**UNITED STATES MARINE CORPS**
MARINE CORPS AIR STATION
POSTAL SERVICE CENTER BOX 8003
CHERRY POINT, NORTH CAROLINA 28533-0003

IN REPLY REFER TO:
5090/17160
LN
July 13, 2012

Ms. Helen Golde
Director, Office of Protected Resources
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910-3282

Dear Ms. Golde:

The United States Marine Corps (USMC), Marine Corps Air Station (MCAS) Cherry Point requests the issuance of a Letter of Authorization (LOA) for the incidental take of common bottlenose dolphin (*Tursiops truncatus*) related to range operations at the USMC Cherry Point Range Complex in Pamlico Sound, North Carolina. An environmental assessment for MCAS Cherry Point Range Operations prepared and completed in 2009 provides the basis for determining the impacts of our military range operations on marine mammals (Enclosure 1). Enclosure 2 has been prepared to provide information specific to marine mammals and this request for an LOA.

MCAS Cherry Point has implemented a new sound source propagation model, based on the best available science as previously coordinated by the Department of the Navy (DoN) and the National Marine Fisheries Service, to estimate levels of take in Pamlico Sound. While we have successfully coordinated two previous Incidental Harassment Authorizations (IHAs) with your office, application of the new model in the absence of any monitoring or mitigation predicts the potential of Level A harassment on 1 dolphin, prompting us to seek an LOA.

Enclosure (2) is a report covering the type and magnitude of range operations, or activities, conducted at the Cherry Point Range Complex and an analysis of the potential for these activities to interact with marine mammals, specifically bottlenose dolphin. Methods used to estimate the impacts of inert ordnance (direct strike) and small boat sorties remain unchanged from past IHA requests. The least conservative estimates—deployment of maximal levels of ordnance in the absence of any means of effecting the least practicable adverse impact—predict the greatest level of impact to be:

| Impact | Explosive Ordnance | Inert Ordnance | Boat Sorties |
|---|---|---|---|
| Level B | 58.651 | 0 | 0 |
| Level A | 0.777 | 0 | 0 |
| Mortality | 0.001 | 0.261 | 0 |

[EXAMPLE: Based upon the level of training and munitions delivery at the bombing targets, the following determinations, in the absence of any means of effecting the least practicable adverse impact, have been made:

- The probability of a direct strike to a bottlenose dolphin from ordnance delivery is 2.61 x 10 -7 (0.319) and 9.4 x 10-8 (0.042) for water based targets at BT-9 and BT-11, respectively. A period of 10 years would pass for it to be probable for a single dolphin to be struck by deployed ordnance.

- Take in the form of Temporary Threshold Shift (TTS) is calculated at 33.749 exposures per year. Take in the form of non-injurious behavioral effect is calculated at 24.903 exposures per year. Therefore, take in the form of Level B harassment is calculated at 58.651 exposures per year.

- Take in the form of Level A injury is calculated at 0.777 exposures per year.

- Take in the form of Level A mortality from acoustic effects is calculated at 0.081 exposures per year.]

Of vital importance to the Marine Corps is having the necessary flexibility to modify the types and quantities of munitions used on our ranges to meet evolving training requirements. We are requesting, as part of the LOA, that the type and amounts of training events become fluid as training programs are linking to real world events. As illustrated in the enclosed report, the quantity and type of munitions used during training over the time series has varied annually. This inter-year variation is a result of changes in deployment cycles, training tempo, and an evolving mission for the USMC. Under this flexible approach, take would not exceed authorized levels.

It is our strong belief that standard operating procedures in place at the bombing targets, combined with research and monitoring programs currently funded and/or under development, create an environment that mitigates the potential for serious injury or mortality to marine mammals. The enclosed package is submitted in fulfillment of requirements for the issuance of a Letter of Authorization under the Marine Mammal Protection Act.

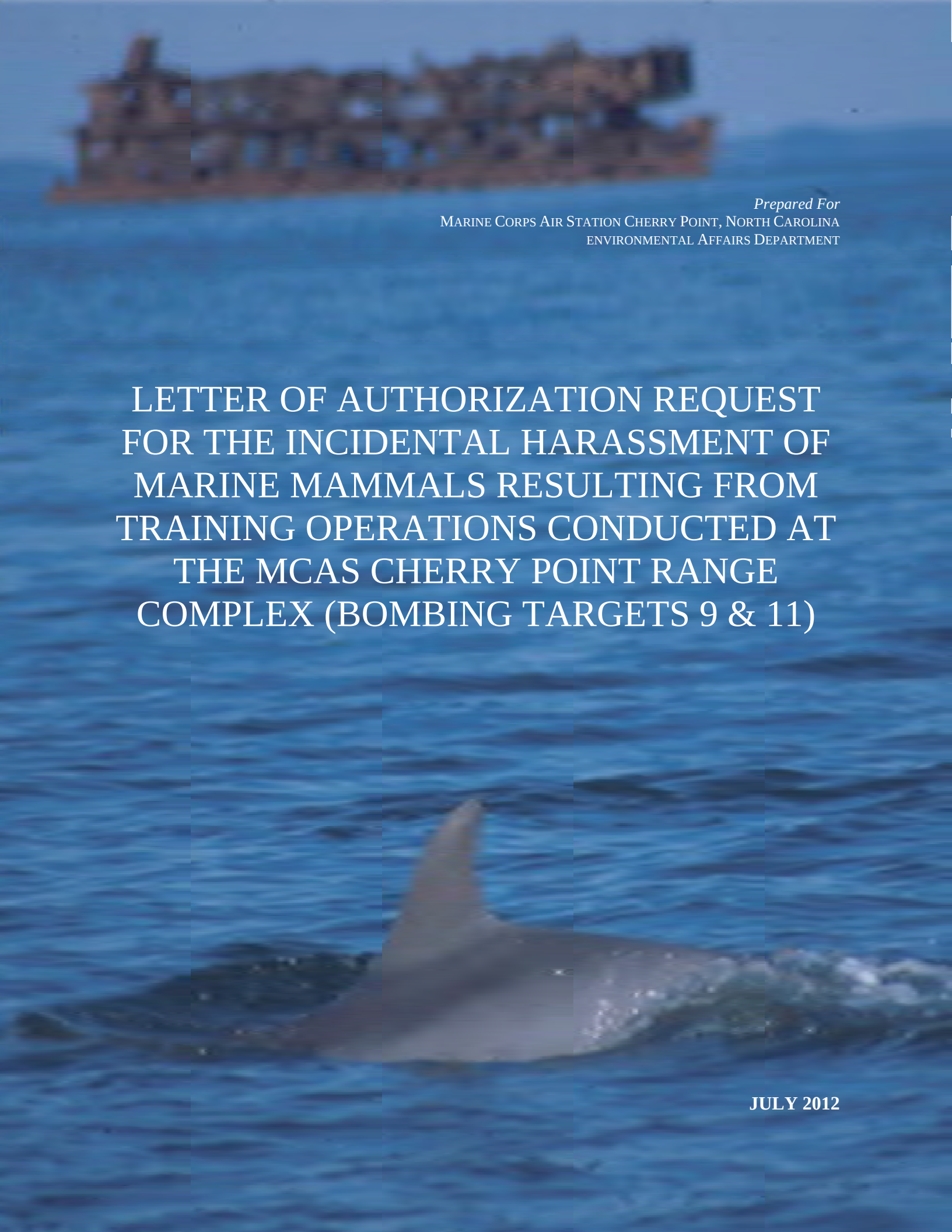
We appreciate your consideration of our request. If you have questions or require additional information, please contact Mr. Carmen A. Lombardo of this office at (252) 466-5870 or e-mail Carmen.Lombardo@usmc.mil.

Sincerely,

G. W. RADFORD
Environmental Affairs Officer
By direction of the
Commanding Officer

Enclosures: 1. MCAS Cherry Point Range Operations EA
2. MMPA Compliance Report

CC: Brian Hopper, NOAA_NMFS



*Prepared For*
MARINE CORPS AIR STATION CHERRY POINT, NORTH CAROLINA
ENVIRONMENTAL AFFAIRS DEPARTMENT

# LETTER OF AUTHORIZATION REQUEST FOR THE INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM TRAINING OPERATIONS CONDUCTED AT THE MCAS CHERRY POINT RANGE COMPLEX (BOMBING TARGETS 9 & 11)

**JULY 2012**

# LETTER OF AUTHORIZATION REQUEST
*for the*
# INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM TRAINING OPERATIONS CONDUCTED
*at the*
# MCAS CHERRY POINT RANGE COMPLEX (BOMBING TARGETS 9 & 11)

**PREPARED FOR:**
**MARINE CORPS AIR STATION CHERRY POINT**
**ENVIRONMENTAL AFFAIRS DEPARTMENT**
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**July 2012**

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## List of Acronyms, Abbreviations, and Symbols

| | |
|---|---|
| **BT** | Bombing Target |
| **°C** | Degree(s) Celsius |
| **cal** | Caliber |
| **CETAP** | Cetacean and Turtle Assessment Program |
| **CFR** | Code of Federal Regulations |
| **cm** | Centimeters |
| **CURRS** | Consolidated Utilization Range Report System |
| **dB** | Decibel(s) |
| **dB re 1 μPa** | Decibels with reference pressure of 1 microPascal |
| **dB re 1 μPa-m** | Decibels referenced to 1 microPascal at 1 meter |
| **dB re 1 $\mu Pa^2$-m** | Decibels with reference to 1 microPascals squared per meter |
| **dB re 1 $\mu Pa^2$-s** | Decibels with reference to 1 microPascals squared per second |
| **DoN** | Department of the Navy |
| **EFD** | Energy flux density |
| **ESA** | Endangered Species Act |
| **°F** | Degree(s) Fahrenheit |
| **FEIS** | Final Environmental Impact Statement |
| **FWRI** | Florida Wildlife Research Institute |
| **ft** | Foot/feet |
| **FY** | Fiscal year |
| **HE** | High explosive(s) |
| **Hz** | Hertz |
| **in** | Inch(es) |
| **kg** | Kilogram(s) |
| **kHz** | kiloHertz |
| **km** | Kilometer(s) |
| **$km^2$** | Square kilometer(s) |
| **lb(s)** | Pound(s) |
| **LGTR** | Laser Guided Training Round |
| **LOA** | Letter of Authority |
| **m** | Meter(s) |
| **$m^2$** | Square meter(s) |
| **m/s** | Meters per second |
| **MCAS** | Marine Corps Air Station |
| **MCB** | Marine Corps Base |
| **MMPA** | Marine Mammal Protection Act |
| **mi** | Mile(s) |
| **$mi^2$** | Square mile(s) |
| **mm** | Millimeter(s) |
| **ms** | Millisecond |
| **N/A** | Not applicable |
| **NC** | North Carolina |
| **NEW** | Net explosive weight |
| **nm** | Nautical mile(s) |
| **NMFS** | National Marine Fisheries Service |
| **NNCES** | Northern North Carolina Estuarine System |

| | |
|---|---|
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NOS** | National Ocean Service |
| **OTO** | One-third-octave |
| **Photo-ID** | Photo-identification |
| **psi** | Pounds per square inch |
| **psu** | Practical salinity unit |
| **PTS** | Permanent threshold shift |
| **SDZ** | Safety Danger Zone |
| **SM** | Statute-mile |
| **SEFSC** | Southeast Fisheries Science Center |
| **SNCEC** | Southern North Carolina Estuarine System |
| **TL** | Transmission loss |
| **TM** | Tympanic membrane |
| **TNT** | Trinitrotoluene |
| **TOW** | Tube-launched, optically tracked, wire-guided |
| **TTS** | Temporary threshold shift |
| **U.S.** | United States |
| **U.S.C.** | U.S. Code |
| **USFWS** | U.S. Fish and Wildlife Service |
| **USMC** | U.S. Marine Corps |
| **ZOI** | Zone of Influence |

# 1. INTRODUCTION

The United States Marine Corps (USMC) requests a Letter of Authorization (LOA) for the incidental take of marine mammals, specifically common bottlenose dolphin (*Tursiops truncatus*), during training operations at the Marine Corps Air Station (MCAS) Cherry Point Range Complex (Figure 1-1). Pursuant to National Marine Fisheries Service (NMFS) requirements for an LOA request, MCAS Cherry Point has prepared this report to analyze potential environmental effects associated with military training within the MCAS Cherry Point Range Complex. The report focuses on the potential effects to marine mammals from bombing and target training at the in-water bombing targets (BTs) Brant Island (BT-9) and Rattan Bay (Piney Island Bombing Range, BT-11) located in Pamlico Sound, North Carolina (NC) (Figure 1-1). These bombing targets are under the control and management of MCAS Cherry Point. Activities evaluated in this document can be part of single unit training exercises or larger-scale training events.

The Marine Mammal Protection Act (MMPA) of 1972, as amended (16 United States Code [U.S.C.] Section [§] 1371[a][5][A] and [D]), authorizes the issuance of regulations and LOAs for the incidental taking of marine mammals by a specified activity for a period of not more than five years. The issuance occurs when the Secretary of Commerce, after publication of notice in the Federal Register and provision of opportunity for public comment, finds that such take will have a negligible impact on the species and stocks of marine mammals, and will not have an immitigable, adverse impact on the availability of the species for subsistence uses. The NMFS promulgated implementing regulations under 50 Code of Federal Regulations (CFR) § 216.101–106 which provide a mechanism for allowing the incidental, but not intentional, take of marine mammals while engaged in a specified activity.

This document has been prepared in accordance with the applicable regulations and the MMPA, as amended by the National Defense Authorization Act for Fiscal Year 2004 (Public Law 108-136). The analyses in this document are based on (1) the spatial distributions of protected marine mammals in the MCAS Cherry Point Range Complex (hereafter referred to as the Range Complex), (2) the scope and scale of operational activities that have the potential to incidentally take marine mammals, and (3) a risk assessment that employs models to determine the likelihood of effects.

The United States Marine Corps requires the best military training in the world to sustain its critical role in national defense and forward deployment in worldwide combat situations. Training provides the physical skills, ability, and knowledge to perform and survive in combat through basic military, skill-specific, and weaponry-specific training, as well as formal education. It builds proficiency, cohesion, and teamwork and is fundamental to achieving unity of effort. Training is the primary means for maintaining, improving, and displaying USMC force readiness to fight and win in times of crisis or conflict. Additionally, training programs must be linked to real-world events and have the flexibility to evolve, which may result in inter-annual variability in type and amount of training operations.

The USMC supports and conducts training operations at the Range Complex. The analyses in this document include only training missions occurring on the Range Complex's water ranges or

those with impact areas over the water, because of their potential to affect marine mammals. Those training missions include:

- **Munitions Firing –** Units conduct air-to-ground, surface-to-surface, and air-to-surface munitions delivery at targets that are located on land or in water. Air-to-ground firing does not impact the water; therefore, it is not analyzed or discussed further in this document.
- **Small Boat Maneuvers –** Units operate small watercraft that use inboard or outboard engines with either propeller or water jet propulsion.

In-water bombing targets at Brant Island (BT-9) and Rattan Bay (BT-11) are used to train military personnel to deliver ordnance on target. Ordnance is primarily delivered from fixed- and rotary-wing aircraft, but is also occasionally delivered from small, military watercraft. Table 1-1 provides a general description of the training activities and munitions used on BT-9 and BT-11.

*Table 1-1: Descriptions of water range operations at the MCAS Cherry Point Range Complex.*

| Range Asset | Training Operations | Type of Munitions Used |
|---|---|---|
| Brant Island Target (BT-9) | Water-based target range for air-to-surface and surface-to-surface warfare training, including bombing, strafing, special (laser systems) weapons, and surface fires, using non-explosive and explosive ordnance; also provides a mining exercise area. | • Small arms<br>• Large arms (live and inert)<br>• Bombs (live and inert)<br>• Pyrotechnics |
| Piney Island Bombing Range (BT-11) | Complex of land- and water-based targets designed to provide training in the delivery of conventional (non-explosive) and special (laser systems) weapons; secondary use for surface-to-surface training by small military watercraft. | • Small arms<br>• Large arms (inert)<br>• Bombs (inert)<br>• Pyrotechnics |

An Environmental Assessment (EA) was prepared for Cherry Point Range Operations which analyzed the environmental impacts of training activities aboard MCAS Cherry Point, its outlying and auxiliary landing fields, its bombing targets in Pamlico Sound and overlying special use airspace (MCAS Cherry Point 2009a). The EA determined that activities associated with the Range Complex are likely to have minor impacts, if any, to marine mammals.

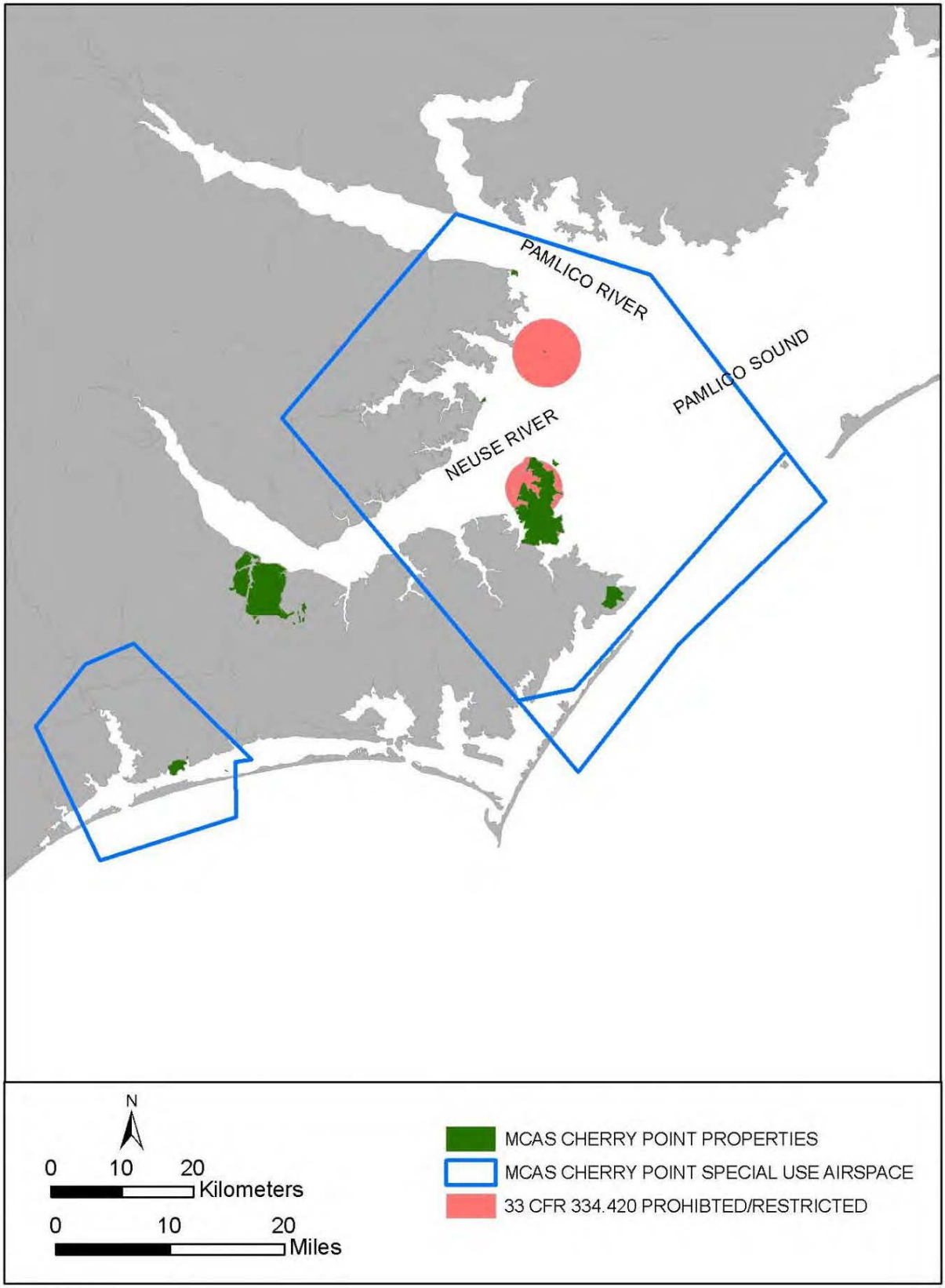


*Figure 1-1: MCAS Cherry Point Range Complex.*

# 2. DESCRIPTION OF ACTIVITIES

The following sections provide a description of the training activities for which an LOA is being requested and represents all training activities conducted at the water ranges that involve the use of live (explosive) and inert (non-explosive) ordnance, and small boat maneuvers.

## 2.1 MUNITIONS FIRING

Munitions firing training conducted on the water ranges includes surface-to-surface (firing from ship or boat to surface targets) and air-to-surface (firing from aircraft to surface water targets). This activity occurs year-round without seasonal restrictions. The number of sorties conducting these missions is presented in Table 2-1. Table 2-2 lists the types of ordnance, or munitions, that can be expended at the Range Complex, including practice bombs, rockets, flares, chaff, gun ammunition, and grenades. Note that deployment of live ordnance is only permitted at BT-9; all munitions fired at BT-11 are inert.

