Appendix F Military Expended Materials and Direct Strike Analysis

Supplemental Environmental Impact Statement/ Overseas Environmental Impact Statement Mariana Islands Training and Testing

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APPENDIX F MILITARY EXPENDED MATERIALS DIRECT STRIKE ANALYSIS

F.1 Estimating the Effect of Military Expended Materials and Underwater Explosions on Abiotic Substrates as a Habitat for Biological Resources

This section discusses the methods and results for quantifying two scenarios under Alternative 1 and Alternative 2 of the Proposed Action: (1) the highly improbable worst-case scenario of all military expended materials or underwater explosions occurring on one particular substrate type; and (2) the unlikely, but slightly more realistic, scenario of uniform or proportional effect distribution within a particular area. Training and testing typically occurs in areas that are not called out or linked to specific activities for various reasons (e.g., flexibility and national security). Because military readiness activities would not be conducted under the No Action Alternative, it will not be discussed in this appendix.

This section describes the calculation of the disturbance footprint (i.e., military expended material footprint or explosive crater footprint) or an instantaneous effect of military expended materials or explosions on the substrate. The actual instantaneous effect on the bottom will depend on the number and location of military expended materials expended and not recovered, which is likely much lower and more concentrated than either scenario being analyzed. Longer-term effects on the bottom are far more difficult to quantify—refer to Section 3.1 (Sediments and Water Quality) and Section 3.3 (Marine Habitats), or Chapter 3 (Affected Environment and Environmental Consequences) for qualitative discussion.

The analysis requires two data elements: (1) a tabular summary of the military expended material or crater (underwater explosions) footprints expected in training and testing areas; and (2) a tabular summary of analysis dimensions, which includes abiotic substrate areas.

- The data for (1) comes from the Mariana Islands Training and Testing (MITT) Action Proponents and represents the most locational flexibility with regard to expenditure of military expended materials and underwater explosions. The data for the number of military expended materials and in-water explosions are then multiplied by an estimate of the footprint size. The footprints listed for various expended materials in previous MITT analyses were rough estimates compared to the more accurate estimates used for the current analysis.
    - The footprint sizes for military expended material are estimated to be twice the size of its material footprint, to account for some disturbed sediment around the object. Items with a casing have two separate entries in the data for their impact footprints. One incorporates that size of the unrecovered casing itself, and the other is for the size of the projectile. A percentage of the casings are assumed to be recovered and are not included in the footprints, which is an improvement over the analyses in previous MITT documents.
    - The footprint sizes for in-water explosive effects on the bottom are based on equations and empirical data reported in Gorodilov and Sukhotin (1996) and O'Keeffe and Young (1984). The crater footprint was then doubled to account for an area of ejected substrate.

- The data for analysis dimensions (data element 2) comes from the Benthic Habitat Database Technical Report, in addition to spatial data depicting training and testing areas.

The combined analysis dimensions data was used to create a table of substrate category acreage by training and testing areas, and large marine ecosystems. The percentage of affected substrate was calculated by totaling the effect footprint of individual activities divided by the total area of a given substrate in the training and testing area for which the effects could occur. The results are provided in Table F-2 and Table F-3.

Assumptions used in the Scenario 1 analysis included the following:

- Areas of unknown substrate type were not included in the analysis.
- The analysis focused on substrates that are likely to have habitat for sedentary benthic organisms; therefore, area that are not likely to have substrate inhabited by these organisms were excluded from the analysis.
- Artificial substrate was removed from the analysis because it was inconsistently mapped or mapped with a degree of uncertainty considered too high for quantitative analysis.

F.2 Effects on Seafloor Habitats – Military Readiness Activities

Table F-1 shows the MITT Study Area bottom types. Using the methodology and assumptions described in Section F.1, Tables F-2 and F-3 show single-year effects on applicable habitat types, from both explosive charges and military expended materials.

