APPENDIX I
MILITARY EXPENDED MATERIALS AND DIRECT STRIKE IMPACT ANALYSIS

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Draft

Supplemental Environmental Impact Statement/ Overseas Environmental Impact Statement Atlantic Fleet Training and Testing

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I MILITARY EXPENDED MATERIALS AND DIRECT STRIKE IMPACT ANALYSIS

I.1 ESTIMATING THE IMPACT OF MILITARY EXPENDED MATERIALS AND IN-WATER EXPLOSIONS ON SEAFLOOR HABITATS

This section discusses the methods and results for quantifying the seafloor disturbance of military expended materials and in-water explosions (associated with explosive ordnance disposal activities) under Alternatives 1 and 2 of the Proposed Action. Because military readiness activities would not be conducted under the No Action Alternative, it will not be discussed in this appendix.

The calculation of the initial disturbance footprint of military expended materials or explosions on or near the substrate is based on the number and location of military expended materials expended and not recovered. The locations described and mapped in Chapter 2 (Description of Proposed Action and Alternatives) are used for this analysis, with a few exceptions. For example, specific sub-locations of "Other AFTT Areas" are used in the analysis of seafloor disturbance to avoid the appearance of impacts to sensitive habitats that would not actually be impacted.

The analysis requires two data elements: (1) a tabular summary of the military expended material and crater (in-water explosions) footprints expected in training and testing locations, and (2) a tabular summary of analysis dimensions for those training and testing locations (e.g., seafloor habitat types).

- The data for (1) comes from the Atlantic Fleet Training and Testing (AFTT) Action Proponents and represents the most locational flexibility regarding expenditure of military expended materials and in-water 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 the 2018 *Final Atlantic Fleet Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement* (hereinafter referred to as the 2018 Final EIS/OEIS) 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 analysis in the 2018 Final EIS/OEIS.
    - 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 (2) comes from a compilation of seafloor habitat mapping presented in Section 3.3 (Habitats).

The analysis also considers geographic mitigation areas for seafloor resources that provides some localized protection from certain stressors (refer to Chapter 5, Mitigation). For example, explosive mines will not be placed near mapped areas of submerged aquatic vegetation, shipwrecks, artificial reefs, or

live hard bottom (includes shallow-water coral reefs). The analysis also accounts for the bottom-disturbing activities the Action Proponents have agreed not to conduct in National Marine Sanctuaries (refer to Chapter 6, Regulatory Considerations, for more information). However, the qualitative analysis in Section 3.3 (Habitats) considers the possibility of lighter materials drifting into these areas based on ocean currents.

Other assumptions used in the habitat analysis included:

- Omission of seafloor habitat types in water greater than 2,500 meters (m) deep due to the nature of the affected environment (refer to Appendix F, Biological Resources Supplemental Information, for supporting details).
- Restriction of explosive mine craters to relatively shallow waters (less than 95 meters deep) of the Study Area based on where the associated activities typically occur.

Important side notes about the analysis of military expended materials include:

- Mitigation measures that pertain to a subset of military expended materials were not accounted for quantitatively. For example, shallow-water coral reefs would not be targeted with heavy munitions against a surface target; the impact on shallow-water coral reefs therefore does not account for over 50 percent of the footprint that would be distributed compared to other habitats.
- Distance from shore for some activities provided in Appendix A (Activity Descriptions) was not accounted for. So, the impact on a relatively small portion of shallow-water habitats would shift to more offshore locations. The direct impact on habitats in the coastal ocean environment (e.g., coastal wetlands and seagrass beds around Key West) is therefore overestimated.

The likelihood of significant impacts from relatively heavy military expended materials (e.g., mine shapes, anchor blocks) beyond a single year on soft and intermediate bottom types is negligible, based on the updated analysis in Section 3.3 (Habitats). However, the impact of lighter materials and impacts on hard substrate could be longer term. Within a given training or testing location, the proportion of a habitat type determines the fraction of military expended material or crater footprints that would impact it.

The analysis results for single-year impacts are provided in Table I-1 through Table I-4 for habitats referenced in multiple resource sections (e.g., submerged aquatic vegetation in Section 3.4, Vegetation; shallow-water coral reefs in Section 3.5, Invertebrates). Seven-year totals are not provided based on the analysis presented Section 3.3 (Habitats).

The total impact area for temporary seafloor devices (anchors, bottom-placed instruments, metal plates, and mine shapes) is approximate 13 acres per year for both Alternatives 1 and 2 across all the range complexes and testing ranges, some inshore areas (Virginia Capes, Jacksonville, and Key West Range Complexes) and various port/pier locations.