*Table 2-1: Aircraft and boat sorties, by mission type, conducted in 2011.*

| Mission Type | BT-9 | BT-11 |
|---|---|---|
| Air-to-Surface | 1,554 | 4,251 |
| Surface-to-Surface | 223 | 105 |
| Total | 1,777 | 4,356 |

MCAS Cherry Point's standard operating procedures set the maximum limit at 100 pounds (lbs) trinitrotoluene (TNT) equivalent for explosive ordnance at BT-9. Net explosive weights (NEW) currently authorized for use at BT-9 range from 0.1019 to 100 lbs. Used at both targets, practice bombs are inert, but do contain a small amount of explosive marking charge in a signal cartridge that allows the target hit to be detected by range scorekeepers and the pilot. Explosives in the signal cartridge are less than 1 lb TNT equivalent (USMC 2001b). Note that all ordnance fired on the BT-11 range is inert with the exception of a signal charge in practice bombs.

Each practice and live-fire exercise at the Range Complex is designed and conducted so that all ammunition and other ordnance strike and/or fall within the existing danger zones or restricted areas for each bombing target. A *danger zone* is a defined water area (or areas) used for target practice, bombing, rocket firing or other especially hazardous operations that may be closed to the public on a full-time or intermittent basis (33 CFR 334.2). A *restricted area* is a defined water are for the purpose of prohibiting or limiting public access to the area generally to provide security for government property and/or protection to the public from the risks of damage or injury arising from the government's use of that area (33 CFR 334.2).

*Table 2-2: Munitions authorized for use at the MCAS Cherry Point Range Complex[1]. Inert ordnance is displayed in plain text; live ordnance is displayed in bold text.*

| Small Arms | Large Arms | Missiles[2] | Rockets | Bombs | Pyrotechnics |
|---|---|---|---|---|---|
| **.22 cal** | 20mm | Hellfire | 2.75-in Rocket | Practice Hand Grenade | Chaff |
| **.40 cal** | **20mm** | Tube-launched, optically tracked, wire-guided (TOW) | 2.75-in Rocket Illumination | Non-Lethal Stun Grenade | LUU-2 |
| **.45 cal** | 25mm | | 2.75-in Rocket White Phosphorous | Smoke Grenade | LUU-19 |
| **.50 cal** | 30mm | | 2.75-in Rocket Red Phosphorous | **G911 Grenade** | MI27 A1-Parachute Flare |
| **5.56mm** | **30mm** | | **2.75-in Rocket** | BA21 0.052 lb | Self Protection Flare |
| **7.62mm** | 40mm | | 5-in Rocket | BDU-48 10 lbs | Signal Illuminations |
| **9mm** | **40mm** | | 5-in Rocket White Phosphorous | BDU-33 25 lbs | Simulated Booby Traps |
| **12 Gauge** | 40mm Illumination | | 5-in Rocket Red Phosphorous | E976 25 lbs | Smokey Sams |
| | 60mm Illuminations | | **5-in Rocket** | MK-76 25 lbs | Artillery Simulator Ground Burst |
| | 60mm Smoke White Phosphorous | | | LGTR 90 lbs | |
| | 81mm | | | **MK-81 250 lbs** | |
| | 81mm Illumination | | | BDU-45 500 lbs | |
| | 81mm Smoke White Phosphorous | | | BDU-50 500 lbs | |
| | 105mm Target Practice | | | GBU-12 500 lbs | |
| | **105mm 40lbs** | | | MK-82 500 lbs | |
| | | | | BDU-38 750 lbs | |
| | | | | GBU-16 1,000 lbs | |
| | | | | MK-83 1,000 lbs | |
| | | | | MK-63 1,061 lbs | |

Notes: 1. Variants of the listed munitions and newly developed munitions that fall into these categories may be approved for use at the Range Complex as they become available.
2. Two types on missiles, Hellfire and TOW, were previously approved for use at BT-9 per Air Station Order P3570.2R; however, use of these missiles at MCAS Cherry Point has been cancelled since Fiscal Year (FY) 2005 due to operational limitations imposed by an insufficient weapon danger zone safety footprint at the water range.

### 2.1.1 Surface-to-Surface

Gunnery exercise is the only category of surface-to-surface activity currently conducted at BT-9 and BT-11.

- **Gunnery Exercise:** A small boat, typically operated by Special Boat Team personnel, uses a machine gun to attack and disable, or destroy, a surface target that simulates another ship, boat, swimmer, floating mine or near-shore land targets. Boats conducting surface-to-surface firing activities will typically use 7.62 millimeter (mm) or .50 caliber (cal) machine guns; 40 mm grenade machine guns; or G911 concussion hand grenades. This exercise is usually a live-fire exercise, but blanks may be used so that the boat crews can practice their ship handing skills. BT-9 is the most common target used for gunnery exercises. A target is not used for the gunnery exercises employing the G911 Concussion grenade, as the goal of this specific training is to learn how to throw the grenade into the water.

### 2.1.2 Air-to-Surface

There are four categories of air-to-surface activities conducted at the MCAS Cherry Point bombing targets—mine laying, bombing, gunnery, and rocket exercises.

- **Mine Laying:** These activities involve a fixed-wing aircraft deploying inert mine shapes in an offensive or defensive pattern. Mine laying operations are conducted in the waters around BT-9.
- **Bombing Exercise:** During these exercises, fixed-wing aircraft deliver bombs against surface maritime targets with the goal of destroying or disabling enemy ships or boats. These exercises occur during day and night. Air-to-surface bombing exercises employ either unguided or precision-guided munitions. Unguided munitions include MK-76 and BDU-45 inert training bombs, as well as the MK-80 series of inert bombs (no cluster munitions are authorized). Precision-guided munitions consist of laser-guided bombs (inert) and laser-guided training rounds (inert).
- **Gunnery Exercise:** Rotary-wing gunnery exercises involve either CH-53, UH-1, CH-46, MV-22, or H-60 rotary-wing aircraft with mounted 7.62 mm or .50 cal machine guns. Each gunner expends approximately 800 rounds of 7.62 mm or 200 rounds of .50 cal ammunition per exercise. Fixed-wing gunnery exercises involve two aircraft that begin descent to the target from an altitude of approximately 914 meters (m) (3,000 feet [ft]) while still several miles away. Within a distance of 1,219 m (4,000 ft) from the target, each aircraft fires a burst of approximately 30 rounds before descending to a minimum altitude of 305 m (1,000 ft) and then breaks off and repositions for another strafing run. This continues until each aircraft expends its exercise ordnance allowance of approximately 250 rounds. Typically fixed-wing gunnery exercises involve F/A-18 with Vulcan M61A1/A2, 20 mm cannon, and AV-8 with GAU-12, 25 mm cannon.
- **Rocket Exercise:** Fixed- and rotary-wing aircraft crews launch rockets at surface maritime targets during rocket exercises with the goal of destroying or disabling enemy ships or boats. Rocket exercises may occur day or night. These operations employ 2.75-inch (in) and 5-in rockets.

### 2.1.3 Quantity and Accuracy of Ordnance Used

The amount of ordnance to be annually expended at BT-9 and BT-11 under the action is 1,225,815 and 1,254,684, respectively (Table 2-3 and Table 2-4). The amounts of ordnance expended at the BTs account for all uses of the targets, including U.S. Navy use. There are five types of explosive sources used at BT-9: 2.75-in Rocket High Explosives (HE), 5-in Rocket HE, 30 mm HE, 40 mm HE, G911 grenades, Hellfire missiles, and TOW missiles. No high explosive munitions are used at BT-11.

*Table 2-3: Level of live and inert munitions to be annually expended at BT-9.*

| Proposed Munitions | | Proposed No. of Rounds | Net Explosive Weight (lb) |
|---|---|---|---|
| Small Arms excluding .50 cal | | 525,610 | N/A |
| .50 cal | | 568,515 | N/A |
| Large Arms – Live | 30mm | 3,120 | 0.1019 |
| | 40mm | 9,472 | 0.1199 |
| Large Arms – Inert | | 109,459 | N/A |
| Rockets – Live | 2.75-in | 184 | 4.8 |
| | 5-in | 57 | 15.0 |
| Rockets – Inert | | 703 | N/A |
| Bombs and Grenades – Live | G911 | 144 | 0.5 |
| | 100-lbs NEW HE Bomb | 0 | 100 |
| Bombs and Grenades – Inert | | 4,055 | N/A |
| Missiles | Hellfire | 0 | 34.4 |
| | TOW | 0 | 13.6 |
| Pyrotechnics | | 4,496 | N/A |
| | Total | 1,225,815 | N/A |

*Table 2-4: Level of inert munitions to be annually expended at BT-11.*

| Proposed Munitions | Proposed No. Rounds |
|---|---|
| Small Arms excluding .50 cal | 610,957 |
| .50 cal | 366,775 |
| Large Arms | 240,334 |
| Rockets | 5,592 |
| Bombs and Grenades | 22,114 |
| Pyrotechnics | 8,912 |
| Total | 1,254,684 |

The quantities of ordnance listed in Tables 2-3 and 2-4 represent conservative figures, meaning that the volume of each type of inert and explosive ordnance proposed to be used is the largest number that can be used in any given year. The reason for the use of conservative figures is to

allow for the greatest level of flexibility in training operations. This is necessary because military training requirements evolve and training volumes must remain flexible as training evolutions are linked to real-world events. These figures attempt to encapsulate potential inter-annual variation in ordnance type and number. To illustrate this point, Figures 2-1 and 2-2 display inter-annual variation between select types of munitions and the volume expended at BT-9 and BT-11 between 2009 and 2011, respectively.

Both bombing targets are located in or near water; therefore, there is potential for rounds that miss the targets to impact or detonate in the water. BT-9 is comprised of two hulls grounded in the water; therefore, as the target is located in water, the Marine Corps assumes that 100 percent of the ordnance expended at BT-9 would detonate in the water at a depth of approximately 1.2 m (3.9 ft). Three of the targets at BT-11 are located either within or immediately adjacent to Rattan Bay. In addition, the location and use of several other targets at BT-11 cause their associated Safety Danger Zones (SDZs) to extend into the water. At BT-11, thirty-six percent of the composite weapons SDZs fall over water. Based on the location of the SDZs, the USMC conservatively estimates that 36 percent of the total number of rounds expended at BT-11 would impact the water.

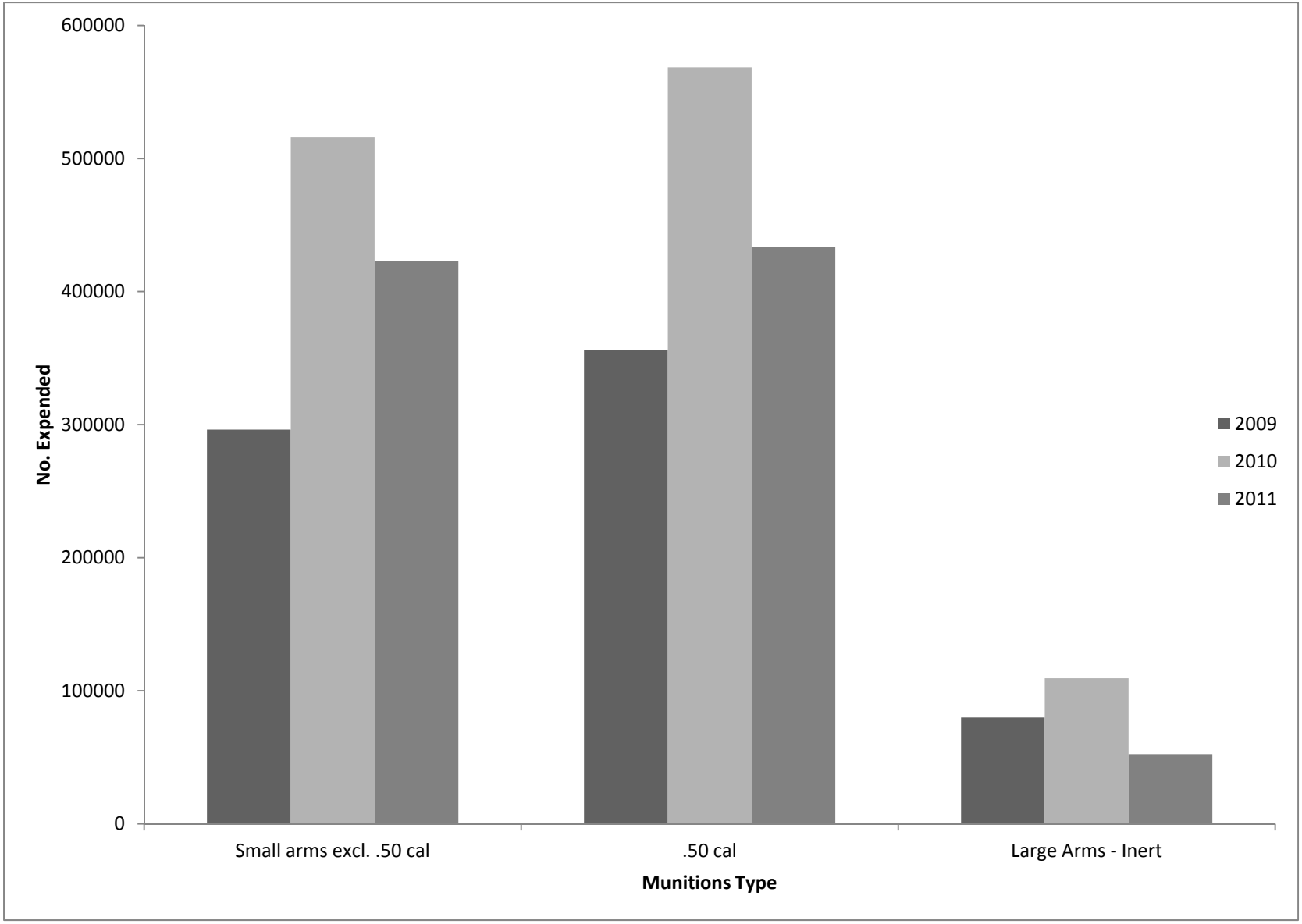


*Figure 2-1: Example of inter-annual variations in munitions expended at BT-9 (data from 2009 to 2011).*

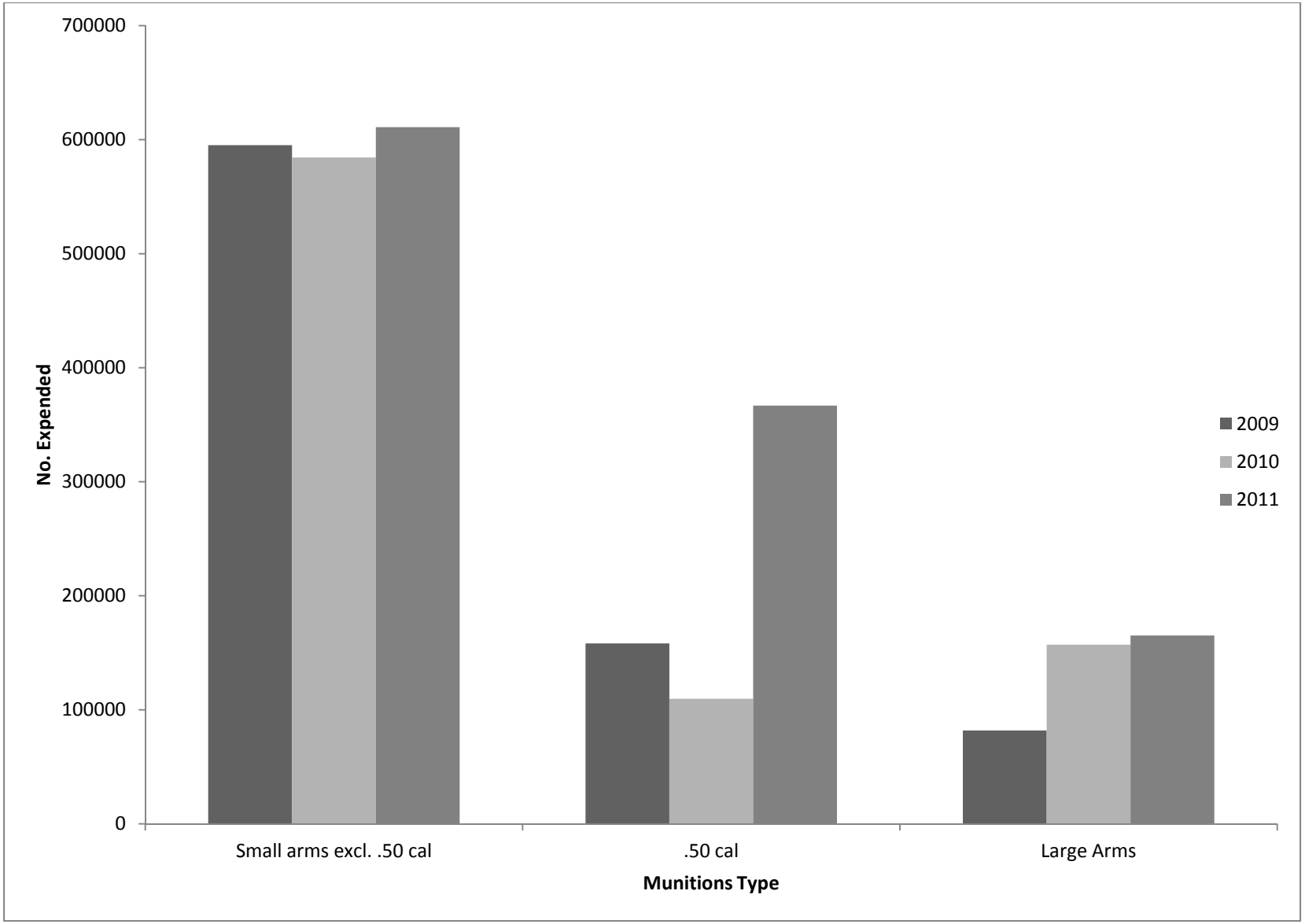


*Figure 2-2: Example of inter-annual variations in munitions expended at BT-11 (data from 2009 to 2011).*

## 2.2 SMALL BOAT MANEUVERS

Small boat maneuvers are conducted by Naval Special Warfare teams, Navy Expeditionary Combat Command units (e.g., Naval Coastal Warfare, Inshore Boat Units, Mobile Security Detachments, Explosive Ordnance Disposal, and Riverine Forces), and U.S. Coast Guard units. These units have missions that include protecting ships and high value units (e.g., aircraft carriers, nuclear submarines, liquid natural gas tankers) while entering and leaving ports; conducting riverine operations, insertions and extractions; and conducting various Naval Special Warfare operations. Boats used by these units include, but are not limited to, small unit river craft, combat rubber raiding craft, rigid hull inflatable boats, and patrol craft. These boats may have either inboard or outboard, diesel or gasoline engines with either propeller or water jet propulsion.

The number of sorties conducted at each range may vary from year to year based on training needs and worldwide operational tempo. These sorties occur in all seasons with roughly a uniform distribution between seasons. The majority of boat sorties at BT-9 originate from Marine Corps Base (MCB) Camp Lejeune. Boats are transported on trailers from MCB Camp Lejeune to the Pamlico Sound for weapons training at BT-9, where live fire of 7.62 mm, .50 cal, and 40 mm grenades, as well as use of G911 concussion grenades, is allowed. Munitions, both live and inert, fired during small boat maneuvers are included in the larger analyses for BT-11 and BT-9 and, therefore, are not broken down here.

*Table 2-5: Boat sorties, by range, for the time period 2010-2012.*

| Bombing Target | Number of Sorties | | |
|---|---|---|---|
| | 2010 | 2011 | 2012 |
| BT-9 | 287 | 311 | 292 |
| BT-11 | 141 | 222 | 53 |

# 3. LOCATION OF THE ACTIVITIES

The bombing targets are located at the convergence of the Neuse River and Pamlico Sound (Figure 3-1). Pamlico Sound and its tributaries represent one of the largest intracoastal, estuarine ecosystems found in the United States. The Sound is a shallow estuary with a mean water depth of 4.5 m (14.7 ft) and a low tidal range of approximately 10 centimeters (cm) (3.9 in) (Eisma *et al*. 1997; Paerl *et al*. 2001). Circulation in the Sound is wind-driven and freshwater input—predominantly from the Neuse River—is low, resulting in long tidal residence times for Sound waters. Salinities are highly variable, ranging from 10 to 31 practical salinity units (psu), and fluctuate seasonally with highest salinities found in the fall (15-31 psu) and lowest salinities found in the spring (10-19 psu) (Wells 1989; NOS 2001). Surface water temperatures for Pamlico Sound also vary seasonally with the average lowest temperatures (15-17 degrees Celsius [°C] or 59-62.6 degrees Fahrenheit [°F]) found in winter and the highest (25-27 °C [78.8-80.6 °F]) occurring in summer (DoN 2003). Fine sand and silt cover the bottom of Pamlico Sound (Wells 1989; Eisma *et al*. 1997).

