwater obstacles to navigation and berthing. Within months the port was capable of handling 25,000 tons of cargo essential to the war effort. After similar efforts in Belgium, the 1056th moved into Germany in March 1945 and built the first fixed railroad bridge across the Rhine River, a span more than 2,000 feet long completed in only 10 days.

Army divers also performed port and harbor reconstruction work during the Korean and Vietnam wars. They performed port security operations in Saudi Arabia and Kuwait during the Persian Gulf War.

Typical Army diver duties include inspection, cleaning, and repair of watercraft propellers and hulls; salvaging sunken equipment; patrolling the waters below watercraft at anchor; and surveying and clearing rivers, beaches, and harbors for underwater obstacles. In the Middle East, Army divers currently provide security sweeps of allied ships for hull-attached explosives that could be brought into harbors, and also help recover bodies of soldiers killed in action. In several recent incidents, divers of the 544th Engineers recovered the bodies of nine Marines lost when their troop carrier flipped over while trying to negotiate a flooded street in Iraq, recovered other Marines whose helicopter crashed into a lake west of Baghdad, and helped find a Marine killed by a roadside bomb on a bridge outside Fallujah; they found his body more than a kilometer downriver from the bridge.

Army diver categories, similar to the Navy's, are second class diver, salvage diver, first class diver, and master diver. For descriptions of these classifications and their responsibilities, please see (Army 2007a).

The Army's official publication on diving (Army 2007b) is the service's guide to its policy on diving. Included are two categories of divers—engineer diver and combat diver. The publication provides requirements, qualifications, etc. for those interested in pursuing this career.

Occasionally the Navy and Army work together on underwater projects. Following are current/recent examples: Army and Navy divers operating from an Army service craft are salvaging a Russian Juliet-class submarine from the harbor in Providence, Rhode Island. The submarine was a tourist attraction until large, storm-generated waves swept into open hatches and sank it. The recovery is providing an invaluable training opportunity for the divers. During the collapse of a major interstate highway bridge in Minneapolis on August 1, 2007, Army Corps of Engineers personnel and Navy divers played key roles in recovery of bodies from the river and removal of vehicles that posed hazards to navigation. Off the coast of Florida, teams of Army, Navy, and Coast Guard divers are working to reverse a well-intentioned environmental effort gone wrong, recovering more than two million tires dumped into the Atlantic to create the world's largest man-made reef; the tires are now destroying the natural reef and are washing ashore as a major environmental problem.

3.0 COMBAT DIVING

Today's Navy combat swimmers/divers are divided into two groups with distinct missions—EOD divers, whose mission is handling, defining, and disposing of munitions and other explosives; and the SEAL special operations teams, the Navy's component of the military's Special Forces. Their missions include special reconnaissance (SR), direct action (DA), unconventional warfare, combat responses to terrorism, foreign internal defense, information warfare, security assistance, counter-drug operations, personnel recovery, and hydrographic reconnaissance. Navy Special Warfare core training is focused on SR and DA—critical skills needed to combat current and future terrorist threats (Naval Special Warfare Command 2007).

According to the Naval Special Warfare Command website, "The most important trait that distinguishes Navy SEALs from all other military forces is that SEALs are maritime Special Forces, as they strike from and return to the sea…Their stealth and clandestine methods of operation allow them to conduct multiple missions against targets that larger forces cannot approach undetected. From 1962 when the first SEAL teams were commissioned, to present day, Navy SEALs have distinguished themselves as an individually reliable, collectively disciplined and highly skilled maritime force."

The major operational components of Naval Special Warfare Command are Naval Special Warfare Groups One and Three in San Diego, California, and Groups Two and Four in Norfolk, Virginia. These components deploy SEAL Teams, SEAL Delivery Vehicle Teams, and Special Boat Teams worldwide to meet the training, exercise, contingency, and wartime requirements of theater commanders.

"Navy Explosive Ordnance Disposal Technicians render safe all types of ordnance, both conventional and unconventional, improvised, chemical, biological, and nuclear to include Improvised Explosive Devices (IEDs) and Weapons of Mass Destruction. They perform land and underwater location, identification, render-safe, and recovery (or disposal) of foreign and domestic ordnance. They conduct demolition of hazardous munitions, pyrotechnics, and retrograde explosives using detonation and burning techniques. They forward deploy and fully integrate with the various Combatant Commanders, Special Operations Force (SOF), and various warfare units within the Navy, Marine Corps, and Army. They are also called upon to support military and civilian law enforcement agencies" (EOD 2007).

The major Navy EOD forces are as follows:

- EOD Group One (San Diego), which includes Mobile Diving and Salvage Unit 1 in Pearl Harbor, Hawaii; ; EOD Mobile Units 1, 3, 5, and 11; and a reserve mobile unit. EOD Mobile Unit 1 focuses its efforts on mine clearance and operates the Navy's mine-hunting dolphins, and EOD Mobile Unit 3, in addition to its traditional duties, operates the Navy's swimmer defense dolphins.
- EOD Group Two (Norfolk), which includes Mobile Diving and Salvage Unit 2; EOD Mobile Units 2, 4, 6, and 8; and a reserve mobile unit.

4.0 SUMMARY

For more than a century and a half, heroic human achievements, inventive experimentation, and technology development have provided the Navy with substantial diving capability. Many lives and numerous platforms have been saved; depth records have been shattered; and warriors from the sea have preceded and ensured the success of major amphibious landings. Today's Navy combat divers have two primary responsibilities: (1) prosecution of underwater ordnance to save ships and lives; and (2) clandestine underwater and nearshore operations in high-threat areas to gather intelligence and to strike quickly and successfully against targets out of the reach of larger forces.

5.0 LITERATURE CITED

Army. 2007a. *US Army Engineer Diver (MOS 21D). Phase 1 Course. Rate/Rank Structure.* http://www.wood.army.mil/577th/diver/Rate.htm (Accessed September 10, 2007).

Army. 2007b. Management of Army Divers. U.S. Army Regulation 611-75, 20 July 2007. http://www.army.mil/usapa/epubs/pdf/r611_75.pdf

Bagley, C. 2007. GM1 (DV) Christian Bagley, USN, Navy diver assigned to Space and Naval Warfare Systems Center San Diego. August 29, 2007. Personal communication, conversation with Tom LaPuzza, SSC San Diego Public Affairs Office, re: Navy dive school training procedures.

Daubon, D. 2007. LCDR Druso Daubon, USN, Assistant Supervisor of Diving and Program Manager for the Saturation Fly Away Diving System. September 20, 2007. Personal communication via telephone with Tom LaPuzza, SSC San Diego Public Affairs Office, re: Navy diver assignments.

EOD. 2007. Navy Explosive Ordnance Disposal website. www.eod.navy.mil (Accessed September 23, 2007).

Foster, J.G. 1869. Submarine Blasting in Boston Harbor, Massachusetts: Removal of Tower and Corwin Rocks. New York: D. Van Nostrand. http://lcweb2.loc.gov/service/gdc/scd0001/2001/20010725002su/20010725002su.pdf

Navy. 2005. U.S. Navy Diving Manual, Rev. 5, August 2005: SS521-AG-PRO-010; 0910-LP-103-8009. http://www.supsalv.org/pdf/Diveman.pdf

Navy. 2007. Diving in the U.S. Navy: A brief history. Naval Historical Center website. http://www.history.navy.mil/faqs/faq100-1.htm (Accessed January 31, 2008).

Navy Special Warfare Command. 2007. Introduction to Naval Special Warfare Command. http://www.sealchallenge.navy.mil/seal/introduction.aspx (Accessed September 19, 2007).

Pomykal, A.D. 2001. Recon is looking for a few good men. *Marine Corps News*, November 25, 2001. (Accessed February 27, 2008) http://www.marines.mil/units/mcieast/mcblejeune/Pages/2001/Recon%20is%20looking%20for%20a%20few%20good%20men.aspx

Verne, J. 1870. *20,000 Leagues Under the Sea*. New York: Signet Classics. Published December 1969. 111-113.

Walker, R. 2004. Recon tests diver propulsion system. *Marine Corps News*, February 13, 2004. (Accessed February 27, 2008) http://www.marines.mil/units/mciwest/mcbjapan/mcbbutler/Pages/2004/Recon%20tests%20diver%20propulsion%20system.aspx

APPENDIX D

REMOTELY OPERATED VEHICLES BACKGROUND

TABLE OF CONTENTS

LIST OF FIGURES

List of Acronyms and Abbreviations

ATV	Advanced Tethered Vehicle
CURV	Cable-controlled Underwater Recovery Vehicle
MTS	Marine Technology Society
NASA	National Aeronautics and Space Administration
NOSC*	Naval Ocean Systems Center
NOTS*	Naval Ordnance Test Station
NRC	National Research Council
NUC*	Naval Undersea Center
ROV	Remotely Operated Vehicle
RUWS	Remote Unmanned Work System
SSC San Diego*	Space and Naval Warfare Systems Center San Diego
U.S.	United States
WSP	Work Systems Package
WSS	Waterside Security System

* Each of these facilities is a Navy research, development, test, and evaluation center that is currently referred to as the Space and Naval Warfare Systems Center San Diego (SSC San Diego). The changing names resulted from Navy internal reorganizations over the years, but the command remained essentially the same in its mission responsibilities related to underwater vehicle development.

1.0 HISTORICAL OVERVIEW

The oceans and seas are resources essential to the world's economy, providing weather effects, food and energy sources, transportation lanes, and recreational opportunities. To use and protect these resources effectively, humans have constructed a variety of structures near, on, or under the water (e.g., docks and piers, breakwaters, gas- and oil-drilling platforms, underwater pipelines, communications lines). In one significant project conducted in three phases, the United States (U.S.) Navy built underwater habitats to experiment with the concept of long-term human habitation on the ocean floor (NRC 1996). Drilling platforms and underwater pipelines require regular and emergency maintenance and repair, requiring post-construction access. In addition to construction and maintenance projects, humans have other interests requiring access to the deep ocean, such as the search for natural treasures (e.g., pearls, sponges) and salvage of ships lost at sea (MTS ROV Committee 2008a). Since the sea is not a natural environment for humans, working safely and effectively in this setting has required careful planning and development of specialized vehicles and equipment.