Table F-1: Area and Percent Coverage of Abiotic Substrate Types in the Study Area

Study Area	Habitat						Total Area (km^2)
	Hard		Mixed		Soft		
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	
MITT	215	68.05	74	23.39	27	8.56	316

Table F-2: Effect from MEM on or Near the Bottom for Military Readiness Activities Under Alternative 1 and Alternative 2 in a Single Year

Alternative	Impact Footprint (Acres)			Effect by Bottom Type (Acres)		
	Training	Testing	Combined	Hard	Mixed	Soft
Alternative 1	16.711	0.6491	17.360	11.814	4.061	1.486
Alternative 2	26.847	1.7680	28.617	19.474	6.693	2.450

Table F-3: Effect from Explosives on or Near the Bottom for Military Readiness Activities under Alternative 1 and Alternative 2 in a Single Year

Alternative	Impact Footprint (Acres)			Effect by Bottom Type (Acres)		
	Training	Testing	Combined	Hard	Mixed	Soft
Alternative 1	0.291	0.078	0.369	0.251	0.086	0.032
Alternative 2	0.291	0.078	0.369	0.251	0.086	0.032

F.3 Statistical and Probability Analysis for Estimating Direct Strike Effect and Number of Potential Exposures from Military Expended Material

This section discusses the methods and results for calculating the probability of a direct strike of a marine animal from any military items resulting from the proposed training and testing activities falling toward (or directed at) the sea surface. For the purposes of this section, military items include non-explosive practice munitions, sonobuoys, acoustic countermeasures, targets, and high-energy lasers. Only marine mammals and sea turtles will be analyzed using these methods because animal densities are necessary to complete the calculations and density estimates are currently only available for marine mammals and sea turtles within the Study Area. The analysis conducted here does not account for explosive munitions because impacts from explosives are analyzed within the Navy Acoustic Effects Model as described in the report, Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase IV Training and Testing (U.S. Department of the Navy, 2024). Table F-4 provides a list of symbols used in the equations located in the preceding sections.

Table F-4: A List of Symbols and Their Brief Descriptions as They Are Used in the Analysis

Symbol	Explanation
A_S	Area of an individual marine animal
L_S	Length of an individual marine animal
W_S	Width of an individual marine animal
N_S	Number of individual animals within a single marine species
D_S	Density of animals within a single marine species
A_{TotS}	The total footprint area of a single marine species
A_{RC}	The area of a single testing/training range
L_{mun}	The length of an individual piece of military expended material
W_{mun}	The width of an individual piece of military expended material
A_{mun}	The area of an individual piece of military expended material
N_{mun}	The total number of military expended materials used of a single type (e.g., non-explosive bomb)
A_I	The total area of military expended materials used of a single type (e.g., non-explosive bomb)
A_{TotI}	The area of impact for all types of military expended materials; the impact footprint
A_{BZ}	The area of the buffer zone around the impact footprint
A_{Final}	The total area of concern, including the buffer zone (A_{BZ}), the impact footprint (A_{TotI}), and the total animal footprint of a single marine species (A_{TotS})
R_{TotS}	The total footprint radius of a single marine species
R_{TotI}	The total footprint radius of the impact footprint for all types of military expended materials
R_{BZ}	The buffer zone radius of the impact footprint for all types of military expended materials
P	The probability of impacting a marine animal through a military expended material direct exposure impact
T	Total number of possible surface animal exposures associated with a direct impact from military expended materials