## 3.1 BRANT ISLAND – BOMBING TARGET-9

The Brant Island Target, also known as Bombing Target-9 (Figure 3-1), is a water-based target area located approximately 52 kilometers (km) (28 nautical miles [nm]) northeast of MCAS Cherry Point in Pamlico Sound, Pamlico County, NC. The target consists of two ship hulls grounded on Brant Island Shoals in extremely shallow water. Brant Island Shoals is located approximately 4.8 km (3 miles [mi]) southeast of Goose Creek Island. Inert ordnance up to 454 kilograms (kg) (1,000 lbs) and live ordnance up to 45.4 kg (100 lbs) TNT-equivalent, including ordnance released during strafing, are authorized for use at this bombing target.

The target is defined by a 6 statute-mile (SM) diameter prohibited area having its center on the southern side of Brant Island at latitude 35°12’30”, longitude 76°26’30” (33 CFR 334.420). The area is closed to navigation and personnel at all times, and is delineated by large signs on pilings surrounding the perimeter of BT-9.

Brant Island Shoals is roughly oriented northwest to southeast through the center of the circular target area. Hydrographic survey data collected for the vicinity of BT-9 indicate that water depths within the BT range from approximately 1.2 m along the crest of the shoals to 6 m at the perimeter of the prohibited area (USMC 2001b). Bottom substrate exhibits a gradient ranging from harder-packed sediments (sand and possibly hard bottom) along the shoal crest in the shallowest water (1.2-3 m [4-10 ft]) to soft sediments (mud or silt) in the deeper regions off the flank of the shoal (depths greater than 4.9 m [16 ft]) (USMC 2001b). Surveys of BT-9 also indicate that areas of submerged debris appear to be clustered along the eastern half of the prohibited area (USMC 2001b).

Water temperatures at BT-9 average 8 °C (46.4 °F) in winter (December through March), 18 °C (64.4 °F) during spring and fall (May and October, respectively), and 27 °C (80.6 °) in summer (June through September) (USMC 2001b). Salinities remain fairly constant at 16.8 psu throughout the year (USMC 2001b).

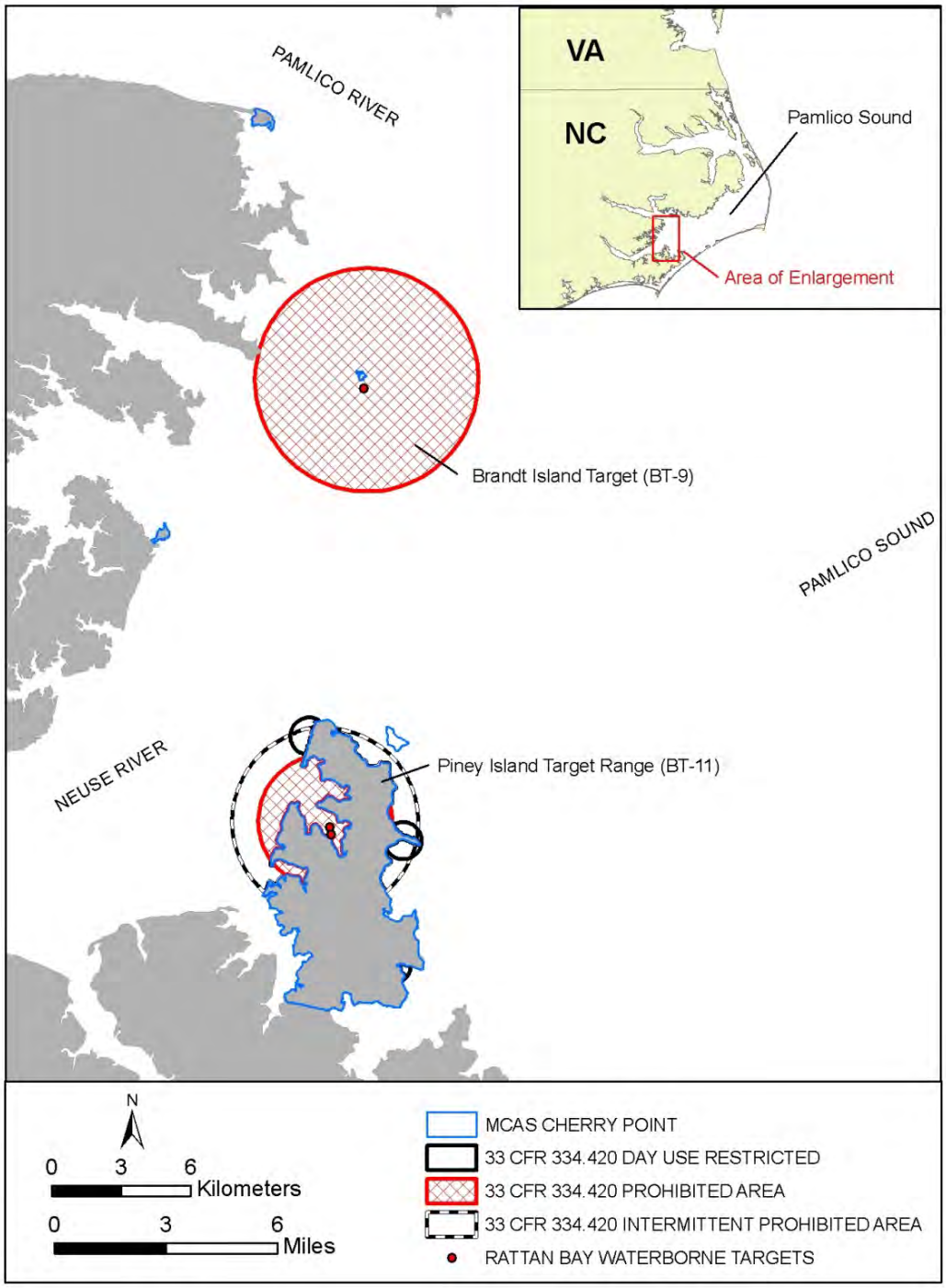


*Figure 3-1: MCAS Cherry Point bombing targets Brant Island Bombing Target (BT-9) and Piney Island Bombing Range (BT-11) (33 CFR 334.420; USMC 2001a).*

## 3.2 PINEY ISLAND – BOMBING TARGET-11

Bombing Target-11 is a 50.6 square kilometer ($km^2$) (19.5 square mile [$mi^2$]) complex of land- and water-based targets at the Piney Island Bombing Range, and includes all of the island and the surrounding waters in Pamlico Sound. The in-water stationary targets of BT-11 consist of a barge and PT boat roughly located at the center of Rattan Bay (Figure 3-2). There are designated danger zones around the BT-11 target.

A designated danger zone with a radius of 1.8 SM having its center at latitude 35°02’12”, longitude 76°28’00” is associated with Rattan Bay. This prohibited area, roughly centered on the Rattan Bay target, is closed to navigation at all times, unless vessels are authorized by MCAS Cherry Point to enter the target area. This prohibited area includes approximately 9.3 $km^2$ (3.6 $mi^2$) of water surface.

A second danger zone with an inner radius of 1.8 SM and an outer radius of 2.5 SM having its center point its center at latitude 35°02’12”, longitude 76°28’00” is used for strafing at water borne and land based targets. This danger zone is intermittent in nature and scheduled for one 5 consecutive day block (Monday-Friday) per month during the months of February through November. Use of this danger zone by the military is scheduled at least two weeks in advance and publicized via various media to adequately inform the public.

Additional restricted areas around BT-11, which are open at night and closed during daylight hours, are located at:

- The waters within a circular area with a radius of 0.5 SM having its center at latitude 35°04’12”, longitude 76°25’48”;
- The waters within a circular area with a radius of 0.5 SM having its center at latitude 35°01’42”, longitude 76°25’48”; and
- The waters within a circular area with a radius of 0.5 SM having its center at latitude 34°58’48”, longitude 76°26’12”.

Water depths in the center of Rattan Bay are estimated at 2.4 to 3 m (8-10 ft) (USMC 2001b). Bottom depths range from 0.3 to 1.5 m (1-5 ft) adjacent to the shoreline of Piney Island (USMC 2001b). A shallow ledge, with substrate expected to be hard-packed to hard bottom, surrounds Piney Island.

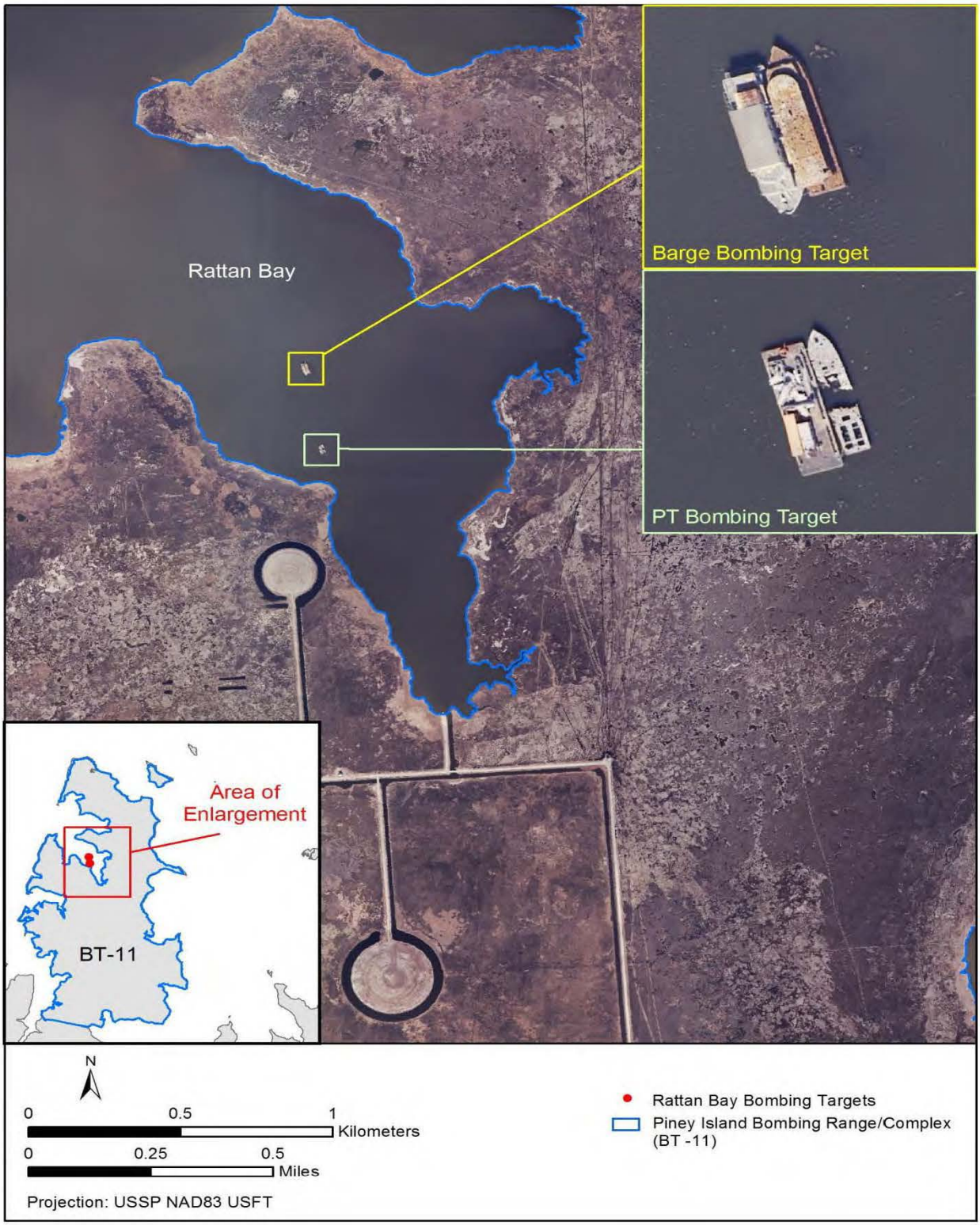


*Figure 3-2: Targets in Rattan Bay, Piney Island Bombing Range (BT-11) (USMC 2001a, 2004).*

# 4. AFFECTED SPECIES, STATUS, STOCK DISTRIBUTION, AND DENSITY AT MCAS CHERRY POINT RANGE COMPLEX

While there are records showing the occurrence of 40 marine mammal species in the nearshore and offshore waters of North Carolina, the vast majority of these species are oceanic in distribution. Only one marine mammal species—the common bottlenose dolphin (*Tursiops truncatus*)—has been repeatedly sighted in Pamlico Sound, while an additional species—the endangered West Indian manatee (*Trichechus manatus*)—has been rarely sighted (Lefebvre *et al*. 2001; DoN 2003). A review of the records contained in the North Atlantic Right Whale Database, maintained by the NMFS, shows that no sightings of the endangered North Atlantic right whale (*Eubalaena glacialis*) have ever been recorded within Pamlico Sound or in the vicinity of the bombing targets (Kenney 2006). No suitable North Atlantic right whale habitat exists in the shallow Pamlico Sound, including the vicinity of the BTs; therefore, no further information regarding this species is included in this document. All other marine mammal species potentially occurring in the southwestern portion of Pamlico Sound are considered extralimital.

Marine mammal distribution is affected by demographic, evolutionary, ecological, habitat-related, and anthropogenic factors (Bjørge 2002; Stevick *et al*. 2002). Marine mammal movements are often related to feeding or breeding activity (Stevick et al. 2002). Cetacean movements are often a reflection of the distribution and abundance of prey (Kenney *et al*. 1996). Marine mammal movements have also been linked to environmental parameters indirectly indicative of prey distribution such as temperature variations (oceanic fronts), sea-surface chlorophyll-a concentrations, and bottom depth (Fiedler 2002).

In fulfillment of the MMPA, the NMFS has identified certain cetacean stocks as strategic. All marine mammal species listed under the Endangered Species Act (ESA) are strategic stocks. Additional marine mammal stocks are listed as strategic if non-natural mortalities or serious injuries (e.g., fishery takes) have either exceeded the predicted maximum the stock can withstand or if insufficient information exists to make such a determination. When applicable to a stock, such information has been included with the species' description that follows.

## 4.1 COMMON BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*)

The common bottlenose dolphin is large and relatively robust, varying in color from light gray to charcoal. The genus *Tursiops* is named for its short, stocky snout, which is distinct from the melon (Jefferson *et al*. 1993). The dorsal fin is tall, curved, and pointed. Striking regional variations exist in body size, with adult body lengths ranging from 1.8 to 3.8 m (6.0-12.5 ft) (NMFS 2011; Jefferson *et al*. 1993). This is a long-lived species with a lifespan of 40 to 45 years for males and 50 years for females (NMFS 2001). Bottlenose dolphins are commonly found in groups of 2 to 15 individuals (NMFS 2011). *Tursiops* employ a wide variety of feeding strategies and feed opportunistically on an assortment of fish, cephalopod, and shrimp species (Shane 1990; Wells and Scott 1999).

The overall range of the bottlenose dolphins is worldwide in both tropical and temperate waters. This species occurs in all three major oceans and many seas. Dolphins of the genus *Tursiops* generally do not range poleward of 45° latitude, except around the United Kingdom and northern

Europe (Jefferson *et al*. 1993). Climate changes can contribute to range extensions as witnessed in association with the 1982-1983 El Niño event when the range of some bottlenose dolphins known to the San Diego, California area was extended 600 km (324 nm) northward to Monterey Bay, California (Wells *et al*. 1990). Bottlenose dolphins continue to occur in Monterey Bay to this day. In the most western North Atlantic, bottlenose dolphins occur as far north as Nova Scotia but are most common in coastal waters from New England to Florida, the Gulf of Mexico, the Caribbean, and southward to Venezuela and Brazil (Würsig *et al*. 2000). Bottlenose dolphins occur seasonally in estuaries and coastal embayments as far north as Delaware Bay (Kenney 1990) and in waters over the outer continental shelf and inner slope, as far north as Georges Bank (CETAP 1982; Kenney 1990).

There are two morphotypes of bottlenose dolphins in the western North Atlantic Ocean: coastal and offshore. The morphotypes can be distinguished by genetics, diet, blood characteristics, and outward appearance (Duffield *et al*. 1983; Hersh and Duffield 1990; Mead and Potter 1995; Curry and Smith 1997). The coastal morphotype is morphologically and genetically distinct from the larger, more robust morphotype primarily occupying habitats farther offshore (Mead and Potter 1995; Hoelzel *et al*. 1998; Rosel *et al*. 2009). Genetic analyses and spatial patterns observed in aerial surveys indicate both regional and seasonal differences in the longitudinal distribution of the two morphotypes in coastal Atlantic waters. The primary habitat of the coastal morphotype of bottlenose dolphin extends from Florida to New Jersey during summer months, in waters less than 20 m deep, to include estuarine and inshore waters (Waring *et al*. 2011). South of Cape Lookout, the coastal morphotype occurs in lower densities over the continental shelf (waters between 20 m and 100 m depth) and overlaps spatially with the offshore morphotype (Waring *et al*. 2011).

The coastal morphotype of bottlenose dolphin is continuously distributed along the Atlantic coast south of Long Island, New York, around the Florida peninsula, and along the Gulf of Mexico. Based on differences in mitochondrial DNA haplotype frequencies, nearshore animals in the northern Gulf of Mexico and western North Atlantic represent separated stocks (Duffield and Wells 2002; Rosel *et al*. 2009). On the Atlantic coast, Scott *et al*. (1988) hypothesized a single coastal migratory stock ranging seasonally from as far north as Long Island, to as far south as central Florida, citing stranding patterns during a high mortality even in 1987-1988 and observed density patterns. However, re-analysis of stranding data (McLellan *et al*. 2003) and extensive analysis of genetic (Rosel *et al*. 2009), photo-identification (photo-ID) (Zolman 2002), and satellite telemetry (Southeast Fishery Science Center, unpublished data) data demonstrate a complex mosaic of coastal bottlenose dolphin stocks. Integrated analysis of these multiple lines of evidence suggests that there are five coastal stocks of bottlenose dolphin: the Northern Migratory and Southern Migratory stocks, a South Carolina/Georgia Coastal stock, a Northern Florida Coastal Stock, and a Central Florida Coastal stock. Of these five stocks, only the Northern Migratory and Southern Migratory stocks have been observed in Pamlico Sound, NC.

In addition to inhabiting coastal nearshore waters, the coastal morphotype of bottlenose dolphin inhabits inshore estuarine waters along the U.S. east coast and Gulf of Mexico (Wells *et al*. 1987; Wells *et al*. 1996; Weller 1998; Scott *et al*. 1990; Gubbins 2002; Zollman 2002; Mazzoil *et al*. 2005; Speakman *et al*. 2006; Litz 2007; Stolen *et al*. 2007; Balmer *et al*. 2008; Mazzoil *et al*. 2008). There are multiple lines of evidence supporting demographic separation of bottlenose dolphins residing within estuaries along the Atlantic coast. A few published studies demonstrate

that these resident animals are genetically distinct from animals in nearby coastal waters (Cortese 2000; Caldwell 2001; Rosel *et al*. 2009). Despite evidence for genetic differentiation between estuarine and nearshore populations, the degree of spatial overlap between these populations remains unclear. Photo-ID studies within estuaries demonstrate seasonal immigration and emigration, and the presence of transient animals (e.g., Speakman *et al*. 2006). In addition, the degree of movement of resident estuarine animals into coastal waters on seasonal, or shorter, time scales is poorly understood. Yet for the purposes of the 2010 U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments, the NMFS considered bottlenose dolphins inhabiting primarily estuarine habitats distinct from those inhabiting coastal habitats (Waring *et al*. 2011). Two estuarine stocks occur in Pamlico Sound, NC: the Northern North Carolina Estuarine System (NNCES) stock and the Southern North Carolina Estuarine System (SNCES) stock.

### 4.1.1 Spatial Distribution

Bottlenose dolphins in North Carolina concentrate in shallow water habitats along the shorelines, and few, if any, individuals are present in the central portions of the sounds (Gannon 2003; Read *et al*. 2003a, 2003b). Bottlenose dolphins in the area of the bombing targets select shallow habitats, such as tributary creeks and the edges of the Neuse River, where the bottom depth is less than 3.5 m (11.5 ft) (Gannon 2003). Bottlenose dolphins use the downstream portion of the Neuse River estuary and lateral creeks more than the upstream area, and their density is highest during spring (May and June) and lowest during the summer (July and August) (Gannon 2003). Fine-scale distribution of dolphins seems to relate to the presence of topography or vertical structure, such as the steeply-sloping bottom near the shore and oyster reefs, which may be used to facilitate prey capture (Gannon 2003).

Between 2002 and 2003, researchers from Duke University, on behalf of the USMC, conducted 11 boat-based surveys for bottlenose dolphins in the waters surrounding BT-9 and BT-11. During this time, one sighting in the restricted area surrounding BT-9 and two sightings in proximity of BT-11 were observed in addition to seven sighting in adjacent waters, for a total of 276 bottlenose dolphins sighted (Read *et al*. 2002, 2003b, 2003c). Some large groups of dolphins have been reported in the restricted areas. In October 2002, a sighting of 50 dolphins was made within BT-9, and two months later a group of 70 dolphins moved into the prohibited area of the in-water targets of BT-11 (Read *et al*. 2003b).