The Navy's early effort to develop technology that would perform underwater tasks (such as inspection, search, and recovery) included a multi-faceted approach, according to one of the Navy's premier research, development, and engineering centers: "One of the primary mission responsibilities of the Naval Undersea Research and Development Center (NUC) is to develop and utilize expertise in ocean engineering…employing not only men, manned submersibles, and unmanned remotely controlled machine systems but also mammals" (Talkington 1972). The report describes the development and operation of a variety of manned submersibles with panoramic viewing capability, remotely controlled unmanned vehicles, ocean platforms, and other related subjects (such as underwater vehicle materials, imaging systems, and diver equipment). The report notes the substantial cost and potential risk to human life of the manned systems and states, "Missions that require the submersible to perform complex manipulative tasks in close proximity of such entangling obstructions like cables, net, or wreckages, generally are more suited for unmanned remotely controlled systems."

Although several descriptive names were employed over the years—unmanned submersible, remotely controlled vehicle, unmanned undersea vehicle—the term of choice for these systems beginning in the 1970s was "remotely operated vehicle," or ROV. The Marine Technology Society (MTS), a "not-for-profit professional society of ocean engineers, technologists, policy makers and educators" (MTS 2007), is a focus group for the combined military-academic-industry desire to develop technologies that could perform useful tasks on and in the ocean. MTS created an ROV Subcommittee under its Undersea Vehicle Committee in 1978. The subcommittee staged its first major conference in San Diego in 1983, developed an industry standard publication titled *Operational Guidelines for Remotely Operated Vehicles* in 1984, and in 1989 split from the parent Undersea Vehicle Committee to form a separate ROV Committee (MTS ROV Committee 2007).

According to the committee, an ROV is described as "an underwater robot that allows the vehicle's operator to remain in a comfortable environment while the vehicle performs the work underwater" (MTS ROV Committee 2008b). Although some uncertainty exists about which was the first ROV, a tethered vehicle titled POODLE was developed in the early 1950s by underwater archaeologist and photographer Dimitri Rebikoff (Broadwater 2002).

1.1 CURV VEHICLES

The U.S. Navy's venture into ROVs began in the early 1960s with the Cable-controlled Underwater Recovery Vehicle (CURV I) (Jacobsen 1986). This original CURV was based loosely on a commercially produced ROV that was almost completely rebuilt by Navy civilian engineers and technicians of the Pasadena Annex of the Naval Ordnance Test Station (NOTS), a Navy research, development, and engineering center in California. After six decades and a number of organizational changes and titles, the development organization is currently referred to as the Space and Naval Warfare Systems Center San Diego (Naval Ocean Systems Center [NOSC] 1990a; NOSC 1990b). A primary mission of NOTS and its successor organizations was the development of torpedoes and other anti-submarine warfare weapons; the family of CURV vehicles was developed principally to recover these weapons fired in test exercises on sea ranges, as a safer and more effective alternative to recoveries by human divers.

CURV I was a tubular frame vehicle with four torpedo-shaped buoyancy tanks (Figure D–1). The ROV was 11 feet long, 4 feet wide, and 4 feet high. Propelled by three 10-horsepower motors (port, starboard, and vertical), it carried sonar projectors and hydrophones, lights, a TV camera, and a 35 mm still camera. Most importantly, it was equipped with a seven-function manipulator arm terminating in a hydraulic claw that enabled the operator to grasp (generally round) objects underwater (Uhrich 1971). The cameras, lights, sonar mechanisms, manipulator, and various claw functions were operated hydraulically as opposed to the more conventional electrically operated systems. This provided a number of advantages, including lower cost, less weight, higher strength, and greater reliability (Pace 1968). The vehicle was directed by an operator in a control van on a surface craft, through a coaxial cable that transmitted the operator's commands to the vehicle and returned images from the submersible's sonars and cameras.

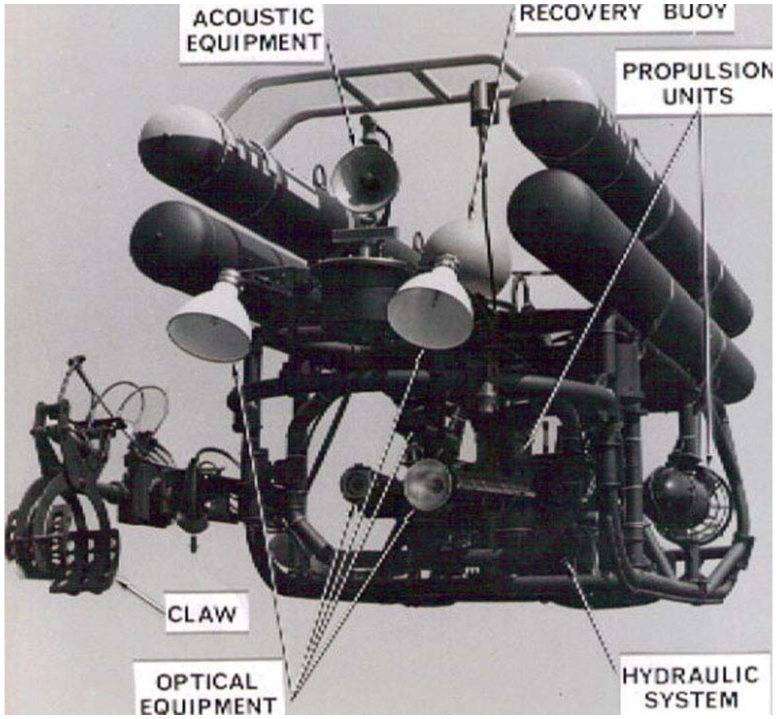

Figure D–1. CURV I Cable-controlled Underwater Recovery Vehicle

CURV I gained world-wide prominence in 1966 when it played a key role in the recovery of a hydrogen bomb dropped into the Mediterranean Sea near Palomares, Spain, following a mid-air collision of a U.S. Air Force B-52 bomber and a KC-135 re-fueling plane (Jacobs 1966). Following that accident, which claimed the lives of seven U.S. airmen, four unarmed hydrogen bombs parachuted to earth. Three landed in the Spanish countryside and were quickly recovered by U.S. military personnel. The fourth bomb fell into the Mediterranean Sea, and an armada of U.S. Navy ships (Task Force 65) began a two-month search for the bomb, which was later found in a 2,500-foot water depth. For the rescue, a recovery line was attached to the vehicle to pull the bomb up from the ocean floor; however, the line was lost and the bomb slid down an adjacent steep slope preventing recovery. When the bomb was found more than a week later, it was at a depth of 2,850 feet, and just on the edge of an abyss another 3,000 feet deep, where, if it slipped over the edge, it would have been virtually unrecoverable with available technology. At that point, Navy civilian engineers in charge of the CURV program were flown to Spain, briefed on the status of the operation, and asked to bring their vehicle to the scene. Over a three-day period, CURV made three dives, far beyond its design depth of 2,000 feet, and attached three recovery lines to the bomb. On April 7, 1966, the winch aboard the support craft hauled CURV and the H-bomb to the surface, to world-wide front-page stories. Among them was a precisely detailed, if somewhat overly dramatic, account that appeared in *Weekend Magazine*, a Sunday supplement to newspapers across Canada (Joseph 1966).

Similar headlines resulted from the prominent role played by a successor ROV, CURV III, which in 1973 rescued two Canadians trapped in the PISCES III manned submersible 1,350 feet underwater in the Irish Sea off the coast of Cork, Ireland (Sunday Mirror 1973; Watts 1973).

The CURV development effort consisted of a handful of vehicles, each demonstrating substantial increases in technical sophistication and depth capability:

- CURV I was rated at 2,000 feet, but for the bomb recovery in the Mediterranean Sea, the ROV dove to more than 2,800 feet.

- CURV II was a follow-on development model, which served as the workhorse on the weapons test ranges, recovering hundreds of exercise torpedoes off San Clemente Island, California, during year-round weapons testing.

- CURV III was intended to provide major technical advances over CURV I, as part of the Navy's long-term goal of developing a vehicle capable of operating at a 20,000-foot depth. The first model of CURV III (CURV IIIA) sustained major failures on its first deep dive, losing its buoyancy units and suffering frame collapse. The subsequent model, CURV IIIB, functioned well but was lost during a recovery operation in heavy seas. Finally, CURV IIIC (Figure D–2) achieved design requirements of successful operation at 7,000-foot depths. Among other significant operations, CURV IIIC rescued the PISCES III crew (as noted above), recovered a high-value instrument package lost underwater by the National Aeronautics and Space Administration (NASA), and recovered an F-14 aircraft and its sophisticated weapons after the plane rolled off the deck of an aircraft carrier into deep water.

- A radically re-designed CURV III is now one of the significant resources at the command of the Navy Supervisor of Salvage and Diving to perform required work in the deep ocean (20,000 feet of seawater) (Navy 2007).

Figure D–2. CURV III Cable-controlled Underwater Recovery Vehicle

1.2 SUBSEQUENT DEVELOPMENT OF ROVS

In addition to the CURV family of vehicles, Space and Naval Warfare Systems Center San Diego (SSC San Diego), a Navy research, development, and engineering center, developed a number of other ROVs of substantially varying sizes, depth capabilities, and missions. These ROVs included:

- Snoopy, a 50-pound vehicle that performed as an underwater camera attached to a metal frame, with a propeller;
- the Submersible Cable-Actuated Teleoperator, a vehicle that allowed "telepresence," the illusion that an operator on the surface was underwater, provided by wearing a helmet that moved the vehicle's underwater cameras with the motion of the operator's head and presented the binocular vision of the two vehicle cameras on small TV screens immediately in front of his eyes (NUC 1973);
- the several-ton Remote Unmanned Work System (RUWS), the first of the Navy's deep-ocean (20,000-foot) heavy-duty work platforms; and
- RUWS' immediate successor, the Advanced Tethered Vehicle (ATV).