F.3.1 Direct Impact Analysis

A probability was calculated to estimate the impact probability (P) and number of exposures (T) associated with direct impact of military items on marine animals and sea turtles on the sea surface within the specified training or testing area (A_{RC}) in which the activities are occurring. The statistical probability analysis is based on probability theory with "footprint" areas for marine animals and total impact inscribed inside the training or testing area. The analysis is over-predictive and conservative, in that it assumes: (1) that all animals would be at or near the surface 100 percent of the time, when in fact, marine mammals spend the majority of their time underwater (e.g., Fonseca et al., 2022; Hochscheid, 2014; Irvine et al., 2017; Lagerquist et al., 2000; Mate et al., 1995), and (2) that the animals are stationary, which does not account for any movement or any potential avoidance of the training or testing activity area. There is some research that suggests marine mammals will avoid areas where there is sonar activity but not areas where there is just vessel traffic noise; so, avoidance behavior in marine mammals is situationally dependent (for review see (Ellison et al., 2012)). For sea turtles, research has demonstrated changes in behavior of sea turtles in response to anthropogenic sounds (O'Hara & Wilcox, 1990; Samuel et al., 2005), but more research is needed to determine if they portray avoidance behavior to any form of anthropogenic activity.

There are three types of areas incorporated into the analyses: species area (A_S), total impact footprint area (A_{TotI}), and the buffer zone of the impact area (A_{BZ}). For each calculation, a basic area is assessed using either the area calculation for a rectangle (A = length * width) or a circle ($A = \pi R^2$, where R is the radius of a circle). These area calculations were used in four different scenarios that make assumptions about the type of interaction between the marine animal and the military expended materials. For the initial three scenarios, all areas are calculated using the rectangular method. For the fourth scenario, all areas are calculated using the circular method.

- Scenario 1: Purely static, rectangular scenario. Impact is assumed to be static (i.e., direct impact effects only; non-dynamic; no explosions or scattering of military items after the initial impact) with a military expended material directly hitting a marine animal. This scenario assumes the marine animal is fully inside the impact area when contact with the military expended material is made.
- Scenario 2: Dynamic scenario with end-on collision. It is assumed that the military expended material is moving through the water, in the same direction as the length of the impact zone, for a distance of six times the initial length of the impact area. The concept here is that the military expended material has forward momentum along the length of the impact area and can make contact with the marine animal at any point inside of this new impact footprint area.
- Scenario 3: Dynamic scenario with broadside collision. It is assumed that the military expended material is moving through the water, in the same direction as the width of the impact zone, for a distance of six times the initial width of the impact area. The concept here is that the military expended material has forward momentum along the width of the impact area and can make contact with the marine animal at any point inside of this new impact footprint area.

- Scenario 4: Purely static, radial scenario, in which the rectangular animal, buffer zone, and impact footprints are replaced with circular footprints. Basically, the assumption is that the animal and the military expended materials are moving in circular patterns, rather than straight paths. This scenario assumes the marine animal is fully inside the impact area when contact with the military expended material is made.

Static impacts (Scenarios 1 and 4) assume no additional aerial coverage effects of scattered military items beyond the initial impact. For dynamic impacts (Scenarios 2 and 3), the distance of any scattered military items must be considered by increasing the length (Scenario 2) or width (Scenario 3), depending on orientation (broadside versus end-on collision), of the impact footprint to account for the forward horizontal momentum of the falling object. Forward momentum typically accounts for six times the impact area's length or width. Significantly different values may result from the static and dynamic orientation scenarios. Both types of collision conditions can be calculated each with 50 percent likelihood (i.e., equal weighting between Scenarios 2 and 3, to average these potentially different values).

The method of area (A_S, A_{TotI}, and A_{BZ}) calculation will vary slightly with each scenario. First, the basic concepts behind the area calculations are addressed below.