From July 2004 through June 2005, the NMFS-Southeast Fisheries Science Center (SEFSC) in Beaufort, NC, aerially surveyed the area of southwestern Pamlico Sound encompassed by the restricted airspace R-5306A. The NMFS-SEFSC conducted 23 aerial surveys of the water beneath the restricted airspace, during which time no dolphins were observed near BT-9 or BT-11, although a total of 296 bottlenose dolphins were observed in the waters under the restricted airspace (Goodman *et al*. 2004, 2005a, 2005b, 2005c).

### 4.1.2 Northern Migratory Coastal Stock

Among the coastal stocks, the migratory movements and spatial distribution of the Northern Migratory stock are the best understood (based on aerial survey data, tag-telemetry studies, photo-ID data and genetic studies). During summer months (July-September), this stock occupies coastal waters from the shoreline to approximately the 25-m isobaths between the Chesapeake Bay mouth and Long Island (CETAP 1982; Kenney 1990; Garrison *et al*. 2003).

During winter months (January-March), the stock moves south to waters of North Carolina and occupies coastal waters from Cape Lookout, NC to the North Carolina/Virginia border (NMFS 2001).

During summer months, the degree of overlap between the Northern Migratory and the Southern Migratory stocks in coastal waters of northern North Carolina and Virginia is unknown. During winter months, the stock spatially overlaps with the NNCES stock. These complex seasonal spatial movements and the overlap of coastal and estuarine stocks in the waters of North Carolina greatly limit the ability to fully assess the mortality of each of these stocks (Waring *et al*. 2011). According to the NMFS U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2010, the abundance estimate for the Northern Migratory stock is 9,604 and the minimum population estimate is 7,147 (Waring *et al*. 2011).

### 4.1.3 Southern Migratory Coastal Stock

Of the coastal stocks, the migratory movements and spatial distribution of the Southern Migratory stock are most poorly understood. The limited data available supports the definition of a Southern Migratory stock of coastal morphotype bottlenose dolphins; however, there is a large amount of uncertainty in its spatial movements. The seasonal movements are best described by tag telemetry data. During the fall (October-December), this sock occupies waters of southern North Carolina (South of Cape Lookout) where it overlaps spatially with the SNCES stock in coastal waters. In winter months (January-March), the Southern Migratory stock moves as far south as northern Florida where it overlaps spatially with the South Carolina/Georgia and Northern Florida Coastal stocks. In spring (April-June), the stock moves north to waters of North Carolina where it overlaps with the SNCES stock and the NNCES stock. In summer months (July-September), the stock is presumed to occupy coastal waters north of Cape Lookout, NC, to the eastern shore of Virginia. It is possible that these animals also occur inside the Chesapeake Bay and in nearshore coastal waters where there is evidence that NNCES stock animals also occur (Waring *et al* 2011).

Genetic analyses (Rosel *et al*. 2009) and tagging studies demonstrate that the Northern Migratory stock is distinct from the potential Southern Migratory stock. Yet there is limited capability to demonstrate genetic differentiation of the Southern Migratory stock from other coastal and estuarine bottlenose dolphin stocks because the Southern Migratory stock overlaps spatially with at least one other stock of bottlenose dolphins throughout the year (Waring *et al*. 2011).

The NMFS abundance estimate for the Southern Migratory stock is 12,482 and the minimum population estimate is 9,591 (Waring *et al*. 2011).

### 4.1.4 Northern North Carolina Estuarine System Stock

The Northern North Carolina Estuarine System stock is defined as animals that occupy estuarine waters of Pamlico Sound during summer months (July-August) (Waring *et al*. 2011). The estuarine waters of Pamlico Sound had previously been included in the abundance estimates and stock assessment reports for the Northern Migratory stock and the winter "mixed" North Carolina management unit of coastal bottlenose dolphins (Waring *et al*. 2007). Now they are recognized as a distinct stock based upon these differences in seasonal ranging patterns and stable isotope signatures (Waring *et al*. 2011).

During summer and fall months (July-October), the NNCES stock occupies waters of Pamlico Sound and nearshore coastal and estuarine waters of northern North Carolina to Virginia Beach. It likely overlaps with animals from the Southern Migratory stock in coastal waters during this period. In late fall and winter (November-March), the NNCES stock moves out of estuarine waters and occupies nearshore coastal waters between the New River and Cape Hatteras. The NNCES stock overlaps with the Northern Migratory stock during this period, particularly between Cape Lookout and Cape Hatteras. It appears that the region near Cape Lookout, NC, including Bogue Sound and Core Sound, is an area of overlap with the SNCES stock in late summer (Waring *et al*. 2011).

Read *et al*. (2003a) provided the only available abundance estimate of bottlenose dolphins that occur within the estuarine portion of the NNCES stock range (919 animals). The NMFS 2010 population estimate is 1,387, and the minimum population estimate is unknown (Waring *et al*. 2011).

### 4.1.5 Southern North Carolina Estuarine System Stock

The Southern North Carolina Estuarine System stock is defined as animals occupying estuarine and nearshore coastal waters between the North Carolina/South Carolina border and the New River during winter months, and that do not undertake large-scale migratory movements (Waring *et al*. 2011). In prior stock assessment reports, the animals within this region were referred to as the "Southern North Carolina" coastal stock during summer months, and were part of the winter "mixed" North Carolina management unit of coastal bottlenose dolphins (Waring *et al*. 2009). They are now recognized as a distinct stock based upon differences in seasonal ranging patterns and genetic analysis (Waring *et al*. 2011).

During summer and fall months (July-October), the SNCES stock occupies estuarine and nearshore coastal waters (<3km from shore) between the North Carolina/South Carolina border and Core Sound. The stock likely overlaps with the NNCES stock in the northern portion of its range during late summer. From late fall through spring, the SNCES stock moves south to waters near Cape Fear. In coastal waters, it overlaps with the Southern Migratory stock during this period (Waring *et al*. 2011).

According to the 2010 NMFS stock assessment, the estimated abundance of the SNCES stock is 2,454; however, they acknowledge that this is an underestimate of total abundance because the data excludes estuarine waters (Waring *et al*. 2011). The 2010 minimum population estimate is 1,614.

### 4.1.6 Density Estimates at the MCAS Cherry Point Range Complex

Aerial surveys conducted specifically for dolphins and turtles were flown in Pamlico and Core sounds from July 2004 to April 2006 (Goodman *et al*. 2007). From these surveys, Goodman *et al*. (2007) created density estimates for bottlenose dolphins in the western portion of Pamlico Sound (including the MCAS Cherry Point Range Complex) ranging from 0.0272/km$^2$ (0.0105/mi$^2$) in winter to 0.2158/km$^2$ (0.0833/mi$^2$) in autumn. Researchers noted animal counts from aerial surveys would likely be lower than counts from boat-based surveys because during aerial surveys there is a shorter amount of time for observers to make sightings, which would likely result in underestimated densities (Goodman *et al*. 2007). Accordingly, Goodman *et al*.

incorporated correction factors for both animals residing at the surface but not sighted during the aerial survey and animals below the surface that were not sighted.

A "mark-and-sight" survey was conducted in the estuaries, bays and sounds of North Carolina by Read *et al*. (2003a) in summer 2000, which yielded a density of 0.183/km$^2$ (0.071/mi$^2$) (based on an estimate of 919 dolphins for the northern inshore waters divided by an estimated 5,015 km$^2$ [1,936 mi$^2$] survey area) for dolphins in North Carolina's inland waters. Although this density estimate is slightly lower than the highest density estimate from Goodman *et al*. (2007), it is likely more precise and incorporates less bias than estimates derived from aerial surveys and is therefore a more conservative and applicable estimate. Although the surveys by Read *et al*. were only conducted in the summer, there is a resident population in Pamlico Sound that does not likely leave the area; therefore, this density estimate can be applied year-round to the entire MCAS Cherry Point Range Complex.

### 4.1.7 Dive Behavior

Researchers have recorded bottlenose dolphin dive durations lasting as long as 15 minutes for trained individuals (Ridgway *et al*. 1969); however, typical dives are often shallow and of shorter duration. Mean dive durations of bottlenose dolphins typically range from 20 to 40 seconds at shallow depths (Mate *et al*. 1995) and may last longer than five minutes during deep offshore dives (Klatsky *et al*. 2005). Offshore bottlenose dolphins regularly dive to 450 m (1,476 ft) and may potentially dive as deep as 700 m (2,297 ft) (Klatsky *et al*. 2005). Dive behavior of bottlenose dolphins may correlate with the 24-hour cycle of day and night, or diel cycle (Mate *et al*. 1995; Klatsky *et al*. 2005); this may be especially true for offshore stocks, which dive deeper and more frequently at night to feed at the deep scattering layer (Klatsky *et al*. 2005).

### 4.1.8 Sound Production and Hearing

Sounds emitted by bottlenose dolphins have been classified into two broad categories: (1) pulsed sounds, including clicks and burst-pulses; and (2) narrow-band, continuous sounds like whistles, which usually are frequency modulated. Clicks have a dominant frequency range of 110 to 130 kiloHertz (kHz) and a source level of 218 to 228 decibels referenced to 1 microPascal at 1 meter (dB re 1 µPa-m) peak-to-peak (Au 1993) and 3.4 to 14.5 kHz and 125-173 dB re 1 µPa-m peak-to-peak, respectively (Ketten 1998). Whistles are primarily associated with communication and can serve to identify specific individuals (i.e., signature whistles) (Caldwell and Caldwell 1965; Janik *et al*. 2006). Up to 52 percent of whistles produced by bottlenose dolphin groups with mother-calf pairs can be classified as signature whistles (Cook *et al*. 2004).

Sound production is also influenced by group type (single or multiple individuals), habitat, and behavior (Nowacek 2005). Bray calls (low frequency vocalizations; majority of energy below 4kHz), for example, are used when capturing fish in some regions (i.e., Moray Firth, Scotland) (Janik 2000). Additionally, whistle production has been observed to increase while feeding (Acevedo-Gutiérrez and Stienessen 2004; Cook *et al*. 2004). Furthermore, both whistles and clicks have been demonstrated to vary geographically in terms of overall vocal activity, group size, and specific context (e.g., feeding, milling, traveling, socializing) (Jones and Sayigh 2002; Zaretsky *et al*. 2005; Baron 2006). For example, preliminary research indicates that characteristics of whistles from populations in the northern Gulf of Mexico significantly differ in frequency and duration from those in the western North Atlantic (Zaretsky *et al*. 2005; Baron 2006).

Bottlenose dolphins can typically hear within a broad frequency range of 0.04 to 160 kHz (Au 1993; Turl 1993). Electrophysiological experiments suggest that the bottlenose dolphin brain has a dual analysis system—one specialized for ultrasonic clicks and another for lower frequency sounds (e.g., whistles) (Ridgway 2000). Scientists have reported a range of highest sensitivity between 25 and 70 kHz, with peaks in sensitivity at 25 and 50 kHz (Nachtigall *et al*. 2000). Recent research on the same individuals indicates that auditory thresholds obtained by electrophysiological methods correlate well with those obtained in behavior studies, except at some lower (10 kHz) and higher (80-100 kHz) frequencies (Finneran and Houser 2006).

Temporary threshold shifts (TTS) in hearing have been experimentally induced in captive bottlenose dolphins using a variety of noises (i.e., broad band, pulses) (Ridgway *et al*. 1997; Schlundt *et al*. 2000; Nachtigall *et al*. 2003; Finneran *et al*. 2005; Mooney *et al*. 2005; Mooney 2006). For example, TTS has been induced with exposure to a 3 kHz, one-second pulse with sound exposure level of 195 decibels referenced to 1 microPascal squared per second (dB re 1 $\mu PA^2$-s) (Finneran *et al*. 2005), one-second pulses from 3 to 20 kHz at 192-201 dB re 1 µPA-m (Schlundt *et al*. 2000), and octave band noise (4-11 kHz) for 50 minutes at 17 dB re 1 µPA-m (Nachtigall *et al*. 2003). Preliminary research indicates that TTS and recovery after noise exposure are frequency dependent, and that an inverse relationship exists between exposure time and sound pressure level associated with exposure (Mooney *et al*. 2005; Mooney 2006). Observed changes in behavior were induced with an exposure to a 75 kHz one-second pulse at 178 dB re 1 µPA-m (Ridgway *et al* 1997; Schlundt *et al*. 2000). Finneran *et al*. (2005) concluded that a sound exposure level of 195 dB re 1 $\mu PA^2$-s is a reasonable threshold for the onset of TTS in bottlenose dolphins exposed to mid-frequency tones.

## 4.2 WEST INDIAN MANATEE (*TRICHECHUS MANATUS*)

West Indian manatees are massive, fusiform-shaped animals with skin that is uniformly dark grey, wrinkled, sparsely haired, and rubber-like. Manatees possess paddle-like forelimbs, no hind limbs, and a rounded, horizontally flattened tail. The animals' backs are often covered with distinctive scars resulting from collisions with boat propellers (Moore 1956). Adults average about 3.0 m (9.8 ft) in length and 1,000 kg (2,200 lbs) in weight, but may reach lengths of up to 4.6 m (15 ft) (Gunter 1941) and weigh as much as 1,620 kg (3,570 lbs) (Rathbun *et al*. 1990). The nostrils, located on the upper snout, open and close by means of valves as the animals surface and dive (Husar 1977; Hartman 1979). A muscular, flexible upper lip is used with the forelimbs to manipulate food into the mouth (Odell 1982). Bristles are located on the upper and lower lip pads. The eyes are very small, close with sphincter action, and are equipped with inner membranes that can be drawn across the eyeball for protection. Externally, the ears are minute with no pinnae. Internally, the ear structure suggests that they can hear sound within a relatively narrow low-frequency range, that their hearing is not acute, and that they have difficulty in localizing sound (Ketten *et al*. 1992). This indirect "structured" evidence is not entirely concordant with actual electrophysiological measurements, as discussed below.

West Indian manatees produce a variety of squeak-like sounds that have a typical frequency range of 0.6 to 12 kHz (dominant frequency range from 2 to 5 kHz), and last 0.25 to 0.5 s (Steel and Morris 1982; Thomson and Richardson 1995; Niezrecki *et al*. 2003). Vocalizations below 0.1 kHz have also been recorded (Frisch and Frisch 2003; Frisch 2006). Overall, West Indian manatee vocalizations are considered relatively stereotypic, with little variation between the

isolated populations examined (i.e., Florida and Belize) (Nowacek *et al*. 2003). However, vocalizations have been shown to possess nonlinear dynamic characteristics (e.g., subharmonics or abrupt, unpredictable transitions between frequencies). These characteristics could aid in individual recognition and mother-calf communication (Mann *et al*. 2006). Average source levels for vocalizations have been calculated to range from 90 to 138 decibels with reference pressure of 1 microPascal (dB re 1 µPa) (average 100-112 dB re 1 µPa) (Nowacek *et al*. 2003; Phillips *et al*. 2004). Behavioral data on two animals indicate an underwater hearing range of approximately 0.4-46 kHz, with best sensitivity between 16 and 18 kHz (Gerstein *et al*. 1999), while earlier electrophysiological studies indicated best sensitivity from 1 to 1.5 kHz (Bullock *et al*. 1982).

West Indian manatees occur in the warm, subtropical and tropical waters of the western North Atlantic Ocean, from the southeastern United States to Central America and the West Indies (Lefebvre *et al*. 2001). West Indian manatees occur along both the Atlantic and Gulf coasts of Florida, and are sometimes reported in the Florida Keys (Moore 1951a, 1951b; Beck 2006). Based on telemetry, aerial surveys, photo-ID records, and other studies, manatee distribution in the southeastern United States is well known (Marine Mammal Commission 1984, 1986; Beeler and O'Shea 1988; O'Shea 1988; Lefebvre *et al*. 2001). In general, the data show that manatees exhibit opportunistic and predictable patterns in their distribution and movement. They are able to undertake extensive north-south migrations with seasonal distribution determined by water temperature.

When ambient water temperatures drop below 20°C (68°F) in autumn and winter, manatees aggregate within the confines of natural and artificial warm-water refuges (Lefebvre *et al*. 2001) or move to the southern tip of Florida (Snow 1991). The northernmost natural warm-water refuge used regularly is at Crystal River on the west coast and at Blue Springs in the St. Johns River on the east coast. Most manatees return to the same warm-water refuges each year; however, some use different refuges in different years and other use two or more refuges in the same winter (Reid and Rathbun 1984, 1986; Rathbun *et al*. 1990; Reid *et al*. 1991; Reid *et al*. 1995).

As water temperatures rise, manatees disperse from winter aggregation areas. While some remain near their winter refuges, others undertake extensive travels along the coast and far up rivers and canals (USFWS 2001b). On the east coast, summer sightings drop off rapidly north of Georgia (Lefebvre *et al*. 2001) and are rare north of Cape Hatteras (Rathbun *et al*. 1982; Schwartz 1995); the northernmost sighting is from Rhode Island (Reid 1996). The first recorded sightings of manatees in North Carolina waters occurred in 1919 and have been intermittently observed there since (Schwartz 1995). Most reported sightings in the inshore waters of North Carolina occur during the summer months, but sightings have been reported from June through October (DoN 2003; North Carolina Natural Heritage Program 2010). Manatees have not been observed in the vicinity of the BTs in Pamlico County, NC, in the past 20 years, but they are known to occur in the waters of Carteret County, NC (North Carolina Natural Heritage Program 2010). On 13 August 2002, the BT-11 range operators sighted a manatee in the canal directly adjacent to the range complex.

During summer, manatees may be found where water depths and access channels are greater than 1 to 2 m (3.3.-6.6 ft) (O'Shea 1988). Manatees can also be found in very shallow water.

Hartman (1979) observed manatees utilizing waters as shallow as 0.4 m with their backs out of the water. In warm seasons they usually occur alone or in pairs, although interacting groups of five to ten animals are not unusual.

Shallow grass beds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats. Manatees often use secluded canals, creeks, embayments, and lagoons, particularly near the mouths of coastal rivers and sloughs, for feeding, resting, cavorting, mating and calving (Marine Mammal Commission 1986, 1988). In estuarine and brackish areas, natural and artificial freshwater sources are sought by manatees. As in winter, manatees often use the same summer habitats year after year (Reid *et al*. 1991; Koelsch 1997).

Manatees are herbivores that opportunistically feed on a wide variety of submerged, floating, and emergent vegetation. Because of their broad distribution and migratory patterns, Florida manatees utilize a wider diversity of food items and are possibly less specialized in their feeding strategies than manatees in tropical regions (Lefebvre *et al*. 2000). Seagrasses appear to be a staple of the manatee diet in coastal areas (Ledder 1986; Lefebvre *et al*. 2000; Provancha and Hall 1991; Kadel and Patton 1992; Koelsch 1997). Manatees have a preference for manatee grass (*Syringodium filiforme*) and shoalgrass (*Halodule wrightii*) over the macroalga *Caulerpa* spp.; however, along the Florida-Georgia border, manatees feed in salt marshes on smooth cordgrass (*Spartina alterniflora*) (Baugh *et al*. 1989; Provancha and Hall 1991; Zoodsma 1991).

West Indian manatees are classified as *endangered* under the ESA and afforded additional protection under the MMPA. A species may be considered *endangered* if it is in danger of extinction throughout all or a significant portion of its range. The U.S. Fish and Wildlife Service (USFWS) developed the initial recovery plan for the West Indian manatee in 1980. That plan focused primarily on manatees in Florida, but included Antillean manatees in Puerto Rico and the U.S. Virgin Islands (USFWS 2001a). In 1986, the USFWS adopted a separate recovery plan for manatees in Puerto Rico, and in 1989 they revised the original plan to focus specifically on Florida manatees (USFWS 2001a). The current plan was last updated in 2001.

Florida's West Indian manatee minimum population size is assessed by aerial survey during winter months when manatees are concentrated in warm-water refuges. Aerial surveys conducted in 2011 by the Florida Wildlife Research Institute (FWRI) produced a minimum abundance estimate of 4,834 individuals (FWRI 2011). Along Florida's Gulf Coast, observers counted 2,402 manatees, while observers on the Atlantic coast counted 2,432 (FWRI 2011). The 2001 recovery plan divided Florida's West Indian manatee population into four relatively discrete management units, or subpopulations. These subpopulations each represent a significant portion of the species' range (USFWS 2001b). Manatees found along the U.S. Atlantic coast are of the Atlantic subpopulation (USFWS 2001b). The other three subpopulations in Florida are the Upper St. Johns River, Northwest, and Southwest.

Because the West Indian manatee occurs so rarely in North Carolina waters, no density estimate can be derived for this species in Pamlico Sound.

# 5. TAKE AUTHORIZATION REQUESTED

A Letter of Authorization for the taking of marine mammals is requested pursuant to § 101 (a)(5)(A) [16 U.S.C. § 1371 (a)(5)(A)] of the MMPA. The request is for a 5-year period commencing upon issuance of the permit. The term *take*, as defined in § 3 (16 U.S.C. § 1362) of the Marine Mammal Protection Act [16 U.S.C. § 1361 to 1423h], means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." *Harassment* was further defined in the 1994 amendments to the MMPA, which provide two levels of harassment, Level A (potential injury) and Level B (potential disturbance) [16 U.S.C. § 1362 (18)(A); MMPA § 3 (18)(A)].