Both RUWS and ATV had several manipulator arms and a variety of tools—drills, spreaders, wrenches, and rotary saws—to perform the kinds of work tasks a diver could handle in shallower water. ATV was featured in a widely shown television production while it supported the National Geographic Society in locating and filming the wreck of USS Yorktown, a Navy aircraft carrier sunk in World War II and lying on the Pacific sea floor 16,650 feet below the water surface. Less well known but demonstrative of the Navy's interest in using ROVs for unique missions are the NASA Nozzle Plug, an unmanned vehicle designed to plug the open end of Space Shuttle booster rocket cylinders floating in the ocean after separation from the shuttle and pump water out of the cylinders for recovery and re-use on another mission (Schlosser 1977). The Navy also developed a Mine Neutralization System, which featured an ROV that could destroy underwater mines. Ultimately, 60 operational vehicles were deployed on Navy minesweepers.

1.3 Commercial Industry Development

SSC San Diego and its predecessors, like other research and development centers maintained by the Navy, function as development centers for maturing new technologies for future Navy production and use (NOSC 1990b). These centers develop new technology (sometimes exclusively and sometimes in close conjunction with private industry), usually expending 50 to 75 percent of their annual funding on contractors to support the development and ultimately to provide the production capability for new technology for Navy ships, submarines, and aircraft. An initially small cadre of private companies emerged in the San Diego area to provide electronics, propulsion motors, underwater cameras, and tools for the ROVs created at SSC San Diego. As one long-time ocean engineer notes, this was "an industry looking for a market," since the Navy's funding was generally limited (Wernli 2007, personal communication). The market emerged when oil was discovered in the North Sea. A body of water with unusually violent storms, in addition to substantial depths, the North Sea challenged companies seeking to tap the extensive oil and gas reserves buried under its sea floor. Human divers were of little use in such an environment. ROV manufacturers and suppliers had found their market.

A number of companies began producing a wide range of ROVs for various missions and applications, from underwater filming and small object search and recovery at relatively shallow depths to heavy-duty missions thousands of feet in the depths of the sea. One of those at the forefront was HydroProducts, with its "flying eyeballs"—the RCV-150 and RCV-225.

Prior to this time, in the early 1980s, a Navy project engineer had analyzed a commercial ROV for Navy operational missions, meaning that the system met operating cost, transportation, ease of deployment, operational depth, and work function considerations essential for a Navy underwater system. It was also essential that the system could be operated and maintained by Navy uniformed personnel on two-year rotation cycles. Following an internal Navy evaluation, the engineer's report concluded commercial systems could meet some of the requirements, but noted there were serious limitations—depth and work capability, documentation and reliability deficiencies (Hoffman 1982). Today those limitations have been overcome, with a number of vehicles available with the appropriate capabilities, documentation, and reliability for effective operation by individuals with little formal engineering background or technical expertise, according to a long-time Navy ocean engineer who has worked extensively with private industry (Wernli 1992; Wernli 2007, personal communication).

1.4 SECURITY VEHICLES

Engineers at the Naval Ocean Systems Center (today SSC San Diego) also performed some initial experimentation in the early 1990s with commercial ROVs re-designed for security missions (Fletcher 2007, personal communication). With sponsorship from the Defense Nuclear Agency, these engineers evaluated five commercially available ROVs to determine the feasibility of using an ROV for underwater security applications. The objective was "to prevent underwater threats to critical waterside or waterborne assets such as weapon depots, loading areas, power plants, ships, and submarines" (Fletcher 1991a).

The ROVs were intended to work in conjunction with a fixed capability, such as the Waterside Security System (WSS), in detecting and assessing a potential threat to a Naval facility or platform. Two of the ROVs demonstrated acceptable operational capabilities; Navy engineers combined these vehicles by placing the sonar of one of the ROVs onto the other vehicle, and conducted performance testing to determine if this combined system could locate, track, and intercept the target (a diver). Following two months of testing in early 1990, engineers concluded that the ROV was an effective underwater security tool, able to detect, track, and illuminate threat divers before they reached their objectives (Fletcher 1991b). The report noted additional requirements (such as launch and recovery capabilities and integration with WSS and other systems) that would be needed for a fully operational system.

Based on these initial tests, the engineers performed design studies and performance simulations for an Advanced Security Vehicle ROV (Fletcher and Fuqua 1991; Murphy 1994), which was envisioned as a supervised autonomous underwater or semi-submerged security vehicle for patrolling the area around ships, piers, and other waterside facilities. Although the ROV was not constructed, various communication and sensor capabilities were examined during research for this ROV. Given patrolling requirements, the vehicle was to be self-contained, eliminating the conventional communication and power tether previously developed for ROVs. The technology would have provided patrolling and detection, but little interdiction capability. However, funding shortfalls resulted in project cancellation.

2.0 ROV OPERATION AND MISSIONS

A significant advantage of an ROV is its ability to allow a human being to work within a dangerous underwater environment using an ROV, thereby providing human safety from the immediate danger. Lights and cameras on a mobile diving platform allow an ROV operator and others a clear view of underwater landscapes, vehicles, equipment, and shipwrecks, all from the relative safety and comfort of a control structure on a surface ship.

In a typical operation, the vehicle and its control cable are hoisted over the side of the support craft and into the water using a crane. This (and subsequent vehicle recovery) is the most dangerous part of the entire operation, as a surface craft rocking in medium waves provides a huge target for the delicate underwater vehicle swinging on a line attached to the crane. A number of Navy inventions sought to minimize the danger of launch and recovery (see Section 2.2, Launch and Recovery). Once in the water, the crane detaches and the vehicle powers itself down and in the appropriate direction of the work site, at the direction of the operator, who watches camera(s) on the ROV for the underwater picture and uses joy sticks to control ROV direction and speed. At the underwater work site, the vehicle hovers above the sea floor, and the manipulator arm is extended, using a variety of approaches (on-off switches, master-slave arm frameworks, and joy sticks) until the arm contacts the object within the work site that is to be worked on or recovered. For recoveries, the claw on the manipulator arm is closed around the object and the vehicle returns to the surface with the recovered object. The CURV systems provided an alternate approach, positioning the manipulator claw around the object, then ejecting the claw, which was separately attached to an appropriate strength recovery line. The CURV then was brought back to the water surface at the direction of its operator, and a winch on-board a surface craft hauled the object attached to the recovery line to the surface.

2.1 DEEP OCEAN PROJECTS

As noted previously (Hoffman 1982), the Navy has specialized underwater missions requiring a variety of special tools. One such mission envisioned was the recovery of in-flight recorders following a plane crash at sea to assist in determining causes of an accident. A typical ROV would have a suite of tools to conduct this type of mission: drills to penetrate the fuselage, a spreading device to widen the hole in the airplane surface appropriately, a hydraulic jack to push aside the ribs of the fuselage, a wrench to unbolt the recorders, and a grabber to remove the recorder. Historically, an ROV had the ability to use all those tools effectively, but sequentially between dives. The process required a dive to the site to drill, return to the surface to exchange the drill for the spreader, and another dive to the site, etc. Many hours were expended with the vehicle diving and surfacing repetitiously.

In the early 1970s, Navy engineers developed a concept for a suite of tools that could be taken underwater and exchanged on the ocean bottom, with no surfacing required for the process. Titled the Work Systems Package (WSP), it was designed to be adapted for use on several manned submersibles and on the CURV III and RUWS ROVs. It could also be operated by divers in shallow water. WSP included two simple grasping manipulators to secure the package at the work site with appropriate stability, a dexterous manipulator for exchanging and using tools, a closed-circuit TV camera for the surface operator to view the work site, and a set of tools commonly used by divers and ROVs in underwater construction, installation, debris clearance, and repair. These tools included drills, dies, sockets, cable cutters, and stud guns. The tools were relatively small and of a type that might be used by a mechanic working on land (Estabrook et al. 1975). Subsequent testing demonstrated successful operation of the WSP on the manned submersible Alvin and on both CURV and RUWS vehicles.

2.2 LAUNCH AND RECOVERY

A remotely operated vehicle is designed to perform work at some distance from its controller. In the typical mission of an ROV, the vehicle is hundreds or thousands of feet underwater, and the operator is in a control van in some type of surface craft. Almost without exception, the most critical parts of the entire operation are launching and recovery of the ROV. Even fairly small swells make it difficult to swing a vehicle on the end of a crane over the side of a boat and lower the ROV into the water, with the ship rolling one direction and the vehicle swinging the other direction. A collision between the hardened steel of a ship hull and the fragile electronics of ROV sonars, lights, and TV cameras can easily end the mission before it begins. Although there are obvious exceptions (The CURV III operation mentioned above began in a high sea state but proceeded as the PISCES III air supply dwindled and two lives were in significant danger), most ROV operations are scrubbed as swells increase even slightly. This was one major reason more ROVs were not tested and implemented for Navy operations.

Navy engineers attempted to develop several solutions to this problem of high seas influencing launch and recovery. The first, in the early 1970s, was the Launch and Recovery Platform, which was a catamaran structure with two 35-foot-long, 4-foot-diameter fiberglass cylinders for hulls, joined by four aluminum pipes, covered by an aluminum grating deck. Three foam blocks on each cylinder provided buoyancy and housings for compressed air cylinders to blow the ballast water out of the hulls. A control station at the front of the vehicle allowed a diver to regulate air and water volumes in the hull cylinders, to submerge and surface the platform.

During an actual operation, a manned or unmanned submersible was placed on the platform in the quiet waters of a harbor. The platform was towed to the work site and submerged to a depth where turbulence from the air-water interface was non-existent. The underwater vehicle was then directed by its operator to lift off the platform, which hovered underwater until the vehicle was directed back onto the platform to reverse the process. Engineers demonstrated the feasibility of the system in a series of tests off San Clemente Island, California, with the manned submersibles Makakai and Deep View, and with CURV III (Estabrook 1972).