- The individual animal area (A_S) was calculated by multiplying the length and the width of the animal ($A_S = L_S * W_S$), where width was 20 percent of the length for marine mammals and 84% of the length for sea turtles. Then, the species density and the range complex (A_{RC}) size were incorporated to produce the species total area (A_{TotS}). A_S was multiplied by the number of animals (N_S) in the specified training or testing area, where N_S was the product of the highest average month animal density (D_S) and the area of the range complex ($A_{TotS} = A_S * N_S = A_S * D_S * A_{RC}$). As a conservative scenario, the total animal footprint area was calculated for the species with the highest average monthly density in the training or testing area with the highest use of military items within the entire Study Area. For the remainder of the calculations A_{TotS} was used to represent the presence of the species within the area.
- To assess the impact footprint area (A_I) for a single type of munition used in the range complex, the area of the munition (A_{mun}) was calculated by multiplying the length and width of the munition ($A_{mun} = L_{mun} * W_{mun}$). Then, A_{mun} was multiplied by the total number of that munition type used in a year (N_{mun}). Thus, $A_I = N_{mun} * A_{mun}$ is the impact footprint for a single type of munition in a single range complex over a year.
- The A_I for each munition type used in the range complex was then summed across all munition types to get a total impact footprint (A_{TotI}) for a year within a single range complex. As a conservative scenario, the total impact footprint area was calculated for the training or testing area with the highest use of military items within the entire Study Area. This total impact footprint area was then converted back into the length-width assessment, with the ratio of the impact area mirroring the animal $\frac{W_S}{L_S} = \frac{W_{TotI}}{L_{TotI}}$.
- In addition to the impact footprint and the species footprint, a buffer zone around the impact area footprint was included in the analysis. The purpose of this buffer zone was to be overly protective of the species to ensure that any species just outside of the impact area were also included in the analysis. The buffer zone was simply calculated by

taking half of the area of the total impact footprint ($A_{BZ} = A_{TotI} * 0.5$) for the rectangular scenarios. For the circular scenarios, an additional buffer zone radius (R_{BZ}) was calculated.

These calculations were then fed into the final calculation area (A_{Final}) for the three rectangular scenarios (Scenarios 1-3). So, $A_{Final1} = A_{BZ1} + A_{TotI1} + A_{TotS}$, where 1 designates Scenario 1. The same concept was applied for Scenarios 2 and 3, except the L_{TotI} for Scenario 2 was multiplied by 6 and the W_{TotI} for Scenario 3 was multiplied by 6, which influence both A_{TotI} and A_{BZ} for each of the scenarios. In each case, the buffer zone could also be calculated by simple subtraction $A_{BZ} = A_{Final} – A_{TotI} – A_S$, for each respective scenario. For Scenario 4, the radial scenario, the area calculation was based on a circle. $A_{Final4} = \pi * (R_{TotS} + R_{TotI} + R_{BZ})^2$. To calculate the buffer zone from the final area, the following equation could also be used:

$$A_{BZ4} = \sqrt{(\frac{A_{Final4}}{\pi})} - R_{TotI} - R_{TotS}.$$

Impact probability (P) is the probability of impacting one animal at its species peak density, with the given number, type, and dimensions of all military items used in training or testing activities occurring in the area per year. Therefore, P is the ratio of the final area for each scenario, which includes the species area, the impact footprint, and the buffer zone of the impact footprint, and the range complex area ($P = \frac{A_{Final}}{A_{RC}}$, where A_{Final} is based on the value calculated in each scenario). The total number of possible exposures (T) within a given year is a product of the species density, the area of the range complex, and the impact probability ($T = (D_S * A_{RC})*P$). Using this procedure, P and T were calculated for each of the four scenarios, for the Endangered Species Act (ESA)-listed marine mammals and the non-ESA marine mammal and ESA-listed sea turtle species with the highest average month density (used as the annual density value) and for each military item type. The scenario-specific P and T values were averaged over the four scenarios (using equal weighting) to obtain a single scenario, averaged-annual estimate of P and T.

The analysis is expected to provide an overestimation of the probability of a strike for the following reasons: (1) it calculates the probability of a single military item (of all the items expended over the course of the year) hitting a single animal at its species' highest seasonal density; (2) it does not take into account the possibility that an animal may avoid military activities; (3) it does not take into account the possibility that an animal may not be at the water surface; (4) it does not take into account that most projectiles fired during training and testing activities are fired at targets, and so only a very small portion of those projectiles that miss the target would hit the water with their maximum velocity and force; and (5) it does not quantitatively take into account the Navy avoiding animals that are sighted through the implementation of mitigation measures.