The National Defense Authorization Act of Fiscal Year 2004 (Public Law 108-136) amended the definition of harassment as applied to military readiness activities or scientific research activities conducted by or on behalf of the federal government, consistent with § 104(c)(3) [16 U.S.C. § 1374 (c)(3)]. In the case of a military readiness activity[1], such as the activities described in this request, the term *harassment* means:

> (i) Any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A harassment]; or
> (ii) Any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B harassment].

The MMPA provides for "incidental take" authorizations for maritime activities, provided that the NMFS found takings would be of small numbers and have no more than "negligible impact[2]" on marine mammals stocks or populations, and not having an "unmitigable adverse impact" on subsistence harvests of these species. These "incidental take" authorizations, also known as Letters of Authorization, require that the Secretary of Commerce promulgate and publish in the Federal Register regulations outlining:

> (1) Permissible methods and specified geographical region of taking;
> (2) The means of affecting the least practicable adverse impact on the species or stock[3] and its habitat, and on the availability of the species or stock for subsistence uses; and
> (3) Requirements for monitoring and reporting, including requirements for the independent peer-review of proposed monitoring plans where the proposed

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[1] The Fiscal Year 2004 National Defense Authorization Act adopted the definition of *military readiness activity* as set forth in Fiscal Year 2003 National Defense Authorization Act (Public Law 107-314). Public Law 107-314 §315(f) defined the term *military readiness activity* to include all training and operations of the Armed Forces that relate to combat; and the adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability of use.

[2] The NMFS defines *negligible impact* as an impact that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival (50 CFR 216.103).

[3] For a military readiness activity, a determination of "least practicable adverse impact on such species or stock" shall include consideration of personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity. The Secretary of Commerce shall consult with the Department of Defense on these matters.

activity may affect the availability of a species or stock for taking for subsistence uses.

Actions involving sound in the water include the potential to harass marine animals in the surrounding waters. Most LOAs to date have involved the incidental harassment of marine mammals by noise. The NMFS identifies the following activities as those with the greatest potential to harass marine mammals by noise: seismic air guns, ship and aircraft noise, high energy sonar, and explosive detonations.

Modeling results from explosive ordnance use at Brant Island (BT-9) predict MMPA – Level B exposure for up to 59 common bottlenose dolphins, and MMPA – Level A and mortality exposure for up to 1 animal. Modeling results for direct strike by ordnance at Piney Island (BT-11) and BT-9 predict a risk of mortality for up to 1 common bottlenose dolphin, and no MMPA – Level A or Level B exposures. There are no predicted harassment exposures for small boat maneuvers within the MCAS Cherry Point Range Complex. A summary of model results is displayed in Table 5-1. These estimates do not take into account the mitigation measures in Section 9. Given the implementation of those measures, the actual exposures would likely be lower than the anticipated amount.

*Table 5-1: Predicted levels of potential take resulting from military readiness activities at BT-9 and BT-11, annually.*

| Activity | Level B (Behavioral + TTS) | Level A | Mortality |
|---|---|---|---|
| Explosive Ordnance Deployment | 58.6516647 | 0.77743929 | 0.08089688 |
| Direct Strike by Inert and Explosive Ordnance Deployment | 0 | 0 | 0.360921183 |
| Small Boat Maneuvers | 0 | 0 | 0 |

# 6. IMPACTS OF ACTIVITIES ON MARINE MAMMALS

## 6.1 ESTIMATING MARINE MAMMAL HARASSMENT FROM EXPLOSIVE ORDNANCE

### 6.1.1 Development of Criteria for Impact

For explosions of ordnance planned for use at the MCAS Cherry Point Range Complex, in the absence of any mitigation or monitoring measures, there is a very small chance that a marine mammal could be injured or killed when exposed to the energy generated from an explosive force. Analysis of noise impacts is based on criteria and thresholds initially presented in Final Environmental Impact Statements (FEISs) for ship shock trials of the Seawolf submarine and the *Winston S. Churchill* (DDG 81), and subsequently adopted by the NMFS (DoN 1998, 2001; NOAA 1998).

Non-lethal injurious impacts (Level A harassment) are defined in those documents as tympanic membrane (TM) rupture and the onset of slight lung injury. The threshold for Level A harassment corresponds to a 50-percent rate of TM rupture, which can be stated in terms of an energy flux density (EFD) value of 205 dB re 1 $\mu Pa^2$-s. TM rupture is well-correlated with permanent hearing impairment. Ketten (1998) indicates a 30-percent incidence of permanent threshold shift (PTS) at the same threshold.

The criteria for onset of slight lung injury were established using partial impulse because the impulse of an underwater blast wave was the parameter that governed damage during a study using mammals, not peak pressure or energy (Yelverton 1981). Goertner (1982) determined a way to calculate impulse values for injury at greater depths, known as the Goertner "modified" impulse pressure. Those values are valid only near the surface because as hydrostatic pressure increases with depth, organs like the lung, filled with air, compress. Therefore the "modified" impulse pressure thresholds vary from the shallow depth starting point as a function of depth.

The shallow depth starting points for calculation of the "modified" impulse pressures are mass-dependent values derived from empirical data for underwater blast injury (Yelverton 1981). During the calculations, the lowest impulse and body mass for which slight, and then extensive, lung injury found during a previous study were used to determine the positive impulse that may cause lung injury. The Goertner model is sensitive to mammal weight such that smaller masses have lower thresholds for positive impulse so injury and harassment will be predicted at greater distances from the source for them. Impulse thresholds of 13.0 and 31.0 psi-ms, found to cause slight and extensive injury in a dolphin calf, were used as thresholds in the analysis contained in this document.

Level B (non-injurious) harassment includes temporary (auditory) threshold shift (TTS), a slight, recoverable loss of hearing sensitivity. One criterion used for TTS, the total energy flux density of the signal, is a threshold of 182 dB re 1 $\mu Pa^2$-s maximum EFD level in any 1/3-octave (OTO) band above 100 Hertz (Hz) for toothed whales (e.g., dolphins). A second criterion, a maximum allowable peak pressure of 23 psi, has recently been established by the NMFS to provide a more conservative range for TTS when the explosive or animal approaches the sea surface, in which case explosive energy is reduced, but the peak pressure is not. The NMFS applies the more conservative of these two.

For multiple successive explosions, the acoustic criterion for non-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. The non-TTS threshold is derived following the approach of the *Churchill* FEIS for the energy-based TTS threshold. The research on pure-tone exposures reported in Schlundt *et al*. (2000) and Finneran and Schlundt (2004) provided a threshold of 192 dB re 1 $\mu Pa^2$-s as the lowest TTS value. This value for pure-tone exposures is modified for explosives by (a) interpreting it as an energy metric, (b) reducing it by 10 decibels (dB) to account for the time constant of the mammal ear, and (c) measuring the energy in OTO bands, the natural filter band of the ear. The resulting TTS threshold for explosives is 182 dB re 1 $\mu Pa^2$-s in any OTO band. As reported by Schlundt *et al*. (2000) and Finneran and Schlundt (2004), instances of altered behavior in the pure-tone research generally began five dB lower than those causing TTS. The non-TTS threshold is therefore derived by subtracting 5 dB from the 182 dB re 1 $\mu Pa^2$-s in any OTO band threshold, resulting in a 177 dB re 1 $\mu Pa^2$-s (SEL) non-TTS behavioral disturbance threshold for multiple explosions.

*Table 6-1: Explosives threshold levels.*

| Effect | Threshold Type | Threshold Level | MMPA Harassment Level |
|---|---|---|---|
| Onset Mortality | 1% Mortal lung injury (positive impulse) | 31 psi-ms | Mortality |
| Injurious Physiological | 50% TM rupture | 205 dB re 1 $\mu Pa^2$-s | Level A |
| | Slight lung injury (positive impulse) | 13 psi-ms | Level A |
| Non-injurious Physiological | TTS (peak OTO energy) | 182 dB re 1 $\mu Pa^2$-s | Level B |
| | TTS (peak pressure) | 23 psi | Level B |
| Non-injurious Behavioral | Non-TTS threshold for multiple successive explosions (peak OTO energy) | 177 dB re 1 $\mu Pa^2$-s | Level B |

Level A harassment criteria and thresholds under the MMPA are appropriate to apply as *harm* criteria and thresholds under the ESA. Analysis that predicts MMPA – Level A harassment will occur as a result of the proposed action would correspond to harm under the ESA. Level B harassment criteria and thresholds under the MMPA are appropriate to apply as harassment criteria and thresholds under the ESA.

*Harm* defined under ESA regulations is "…an act which actually kills or injures…" listed species (50 CFR 222.102). *Harassment* is an "intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering" (50 CFR 17.3).

### 6.1.2 Explosive Acoustic Sources

#### *Acoustic Characteristics of Explosives*

The acoustic sources employed at the MCAS Cherry Point BT-9 target area are categorized as broadband explosives. Broadband explosives produce significant acoustic energy across several frequency decades of bandwidth. Propagation loss is sufficiently sensitive to frequency as to require model estimates at several frequencies over such a wide band. Explosives are impulsive

sources that produce a shock wave, which dictates additional pressure-related metrics (i.e., peak pressure and positive impulse).

Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. Three source parameters influence the effect of an explosive: the weight of the explosive material, the type of explosive material, and the detonation depth. The net explosive weight accounts for the first two parameters. NEW is a metric used to describe an explosive; the NEW is the weight of TNT required to produce an equivalent explosive power.

The detonation depth of an explosive is particularly important due to a propagation effect known as surface-image interference. For acoustic sources located near the sea surface, a distinct interference pattern arises from the coherent sum of the two paths that differ only by a single reflection from the pressure-release surface. As the source depth and/or the source frequency decreases, these two paths increasingly, destructively interfere with each other, reaching total cancellation at the surface (barring surface-reflection scattering loss).

For the BT-9 in-water target, the following types of ordnance were modeled: Bomb (GBU, BDU, MK), Hellfire Missile, 2.75-in Rocket HE, 5-in Rocket HE, TOW Missile, G911 Grenades, 30 mm HE, and 40 mm HE.

### *Animal Harassment Effects of Explosive Acoustic Sources*

The harassments expected to result from explosive acoustic sources are computed on a per in-water explosive basis; to estimate the number of harassments for multiple explosives, consider the following. Let A represent the impact area (i.e., the area in which the chosen metric exceeds the threshold) for a single explosive. The cumulative effect of a series of explosives is then dictated by the spacing of the explosives relative to the movement of the marine wildlife. If the detonations are spaced widely in time or space, allowing for sufficient animal movements as to ensure a different population of animals is considered for each detonation, the cumulative impact area of N explosives is merely NA regardless of the metric. This leads to a worst case estimate of harassments and is the method used in this analysis.

At the other extreme is the case where the detonations occur at essentially the same time and location (but not close enough to require the source emissions to be coherently summed). In this case, the pressure metrics (peak pressure and positive impulse) are constant regardless of the number of detonations spaced closely in time, while the energy metrics increase at a rate of $N^{1/2}$ (under spherical spreading loss only) or less.

The firing sequence for some of the munitions consists of a number of rapid bursts, often lasting a second or less. Due to the tight spacing in time, each burst can be treated as a single detonation. For the energy metrics the impact area of a burst is computed using a source energy spectrum that is the source spectrum for a single detonation scaled by the number of rounds in a burst. For the pressure metrics, the impact area for a burst is the same as the impact area of a single round. For all metrics, the cumulative impact area of an event consisting of N bursts is merely the product of the impact area of a single burst and the number of bursts, as would be the case if the bursts are sufficiently spaced in time or location as to insure that each burst is affecting a different set of marine wildlife.

All explosives are modeled as detonating at a 1.2-meter depth. This depth is the same depth used for the 2009 MCAS Cherry Point MMPA compliance report. The NEW for these sources are provided in Table 6-2. Included in this table are the peak OTO source level (SL) and the approximate frequency at which the peak occurs.

*Table 6-2: Source weights and peak source levels.*

| Source Type | NEW (lbs) | Peak OTO SL (dB) | Center Frequency of Peak OTO (Hz) |
|---|---|---|---|
| Bomb (GDU, BDU, MK) | 100 | 237 | 635 |
| Hellfire Missile | 34.4 | 232 | 800 |
| 5-in Rocket | 15.0 | 229 | 1008 |
| TOW Missile | 13.6 | 228 | 1008 |
| 2.75-in Rocket | 4.8 | 224 | 1270 |
| G911 Grenade | 0.5 | 214 | 2540 |
| 40 mm-HE(I) | 0.1199 | 208 | 4032 |
| 30 mm-HE(I) | 0.1019 | 207 | 4032 |

For sources that are detonated at shallow depths, it is frequently the case that the explosion may breech the surface with some of the acoustic energy escaping the water column. The source levels presented in the table above have not been adjusted for possible venting nor does the subsequent analysis attempt to take this into account. However, for the source weights and depths involved this is not a significant over-simplification.

### 6.1.3 Environmental Characterization

#### *Important Environmental Parameters for Estimating Animal Harassment*

Propagation loss ultimately determines the extent of the Zone of Influence (ZOI) for a particular acoustic source activity. In turn, propagation loss as a function of range depends on a number of environmental parameters, including:

- Water depth,
- Sound speed variability throughout the water column,
- Bottom geo-acoustic properties, and
- Surface roughness, as determined by wind speed.

Due to the importance that propagation loss plays in Anti-Submarine Warfare, the Navy has invested heavily in measuring and modeling these environmental parameters. The result of this effort is a collection of global databases containing these environmental parameters, which are accepted as standards for Navy modeling efforts. Table 6-3 contains the version of the databases used in the modeling for this report.

*Table 6-3: Navy standard databases used in modeling.*

| Parameter | Database | Version |
|---|---|---|
| Water Depth | Digital Bathymetry Data Base Variable Resolution | DBDBVR 6.0 |
| Sound Speed | Generalized Digital Environmental Model | GDEM 3.0 |
| Bottom Loss <1500 Hz | Low-Frequency Bottom Loss Database with Sediment Thickness | LFBL 11.1 |
| Bottom Loss > 1000 Hz | High-Frequency Bottom Loss Database | HFBL 2.2 |
| Ocean Sediment | Re-packed Bottom Sediment Type | BST 2.0 |
| Wind Speed | Surface Marine Gridded Climatology Database | SMGC 2.0 |

The sound speed profile directs the sound propagation in the water column. The spatial variability of the sound speed field is generally small over operating areas of typical size. The presence of a strong oceanographic front is a noteworthy exception to this rule. To a lesser extent, variability in the depth and strength of a surface duct can be of some importance. If the sound speed minimum occurs within the water column, more sound energy can travel further without suffering as much loss (ducted propagation). But if the sound speed minimum occurs at the surface or bottom, the propagating sound interacts more with these boundaries and may become attenuated more quickly. In the mid-latitudes, seasonal variation often provides the most significant variation in the sound speed field. For this reason, both summer and winter profiles are modeled to demonstrate the extent of the difference.

Losses of propagating sound energy occur at the boundaries. The water-sediment boundary defined by the bathymetry can vary by a large amount. In a deep water environment, the interaction with the bottom may matter very little. In a shallow water environment the opposite is true and the properties of the sediment become very important. The sound propagates through the sediment, as well as being reflected by the interface. Soft (low density) sediment behaves more like water and the sound has relatively more transmission and relatively less reflection than a hard (high density) bottom or thin sediment.

The roughness of the boundary at the water surface depends on the wind speed. Average wind speed can vary seasonally, but could also be the result of local weather. A rough surface scatters the sound energy and increases the transmission loss. Boundary losses affect higher frequency sound energy much more than lower frequencies.

### *Characterizing the Acoustic Marine Environment*

Each environment for modeling impact value is characterized by a fixed water depth, sound velocity profile, and bottom loss type. The bathymetry database is on a grid of variable resolution. In a deep water area, the modeling is done on a grid of depth intervals to capture water depth dependence. In a shallow water area with bathymetric features, the bathymetry values can be averaged over the area of interest.

The sound velocity profile database has a fixed spatial resolution storing temperature and salinity as a function of time and location. The low frequency bottom loss database is organized in provinces with a set of geo-acoustic parameters in each province. The high frequency bottom loss database is globally partitioned into nine classes. The area of interest can be characterized

by the appropriate sound speed profile, set of low frequency bottom loss parameters, and high frequency bottom loss class. If the operating area falls across a province boundary, the modeling environment is partitioned into homogenous regions. Partitioning takes account of the fact that the lower frequency acoustic energy (below about 1,000 Hz) is secondary to the higher frequency acoustic energy.

In addition, seasonal variation is sampled by looking at summer and winter cases. The environmental characteristics affecting acoustic propagation that have seasonal variation are the sound speed profile and the wind speed.

ZOI volumes in the operating area are then computed using propagation loss estimates derived for the representative environment. Finally, a weighted average of the ZOI volumes is taken over all representative environments; the weighting factor is proportional to the geographic area spanned by the environmental province.

#### *Description of the Brant Island (BT-9) Target Environment*

As described in Section 3.1, BT-9 is in an extremely shallow area with a relatively flat bottom of sandy sediment. There is seasonal variation. For modeling efforts, environmental values were extracted from the Navy standard databases in a radius of 9.3 km (5.8 mi) around the center point (35°12’30”N, 76°26’40”W).

The Navy standard database for bathymetry has a resolution of 0.05 minutes in Pamlico Sound. Values for the bathymetry from the DBDBV in the extracted area were found between approximately 1 m and 8 m. A median depth of 5 m (rounded to the nearest meter) was used as the water depth in the modeling.

The sound speed profile in the area of interest is almost constant because of mixing in the shallow water. The Navy standard GDEM database provided a nearly-isospeed profile for the area. Seasonal changes were captured by modeling the propagation with a winter (February) profile of about 1502 meter per second (m/s) and a summer (August) profile of about 1538 m/s. Although the sound speed is isovelocity with less than 1 m/s of change in the water column, the database profile of the top five meters was used, rather than a single number.

In very shallow water, the bottom loss databases tend to revert to a generic sandy bottom. The sources modeled in the BT-9 area generate peak OTO source levels near 1,000 Hz. At that frequency, a sandy bottom tends to be a relatively low-loss bottom. (Note: This may lead to a somewhat conservative [or over-] estimate of the number of takes.)

The seasonal variability in wind speed was modeled as 12.25 knots in the summer and 13.61 knots in the winter.

### 6.1.4 Modeling Impact on Marine Mammals

Many underwater actions include the potential to injure or harass marine animals in the neighboring waters through noise emissions. The number of animals exposed to potential harassment in any such action is dictated by the propagation field and the characteristics of the noise source.

In this analysis, estimating the number of animals that may be injured or otherwise harassed entailed the following steps:

- For the relevant environmental acoustic parameters, transmission loss (TL) estimates were computed, sampling the water column over the appropriate depth and range intervals. TL calculations were also made over non-overlapping, OTO bands for a wide range of frequencies.
- The accumulated energy within the waters where the source is "operating" was sampled over a volumetric grid. At each grid point, the received energy from each source emission was modeled as the effective energy source level reduced by the appropriate propagation loss from the location of the source at the time of the emission to that grid point and summed. For the peak pressure or positive impulse, the appropriate metric was similarly modeled for each emission. The maximum value of that metric, over all emissions, was stored at each grid point.
- The impact volume for a given threshold was estimated by summing the incremental volumes represented by each grid point for which the appropriate metric exceeds that threshold.
- Finally, the number of harassments was estimated as the vector product of the animal density depth profile and the impact volume, and scaled by user-specifiable surface animal densities.

Appendix A describes in detail the process of computing impact volumes.

### 6.1.5 Impacts from Explosive Ordnance

Species densities are usually reported by marine biologists as animals per square kilometer, which is an area metric. This gives an estimate of the number of animals below the surface in a certain area, but does not provide any information about their distribution in depth. The impact volume vector specifies the volume of water ensonified above the specified threshold in each depth interval. A corresponding animal density for each of those depth intervals is required to compute the expected value of the number of exposures. The two-dimensional area densities do not contain this information, so three-dimensional densities must be constructed by using animal depth distributions to extrapolate the density at each depth.

Impact volumes for all depth intervals are scaled by their respective depth densities, divided by their depth interval widths, summed over the entire water column, and finally converted to square kilometers to create impact areas. Since the impact volume vector is the volume of water at or above a given threshold per unit operation (e.g., per detonation, or clusters of munitions explosions), the final harassment count for each animal is the unit operation harassment count multiplied by the number of units deployed.

The detonations of explosive sources are generally widely spaced in time and/or space. This implies that the impact volume for multiple firings can be easily derived by scaling the impact volume for a single detonation. Thus the typical impact volume vector for an explosive source is presented on a per-detonation basis.

Model results predict explosive ordnance use at BT-9 at levels identified in Table 2-3 to produce exposure to sound levels that produce a non-injurious behavioral effect (between 177 and 182 dB

SEL) and TTS (182 dB SEL or 23 psi) for up to 25 and 34 common bottlenose dolphin, respectively. The sum of these two effects results in a prediction of MMPA – Level B harassment for up to 59 dolphins. Predictions for MMPA – Level A harassment and mortality do not exceed one common bottlenose dolphin. Model results are displayed in Table 6-4.