A much more sophisticated launch and recovery system called the Motion Compensating Deck Handling System was an integral part of the development of the ATV. Components consisted of an over-center A-frame, ram tensioner, lift line and line winch, cable traction drive, cable storage drum, launch/recovery station, and a hydraulic power unit. Its purpose was to launch and recover the vehicle in fairly high sea states, serving as a shock absorber during those operations and reducing snap loads in the tether due to ship motion during deep operations (Hoffman 1991).

3.0 RECENT DEVELOPMENTS

As noted throughout this document, the early history of ROVs focused on Navy development for Navy applications. Since both the Navy's funding and applications are relatively limited, the supporting commercial industry was initially small. A number of events, most notably the discovery of oil in the North Sea, stimulated industrial growth in other areas than those required by the Navy. Underwater exploration, treasure hunting, pipeline surveys, inspections of the underwater sections of bridges and dams, and aquaculture and maritime security represent some of the commercial applications for ROVs.

In the latter area—maritime security—several companies have fielded security vehicles of various sizes and descriptions. Nova Ray, Inc. advertises its Nova Ray ® "exceptionally modular" vehicle for a number of homeland security applications, including "repetitive imaging, wide area sweeps and reconnaissance missions" (Nova Ray 2007).

Another company features an array of undersea vehicles to "inspect hulls for objects or contraband, search home ports and waterways for potential danger and even locate mines" (SeaBotix 2007). Commercial applications tend to favor "monitoring local ship and boat traffic, inspecting suspicious objects and detecting swimmers" (Deep Ocean 2007). Taking some action should the target prove dangerous, such as interdiction, is not listed as an available application of commercial ROVs researched.

Additionally, a number of inherent challenges would require solutions to improve ROV performance in detection and interdiction of a swimmer/diver threat, including:

- power/communications cable length, weight and entanglement potential,
- speed, particularly in strong currents,
- on-board target re-acquisition and real-time course plot updating,
- vulnerability of the vehicle to diver-inflicted damage rendering it inoperable,
- interdiction or positive control features, and
- operator skills.

4.0 LITERATURE CITED

Broadwater, J.D. 2002. Timelines of underwater archaeology. In International Handbook of Underwater Archaeology, eds. C.V. Ruppé and J.F. Barstad. New York: Kluwer Academic/Plenum Publishers. 17-24.

Deep Ocean. 2007. Remotely Operated Vehicle (ROV) Role in Homeland Security. Article on company website accessed Dec. 14, 2007.

Estabrook, N.B. 1972. Launch and recovery platform for submersibles. Presented at ASME Winter Annual Meeting, New York, NY. November 26-30, 1972.

Estabrook, N., H. Wheeler, and D. Hackman. 1975. Development of deep-ocean work system. Proceedings, IEEE Ocean '75 Conference. 573-577.

Fletcher, B.E. 1991a. Underwater security vehicle. Naval Ocean Systems Center Technical Report 1472. 23 pp.

Fletcher, B.E. 1991b. Remotely operated vehicle/assessment and response (ROVAR), Naval Ocean Systems Center Technical Report 1473. 19 pp.

Fletcher, B.E. and J.L. Fuqua. 1991. Advanced security vehicle major bid and proposal. Naval Ocean Systems Center Technical Report 1471. 162 pp.

Fletcher, B.E. 2007. Barbara Fletcher, Navy underwater vehicle engineer. August 27, 2007. Personal communication with T.J. LaPuzza, Public Affairs Office, Space and Naval Warfare Systems Center San Diego, re: ROV security vehicles.

Hoffman, R.T. 1982. Remotely operated vehicle evaluation: Final report. Naval Ocean Systems Center Technical Document 489. 23 pp.

Hoffman, R.T. 1991. Advanced tethered vehicle design and description. Proceedings, Association for Unmanned Vehicle Systems conference, August 1991.

Jacobsen, M. 1986. The U.S. Navy and remotely operated vehicles, 1962-1966. Presented at American Society of Mechanical Engineers Winter Annual Meeting, Anaheim, California. December 7-12, 1986.

Jacobson, D. 1966. CURV, Scavenger of the deep and hero of Palomares. *Navy* Magazine. May 1966. 15-17.

Joseph, J. 1966. How they raised the bomb. *Weekend Magazine*, Canada, No. 30, 1966.*[1]

MTS. 2007. Website of Marine Technology Society. Available at: http://www.mtsociety.org (Accessed August 19, 2007).

MTS ROV Committee. 2007. Website of Marine Technology Society's Remotely Operated Vehicle Committee. Available at: http://www.rov.org/info.cfm (Accessed August 22, 2007).

MTS ROV Committee. 2008a. What can ROVs do? Marine Technical Society ROV Committee Educational pages. http://www.rov.org/educational/pages/WHAT%20CAN%20ROVs%20DO.html

MTS ROV Committee. 2008b. What is an ROV? Marine Technical Society ROV Committee Educational pages. http://www.rov.org/educational/pages/whatis.html (Accessed February 27, 2008).

Murphy, D.W. 1994. Marine facilities security and resource protection: Robotics and security. Proceedings, 19th Joint Meeting of the UJNR Marine Facilities Panel. 483-488.

National Research Council (NRC). 1996. National Research Council Committee on undersea vehicles and national needs. Undersea Vehicles and National Needs. Washington, D.C.: National Academy Press.

[1] Stuart Henderson Thesis Weekend Magazine. This reference might be difficult to find; it is, however, an excellent description of the operation and worthwhile for anyone interested in ROV operations. In the period 1963-1973, Weekend Magazine was the most widely-circulated periodical in Canada, claiming more than two-million weekly readers. An English-language publication, Weekend Magazine largely overcame the difficulties which beset the Canadian magazine industry in the 1950s and 1960s by circulating as an insert in the Saturday edition of local newspapers across the country. As a national magazine aimed at a general audience of Canadians, Weekend was involved in the difficult pursuit of inventing a kind of national entertainment for its readers- representing the diversity of local identity without betraying the integrity of the national context.

Naval Undersea Center (NUC). 1973. Submersible cable-actuated teleoperator. Naval Undersea Center. Tech Review, Vol. 4, No. 3.

Navy. 2007. Supervisor of salvage website. Available at: http://www.supsalv.org/00c2_curvIIIRov.asp?destPage=00c2 (Accessed September 20, 2007).

Naval Ocean Systems Center (NOSC). 1990a. A short history of NOSC on Point Loma. Naval Ocean Systems Center, Technical Document 1758.

Naval Ocean Systems Center (NOSC). 1990b. Fifty years of research and development on Point Loma, 1940-1990. Naval Ocean Systems Center, Technical Document 1940.

Nova Ray. 2007. Company web site at: http://www.novaray.com/index.htm, accessed Dec. 14, 2007.

Pace, R.E. 1968. CURV—The evolution of an underwater hydraulic system. *Hydraulics & Pneumatics*, March 1968. 81-85.

Schlosser, A.J. 1977. Remote, unmanned dewatering system for recovery of the solid rocket boosters of the Space Shuttle. Naval Ocean Systems Center, Technical Report 144. 16 pp.

SeaBotix 2007. Company web site at: http://www.seabotix.com, accessed Dec. 14, 2007

Sunday Mirror newspaper. 1973. "We're safe, love." September 2 issue, pp. 1 and 4.

Talkington, H.R. 1972. Ocean Engineering Programs at Naval Undersea Research and Development Center. Naval Undersea Research and Development Center, Technical Note 749.

Uhrich, R. 1971. CURV linkage manipulator. Naval Undersea Research and Development Center, Technical Publication 271.

Watts, R.L. 1973. Guide to the cable-controlled underwater recovery vehicle for deep operation (CURV III). Naval Undersea Center, Technical Publication 338.

Wernli, R.L. 1992. An international perspective on ROV technology. Proceedings, Black Sea '92 conference, Varna, Bulgaria. 5-7.

Wernli, R.L. 2007. R.L. Wernli, chair, Marine Technology Society ROV Committee, 1980-1992. August 24, 2007. Personal communication with T.J. LaPuzza, Public Affairs Office, Space and Naval Warfare Systems Center San Diego, re: the growing market for ROV technology.

APPENDIX E

FISH AND WILDLIFE SPECIES KNOWN OR EXPECTED TO OCCUR AT NBK–BANGOR

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species		Essential Fish Habitat Species[2]
			Federal Status	Washington State Status	
American shad *Alosa sapidissima*	Herrings				
Arrow goby *Clevelandia ios*	Gobies				
Arrowtooth flounder *Atheresthes stomias*	Righteye Flounders				G
Bay goby *Lepidogobius lepidus*	Gobies				
Bay pipefish *Syngnathus leptorhynchus*	Pipefishes and Seahorses	X			
Big skate *Raja binoculata*	Skates				G
Bigeye starsnout poacher *Bathyagonus pentacanthus*	Poachers				
Black eelpout *Lycodes diapterus*	Eelpouts				
Black rockfish *Sebastes melanops*	Scorpionfishes/Rockfishes			Candidate	G
Blackbelly eelpout *Lycodes pacifica*	Eelpouts				
Blackeye goby *Coryphopterus nicholsii*	Gobies				
Blackfin sculpin *Malacocottus kincaidi*	Fathead Sculpins				
Blackfin starsnout poacher *Bathyagonus nigripinnis*	Poachers				
Blacktip poacher *Xeneretmus latifrons*	Poachers				