F.3.2 Parameters for Analysis

Impact probabilities (P) and number of exposures (T) were estimated by the analysis for the following parameters:

- Two action alternatives: Alternative 1 and Alternative 2. Animal densities, animal dimensions, and military item dimensions are the same for the two action alternatives.

- One training or testing area: Mariana Islands Training and Testing Study Area. Area is approximately 3,441,423 square kilometers respectively.
- The following types of non-explosive munitions or other items:
    - **Small-caliber projectiles:** up to and including 0.50 caliber rounds
    - **Medium-caliber projectiles:** larger than 0.50 caliber rounds but smaller than 57 millimeters (mm) projectiles
    - **Large-caliber projectiles:** includes projectiles greater than or equal to a 57 mm projectile
    - **Missiles:** includes rockets and jet-propelled munitions
    - **Bombs:** Non-explosive practice bombs and mine shapes, ranging from 10 to 2,000 pounds
    - **Torpedoes:** includes all lightweight torpedoes
    - **Sonobuoys:** includes all sonobuoys
    - **Targets:** includes expended airborne and surface, as well as mine shapes
    - **Lightweight torpedo accessories:** includes all accessories that are dropped along with the torpedo (e.g., nose cap, air stabilizer)
    - **Anchors:** includes blocks used to anchor mine shapes to the seafloor
    - **Acoustic countermeasures:** includes aircraft deployed acoustic countermeasures
    - **High-energy lasers:** includes high-energy laser weapons that are directed at a surface target
    - **Expended bathythermographs:** small sensor deployed from ships
    - **Animal species of interest:** The species of ESA-listed marine mammals expected in the MITT Study Area and the non-ESA listed marine mammal with the highest average month density in the MITT Study Area

F.3.3 Output Data

Estimates of impact probability (P) and number of exposures (T) for a given species of interest were made for the specified training or testing area with the highest annual number of military items used for each of the two action alternatives. The calculations derived P and T from the highest annual number of military items used in the Study Area for the given alternative. Differences in P and T between the alternatives arise from different numbers of events (and therefore military items) for the two alternatives.

Results for marine mammals and sea turtles are presented in Table F-5 through Table F-8.

Table F-5: Estimated Representative Marine Mammal Exposures from Direct Strike of a High-Energy Laser by Area and Alternative in a Single Year

MITT Study Area				
Species	Training		Testing	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Blue Whale	0.0000021	0.0000022	0.0000021	0.0000021
Fin Whale	0.0000017	0.0000017	0.0000017	0.0000017
Humpback Whale	0.1290252	0.1290840	0.1289779	0.1289779
Sperm Whale	0.0454001	0.0454291	0.0453769	0.0453769
Sei Whale	0.0000109	0.0000110	0.0000109	0.0000109
Pantropical Spotted Dolphin	0.0000000	0.0000000	0.0000000	0.0000000

Table F-6: Estimated Representative Sea Turtle Exposures from Direct Strike of a High-Energy Laser by Area and Alternative in a Single Year

MITT Study Area				
Species	Training		Testing	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Green Turtle	0.0321414	0.0322051	0.0320912	0.0320912

Table F-7: Estimated Representative Marine Mammal Exposures from Direct Strike of Military Expended Material by Area and Alternative in a Single Year

MITT Study Area				
Species	Training		Testing	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Blue Whale	0.0000244	0.0000371	0.0000034	0.0000146
Fin Whale	0.0000266	0.0000410	0.0000030	0.0000156
Humpback Whale	0.1502127	0.1589340	0.1317434	0.1428359
Sperm Whale	0.0575342	0.0628676	0.0468014	0.0531154
Sei Whale	0.0001041	0.0001570	0.0000162	0.0000633
Pantropical Spotted Dolphin	0.1672362	0.2048580	0.0982709	0.1371733

Table F-8: Estimated Representative Sea Turtle Exposures from Direct Strike of Military Expended Materials by Area and Alternative in a Single Year

MITT Study Area				
Species	Training		Testing	
	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Green Turtle	0.0849260	0.1125958	0.0361857	0.0631411

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