*Table 6-4: Predicted levels of potential take resulting from use of explosive ordnance at BT-9, annually.*

| Activity | Level B (Behavioral + TTS) | Behavioral (Between 177 and 182 dB SEL) | TTS | Level A | Mortality |
|---|---|---|---|---|---|
| Explosive Ordnance Deployment | 58.6516647 | 24.9030858 | 33.7485789 | 0.77743929 | 0.08089688 |

## 6.2 IMPACTS FROM INERT ORDNANCE

The potential threats to marine mammals from inert, or non-explosive, ordnance in the absence of conservation measures are noise and direct strike. Estimates of noise fields generated in the water by the impact of non-explosive ordnance indicate that the energy radiated is about 1 to 2 percent of the total kinetic energy of the impact. This energy level (and likely the peak pressure levels) is well below the impact threshold, even at a 1-m distance from the impact location. Therefore, the noise generated by the in-water impact of inert ordnance will not pose a risk to marine life.

The potential risk of a direct hit to an animal in the target area is estimated to be so low it is discountable. The MCAS Cherry Point Range Air Installation Compatible Use Zone study generated the surface area, or footprints, of weapon impact areas associated with air-to-ground ordnance delivery (USMC 2001b); statistically, a weapon safety footprint describes the area needed to contain 99.99 percent of initial and ricochet impacts at the 95 percent confidence interval for each type of aircraft and the ordnance utilized at the BTs. Therefore, at both BT-9 and BT-11, the probability of deployed ordnance landing in the impact footprint is essentially 1.0. At BT-11 only 36 percent of the weapons footprint is over water, so the likelihood of a weapon striking an animal at that BT is 64 percent less. Water depths in Rattan Bay (the in-water portion of BT-11) range from 0.5 m (1.6 ft) to 3 m (10 ft), meaning that nearly the entire impact footprint in Rattan Bay is suitable for marine mammal use.

The probability of hitting a bottlenose dolphin at the BTs can be derived by:

Probability = dolphin's dorsal surface area x density of dolphins

Example: Probability for BT-9 = 1.425 $m^2$ x 0.183/$km^2$ = 2.61 x $10^{-7}$

The estimate of the dorsal surface area of a bottlenose dolphin is assumed to be 1.425 square meter ($m^2$) (average length 2.85 m and average both width 0.5 m). Thus, using Read *et al.*'s (2003d) density estimates (0.183/$km^2$), the probability of a dolphin being hit in the waters of BT-9 is 2.61 x $10^{-7}$ and of BT-11 is 9.4 x $10^{-8}$. Using the proposed levels of ordnance expenditures,

excluding pyrotechnics, at each in-water BT (Tables 2-3 and 2-4) and taking into account that only 36 percent of ordnance deployed at BT-11 is over water, the estimated potential number of ordnance strikes on a marine mammal per year is estimated as 0.318764259 at BT-9 and 0.042156924 at BT-11 (Table 6-5). Pyrotechnics are not included in these analyses, because these types of ordnance do not strike land/surface with any velocity.

Table 6-5: Estimated potential number of strikes on common bottlenose dolphin from inert ordnance fired at the bombing targets, annually.

| Bombing Target | Estimated Ordnance Levels[1] | Probability of Striking a Dolphin/Ordnance Deployment | Estimated Number of Ordnance Strikes per Year |
|---|---|---|---|
| Brant Island (BT-9) | 1,221,319 | $2.61 \times 10^{-7}$ | 0.318764259 |
| Piney Island (BT-11) | 1,245,772[2] | $9.4 \times 10^{-8}$ | 0.042156924 |

Note: 1. Does not include pyrotechnics. 2. Calculations are based on 36% of this figure, accounting for the fact that only this percentage of ordnance is deployed over water at BT-11.

## 6.3 IMPACTS FROM SMALL BOAT MANEUVERS

The bottlenose dolphin is the most common marine mammal in the MCAS Cherry Point Range Complex. Small boats operating at high speeds have the potential to strike a bottlenose dolphin, though Wells and Scott (1997) note that in the busy boating waters of Sarasota Bay, Florida, bottlenose dolphins suffer few injuries from boat traffic. Still, boat and dolphin collisions can occur. Wells and Scott (1997) have documented a few injuries and note that mothers with calves and unhealthy dolphins may be particularly susceptible to injury by boat as their movements are limited. Wells and Scott (1997) also noted obvious propeller-caused injuries to dolphins in Sarasota Bay during times of high recreational usage and high speed powerboat races, though they did not correlate boat races or a particular boat speed with dolphin injury.

Small military boats operating within the MCAS Cherry Point Range Complex water ranges may travel at speeds up to 74 km per hour (40 knots). It still remains that the bottlenose dolphin is less susceptible to serious injury from vessels because of its swimming speed and its ability to maneuver around moving vessels. Based on the limited number of small boat maneuvers, low concentrations of common bottlenose dolphins, and the low likelihood of serious injury, Level A harassment is unlikely to result from such activity.

Beyond direct vessel strikes, the presence of boats can result in disturbance, causing dolphins to alter their swimming patterns and behaviors. Impacts of such a disturbance are difficult to assess given the affinity this species has to bowride in front of moving vessels. Some researchers have noted changes in behavior of bottlenose dolphins at a distance of 100 m (328 ft) from moving vessels. These alterations include changes in direction, changes in breathing rate, and decreased spacing between dolphins traveling in the same group (Lemon *et al*. 2006). While the effects caused by the presence of small boat maneuvers cannot be directly assessed, there may be a short-term effect on dolphins at the location, but no adverse effect is expected.

The West Indian manatee is susceptible to injury because it is slow moving, and when near the surface or when surfacing to breathe, it may be strike by boats and propellers. Because this

species rarely occurs within the MCAS Cherry Point Range Complex, the likelihood of an encounter with a military small boat is very low.

## 6.4 INDIRECT IMPACTS

Explosive ordnance may have an impact not only on marine mammals but also on other species and the habitat at BT-9. Physical effects associated with pressure waves generated by underwater detonations of explosives might affect fish species within the vicinity of BT-9. In particular, the rapid oscillation between high- and low-pressure peaks has the potential to burst the swim bladders and other gas-containing organs of fishes (Keevin and Hempen 1997). Sub-lethal effects, such as changes in behavior, have been observed on several occasions as a result of noise produced by explosives (Wright 1982; National Resource Council 2003). The abundances of various fish species and invertebrates near the detonation point could be altered for a few hours before repopulation occurs. As a result, a short-term and localized effect on prey availability may be expected in the vicinity of BT-9, but no adverse effect is expected on the trophic regime or ecosystem at BT-9.

The likelihood of any permanent ecosystem impact at BT-11 due to inert ordnance use is extremely unlikely. Effects on habitat are further discussed in Section 8.

# 7. IMPACTS ON SUBSISTENCE USE

None of the marine mammal species discussed in this document is sought for subsistence use in the United States. Therefore, these activities would not effect on the availability of subsistence use species or stocks as identified in MMPA Section 101(a)(5)(A)(i).

# 8. IMPACTS TO MARINE MAMMAL HABITAT AND HABITAT RESTORATION

Potential impacts to marine mammal habitat within the MCAS Cherry Point Range Complex have previously been evaluated during a Section 7 consultation with the NMFS (USMC 2001b) and were determined to be minimal (NMFS 2002). Delivery of explosive and inert ordnance may involve a temporary disturbance to the substrate (sediments) and a subsequent increase in localized turbidity, as may the actions of target replacement or routine equipment/system maintenance.

Natural fluctuations in turbidity are driven by rainfall, wind, tides, and season. It is difficult to predict the amount of disturbance that would occur immediately after ordnance hits the substrate. The amount of sediment disturbance will be influenced by whether or not the ordnance hits the target first before hitting the substrate, as well as the orientation of the ordnance (i.e., whether it lands upright or on its side) upon impact with the sediments (USMC 2001b). The substrates at the bombing target sites are primarily soft sediments such as sand and mud, which should experience only minimal disturbance and quickly resettle. Impacts to the substrate are considered temporary and negligible with no adverse or long-term effects anticipated. Water quality studies of BT-9 and BT-11 compared samples taken directly following ordnance deployment with those taken from control sites, and found that turbidity levels at both sites were low and within North Carolina Division of Water Quality standards (Sirrine Environmental Consultants 1991). Impacts to turbidity caused by ordnance deployment are not likely to disturb the feeding or transiting behavior of bottlenose dolphins in the vicinity of the bombing targets as the species does not depend up vision for either behavior, and as turbidity changes caused by deployment of ordnance is within the range of acceptable levels.

Chemical by-products from use of explosive ordnance during training are considered to have negligible effects here, as they did during the shock trial of the *Winston S. Churchill* (DoN 2001). Initial concentrations of the chemical by-products of ordnance detonations are not hazardous to marine life (O'Keefe and Young 1984; DoN 2001). Water quality parameters at BT-9 and BT-11 are all within the limits set by the North Carolina Water Quality Standards for Saltwater Classifications (for those parameters with standards) (Sirrine Environmental Consultants 1991). Neither elevated aluminum concentrations nor visual signs of chaff were detected in the water or sediment samples from the sampled areas (USMC 2001b).

While debris associated with ordnance delivery occurs at the bombing targets (e.g., parachutes, strands of chaff, ordnance remains), no reports of ingestion of debris have been reported nor have any stranded animals been reported with such contents in their stomachs (MCAS Cherry Point 2009b). It is most likely that ordnance debris will sink to the bottom and become incorporated into the sediments, thus is not likely to be ingested by marine mammals.

Target establishment and maintenance occurs infrequently (i.e., every five years). MCAS Cherry Point personnel are required to ensure that new targets are free of environmental contaminants prior to placing them in the water for use. Small boat operations or target replacement activities may also occasionally result in temporary and infrequent sediment disturbance, resulting in effects on sediments and turbidity similar to those caused by ordnance deployment.

# 9. MITIGATION MEASURES

MCAS Cherry Point incorporates procedures into their operations which help to minimize, or mitigate, the potential adverse effects of activities at the Range Complex on marine mammals (USMC 2001b; NMFS 2002). Protective measures are, and will continue to be, implemented to ensure the least practicable adverse impacts to marine mammals, and in particular common bottlenose dolphins. As discussed in Section 4, bottlenose dolphins in Pamlico Sound, to include the waters of the MCAS Cherry Point Range Complex, prefer habitats close to shore and have most often been sighted in waters with depths less than 2 m (6.6 ft) (Read *et al*. 2003b, 2003c, 2003d). Therefore, most protective measures will be tailored to focus on areas where this species is known to commonly occur. Adherence to protective measures listed below greatly diminishes the potential impacts on marine mammals:

- **Visual Surveys –** Range operators will conduct or direct visual surveys to monitor the target areas for unauthorized civilian vessels or persons and protected species pre- and post-exercise. They will use either (1) real-time passive acoustic monitoring via sonobuoy or hydrophones; (2) active acoustic detection; or (3) remotely operated, high-resolution cameras with night vision capabilities to identify animals at the surface or breaking the surface. A camera system with night vision capability
- **Cold Pass** – Pilots will perform a visual check, known as a *cold pass*, of the target area where they will fly low over the target (no ordnance delivered). The visual check serves to determine the presence or absence of unauthorized civilian vessels or persons and protected species. No ordnance may be delivered during the cold pass. The Range Controller may grant the aircrew a *first hot pass* (use of ordnance) after their visual check (see above) and the cold pass, as conditions warrant.
- **Search and Rescue Aircraft Range Sweeps** – MCAS Cherry Point personnel will conduct search and rescue sweeps with a HH-46D helicopter, known as PEDRO, weekday morning prior to the commencement of the day's range operations. The aircrew aboard PEDRO are trained in search and rescue and are experts at spotting objects in the water. The primary goal of the sweep is to ensure that the bombing target area is clear of unauthorized vessels or persons, but it also includes a visual inspection of the waters for protected species. Sweeps are flown at 30.5 to 91.4 m (100-300 ft) above the surface at speeds of 60 to 100 knots. The helicopter crews can communicate directly with range operators, allowing immediate notification if the target area is not clear.
- **Small Boat Visual Checks** – Operators of small boats will be knowledgeable of marine mammals, protected species, and visual clues related to the presence of marine mammals and protected species. All members of small boat crews shall be required to take the Marine Species Awareness Training maintained and promoted by the Department of the Navy.
- **Closing Targets** – Range operators will declare a target *foul* (i.e., close the target) if a protected species is either sighted within 3,000 ft of the bombing targets or sighted within Rattan Bay (BT-11). Exercises may not recommence until the animal(s) has moved outside of the target area.

Further descriptions of these mitigation activities can be found in the USMC Cherry Point Range Complex Marine Mammal Monitoring and Protected Species Plan (Appendix B) and the real-time acoustic monitoring pre-proposal (Appendix C).

## 9.1 ADDITIONAL MEASURES CONSIDERED

Other mitigation alternatives considered during development of the protective measures but dismissed because of their negative impact to military readiness include:

- **Time or seasonal restrictions** – The MCAS Cherry Point Range Complex operates continuously and the common bottlenose dolphin population in Pamlico Sound is largely resident and the density is presumed constant throughout the year. Therefore, time and seasonal restrictions are of no benefit to the species, and are considered impracticable and unwarranted. Such restrictions would severely compromise training flexibility, which is an important asset to the Marine Corps as squadrons regularly rotate between deployments and training.
- **Visual monitoring by boat or vessel** – Visual monitoring of the impact area by boat or vessel would not be possible due to concerns for personnel safety. Persons or vessels are not permitted within danger zones or impact areas due to safety concerns.

# 10. MONITORING AND REPORTING MEASURES

As described in the previous section, the Marine Corps monitors the bombing targets for marine mammals when the MCAS Cherry Point Range Complex is operating. Range operators keep records of all protected species sightings, to include data on the number of animals, their location, the weather, and other ancillary information. MCAS Cherry Point is implementing an online data registry for marine mammal sighting reporting that employs Microsoft SharePoint as its platform. Range Management officials will use the registry site to input data on marine mammal sightings to include (1) location (either an approximate location or latitude and longitude); (2) the platform that sighted the animal; (3) date and time; (4) species; (5) number of animals; (6) the animals' direction of travel and/or behavior; and (7) weather. Monthly, the Environmental Affairs Department will pull data from the registry to monitor sightings and for data quality control. Data collected in this database will be included in the annual reporting to the National Marine Fisheries Service, as required by NMFS.

Any observation of stranded or injured marine mammals in the vicinity of the MCAS Cherry Point Range Complex will be immediately reported to the NMFS Marine Mammal Stranding Network. MCAS Cherry Point personnel are responsible for ensuring the MCAS Cherry Point Chain of Command and the Marine Corps Installation-East Command are notified of such observations.

# 11. RESEARCH EFFORTS

MCAS Cherry Point has made significant effort to improve the availability of data on the abundance and seasonal distribution of marine mammals in the vicinity of the MCAS Cherry Point Range Complex. Specifically, MCAS Cherry Point has funded surveys performed by Duke University researchers and provided financial support to augment surveys conducted by the NMFS Southeast Fisheries Science Center. Information and knowledge gained from the MCAS Cherry Point-funded research has contributed significantly to the understanding of bottlenose dolphin stocks, including their distribution and movement, in Pamlico Sound, NC.

The following are highlights of research on bottlenose dolphin that was wholly or partially funded by MCAS Cherry Point:

- Duke University researchers performed boat-based sighting surveys that targeted common bottlenose dolphin from July 2002 to July 2003. Their work also involved photo identification of the sighted dolphins, and compilation and cataloguing the IDs (Read *et al*. 2002, 2003b, 2003c, 2003d).
- Researchers with Duke University conducted acoustic monitoring studies of common bottlenose dolphin at BT-9 and BT-11. Since August 2005, two pop-up hydrophone buoys have been deployed for use at BT-9 and one has been deployed for use in Rattan Bay (BT-11) (Urian 2005a, 2005b).
- NMFS Southeast Fisheries Science Center researchers have conducted aerial surveys within the R-5306A restricted airspace, which encompasses portions of Pamlico and Core sounds (Goodman *et al*. 2005a, 2005b, 2005c, 2004). Previously access to this airspace had been restricted. Conducted over a 16-month period, the aerial surveys were designed to document abundance and seasonal distribution of sea turtles and marine mammals. The survey results were used to develop an index of abundance by season. Additionally, the aerial surveys were used to train MCAS Cherry Point personnel to be marine mammal observers—a skill which is employed during pre- and post-exercise visual checks.

MCAS Cherry Point has contracted Duke University to develop and test a real-time passive acoustic monitoring system that will allow automated detection of bottlenose dolphin whistles (Appendix C). The work has been performed in two phases. Phase I was the development of an automated signal detector (a software program) to recognize the whistles of dolphins at BT-9 and BT-11. Phase II, currently in progress, is the assembly and deployment of a prototype real-time monitoring unit on one of the towers in the BT-9 range. The success of this effort will help direct future monitoring initiatives and activities within the MCAS Cherry Point Range Complex.

As funding becomes available and research opportunities arise, MCAS Cherry Point will continue to fund and participate in studies that will enhance the Marine Corps' understanding of marine mammals in Pamlico Sound.

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# MCAS Cherry Point BT-9 MMPA Compliance Acoustic Impact Modeling: Modeling Appendix

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# APPENDIX A

## *A.1 Background and Overview*

### A.1.1 Federal Regulations Affecting Marine Animals

All marine mammals are protected under the Marine Mammal Protection Act (MMPA). The MMPA prohibits, with certain exceptions, the take of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.

The Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of their ecosystems. A "species" is considered endangered if it is in danger of extinction throughout all or a significant portion of its range. A species is considered threatened if it is likely to become an endangered species within the foreseeable future. There are marine mammals, already protected under MMPA, listed as either endangered or threatened under ESA, and afforded special protections.

Actions involving sound in the water include the potential to harass marine animals in the surrounding waters. Demonstration of compliance with MMPA and the ESA, using best available science, has been assessed using criteria and thresholds accepted or negotiated, and described here.

Sections of the MMPA (16 U.S.C. 1361 et seq.) direct the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity, other than commercial fishing, within a specified geographical region. Through a specific process, if certain findings are made and regulations are issued or, if the taking is limited to harassment, notice of a proposed authorization is provided to the public for review.

Authorization for incidental takings may be granted if National Marine Fisheries Service (NMFS) finds that the taking will have no more than a negligible impact on the species or stock(s), will not have an immitigable adverse impact on the availability of the species or stock(s) for subsistence uses, and that the permissible methods of taking, and requirements pertaining to the mitigation, monitoring and reporting of such taking are set forth.

NMFS has defined negligible impact in 50 CFR 216.103 as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to adversely affect the species or stock through effects on annual rates of recruitment or survival.

Subsection 101(a)(5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. The National Defense Authorization Act of 2004 (NDAA) (Public Law 108-136) removed the small numbers limitation and amended the definition of "harassment" as it applies to a military readiness activity to read as follows:

> (i) *any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or*
> (ii) *any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered [Level B Harassment].*

The primary potential impact to marine mammals from underwater acoustics is Level B harassment from noise.

### A.1.2 Development of Animal Impact Criteria

For explosions of ordnance planned for use in the Cherry Point Exercise Area, in the absence of any mitigation or monitoring measures, there is a very small chance that a marine mammal could be injured or killed when exposed to the energy generated from an explosive force. Analysis of noise impacts is based on criteria and thresholds initially presented in U.S. Navy Environmental Impact Statements for ship shock trials of the Seawolf submarine and the Winston Churchill (DDG 81), and subsequently adopted by NMFS.

Non-lethal injurious impacts (Level A Harassment) are defined in those documents as tympanic membrane (TM) rupture and the onset of slight lung injury. The threshold for Level A Harassment corresponds to a 50-percent rate of TM rupture, which can be stated in terms of an energy flux density (EFD) value of 205 dB re 1 $\mu Pa^2$-s. TM rupture is well-correlated with permanent hearing impairment. Ketten (1998) indicates a 30-percent incidence of permanent threshold shift (PTS) at the same threshold.

The criteria for onset of slight lung injury were established using partial impulse because the impulse of an underwater blast wave was the parameter that governed damage during a study using mammals, not peak pressure or energy (Yelverton, 1981). Goertner (1982) determined a way to calculate impulse values for injury at greater depths, known as the Goertner "modified" impulse pressure. Those values are valid only near the surface because as hydrostatic pressure increases with depth, organs like the lung, filled with air, compress. Therefore the "modified" impulse pressure thresholds vary from the shallow depth starting point as a function of depth.

The shallow depth starting points for calculation of the "modified" impulse pressures are mass-dependent values derived from empirical data for underwater blast injury (Yelverton, 1981). During the calculations, the lowest impulse and body mass for which slight, and then extensive, lung injury found during a previous study (Yelverton et al, 1973) were used to determine the positive impulse that may cause lung injury. The Goertner model is sensitive to mammal weight such that smaller masses have lower thresholds for positive impulse so injury and harassment will be predicted at greater distances from the source for them. Impulse thresholds of 13.0 and 31.0 psi-msec, found to cause slight and extensive injury in a dolphin calf, were used as thresholds in the analysis contained in this document.