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species: Federal Status	Federal and State Listed Species: Washington State Status	Essential Fish Habitat Species[2]
Bluebarred prickleback *Plectobranchus evides*	Pricklebacks				
Bluespotted poacher *Xeneretmus triacanthus*	Poachers				
Bluntnose sixgill shark *Hexanchus griseus*	Cow Sharks				
Bocaccio *Sebastes paucispinis*	Scorpionfishes/Rockfishes			Candidate	G
Brown cat shark *Apristurus brunneus*	Cat Sharks				
Brown Irish lord *Hemilepidotus spinosus*	Sculpins	X			
Brown rockfish *Sebastes auriculatus*	Scorpionfishes/Rockfishes			Candidate	G
Buffalo sculpin *Enophrys bison*	Sculpins	X			
Bull trout *Salvelinus confluentus*	Salmonids				
Butter sole *Isopsetta isolepis*	Righteye Flounders				G
Cabezon *Scorpaenichthys marmoratus*	Sculpins				G
California barracuda *Sphyraena argentea*	Barracudas				
California headlightfish *Diaphus theta*	Lanternfishes				
Canary rockfish *Sebastes pinniger*	Scorpionfishes/Rockfishes			Candidate	G
Chinook (chinook) salmon *Oncorhynchus tshawytscha*	Salmonids	X	(Puget Sound) Threatened	(Puget Sound) Candidate	S

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species: Federal Status	Federal and State Listed Species: Washington State Status	Essential Fish Habitat Species[2]
Chum salmon *Oncorhynchus keta*	Salmonids	X	(Hood Canal SU) Threatened	(Hood Canal SU) Candidate	
C-O turbot (sole) *Pleuronichthys coenosus*	Righteye Flounders	X			
Coho (silver) salmon *Oncorhynchus kisutch*	Salmonids	X	(Puget Sound) Threatened	(Puget Sound) Candidate	S
Copper rockfish *Sebastes caurinus*	Scorpionfishes/Rockfishes			Candidate	G
Cresent gunnel *Pholis laeta*	Gunnels				
Cutthroat trout *Oncorhynchus clarki clarki*	Salmonids	X	Concern		
Decorated warbonnet *Chirolophis decoratus*	Pricklebacks				
Dolly varden *Salvelinus malma*	Salmonids				
Dover sole *Microstomus pacificus*	Righteye Flounders	X			G
Dusky sculpin *Icelinus burchami*	Sculpins				
Dwarf wrymouth *Lyconectes aleutensis*	Wrymouths				
English sole *Parophrys vetulus*	Righteye Flounders	X			G
Flathead sole *Hippoglossoides elassodon*	Righteye Flounders				G
Gray starsnout poacher *Bathyagonus alascanus*	Poachers				
Great sculpin *Myoxocephalus polyacanthocephalus*	Sculpins				

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species		Essential Fish Habitat Species[2]
			Federal Status	Washington State Status	
Greenstriped rockfish *Sebastes elongatus*	Scorpionfishes/Rockfishes			Candidate	G
Grunt sculpin *Rhamphocottus richardsonii*	Grunt Sculpins				
Gunnel Order – Pholidae	Gunnels	X			
High cockscomb *Anoplarchus purpurescens*	Pricklebacks				
Kelp greenling *Hexagrammos decagrammus*	Greenlings and Lingcod	X			G
Kelp surfperch *Brachyistius frenatus*	Surfperches	X			
Lingcod *Ophiodon elongatus*	Greenlings and Lingcod	X			G
Longfin sculpin *Jordania zonope*	Sculpins				
Longfin smelt *Spirinchus thaleichthys*	Smelts				
Longnose skate *Raja rhina*	Skates				G
Longspine combfish *Zaniolepis latipinnis*	Combfishes				
Manacled sculpin *Synchirus gilli*	Sculpins				
Market Squid *Loligo opalescens*	Squid				CP
Mosshead warbonnet *Chirolophis nugator*	Pricklebacks				
Northern spearnose poacher *Agonopsis vulsa*	Poachers				

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

COMMON NAME *SCIENTIFIC NAME*	COMMON FAMILY NAME	CAPTURED IN BEACH SEINE[1]	FEDERAL AND STATE LISTED SPECIES		ESSENTIAL FISH HABITAT SPECIES[2]
			FEDERAL STATUS	WASHINGTON STATE STATUS	
Northern anchovy *Engraulis mordax*	Anchovies	X			PC
Northern clingfish *Gobiesox maeandricus*	Clingfishes				
Northern lampfish *Stenobrachius leucopsarus*	Lanternfishes	X			
Northern rock sole *Lepidopsetta polyxystra*	Righteye Flounders				
Northern ronquil *Ronquilus jordani*	Ronquils				
Northern sculpin *Icelinus borealis*	Sculpins				
Northern spearnose poacher *Agonopsis vulsa*	Poachers				
Pacfic staghorn sculpin *Leptocottus armatus*	Sculpins				
Pacific butterfish *Peprilus simillimus*	Butterfishes				
Pacific cod *Gadus macrocephalus*	Cods				G
Pacific electric ray *Torpedo californica*	Electric Rays				
Pacific hake (whiting) *Merluccius productus*	Hakes and Relatives				G
Pacific halibut *Hippoglossus stenolepis*	Righteye Flounders				
Pacific herring *Clupea harengus pallasi*	Herrings	X			
Pacific lamprey *Lampetra tridentata*	Lampreys				

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species		Essential Fish Habitat Species[2]
			Federal Status	Washington State Status	
Pacific sand lance *Ammodytes hexapterus*	Sand Lances	X			
Pacific sanddab *Citharichthys sordidus*	Lefteye Flounders	X			G
Pacific snake prickleback *Lumpenus sagitta*	Pricklebacks	X			
Pacific spiny lumpsucker *Eumicrotremus orbis*	Lumpfishes				
Pacific staghorn sculpin *Leptocottus armatus*	Sculpins	X			
Pacific tomcod *Microgadus proximus*	Cods	X			
Padded sculpin *Artedius fenestralis*	Sculpins				
Painted greenling *Oxylebius pictus*	Greenlings and Lingcod				
Pallid eelpout *Lycodapus mandibularis*	Eelpouts				
Penpoint gunnel *Apodichthys flavidus*	Gunnels	X			
Petrale sole *Eopsetta jordani*	Righteye Flounders				G
Pile perch *Rhacochilus vacca*	Surfperches	X			
Pile surfperch *Damalichthys vacca*	Surfperches	X			
Pink salmon *Oncorhynchus gorbuscha*	Salmonids	X			S
Plainfin midshipman *Porichthys notatus*	Toadfishes	X			

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species: Federal Status	Federal and State Listed Species: Washington State Status	Essential Fish Habitat Species[2]
Prickly sculpin *Cottus asper*	Sculpins				
Puget Sound rockfish *Sebastes emphaeus*	Scorpionfishes/Rockfishes				
Pygmy poacher *Odontopyxis trispinosa*	Poachers	X			
Quillback rockfish *Sebastes maliger*	Scorpionfishes/Rockfishes			Candidate	G
Quillfish *Ptilichthys goodei*	Quillfish				
Red brotula *Brosmophycis marginata*	Viviparous Brotulas				
Red Irish lord *Hemilepidotus hemilepidotus*	Sculpins	X			
Redbanded rockfish *Sebastes babcocki*	Scorpionfishes/Rockfishes				G
Redstripe rockfish *Sebastes proriger*	Scorpionfishes/Rockfishes			Candidate	G
Rex sole *Glyptocephalus zachirus*	Righteye Flounders	X			G
Ribbed sculpin *Triglops pingelii*	Sculpins				
Ribbon snailfish *Liparis cyclopus*	Snailfishes	X			
River lamprey *Lampetra ayresii*	Lampreys				
Rockfish (juv.) *Sebastes* spp.	Scorpionfishes/Rockfishes	X			
Rock greenling *Hexagrammos lagocephalus*	Greenlings				

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name / *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species		Essential Fish Habitat Species[2]
			Federal Status	Washington State Status	
Rock sole *Lepidopsetta bilineata*	Righteye Flounders				X
Roughback sculpin *Chitonotus pugetensis*	Sculpins				
Roughspine sculpin *Triglops macellus*	Sculpins				
Sablefish *Anoplopoma fimbria*	Sablefishes/Skillfishes				G
Saddleback gunnel *Pholis ornata*	Gunnels				
Sailfin sculpin *Nautichthys oculofasciatus*	Searavens				
Sand sole *Psettichthys melanostictus*	Righteye Flounders				G
Scalyhead sculpin *Artedius harringtoni*	Sculpins				
Sculpin spp. Order – Cottidae	Sculpins	X			
Sharpchin rockfish *Sebastes zacentrus*	Scorpionfishes/Rockfishes				X
Sharpnose sculpin *Clinocottus acuticeps*	Sculpins				
Shiner surfperch *Cymatogaster aggregata*	Surfperches	X			
Shortfin eelpout *Lycodes brevipes*	Eelpouts				
Shortspine thornyhead *Sebastolobus alascanus*	Scorpionfishes/Rockfishes				
Showy snailfish *Liparis pulchellus*	Snailfishes				

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species		Essential Fish Habitat Species[2]
			Federal Status	Washington State Status	
Silvergray rockfish *Sebastes brevispinis*	Scorpionfishes/Rockfishes				X
Sixgill shark *Hexanchus griseus*	Cow Sharks				
Slender Cockscomb *Anoplarchus insignis*	Pricklebacks				
Slender snipe eel *Nemichthys scolopaceus*	Snipe Eels				
Slender sole *Lyopsetta exilis*	Righteye Flounders				
Slim sculpin *Radulinus asprellus*	Sculpins				
Smooth alligatorfish *Anoplagonus inermis*	Poachers				
Smoothead sculpin *Artedius lateralis*	Sculpins				
Snake prickleback *Lumpenus sagitta*	Pricklebacks	X			
Sockeye (red) salmon *Oncorhynchus nerka*	Salmonids	X			
Soft sculpin *Psychrolutes sigalutes*	Fathead Sculpins				
Sole spp. Order – Pleuronectiformes	Righteye Flounders				
Southern rock sole *Lepidopsetta bilineata*	Righteye Flounders				
Speckled sanddab *Citharichthys stigmaeus*	Lefteye Flounders	X			
Spiny dogfish *Squalus acanthias*	Dogfish Sharks				G

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

COMMON NAME *SCIENTIFIC NAME*	COMMON FAMILY NAME	CAPTURED IN BEACH SEINE[1]	FEDERAL AND STATE LISTED SPECIES		ESSENTIAL FISH HABITAT SPECIES[2]
			FEDERAL STATUS	WASHINGTON STATE STATUS	
Spinycheek starsnout poacher *Bathyagonus infraspinatus*	Poachers				
Spinyhead sculpin *Dasycottus setiger*	Fathead Sculpins				
Splitnose rockfish *Sebastes diploproa*	Scorpionfishes/Rockfishes				G
Spinynose sculpin *Dasycottus setiger*	Sculpins				
Spotfin sculpin *Icelinus tenuis*	Sculpins				
Spotted ratfish *Hyrolagus colliei*	Chimeras				
Starry flounder *Platichthys stellatus*	Righteye Flounders	X			G
Steelhead *Oncorhynchus mykiss*	Salmonids	X	(Puget Sound) Threatened		
Striped surfperch *Embiotoca lateralis*	Surfperches	X			
Stripetail rockfish *Sebastes saxicola*	Scorpionfishes/Rockfishes				G
Sturgeon poacher *Agonus acipenserinus*	Poachers				
Surf smelt *Hypomesus pretiosus*	Smelts	X			
Tadpole sculpin *Psychrolutes paradoxus*	Fathead Sculpins				
Threadfin sculpin *Icelinus filamentosus*	Sculpins				
Three-spined stickleback *Gasterosteus aculeatus*	Sticklebacks	X			

Table E–1. Marine Fish Species Known or Expected to Occur in Hood Canal (continued)

Common Name *Scientific Name*	Common Family Name	Captured in Beach Seine[1]	Federal and State Listed Species: Federal Status	Federal and State Listed Species: Washington State Status	Essential Fish Habitat Species[2]
Tidepool sculpin *Oligocottus maculosus*	Sculpins	X			
Tubesnout *Aulorhynchus flavidus*	Tubesnouts	X			
Vermillion rockfish *Sebastes miniatus*	Scorpionfishes/Rockfishes				G
Walleye pollock *Theragra chalcogramma*	Cods	X	(S. Puget Sound) Concerned	(S. Puget Sound) Candidate	
Wattled eelpout *Lycodes palearis*	Eelpouts				
White sturgeon *Acipenser transmontanus*	Sturgeons				
Whitebarred prickleback *Poroclinus rothrocki*	Pricklebacks				
Whitespotted greenling *Hexagrammos stelleri*	Greenlings and Lingcod	X			
Wolf-eel *Anarrhichthys ocellatus*	Wolffishes				
Yelloweye rockfish *Sebastes ruberrimus*	Scorpionfishes/Rockfishes			Candidate	G
Yellowtail rockfish *Sebastes flavidus*	Scorpionfishes/Rockfishes			Candidate	G

1 SAIC 2006
2 CP = Coastal pelagic, G = Groundfish, S = Salmon.

Sources: University of Washington 2000; Palsson 2007; Puget Sound Action Team 2007; WDFW 2007; REEF 2008; WDFW 2008a,b.

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Shorebirds and Wading Birds						
Black-bellied plover *Pluvialis squatarola*	fall and spring migrant and winter resident					
Semipalmated plover *Charadrius semipalmatus*	fall and spring migrant					
Killdeer *Charadrius vociferus*	year-round					
Greater yellowlegs *Tringa melanoleuca*	fall and spring migrant					
Lesser yellowlegs *Tringa flavipes*	fall migrant					
Spotted sandpiper *Actitis macularia*	summer resident					
Ruddy turnstone *Arenaria interpres*	fall and spring migrant					
Black turnstone *Arenaria melanocephala*	migrant and winter resident				X	
Wandering tattler *Heteroscelus incanus*	fall and spring migrant					
Sanderling *Calidris alba*	migrant and winter resident					
Western sandpiper *Calidris mauri*	fall and spring migrant					
Least sandpiper *Calidris minutilla*	fall and spring migrant					
Pectoral sandpiper *Calidris melanotos*	fall migrant					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name *Scientific Name*	Season(s) of Occurrence	Federal and State Listed Species		PIF Bird of Conservation Concern?[1]	USFWS Bird of Conservation Concern?[2]	WDFW Priority Species?[3]
		Federal Status	Washington State Status			
Dunlin *Calidris alpina*	fall and spring migrant					
Short-billed dowitcher *Limnodromus griseus*	fall and spring migrant				X	
Long-billed dowitcher *Limnodromus scolopaceus*	fall and spring migrant					
Wilson's snipe *Gallinago delicata*	fall and spring migrant					
Red-necked phalarope *Phalaropus lobatus*	fall and spring migrant					
Great blue heron *Ardea herodias*	year-round					X
Red-throated loon *Gavia stellata*	fall and spring migrant, winter resident					
Pacific loon *Gavia pacifica*	winter resident					
Common loon *Gavia immer*	winter resident		Sensitive			
Yellow-billed loon *Gavia adamsii*	winter resident				X	
Pied-billed grebe *Podilymbus podiceps*	year-round					
Horned grebe *Podiceps auritus*	winter resident					
Eared grebe *Podiceps nigricollis*	winter resident					
Red-necked grebe *Podiceps grisegena*	winter resident					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name *Scientific Name*	Season(s) of Occurrence	Federal and State Listed Species		PIF Bird of Conservation Concern?[1]	USFWS Bird of Conservation Concern?[2]	WDFW Priority Species?[3]
		Federal Status	Washington State Status			
Western grebe *Aechmophorus occidentalis*	winter resident		Candidate			
Canada goose *Branta canadensis*	year-round					
Snow goose *Chen caerulescens*	winter resident					
White-fronted goose *Anser albifrons*	fall and spring migrant					
Brant *Branta bernicla*	fall and spring migrant, winter resident					X
Trumpeter swan *Cygnus buccinator*	fall and spring migrant, winter resident					
Wood duck *Aix sponsa*	year-round, but less common in winter					X
Gadwall *Anas strepera*	year-round					
Northern pintail *Anas acuta*	winter resident					
Eurasian wigeon *Anas penelope*	winter resident					
American wigeon *Anas americana*	winter resident					
Northern shoveler *Anas clypeata*	year-round					
Mallard *Anas platyrhynchos*	year-round					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name *Scientific Name*	Season(s) of Occurrence	Federal and State Listed Species: Federal Status	Federal and State Listed Species: Washington State Status	PIF Bird of Conservation Concern?[1]	USFWS Bird of Conservation Concern?[2]	WDFW Priority Species?[3]
Green-winged teal *Anas crecca*	fall and spring migrant, winter resident					
Canvasback *Aythya valisineria*	winter resident					
Greater scaup *Aythya marila*	fall and spring migrant, winter resident					
Lesser scaup *Aythya affinis*	fall and spring migrant, winter resident					
Long-tailed duck *Clangula hyemalis*	winter resident					
Surf scoter *Melanitta perspicillata*	winter resident, and non-breeding flocks in summer					
White-winged scoter *Melanitta fusca*	winter resident, and non-breeding flocks in summer					
Black scoter *Melanitta nigra*	winter resident					
Bufflehead *Bucephala albeola*	winter resident					X
Common goldeneye *Bucephala clangula*	winter resident					X
Barrow's goldeneye *Bucephala islandica*	winter resident					X
Hooded merganser *Lophodytes cucullatus*	year-round					X
Common merganser *Mergus merganser*	year-round					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Red-breasted merganser *Mergus serrator*	winter resident					
Ruddy duck *Oxyura jamaicensis*	winter resident					
American coot *Fulica americana*	year-round					
Seabirds						
Parasitic jaeger *Stercorarius parasiticus*	fall migrant, follows common tern migration					
Bonaparte's gull *Larus philadelphia*	fall and spring migrant					
Ring-billed gull *Larus delawarensis*	fall and spring migrant, summer resident					
Mew gull *Larus canus*	winter resident					
Glaucous-winged gull *Larus glaucescens*	year-round					
Herring gull *Larus argentatus*	winter resident					
Thayer's gull *Larus thayeri*	fall and spring migrant, winter resident					
Caspian tern *Sterna caspia*	non-breeding summer resident				X	
Common tern *Sterna hirundo*	fall migrant					
Brant's cormorant *Phalacrocorax penicillatus*	year-round		Candidate			

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Double-crested cormorant *Phalacrocorax auritus*	year-round					
Pelagic cormorant *Phalacrocorax pelagicus*	year-round					
Common murre *Uria aalge*	common in winter, but uncommon to absent in summer		Candidate			
Pigeon guillemot *Cepphus columba*	year-round, numbers greater in winter than summer					
Marbled murrelet *Brachyramphus marmoratus*	year-round	Threatened	Threatened			X
Ancient murrelet *Synthliboramphus antiquus*	late-fall to early-winter resident					
Rhinocerous auklet *Cerorhinca monocerata*	summer resident					
Raptors						
Bald eagle *Haliaeetus leucocephalus*	year-round		Sensitive			X
Osprey *Pandion haliaetus*	summer resident					
Northern harrier *Circus cyaneus*	winter resident					
Sharp-shinned hawk *Accipiter striatus*	fall migrant					
Cooper's hawk *Accipiter cooperii*	fall migrant			X		

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Red-tailed hawk *Buteo jamaicensis*	year-round					
Rough-legged hawk *Buteo lagopus*	winter resident					
Merlin *Falco columbarius*	fall migrant		Candidate			
Peregrine falcon *Falco peregrinus*	fall migrant		Sensitive		X	
Turkey vulture *Cathartes aura*	summer resident					
Great horned owl *Bubo viginianus*	year-round					
Barn owl *Tyto alba*	year-round					
Snowy owl *Nyctea scandiaca*	winter resident					
Western screech-owl *Otus kennicottii*	year-round					
Barred owl *Strix varia*	year-round					
Northern saw-whet owl *Aegolius acadicus*	year-round					
Northern pygmy owl *Glaucidium gnoma*	year-round					
Other Terrestrial Birds						
Ruffed grouse *Bonasa umbellus*	year-round			X		