Level B (non-injurious) Harassment includes temporary (auditory) threshold shift (TTS), a slight, recoverable loss of hearing sensitivity. One criterion used for TTS, the total energy flux density of the signal, is a threshold of 182 dB re 1 $\mu Pa^2$-s maximum EFD level in any 1/3-octave band above 100 Hz for toothed whales (e.g., dolphins). A second criterion, a maximum allowable peak pressure of 23 psi, has recently been established by NMFS to provide a more conservative range for TTS when the explosive or animal approaches the sea surface, in which case explosive energy is reduced, but the peak pressure is not. NMFS applies the more conservative of these two.

For multiple successive explosions, the acoustic criterion for non-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. The non-TTS threshold is derived following the approach of the Churchill Final Environmental Impact Statement (FEIS) for the energy-based TTS threshold. The research on pure-tone exposures reported in Schlundt et al. (2000) and Finneran and Schlundt (2004) provided a threshold of 192 dB re 1 $\mu Pa^2$-s as the lowest TTS value. This value for pure-tone exposures is modified for explosives by (a) interpreting it as an energy metric, (b) reducing it by 10 dB to account for the time constant of the mammal ear, and (c) measuring the energy in 1/3 octave bands, the natural filter band of the ear. The resulting TTS threshold for explosives is 182 dB re 1 $\mu Pa^2$-s in any 1/3 octave band. As reported by Schlundt et al. (2000) and Finneran and Schlundt (2004), instances of altered behavior in the pure-tone research generally began five dB lower than those causing TTS. The non-TTS threshold is therefore derived by subtracting 5 dB from the 182 dB re 1 $\mu Pa^2$-s in any 1/3 octave band threshold, resulting in a 177 dB re 1 $\mu Pa^2$-s (EL) non-TTS behavioral disturbance threshold for multiple explosions.

Table A-1 summarizes the current threshold levels for analysis of explosives used at Marine Corps Air Station (MCAS) Cherry Point.

**Table A-1 - Explosives Threshold Levels**

| Threshold Type | Threshold Level |
|---|---|
| Level A – 50% Eardrum rupture | 205 dB re 1 $\mu Pa^2$-s |
| Temporary Threshold Shift (TTS) (peak 1/3 octave energy) | 182 dB re 1 $\mu Pa^2$-s |
| Non-TTS Threshold for Multiple Successive Explosions (peak 1/3 octave energy) | 177 dB re 1 $\mu Pa^2$-s |
| Temporary Threshold Shift (TTS) (peak pressure) | 23 psi |
| Level A – Slight lung injury (positive impulse) | 13 psi-ms |
| Fatality – 1% Mortal lung injury (positive impulse) | 31 psi-ms |

The sound sources will be located in an area that is inhabited by species listed as threatened or endangered under the ESA (16 USC §§ 1531-1543). Operation of the sound sources, that is, transmission of acoustic signals in the water column, could potentially cause harm or harassment to listed species.

"Harm" defined under ESA regulations is "…an act which actually kills or injures…" (50 CFR 222.102) listed species. "Harassment" is an "intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering" (50 CFR 17.3).

Level A harassment criteria and thresholds under MMPA are appropriate to apply as "harm" criteria and thresholds under ESA. Analysis that predicts Level A harassment under MMPA will occur as a result of the proposed action would correspond to harm to listed species under ESA. Level B harassment criteria and thresholds under MMPA are appropriate to apply as harassment criteria and thresholds under ESA.

If a federal agency determines that its proposed action "may affect" a listed species, it is required to consult, either formally or informally, with the appropriate regulator. There is no permit issuance under ESA, rather consultation among the cognizant federal agencies under Section 7 of the ESA. Such consultations would likely be concluded favorably, subject to requirements that the activity will not appreciably reduce the likelihood of the species' survival and recovery and impacts are minimized and mitigated. If appropriate, the Navy would initiate formal interagency consultation by submitting a Biological Assessment to NMFS, detailing the proposed action's potential effects on listed species and their designated critical habitats. Consultation would conclude with NMFS' issuance of a Biological Opinion that addresses the issues of whether the project can be expected to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.

Work is ongoing in the community to refine the threshold criteria in response to new information about marine animal biology. The new modeling described here allows the threshold criteria to be varied (over a realistic range of values). Results can be generated for possible new criteria, in addition to current criteria.

## *A.2 Explosive Acoustic Sources*

### A.2.1 Acoustic Characteristics of Explosive Sources

The acoustic sources employed at the MCAS Cherry Point BT-9 target area are categorized as broadband explosives. Broadband explosives produce significant acoustic energy across several frequency decades of bandwidth. Propagation loss is sufficiently sensitive to frequency as to require model estimates at several frequencies over such a wide band.

Explosives are impulsive sources that produce a shock wave that dictates additional pressure-related metrics (peak pressure and positive impulse). Detailed descriptions of the sources in the Cherry Point Exercise Area are provided in this subsection.

Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. Three source parameters influence the effect of an explosive: the weight of the explosive material, the type of explosive material, and the detonation depth. The net explosive weight (or NEW) accounts for the first two parameters. The NEW of an explosive is the weight of TNT required to produce an equivalent explosive power.

The detonation depth of an explosive is particularly important due to a propagation effect known as surface-image interference. For sources located near the sea surface, a distinct interference pattern arises from the coherent sum of the two paths that differ only by a single reflection from the pressure-release surface. As the source depth and/or the source frequency decreases, these two paths increasingly, destructively interfere with each other, reaching total cancellation at the surface (barring surface-reflection scattering loss).

For the Cherry Point BT-9 water target, the following types of ordnance were modeled: Bomb (GBU, BDU, Mk), Hellfire Missile, 2.75” Rocket High Explosives, 5” Rocket High Explosives, TOW Missile, G911 Grenades, 20 mm High Explosives, 25 mm High Explosives, 30 mm High Explosives, and 40 mm High Explosives.

### A.2.2 Animal Harassment Effects of Explosive Sources

The harassments expected to result from these sources are computed on a per in-water explosive basis; to estimate the number of harassments for multiple explosives, consider the following. Let A represent the impact area (that is, the area in which the chosen metric exceeds the threshold) for a single explosive. The cumulative effect of a series of explosives is then dictated by the spacing of the explosives relative to the movement of

the marine wildlife. If the detonations are spaced widely in time or space, allowing for sufficient animal movements as to ensure a different population of animals is considered for each detonation, the cumulative impact area of N explosives is merely NA regardless of the metric. This leads to a worst case estimate of harassments and is the method used in this analysis.

At the other extreme is the case where the detonations occur at essentially the same time and location (but not close enough to require the source emissions to be coherently summed). In this case, the pressure metrics (peak pressure and positive impulse) are constant regardless of the number of detonations spaced closely in time, while the energy metrics increase at a rate of $N^{½}$ (under spherical spreading loss only) or less.

The firing sequence for some of the munitions consists of a number of rapid bursts, often lasting a second or less. Due to the tight spacing in time, each burst can be treated as a single detonation. For the energy metrics the impact area of a burst is computed using a source energy spectrum that is the source spectrum for a single detonation scaled by the number of rounds in a burst. For the pressure metrics, the impact area for a burst is the same as the impact area of a single round. For all metrics, the cumulative impact area of an event consisting of N bursts is merely the product of the impact area of a single burst and the number of bursts, as would be the case if the bursts are sufficiently spaced in time or location as to insure that each burst is affecting a different set of marine wildlife.

All explosives are modeled as detonating at a 1.2-meter depth. This depth is the same depth used for the 2009 report. The NEW for these sources are provided in Table A-2. Included in this table are the peak one-third-octave (OTO) source level and the approximate frequency at which the peak occurs.

**Table A-2. Source Weights and Peak Source Levels**

| Source Type | NEW | Peak OTO SL | Center Frequency of Peak OTO |
|---|---|---|---|
| Bomb(GBU,BDU,Mk) | 100 lbs | 237 dB | 635 Hz |
| Hellfire Missile | 34.4 lbs | 232 dB | 800 Hz |
| 5” Rocket | 15.0 lbs | 229 dB | 1008 Hz |
| TOW Missile | 13.6 lbs | 228 dB | 1008 Hz |
| 2.75” Rocket | 4.8 lbs | 224 dB | 1270 Hz |
| G911 Grenade | 0.5 lbs | 214 dB | 2540 Hz |
| 40 mm-HE(I) | 0.1199 lbs | 208 dB | 4032 Hz |
| 30 mm-HE(I) | 0.1019 lbs | 207 dB | 4032 Hz |
| 25 mm-HE(I) | 0.11 lbs | 207 dB | 4032 Hz |
| 20 mm-HE(I) | 0.03 lbs | 202 dB | 5080 Hz |

For sources that are detonated at shallow depths, it is frequently the case that the explosion may breech the surface with some of the acoustic energy escaping the water column. The source levels presented in the table above have not been adjusted for possible venting nor does the subsequent analysis attempt to take this into account. For the source weights and depths involved however, this is not a significant over-simplification.

## *A.3 Environmental Characterization*

### A.3.1 Important Environmental Parameters for Estimating Animal Harassment

Propagation loss ultimately determines the extent of the Zone of Influence (ZOI) for a particular source activity. In turn, propagation loss as a function of range depends on a number of environmental parameters including:

- water depth
- sound speed variability throughout the water column
- bottom geo-acoustic properties, and
- surface roughness, as determined by wind speed

Due to the importance that propagation loss plays in Anti-Submarine Warfare, the Navy has, over the last four to five decades, invested heavily in measuring and modeling these environmental parameters. The result of this effort is the following collection of global databases containing these environmental parameters, which are accepted as standards for Navy modeling efforts. Table A-3 contains the version of the databases used in the modeling for this report.

**Table A-3. Navy Standard Databases Used in Modeling**

| Parameter | Database | Version |
|---|---|---|
| Water Depth | Digital Bathymetry Data Base Variable Resolution | DBDBV 6.0 |
| Sound Speed | Generalized Digital Environmental Model | GDEM 3.0 |
| Bottom Loss <1500 Hz | Low-Frequency Bottom Loss Database with Sediment Thickness | LFBL 11.1 |
| Bottom Loss > 1000 Hz | High-Frequency Bottom Loss Database | HFBL 2.2 |
| Ocean Sediment | Re-packed Bottom Sediment Type | BST 2.0 |
| Wind Speed | Surface Marine Gridded Climatology Database | SMGC 2.0 |

The sound speed profile directs the sound propagation in the water column. The spatial variability of the sound speed field is generally small over operating areas of typical size. The presence of a strong oceanographic front is a noteworthy exception to this rule. To a lesser extent, variability in the depth and strength of a surface duct can be of some importance. If the sound speed minimum occurs within the water column, more sound energy can travel further without suffering as much loss (ducted propagation). But if the sound speed minimum occurs at the surface or bottom, the propagating sound interacts more with these boundaries and may become attenuated more quickly. In the mid-latitudes, seasonal variation often provides the most significant variation in the sound speed field. For this reason, both summer and winter profiles are modeled to demonstrate the extent of the difference.

Losses of propagating sound energy occur at the boundaries. The water-sediment boundary defined by the bathymetry can vary by a large amount. In a deep water environment, the interaction with the bottom may matter very little. In a shallow water environment the opposite is true and the properties of the sediment become very important. The sound propagates through the sediment, as well as being reflected by the interface. Soft (low density) sediment behaves more like water and the sound has relatively more transmission and relatively less reflection than a hard (high density) bottom or thin sediment.

The roughness of the boundary at the water surface depends on the wind speed. Average wind speed can vary seasonally, but could also be the result of local weather. A rough surface scatters the sound energy and increases the transmission loss. Boundary losses affect higher frequency sound energy much more than lower frequencies.

### A.3.2 Characterizing the Acoustic Marine Environment

Each environment for modeling impact value is characterized by a fixed water depth, sound velocity profile, and bottom loss type. The bathymetry database is on a grid of variable resolution. In a deep water area, the modeling is done on a grid of depth intervals to capture water depth dependence. In a shallow water area without bathymetric features, the bathymetry values can be averaged over the area of interest.

The sound velocity profile database has a fixed spatial resolution storing temperature and salinity as a function of time and location. The low frequency bottom loss database is organized in provinces with a set of geo-acoustic parameters in each province. The high frequency bottom loss database is globally partitioned into nine classes. The area of interest can be characterized by the appropriate sound speed profile, set of low frequency bottom loss parameters and high frequency bottom loss class. If the operating area falls across a province boundary, the modeling environment is partitioned into homogeneous regions. Partitioning takes account of the fact that the lower frequency acoustic energy (below about 1 kHz) is secondary to the higher frequency acoustic energy.

In addition, seasonal variation is sampled by looking at summer and winter cases. The environmental characteristics affecting acoustic propagation that have seasonal variation are the sound speed profile and the wind speed.

ZOI volumes in the operating area are then computed using propagation loss estimates derived for the representative environment. Finally, a weighted average of the ZOI volumes is taken over all representative environments; the weighting factor is proportional to the geographic area spanned by the environmental province.

### A.3.3 Description of the MCAS Cherry Point BT-9 Target Environment

The Cherry Point area is located off the coast of North Carolina in Pamlico Sound. It is an extremely shallow area with a relatively flat bottom of sandy sediment. There is seasonal variation. Environmental values were extracted from the Navy standard databases in a radius of 9.3 km around the center point at

35° 12' 30" N 76° 26' 40" W

The Navy standard database for bathymetry has a resolution of 0.05 minutes in Pamlico Sound. Values for the bathymetry from DBDBV in the extracted area were found between approximately 1 m and 8 m. A median depth of 5 m (rounded to the nearest meter) was used as the water depth in the modeling.

The sound speed profile in the area of interest is also almost constant because of mixing in the shallow water. The Navy standard GDEM database provided a nearly-isospeed profile for the area. Seasonal changes were captured by modeling the propagation with a winter (February) profile of about 1502 m/s and a summer (August) profile of about 1538 m/s. Although the sound speed is isovelocity with less than 1 m/s of change in the water column, the database profile of the top five meters was used, rather than a single number.

In very shallow water, the bottom loss databases tend to revert to a generic sandy bottom. The sources modeled in the Cherry Point area generate peak one-third-octave source levels near one kHz. At that frequency, a sandy bottom tends to be a relatively low-loss bottom. Note that this may lead to a somewhat conservative (or over-) estimate of the number of takes.

The seasonal variability in wind speed was modeled as 12.25 knots in the summer and 13.61 knots in the winter.

## *A.4 Modeling Impact on Marine Animals*

Many underwater actions include the potential to injure or harass marine animals in the neighboring waters through noise emissions. The number of animals exposed to potential harassment in any such action is dictated by the propagation field and the characteristics of the noise source.

Estimating the number of animals that may be injured or otherwise harassed in a particular environment entails the following steps.

- For the relevant environmental acoustic parameters, transmission loss (TL) estimates are computed, sampling the water column over the appropriate depth and range intervals. TL calculations are also made over non-overlapping, one-third octave bands for a wide range of frequencies.

- The accumulated energy within the waters where the source is "operating" is sampled over a volumetric grid. At each grid point, the received energy from each source emission is modeled as the effective energy source level reduced by the appropriate propagation loss from the location of the source at the time of the emission to that grid point and summed. For the peak pressure or positive impulse, the appropriate metric is similarly modeled for each emission. The maximum value of that metric, over all emissions, is stored at each grid point.

- The impact volume for a given threshold is estimated by summing the incremental volumes represented by each grid point for which the appropriate metric exceeds that threshold.

- Finally, the number of harassments is estimated as the vector product of the animal density depth profile and the impact volume and scaled by user-specifiable surface animal densities.

This section describes in detail the process of computing impact volumes.

### A.4.1 Calculating Transmission Loss

Transmission loss (TL) was pre-computed for both seasons for thirty non-overlapping frequency bands. The bands had one-third octave spacing around center frequencies from 50 Hz to approximately 40.637 kHz. In the previous report, TL was computed at seven frequencies. The broadband nature of the sources has been well covered in this report. The TL was modeled using the Navy Standard GRAB propagation loss model (Keenan, 2000) for frequencies greater than 150 Hz and the Navy Standard RAM PE propagation loss model for frequencies less than 150 Hz. GRAB is fundamentally a "ray" model and

tends to agree with more precise scientific models, such as mode and wave equation models, at mid-frequencies and higher. Ray models also typically model bottom interaction as a reflection with loss from the sediment surface. This can be a serious limitation at low frequencies (below a few hundred Hertz) in shallow water where the primary contribution to the propagation field is from acoustic energy that propagates through the ocean bottom.

The transmission loss results were interpolated onto a variable range grid with logarithmic spacing. The increased spatial resolution near the source provided greater fidelity for estimates and contributed to the differences seen between the 2009 report and this report.

The transmission loss was calculated from the source depth (1.2 m) to an array of output depths. The output depths were the mid-points of depth intervals with a spacing of 1 m. For the very shallow Cherry Point environment, there were five depths (0.5 m, 1.5 m, 2.5 m, 3.5 m, and 4.5 m) representing depth-interval midpoints. The output depths represent possible locations of the animals and are used with the animal depth distribution to better estimate animal impact. The depth grid is used to make the surface image interference correction and to capture the depth-dependence of the positive impulse threshold. The depth resolution also contributed to the differences seen between the 2009 report and this report.

An important propagation consideration at low frequencies is the effect of surface-image interference. As either source or target approach the surface, pairs of paths that differ by a single surface reflection set up an interference pattern that ultimately causes the two paths to cancel each other when the source or target is at the surface. A fully coherent summation of the eigenrays produces such a result but also introduces extreme fluctuations that would have to be highly sampled in range and depth, and then smoothed to give meaningful results. An alternative approach is to implement what is sometimes called a semi-coherent summation. A semi-coherent sum attempts to capture significant effects of surface-image interference (namely the reduction of the field due to destructive interference of reflected paths as the source or target approach the surface) without having to deal with the more rapid fluctuations associated with a fully coherent sum. The semi-coherent sum is formed by a random phase addition of paths that have already been multiplied by the expression:

$$\sin^2\left(\frac{4\pi f z_s z_a}{c^2 t}\right)$$

where $f$ is the frequency, $z_s$ is the source depth, $z_a$ is the animal depth, $c$ is the sound speed and $t$ is the travel time from source to animal along the propagation path. For small arguments of the sine function this expression varies directly as the frequency and the two depths. It is this relationship that causes the propagation field to go to zero as the depths approach the surface or the frequency approaches zero.

RAM PE calculations for lower frequencies were computed with fully-coherent transmission loss estimates, whereas CASS/GRAB results are semi-coherent with incoherent TL post-processed with a surface-image interference correction.

### A.4.2 Computing Impact Volumes

This section and the next provide a detailed description of the approach taken to compute impact volumes for explosives. The impact volume associated with a particular activity is defined as the volume of water in which some acoustic metric exceeds a specified threshold. The product of this impact volume with a volumetric animal density yields the expected value of the number of animals exposed to that acoustic metric at a level that exceeds the threshold. The acoustic metric can either be an energy term (energy flux density, either in a limited frequency band or across the full band) or a pressure term (such as peak pressure or positive impulse). The thresholds associated with each of these metrics define the levels at which half of the animals exposed will experience some degree of harassment (ranging from behavioral change to mortality).

Impact volume is particularly relevant when trying to estimate the effect of repeated source emissions separated in either time or space. Impact range, which is defined as the maximum range at which a particular threshold is exceeded for a single source emission, defines the range to which marine mammal activity is monitored in order to meet mitigation requirements.

The effective energy source level is modeled directly for the sources to be used at the BT-9 target area. The energy source level is comparable to the model used for other explosives (Arons (1954), Weston (1960), McGrath (1971), Urick (1983), Christian and Gaspin (1974)). The energy source level over a one-third octave band with a center frequency of $f$ for a source with a net explosive weight of $w$ pounds is given by:

$$\mathrm{ESL} = 10 \log_{10} (0.26 f) + 10 \log_{10} ( 2 p_{max}^2 / [1/\theta^2 + 4 \pi^2 f^2] ) + 197 \ \mathrm{dB}$$

where the peak pressure for the shock wave at one meter is defined as

$$p_{max} = 21600 \, (w^{1/3} / 3.28 )^{1.13} \ \mathrm{psi} \qquad \text{(A-1)}$$

and the time constant is defined as:

$$\theta = [(0.058) \, (w^{1/3}) \, (3.28 / w^{1/3})^{0.22} ] / 1000 \ \mathrm{sec} \qquad \text{(A-2)}$$

For each season and explosive source, the amount of energy in the water column is calculated. The propagation loss for each frequency, expressed as a pressure term, modulates the sound energy found at each point on the grid of depth (uniform spacing) and range (logarithmic spacing). If a threshold is exceeded at a point, the impact volume at an annular sector is added to the total impact volume. The impact volume at a point is

calculated exactly using the depth interval, the range interval of the point, and the slice of a sphere centered where the range is zero.

### A.4.3 Effects of Metrics on Impact Volumes

The impact of explosive sources on marine wildlife is measured by three different metrics, each with its own thresholds. The energy metric, the peak pressure metric, and the "modified" positive impulse metric are discussed in this section. The energy metric, using the peak one-third-octave level, is accumulated after the explosive detonation. The other two metrics, peak pressure and positive impulse, are not accumulated but rather the maximum levels are taken.