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Blue grouse *Dendragapus obscurus*	year-round			X		
Ring-necked pheasant *Phasianus colchicus*	year-round					
California quail *Callipepla californica*	year-round					
Mountain quail *Oreortyx pictus*	year-round					X
Common nighthawk *Chordeiles minor*	summer resident					
Rock dove *Columba livia*	year-round					
Mourning dove *Zenaida macroura*	year-round					
Band-tailed pigeon *Columba fasciata*	common summer, uncommon winter resident			X		
Vaux's swift *Chaetura vauxi*	summer resident		Candidate			
Anna's hummingbird *Calypte anna*	year-round					
Rufous hummingbird *Selasphorus rufus*	summer resident			X	X	
Belted kingfisher *Ceryle alcyon*	year-round					
Red-breasted sapsucker *Sphyrapicus ruber*	year-round			X		

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Hairy woodpecker *Picoides villosus*	year-round					
Downy woodpecker *Picoides pubescens*	year-round					
Northern flicker *Colaptes auratus*	year-round					
Pileated woodpecker *Dryocopus pileatus*	year-round		Candidate			
Olive-sided flycatcher *Contopus cooperi*	summer resident			X	X	
Willow flycatcher *Empidonax traillii*	summer resident			X		
Hammond's flycatcher *Empidonax hammondii*	summer resident					
Pacific-slope flycatcher *Empidonax difficilis*	summer resident					
Hutton's vireo *Vireo huttoni*	year-round					
Gray jay *Perisoreus canadensis*	year-round					
Steller's jay *Cyanocitta stelleri*	year-round					
American crow *Corvus brachyrhynchos*	year-round					
Common raven *Corvus corax*	year-round					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name / *Scientific Name*	Season(s) of Occurrence	Federal and State Listed Species: Federal Status	Federal and State Listed Species: Washington State Status	PIF Bird of Conservation Concern?[1]	USFWS Bird of Conservation Concern?[2]	WDFW Priority Species?[3]
Purple martin *Progne subis*	summer resident		Candidate			
Tree swallow *Tachycineta bicolor*	summer resident					
Violet-green swallow *Tachycineta thalassina*	summer resident					
Cliff swallow *Petrochelidon pyrrhonota*	summer resident					
Barn swallow *Hirundo rustica*	summer resident					
Black-capped chickadee *Poecile atricapilla*	year-round					
Chestnut-backed chickadee *Poecile rufescens*	year-round					
Bushtit *Psaltriparus minimus*	year-round					
Red-breasted nuthatch *Sitta canadensis*	year-round					
Brown creeper *Certhia americana*	year-round					
Bewick's wren *Thryomanes bewickii*	year-round					
Winter wren *Troglodytes troglodytes*	year-round					
Marsh wren *Cistothorus palustris*	summer resident					
American dipper *Cinclus mexicanus*	year-round					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Golden-crowned kinglet *Regulus satrapa*	summer resident			X		
Ruby-crowned kinglet *Regulus calendula*	migrant, winter resident					
Swainson's thrush *Catharus ustulatus*	summer resident					
American robin *Turdus migratorius*	year-round					
Varied thrush *Ixoreus naevius*	summer resident					
European starling *Sturnus vulgaris*	year-round					
Yellow warbler *Dendroica petechia*	summer resident					
Yellow-rumped warbler *Dendroica coronata*	summer resident					
Townsend's warbler *Dendroica townsendi*	summer resident					
MacGillivray's warbler *Oporornis tolmiei*	summer resident					
Common yellowthroat *Geothlypis trichas*	summer resident					
Wilson's warbler *Wilsonia pusilla*	summer resident					
Western tanager *Piranga ludoviciana*	summer resident					
Spotted towhee *Pipilo maculatus*	summer resident					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

COMMON NAME *SCIENTIFIC NAME*	SEASON(S) OF OCCURRENCE	FEDERAL AND STATE LISTED SPECIES		PIF BIRD OF CONSERVATION CONCERN?[1]	USFWS BIRD OF CONSERVATION CONCERN?[2]	WDFW PRIORITY SPECIES?[3]
		FEDERAL STATUS	WASHINGTON STATE STATUS			
Song sparrow *Melospiza melodia*	year-round					
White-crowned sparrow *Zonotrichia leucophrys*	summer resident					
Golden-crowned sparrow *Zonotrichia atricapilla*	migrant, summer resident					
Fox sparrow *Passerella iliaca*	winter resident					
Dark-eyed junco *Junco hyemalis*	year-round					
Red-winged blackbird *Agelaius phoeniceus*	summer resident					
Brewer's blackbird *Euphagus cyanocephalus*	year-round					
Brown-headed cowbird *Molothrus ater*	migrant, summer resident					
Purple finch *Carpodacus purpureus*	year-round			X		
House finch *Carpodacus mexicanus*	year-round					
Red crossbill *Loxia curvirostra*	year-round			X		
Pine siskin *Carduelis pinus*	year-round					
American goldfinch *Carduelis tristis*	year-round					
Evening grosbeak *Coccothraustes vespertinus*	summer resident					

Table E–2. Bird Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name *Scientific Name*	Season(s) of Occurrence	Federal and State Listed Species		PIF Bird of Conservation Concern?[1]	USFWS Bird of Conservation Concern?[2]	WDFW Priority Species?[3]
		Federal Status	Washington State Status			
House sparrow *Passer domesticus*	year-round					

[1] Altman 1999a, 1999b.
[2] USFWS 2002.
[3] WDFW 2008c

Sources: Taber and Raedeke 1983; Navy 2001; Opperman 2003; Wahl et al 2005; Nysewander et al 2005; Agness and Tannenbaum 2008a; Kitsap Audubon Society 2008.

Table E–3. Mammal Species Known or Expected to Occur at NBK–Bangor

Common Name	Scientific Name	Season(s) of Occurrence	Federal and State Listed Species		WDFW Priority Species?[1]
			Federal Status	Washington State Status	
Marine Mammals					
Grey whale	*Eschrichtius robustus*	year-round (rare)		Sensitive	**X**
Minke whale	*Balaenoptera acutorostrata*	spring, summer and fall (rare)			
Humpback whale	*Megaptera novaeangliae*	spring and fall (rare)	Endangered	Endangered	
Killer whale (Transient)	*Orcinus orca*	year-round (rare)			
Dall's porpoise	*Phocoenoides dalli*	year-round (rare)			
Harbor porpoise	*Phocoena phocoena*	year-round (rare)			
Harbor seal	*Phoca vitulina richardsi*	year-round (common, resident species)			
Northern elephant seal	*Mirounga angustirostris*	summer and fall (rare)			
California sea lion	*Zalophus californianus californianus*	fall to late spring (common)			**X**
Steller sea lion	*Eumetopias jubatus*	year-round (rare)	Threatened	Threatened	
Game					
Cougar	*Felis concolor*	year-round			
Black bear	*Ursus americanus*	early spring to fall (active), and winter hibernation			
Black-tailed deer	*Odocoileus hemionus*	year-round			

Table E–3. Mammal Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name	Scientific Name	Season(s) of Occurrence	Federal and State Listed Species		WDFW Priority Species?[1]
			Federal Status	Washington State Status	
Non-Game					
Virginia opossum	*Didelphis virginiana*	year-round			
Feral dog	*Canis familiaris*	year-round			
Feral cat	*Felis catus*	year-round			
Masked shrew	*Sorex cinereus*	year-round			
Vagrant shrew	*Sorex vagrans*	year-round			
Trowbridge’s shrew	*Sorex trowbridgii*	year-round			
Coast mole	*Scapanus orarius*	year-round			
Myotis bats	*Myotis spp.*	year-round			X
Hoary bat	*Lasiurus cinereus*	year-round			
Silver-haired bat	*Lasionycteris noctivagans*	year-round			
Big Brown bat	*Eptesicus fuscus*	year-round			
Townsend’s Big-eared bat	*Corynorhinus townsendii*	year-round	Species of concern	Candidate	
Snowshoe hare	*Lepus americanus*	year-round			
Mountain beaver	*Aplodontia rufa*	year-round			
Townsend’s chipmunk	*Tamias townsendii*	year-round			
Eastern gray squirrel	*Sciurus carolinensis*	year-round			

Table E–3. Mammal Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name	Scientific Name	Season(s) of Occurrence	Federal and State Listed Species		WDFW Priority Species?[1]
			Federal Status	Washington State Status	
Douglas's squirrel	*Tamiasciurus douglasii*	year-round			
Northern flying squirrel	*Glaucomys sabrinus*	year-round			
Beaver	*Castor canadensis*	year-round			
Bushy-tailed woodrat	*Neotoma cinerea*	year-round			
Forest deer mouse	*Peromyscus keeni*	year-round			
Deer mouse	*Peromyscus maniculatus*	year-round			
Gapper's red-backed vole	*Clethrionomys gapperi*	year-round			
Long-tailed Vole	*Microtus longicaudus*	year-round			
Townsend's vole	*Microtus townsendii*	year-round			
Creeping vole	*Microtus oregoni*	year-round			
Pacific jumping mouse	*Zapus trinotatus*	year-round			
Muskrat	*Ondatra zibethicus*	year-round			
Porcupine	*Erethizon dorsatum*	year-round			
Nutria	*Myocastor coypus*	year-round			
House mouse	*Mus musculus*	year-round			
Norway rat	*Rattus norvegicus*	year-round			
Black rat	*Rattus rattus*	year-round			
Coyote	*Canis latrans*	year-round			

Table E–3. Mammal Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name	Scientific Name	Season(s) of Occurrence	Federal and State Listed Species		WDFW Priority Species?[1]
			Federal Status	Washington State Status	
Red fox	*Vulpes vulpes*	year-round			
Black bear	*Ursus americanus*	year-round			
Raccoon	*Procyon lotor*	year-round			
Ermine	*Mustela erminea*	year-round			
Long-tailed weasel	*Mustela frenata*	year-round			
Mink	*Mustela vison*	year-round			
Striped skunk	*Mephitis mephitis*	year-round			
Western spotted skunk	*Spilogale gracilis*	year-round			
River otter	*Lutra canadensis*	year-round			

[1] WDFW 2008b

Sources: Osborne et al. 1988; Calambokidis and Baird 1994; Johnson and Cassidy 1997; Osmek et al. 1998; Jeffries et al. 2000; Navy 2001; Paulson 2003b; Jeffries 2006, personal communication; Laake 2006, personal communication; Carretta et al.2007; Agness and Tannenbaum 2008b.