***Energy Metric***
The energy flux density is sampled at several frequencies in one-third-octave bands and only the peak one-third-octave level is accumulated over time. In the case of Level A calculations, the Total Energy is considered.

***Peak Pressure Metric***
The peak pressure metric is a simple, straightforward calculation at each range/animal depth combination. First, the transmission pressure ratio, modified by the source level in a one-third-octave band, is summed across frequency. This averaged transmission ratio (normalized by the total broadband source level). Peak pressure at that range/animal depth combination is then simply the product of:

- the square root of the normalized transmission ratio of the peak arrival,
- the peak pressure at a range of one meter (given by equation A-1), and
- the similitude correction (given by $r^{-0.13}$, where $r$ is the slant range).

If the peak pressure for a given grid point is greater than the specified threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

**"Modified" Positive Impulse Metric**
The modeling of positive impulse follows the work of Goertner (Goertner, 1982). The Goertner model defines a "partial" impulse as

$$\int_0^{T_{min}} p(t)\, \mathrm{d}t$$

where $p(t)$ is the pressure wave from the explosive as a function of time $t$, defined so that $p(t) = 0$ for $t < 0$. This similitude pressure wave is modeled as

$$p(t) = p_{max}\, e^{-t/\theta}$$

where $p_{max}$ is the peak pressure at one meter (see, equation A-1), and $\theta$ is the time constant defined in equation A-2.

The upper limit of the "partial" impulse integral is

$$T_{min} = \min \{T_{cut}, T_{osc}\}$$

where $T_{cut}$ is the time to cutoff and $T_{osc}$ is a function of the animal lung oscillation period. When the upper limit is $T_{cut}$, the integral is the definition of positive impulse. When the upper limit is defined by $T_{osc}$, the integral is smaller than the positive impulse and thus is just a "partial" impulse. Switching the integral limit from $T_{cut}$ to $T_{osc}$ accounts for the diminished impact of the positive impulse upon the animals lungs that compress with increasing depth and leads to what is sometimes call a "modified" positive impulse metric.

The time to cutoff is modeled as the difference in travel time between the direct path and the surface-reflected path in an isovelocity environment. At a range of $r$, the time to cutoff for a source depth $z_s$ and an animal depth $z_a$ is

$$T_{cut} = 1/c \; \{ \; [r^2 + (z_a + z_s)^2]^{1/2} - [r^2 + (z_a - z_s)^2]^{1/2} \; \}$$

where $c$ is the speed of sound.

The animal lung oscillation period is a function of animal mass $M$ and depth $z_a$ and is modeled as

$$T_{osc} = 1.17 \, M^{1/3} \, (1 + z_a/33)^{-5/6}$$

where $M$ is the animal mass (in kg) and $z_a$ is the animal depth (in feet).

The modified positive impulse threshold is unique among the various injury and harassment metrics in that it is a function of depth and the animal weight. So instead of the user specifying the threshold, it is computed as $K \, (M/42)^{1/3} \, (1 + z_a/33)^{1/2}$. The coefficient $K$ depends upon the level of exposure. For the onset of slight lung injury, $K$ is 19.7; for the onset of extensive lung hemorrhaging (1% mortality), $K$ is 47.

Although the thresholds are a function of depth and animal weight, sometimes they are summarized as their value at the sea surface for a typical dolphin calf (with an average mass of 12.2 kg). For the onset of slight lung injury, the threshold at the surface is approximately 13 psi-msec; for the onset of extensive lung hemorrhaging (1% mortality), the threshold at the surface is approximately 31 psi-msec. For the results presented here, the animal mass can be varied to tailor the calculations to the species under consideration.

As with peak pressure, the "modified" positive impulse at each grid point is compared to the derived threshold. If the impulse is greater than that threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

## *A.5 Estimating Animal Harassment*

### A.5.1 Distribution of Animals in the Environment

Species densities are usually reported by marine biologists as animals per square kilometer, which is an area metric. This gives an estimate of the number of animals below the surface in a certain area, but does not provide any information about their distribution in depth. The impact volume vector specifies the volume of water ensonified above the specified threshold in each depth interval. A corresponding animal density for each of those depth intervals is required to compute the expected value of the number of exposures. The two-dimensional area densities do not contain this information, so three-dimensional densities must be constructed by using animal depth distributions to extrapolate the density at each depth.

The following sea turtle example demonstrates the methodology used to account for three-dimensional analysis by merging the depth distributions with user-specifiable surface densities. Loggerhead sea turtles are distributed with:

- 88% in 0-1 m,
- 10% in 1-4 m, and
- 2% in 4-5 m.

The impact volume vector is sampled every meter over the 5 meter water column. Since this is a finer resolution than the depth distribution, densities are apportioned uniformly over depth intervals. 10% of turtles are in the 1-4 meter interval, so approximately

- 88% are in 0-1 meters,
- 3.33% are in 1-2 meters,
- 3.33% are in 2-3 meters,
- 3.33% are in 3-4 meters, and
- 2% are in 4-5 meters.

### A.5.2 Harassment Estimates

Impact volumes for all depth intervals are scaled by their respective depth densities, divided by their depth interval widths, summed over the entire water column and finally converted to square kilometers to create impact areas. The spreadsheet allows a user-specifiable surface animal density in turtles per square kilometer, so the product of these quantities yields number of turtles in ensonified water where they could experience harassment.

Since the impact volume vector is the volume of water at or above a given threshold per unit operation (e.g. per detonation, or clusters of munitions explosions), the final harassment count for each animal is the unit operation harassment count multiplied by the number of units deployed.

The detonations of explosive sources are generally widely spaced in time and/or space. This implies that the impact volume for multiple firings can be easily derived by scaling the impact volume for a single detonation. Thus the typical impact volume vector for an explosive source is presented on a per-detonation basis.

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United States Marine Corps, Marine Corps Air Station Cherry Point

USMC Cherry Point Range Complex

Marine Mammal and Protected Species Monitoring Plan

## Introduction

This Monitoring Plan for the USMC Cherry Point Range Complex has been developed to provide marine mammal and sea turtle monitoring as required by the Endangered Species Act and Marine Mammal Protection Act (MMPA). The monitoring program described herein applies to the organic facility assets and training activities under the control of Marine Corps Air Station (MCAS) Cherry Point and taking place on land and waters within Pamlico Sound and inshore waters adjacent to MCAS Cherry Point facility assets.

Consistent with Section 10(a)(5)(a) of the MMPA and its implementing regulations, MCAS Cherry Point has coordinated this monitoring plan with the National Marine Fisheries Service and has both a Biological Opinion related to threatened and endangered species and an Individual Harassment Authorization related to marine mammals. This monitoring plan covers the terms, conditions, and timelines of the Biological Opinion and Individual Harassment Authorization. This monitoring plan shall be dynamic to future required coordination with NMFS.

## Protected Species within the USMC Cherry Point Complex

There is one (1) marine mammal species, bottlenose dolphin, expected to occur regularly within the inshore waters of Pamlico Sound. A second species of marine mammal, the West-Indian manatee, occurs with limited frequency. There are four (4) species of threatened and endangered turtles that have been recorded within the inshore waters of Pamlico Sound. These species, the green sea turtle, kemp's ridley, loggerhead, and leatherback sea turtle have potential to forage or transit through range areas. The potential presence of both marine mammals and sea turtles on USMC Cherry Point range areas creates a monitoring requirement to ensure the means of affecting the least practicable impact on these species is appropriately administered and implemented.

## Monitoring Plan

MCAS Cherry Point will collect data related to marine mammal and threatened and endangered species sightings and observations during routine monitoring of the bombing targets areas pre- and post exercise as described below. Information shall be collected during monitoring activities only when the collection of data does not interfere with safety of operations taking place, observers, aircraft or water vessels in operation, national security, or the conduct of the military training taking place.

To the extent practical, data shall be collected in a manner that facilitates retrieval for reporting and potential analyses. Data is currently being collected via verbal, written, and other information transfer from observers and observation platforms. Information currently being collected includes date, time, geographic location (lat/long, utm, other), number of animals seen/encountered, direction of travel, weather information, air temperature, and sea surface state.

MCAS Cherry Point has contracted for the development of a web-based information system (database, web-interface, report generator) which will function as the interface between observers and the physical environment. The features of the interface include a spatial component which will automatically display observation information on-screen and will permit heads-up digitizing of observation data when exact locational (lat/long, other) information is not available. When the web-based system is completed, this monitoring plan will be updated.

**Monitoring Plan Updates**

Military training within the MCAS Cherry Point Complex is dynamic and subject to change based upon mission requirements and real-world engagements. The most notable changes take place when new technology and weapon systems are developed and placed into operation. The basic components of this monitoring strategy will remain unchanged unless the timing, intensity and duration of military training activities exceed projected levels or new monitoring capabilities are proposed to enhance data collection and improve the mean of affected the least practical impact on protected species. The monitoring plan will be re-evaluated annually and updated as necessary to meet this objective.

**Range Status**

Cherry Point Bombing Target (BT) 11 (Piney island) and BT-9 (Brandt Island Shoal) are active ranges and access is tightly controlled. The Code of Federal Regulations (33 CFR 443.420) establishes the use restrictions applicable to the public. These regulations are enforced by the Commanding Officer, Marine Corps Air Station Cherry Point as it relates to trespass by non-participating civilians.

An active range is considered “fouled” and not available for use if non-participating vessel traffic or civilians are anywhere on the range, or protected species (marine mammals and sea turtles) are present. For the purpose of range status, conditions on BT-9 and BT-11 are independent from one another. A “fouled” status at BT-9 does not automatically translate into a fouled status at BT-11. BT-9 is considered “fouled” if non-participating vessel traffic or civilians are anywhere on the range, or protected species (marine mammals and sea turtles) are within 1000 yards of the target area. At BT-11, water borne targets are considered fouled if non-participating vessel traffic or civilians, or protected species (marine mammals and sea turtles) are present anywhere within Rattan Bay. If BT-11 waterborne targets are fouled due to protected species, land-based targets

remain open and available for training use. The ranges are monitored by various means to ensure the safety of marine species and civilians.

## Monitoring

### Search and Rescue Aircraft Range Sweeps

The VMR-1 squadron, stationed at MCAS Cherry Point, includes three specially equipped HH-46D helicopters. The primary mission of these aircraft, known as PEDRO, is to provide search and rescue for downed 2d Marine Air Wing aircrews. The squadron also provides search and rescue support to the Coast Guard and other local authorities. Pedro aircraft fly an average of 100 missions each year in search of boaters in distress, lost hunters, and other people in trouble.

On-board are a pilot, co-pilot, crew chief, search and rescue swimmer, and a medical corpsman. Each crew member has received extensive training in search and rescue techniques, and is therefore particularly capable at spotting objects floating in the water.

Pedro normally conducts a range sweep (pre-exercise) every weekday morning prior to the commencement of range operations (in addition to their emergency missions mentioned previously). The primary goal of the pre-exercise sweep is to ensure that the target area is clear of fisherman, other personnel, and protected species. The sweep is flown at 100-300 feet above the water surface, at airspeeds between 60-100 knots. The path of the sweep runs down the western side of BT-11, circles around BT-9 and then continues down the eastern side of BT-11 before leaving. The sweep typically takes 20-30 minutes to complete.

Recording sightings of marine mammals and turtles was incorporated into this range sweep in June of 2000. The Pedro crew has not reported any sightings of turtles, but has reported numerous bottlenose dolphin sightings. The Pedro crew is able to communicate directly with range personnel and can provide immediate notification to range operators. If marine mammal or sea turtle observations are made, Range personnel would plot the location of the observation, monitor with cameras as appropriate based upon location, and provide this information to air or surface units prior to their "cold or clearing pass." The Pedro aircraft would not remain in the area of a sighting due to mission requirements.

Post-exercise monitoring shall be conducted concomitant to the next regularly scheduled pre-exercise sweep. Weekly monitoring events would include a maximum of five (5) pre-exercise and four (4) post-exercise sweeps. The maximum number of days that would elapse between pre- and post-exercise monitoring events would be approximately 3 days, and would normally occur on weekends.

### Range Standard Operating Procedures

## Air to Surface and Ground Activities

Standard operating procedures for water borne targets include a visual check by pilots (rotary wing and fixed wing) prior to ordnance delivery to ensure the target area is clear of unauthorized civilian boats and personnel, and protected species such as turtles and marine mammals. This is referred to as a "cold" or clearing pass. Pilots requesting entry onto the targets are directed to do a low, cold first pass (a pass without any release of ordnance). The ability of pilots operating tactical aircraft to detect animals in the water, even at a low level is much less than that of the Pedro crew (described above in SAR sweeps).

## Surface To Surface (Small Boats)

In addition to search and rescue range sweeps by VMR-1, operators of small boats will be knowledgeable of marine mammals, protected species, and visual cues related to the presence of marine mammals and protected species. All members of small boat crews shall be required to take the Marine Species Awareness Training (Version 2.) maintained and promoted by the Department of the Navy. This on-line training resource, while not specifically tailored to small boat operations, has added value related to impact mitigation on USMC Cherry Point ranges.

## Range Cameras

To increase the safety of persons or property near the targets, Range Operation and Control personnel monitor the target area through tower mounted safety and surveillance cameras. It is not possible to see down into the water with these cameras, so submerged species are not detectable. However, it is possible to see animals breaking the surface of the water. Range personnel report that the camera resolution is sufficient that they can clearly see ducks floating on waters near the target.

A new, enhanced camera system has been purchased and installed on one BT-11 tower and on one tower at BT-9. The new camera system has night vision (IR) capabilities with resolution levels almost as good as during daytime. Lenses on the camera system have a focal length of 250 mm to 1500 mm, with view angle of (2.2°x1.65° in wide-view) and (.55°x41° in narrow-view)' respectively. Using the night-time capabilities, with a narrow view, a 1 x 1 m target can be identified out to three kilometers.

BT-9 is considered "fouled" if protected species (marine mammals and sea turtles) are within 1000 yards of the target area. In the event that a protected species is sighted anywhere within Rattan Bay, the water borne targets of BT-11 are declared fouled. Operations commence in the fouled area after the animal(s) have moved 1000 yards from the BT-9 target and/or out of Rattan Bay.

## Night-Time Operation Procedures

Night-time monitoring procedures mirror day time operations related to “cold” pass requirements by all participating aircraft as noted above. In addition to these procedures, the following operational procedures are being implemented to enhance night-time detection capabilities for marine mammals at water-based targets.

As appropriate, range personnel (Test Range Trackers (TRT)) will utilize the Infrared (IR) capability of surveillance cameras to scan target areas during nighttime operations. The target ‘area’ is identified as a 1000 yard ring surrounding the target at BT-9 and the South Bay of Rattan Bay for BT-11. TRT’s shall ‘pan out’ to obtain screen view of approximately 500 yards (5 x target length) for the BT-9 target once the target user checks in. The initial ‘pan out’ will serve as the initial starting point for scanning and then the TRT will scan 500 yards right and left. The scanning technique will vary depending upon surface conditions of the target area and shall occur concurrently with the user ‘cold pass’. Routine ‘pauses’ are incorporated into the scan to allow for camera auto-focus. Procedures for declaring a range “fouled” are the same for night-time operations.

# APPENDIX C

**Real-Time Acoustic Monitoring of Bottlenose Dolphins in and around the Brant Island Shoal Bombing Target (BT-9) and the Piney Island Bombing Range (BT-11)**

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**Pre-Proposal to Environmental Affairs Division, Cherry Point MCAS**

**Proposed Period of Work: September 2006 to August 2007**

In previous work for the Environmental Affairs Division we have conducted boat-based surveys and passive acoustic monitoring of bottlenose dolphins in the Brant Island Shoal Bombing Target (BT-9) and the Piney Island Bombing Range (BT-11). From the boat-based surveys, we found that bottlenose dolphins used both restricted areas on a frequent basis. The passive acoustic recordings are providing more detailed insight into how dolphins use the two ranges, by monitoring for their vocalizations year-round, regardless of weather conditions or darkness. The utility of this acoustic monitoring is limited, however, by the need to retrieve and download the recordings.

In this proposal, we describe a program that develops and testis a real-time passive acoustic monitoring system that will allow automated detection of bottlenose dolphin whistles. We propose to test this system in the BT-9 range. The methods we describe will enhance the approaches taken in our two previous projects by providing real-time monitoring and detection of dolphin presence in the range. We view this work as a 'proof of concept' that could lead to a full implementation of a functional monitoring system in both ranges the following year. We propose two distinct phases of work in the current proposal.

In **Phase I**, we will develop an automated signal detector (a software program) to recognize the whistles of dolphins in the BT-9 and BT-11 ranges. We will use algorithms to detect energy levels of sounds above a predetermined energy threshold, such as those used by Thomas *et al.* (2002) and Jarvis and Moretti (2002). Background sound levels vary depending on geographical location, so we will test the signal detector using acoustic recordings of dolphins obtained from the focal follows we are currently conducting in the waters around BT-9 and BT-11. We will test and refine the function of the signal detector so that it will meet acceptable rates of false alarm (less than 5%). To prevent a high rate of false detections, we will remove lower frequency sounds using a high-pass filter. This should exclude much of the noise produced by rain, wind, boats and soniferous fishes, all of which produce lower frequency sounds[1]. The lower spectrum of dolphin whistles are approximately 3 kHz and these frequency modulated sounds extend to >20 kHz (Caldwell and Caldwell 1965, Janik *et al.* 1994). In Phase I we will focus on the creation and successful testing of this automated signal detector.

In **Phase II**, we will assemble and deploy a prototype real-time monitoring unit on one of the towers in the BT-9 range. This unit will consist of a waterproof housing that contains a National Instruments CompactRIO controller with an analog input module and chassis. An S.E.A. Datentechnik cRIO Gxxx$^{plus}$ mobile module will be attached to the CompactRIO controller to allow wireless access to the units. We will use the tower's pre-existing power supply to run these components. A single hydrophone will be connected to the analog input module of the CompactRIO. This hydrophone will run from the waterproof casing down the side of one of the tower and hang suspended in the water column at a depth of approximately two meters. The hydrophone cable will be attached to the tower for the hydrophone's entire length to reduce extraneous noise from cable movement due to wind and current. We will power the hydrophone with 9-Volt batteries placed in parallel so that the hydrophone will have approximately three

[1] Most calls of soniferous fishes are less than 2 kHz and mainly occur well below 1 kHz (Mok and Gilmore 1983, Luczkovich *et al.* 1999).

months of power supply. We will need to service these unit approximately every three months to replenish this battery supply.

The CompactRIOs will process acoustic data in real-time using the automated signal detector created in Phase I. This signal detector will constantly monitor acoustic data from the hydrophone in real-time and save time-stamped power spectrums of probable whistles when certain criteria are met. Once a detection has been made, the cRIO Gxxx$^{plus}$ module will send a text message to a cell phone at the Duke University Marine Laboratory providing the detection date and time. After one text message has been sent, the unit will wait a specified amount of time (such as 30 minutes) before sending another message. We will program the units to employ this time delay because it is likely that multiple whistles will occur together as a group of dolphins moves through the range. (We can modify this delay period to meet operational requirements in the full implementation phase). During the first few weeks after deployment, we will save spectrograms as well as the power spectrums of all detections made by the signal detector for further analysis. We will examine these spectrograms to ensure that the detections are in fact dolphin whistles. This will, in turn, either (1) ensure that we have met the desired false detection rate or (2) allow us to adjust our signal detector as needed. As mentioned above, we will use a high-pass filter to eliminate most noise from boats and soniferous fish, thus allowing for lower rates of false detections. In addition, during Phase II we will map the sound fields for BT-9 and BT-11 so that we can calculate the detection ranges of dolphin whistles and determine the optimal placement of hydrophones for complete coverage in each range in the future. We will also conduct experiments in which we will playback dolphin whistles within the detection range of the real-time monitoring unit. These experiments will allow us to assess the performance of the monitoring unit in detecting whistles of varying intensity and waveform. Thus, in Phase II we will focus on the development and testing of this prototype unit.

Even with a real-time monitoring system, dolphins in the ranges may not be detected if they are not vocalizing. We have begun performing focal follows of bottlenose dolphins around the BT-9 and BT-11 ranges and will continue to do so in the upcoming months (Spring and Summer 2006) to determine the frequency with which dolphins vocalize. These recordings will allow us to determine how often groups of dolphins are silent and therefore how often they may be present in the area without being detected.

In summary, we will develop and test a system for real-time monitoring and detection of bottlenose dolphins, while adding to our understanding of the patterns of daily and seasonal habitat use by bottlenose dolphins in the two ranges. This proposed work will allow us to develop and test a prototype before designing a larger, more complex real-time monitoring system in both the BT-9 and BT-11 ranges. If this pilot project is a success, the next step will entail deploying a series of such units in the BT-9 and BT-11 ranges to provide complete coverage of the two areas. We will know the optimal placement of these units after Phase II of this project when we map the sound fields. In addition, our proposed plan will allow for the possibility of localizing dolphins in each range, as each monitoring unit will be able to process data from up to four hydrophones.

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