Table E–4. Amphibian and Reptile Species Known or Expected to Occur at NBK–Bangor

Common Name	Scientific Name	Season(s) of Occurrence	Federal and State Listed Species		WDFW Priority Species?[1]
			Federal Status	Washington State Status	
Amphibians					
Northwestern salamander	*Ambystoma gracile*	year-round			
Long-toed salamander	*Ambystoma macrodactylum*	year-round			
Roughskin newt	*Taricha granulosa*	year-round			
Western red-backed salamander	*Plethodon vehiculum*	year-round			
Ensatina	*Ensatina eschscholtzii*	year-round			
Western toad	*Bufo boreas*	year-round	Species of concern	Candidate	
Pacific treefrog	*Hyla regilla*	year-round			
Northern red-legged frog	*Rana aurora*	year-round			
Bullfrog (Non-native)	*Rana catesbeiana*	year-round			

Table E–4. Amphibian and Reptile Species Known or Expected to Occur at NBK–Bangor (continued)

Common Name	Scientific Name	Season(s) of Occurrence	Federal and State Listed Species		WDFW Priority Species?[1]
			Federal Status	Washington State Status	
Reptiles					
Western painted turtle	*Chrysemys picta bellii*	year-round			
Slider (Introduced)	*Trachemys scripta*	year-round			
Northern alligator lizard	*Elgaria coerulea principis*	year-round			
Western fence lizard	*Sceloporus occidentalis*	year-round			
Rubber boa	*Charina bottae*	year-round			
Western terrestrial garter snake	*Thamnophis elegans*	year-round			
Northwestern garter snake	*Thamnophis ordinoides*	year-round			
Common garter snake	*Thamnophis sirtalis*	year-round			

[1] WDFW 2008b

Sources: Storm and Leonard 1995; Dvornich et al. 1997; Navy 2001; Paulson 2003a; Jones et al. 2005.

REFERENCES CITED

Agness, A. and B. Tannenbaum. 2008a. Naval Base Kitsap at Bangor Marine Bird Resource Report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville MD.

Agness, A. and B. Tannenbaum. 2008b. Naval Base Kitsap at Bangor Marine Mammal Resource Report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville MD.

Altman, B. 1999a. Conservation strategy for landbirds in coniferous forests of western Oregon and Washington, Version 1.0. Prepared for: Oregon-Washington Partners in Flight. 120 pages. http://www.orwapif.org/pdf/western_forest.pdf

Altman, B. 1999b. Conservation strategy for landbirds in lowlands and valleys of western Oregon and Washington, Version 1.0. Prepared for: Oregon-Washington Partners in Flight. 169 pages. http://www.orwapif.org/pdf/western_lowlands.pdf

Calambokidis, J., and R.W. Baird. 1994. Status of marine mammals in the Strait of Georgia, Puget Sound, and the Juan de Fuca Strait, and potential human impacts. *Canadian Technical Report of Fisheries and Aquatic Sciences*. 1948:282-300.

Carretta, J.V., K.A. Forney, M.S. Lowry, J. Barlow, J. Baker, B. Hanson, and M.M. Muto. U.S. Pacific marine mammal stock assessment: 2007. December 2007. National Oceanic and Atmospheric Administration National Marine Fisheries Service. NOAA-TM-NMFS-SWFSC-414.

Dvornich, K.M., K.R. McAllister, and K.B. Aubry. 1997. Amphibians and reptiles of Washington state: location data and predicted distributions, Vol 2. In *Washington State Gap Analysis -- Final Report*, ed. Cassidy, K.M., C.E. Grue, M.R. Smith and K.M. Dvornich. Seattle, WA: Washington Cooperative Fish and Wildlife Research Unit, University of Washington. 146.

Jeffries, S. 2006. WDFW Marine Mammal Specialist. Personal communication with Alison Agness, SAIC, December 14, 2006, re: occurrence of marine mammals in Hood Canal.

Jeffries, S.J., P.J. Gearin, H.R. Huber, D.L. Saul, and D.A. Pruett. 2000. Atlas of seal and sea lion haul-out sites in Washington. Washington Department of Fish and Wildlife, Wildlife Science Division, Olympia, WA. 150 pp. http://wdfw.wa.gov/wlm/research/papers/seal_haulout/

Johnson, R.E., and K.M. Cassidy. 1997. Terrestrial Mammals of Washington State: Location Data and Predicted Distributions. Volume 3 in Washington State Gap Analysis—Final Report (K.M. Cassidy, Fish and Wildlife Research Unit, University of Washington, Seattle.

Jones, L.C., W.P. Leonard, and D.H. Olson, editors. 2005. *Amphibians of the Pacific Northwest*. Seattle Audubon Society, Seattle, WA. 226 pages.

Kitsap Audubon Society. 2008. Kitsap Audubon Society Christmas Bird Counts, 2001-2007. Area 8: NAVBASE Kitsap Bangor. Poulsbo, WA.

Laake, J. 2006. Jeff Laake, Marine Mammal Specialist, National Marine Mammal Laboratory, NOAA Sandpoint, Seattle, WA. December 19, 2006. Personal communication with Alison Agness, Marine Biologist, Science Applications International Corporation, Bothell, WA, re: occurrence of marine mammals in Hood Canal.

Navy. 2001. Integrated Natural Resources Management Plan. Naval Submarine Base Bangor, Washington. Department of the Navy.

Nysewander, D.R., J.R. Evenson, B.L. Murphie, and T.A. Cyra. 2005. Report of marine bird and marine mammal component, Puget Sound ambient monitoring program, for July 1992 to December 1999 period. Prepared for the Washington State Department of Fish and Wildlife and Puget Sound Action Team. Washington State Department of Fish and Wildlife, Wildlife Management Program, Olympia, WA. January 31, 2005.

Opperman, H. 2003. *A birder's guide to Washington*. American Birding Association: Colorado Springs, CO.

Osborne, R., J. Calambokidis, and E.M. Dorsey. 1988. *A guide to marine mammals of Greater Puget Sound*. Anacortes, WA: Island Publishers.

Osmek, S.D., J. Calambokidis, and J.L. Laake. 1998. Abundance and Distribution of Porpoise and Other Marine Mammals of the Inside Waters of Washington and British Columbia. 1998 Puget Sound Research Conference Proceedings. Olympia, WA.

Palsson, W.A. 2007. Wayne A. Palsson, Research scientist, Washington State Department of Fish and Wildlife, July 10, 2007. Personal communication, e-mail to Mary Bhuthimethee, SAIC, re: fish species in Hood Canal.

Paulson, D. 2003a. Amphibians and Reptiles of Washington. In *A Birder's Guide to Washington*, ed. H. Opperman. Colorado Springs: American Birding Association. 598–600.

Paulson, D. 2003b. Mammals of Washington. In *A Birder's Guide to Washington*, ed. H. Opperman. Colorado Springs: American Birding Association. 593–597.

Puget Sound Action Team. 2007. 2007 Puget Sound Update: Ninth Report of the Puget Sound Assessment and Monitoring Program. Puget Sound Action Team. Olympia, WA. 260 pp.

Raedeke, K.J., and R.D. Taber. 1983. Deer populations on Naval Submarine Base Bangor. Final report to Naval Submarine Base Bangor, Bremerton, WA. Contract Number: N00406-82-M-C646. Date: 24 October, 1983.

Reef Environmental Education Foundation (REEF). 2008. REEF Fish Project Survey Data for Hood Canal. Accessed February 2008.

SAIC. 2006. Fish Presence and Habitat Use, Combined Phase I and II Field Survey Report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville MD.

Storm, R.M., and W.P. Leonard, coordinating editors. 1995. *Reptiles of Washington and Oregon*. Seattle Audubon Society, Seattle, WA. September 1995. 176 pages.

University of Washington. 2000. Big Beef Creek Field Station Program Plan—A Working Draft. Karen Schmitt, Program Manager, College of Ocean and Fishery Sciences. http://online.caup.washington.edu/courses/LarcSP00/Larc523/BBCPlan523.doc.html

U.S. Fish and Wildlife Service (USFWS). 2002. Birds of conservation concern 2002. USFWS Division of Migratory Bird Management, Arlington, VA. 99 pages. http://www.fws.gov/migratorybirds/reports/BCC02/BCC2002.pdf

Wahl, T.R., B. Tweit, S.G. Mlodinow. 2005. *Birds of Washington*. Oregon State University Press, Corvallis, WA.

Washington Department of Fish and Wildlife. 2007. Species of Concern in Washington State. Referenced 3 July 2007. http://wdfw.wa.gov/wlm/diversty/soc/soc.htm

Washington Department of Fish and Wildlife (WDFW). 2008a. Marine Protected Areas in Puget Sound - Sund Rock Conservation Area – within south Hood Canal. http://www.wdfw.wa.gov/fish/mpa/puget_sound/08sr.htm (Accessed February 7, 2008)

Washington Department of Fish and Wildlife (WDFW). 2008b. Marine Protected Areas in Puget Sound - Octopus Hole Conservation Area – within south Hood Canal. http://www.wdfw.wa.gov/fish/mpa/puget_sound/08oh.htm (Accessed February 7, 2008)

Washington Department of Fish and Wildlife (WDFW). 2008c. Priority habitat and species list. Olympia, WA. 174 pp.