Table I-1: Potential Impact from Explosive Charges on or near the Bottom for Military Readiness Activities under Alternatives 1 and 2 in a Single Year

EIS Locations	*Crater Footprint (Acres)*			*Percent of Shallow Soft and Intermediate Bottom Area*
	Training	*Testing*	*Combined*	
RC/Testing Range				
Northeast RC[1]	0.000	2.411	2.411	<0.001%
VACAPES RC	1.700	18.189	19.889	<0.001%
Navy Cherry Point RC	0.391	0.068	0.460	<0.001%
JAX RC	0.318	2.552	2.871	<0.001%
Key West RC	1.275	0.738	2.013	<0.001%
GOMEX RC[1]	0.404	14.634	15.039	<0.001%
NUWC Newport Testing Range[1]	0.000	0.019	0.019	<0.001%
NSWC Panama City Testing Range[1]	0.000	2.666	2.666	<0.001%
Other Locations				
Northeast RC Inshore[1]	0.000	0.002	0.002	<0.001%
VACAPES RC Inshore	0.018	0.002	0.021	<0.001%
JAX RC Inshore	0.000	0.005	0.005	<0.001%
Key West RC Inshore[2]	1.600	0.000	1.600	16.187
Grand Total	***5.709***	***45.401***	***51.110***	***N/A[1]***

[1] Overlaps with other locations. Also affects the grand total percentage.
[2] Does not account for efforts to direct explosive energy up and away from the seafloor
Notes: % = percent; < = less than; EIS = Environmental Impact Statement; GOMEX = Gulf of Mexico; JAX = Jacksonville; N/A = not applicable; NSWC = Naval Surface Warfare Center; NUWC = Naval Undersea Warfare Center; RC = Range Complex; VACAPES = Virginia Capes

Table I-2: Potential Impact to Bottom Habitat from Military Expended Materials for Training Activities under Alternative 1 in a Single Year

EIS Locations	Shallow Seafloor (0 to 95 m depths)						Deep Seafloor (95 to 2,500 m depths)			Bathyal/ Abyssal Zone (>2,500 m depths)	Total Impact (Acres)
	Coastal Wetland[1]	Seagrass Bed[1]	Mud/ Sand	Gravel/ Shell	Hard Bottom[2]	Coral Reef[2]	Mud/ Sand	Gravel/ Shell	Hard Bottom[2]		
Range Complex/Testing Range											
Northeast RC	<0.001	<0.001	0.708	0.357	0.058	0.000	0.904	0.229	0.094	1.216	3.566
VACAPES RC	0.000	0.000	3.196	1.744	0.040	0.000	3.324	0.052	0.183	6.883	15.421
Navy Cherry Point RC	0.000	0.000	1.351	0.023	0.124	0.000	1.643	0.103	0.172	1.422	4.839
Jacksonville RC	0.000	0.000	13.110	0.156	0.426	0.000	8.778	4.570	7.492	0.141	34.674
Key West RC	0.000	0.000	0.057	0.023	0.059	0.011	0.184	0.013	0.063	0.051	0.460
Gulf of Mexico RC	<0.001	0.000	0.655	0.191	0.036	0.000	0.744	0.037	0.058	0.083	1.804
Other Locations											
Other AFTT Areas	0.000	0.000	0.000	0.000	0.000	0.000	<0.001	0.000	<0.001	0.486	0.486
SINKEX Box	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.264	7.264
VACAPES RC Inshore	<0.001	<0.001	0.019	0.001	<0.001	0.000	0.000	0.000	0.000	0.000	0.020
Jacksonville RC Inshore	<0.001	0.000	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	0.000	<0.001
Key West RC Inshore	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
Gulf of Mexico RC Inshore	<0.001	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Total Impact	***<0.001***	*0.001*	*19.096*	*2.495*	*0.743*	*0.011*	*15.577*	*5.006*	*8.061*	*17.546*	***68.536***

[1] A habitat comprising "Submerged Aquatic Vegetation" (includes seagrass or benthic macroalgae habitat).
[2] A habitat comprising "Live Hard Bottom."
Notes: % = percent; < = less than; > = greater than; AFTT = Atlantic Fleet Training and Testing; EIS = Environmental Impact Statement; GOMEX = Gulf of Mexico; JAX = Jacksonville; m = meters; N/A = not applicable; RC = Range Complex; SINKEX = Sinking Exercise; VACAPES = Virginia Capes

Table I-3: Potential Impact to Bottom Habitat from Military Expended Materials for Testing Activities under Alternative 1 in a Single Year

EIS Locations	*Shallow Seafloor (0 to 95 m depths)*						*Deep Seafloor (95 to 2,500 m depths)*			*Bathyal/ Abyssal Zone (>2,500 m depths)*	*Total Impact (Acres)*
	Coastal Wetland[1]	*Seagrass Bed[1]*	*Mud/ Sand*	*Gravel/ Shell*	*Hard Bottom[2]*	*Coral Reef[2]*	*Mud/ Sand*	*Gravel/ Shell*	*Hard Bottom[2]*		
Range Complex/Testing Range											
Northeast RC[3]	<0.001	0.001	2.271	1.147	0.186	0.000	2.903	0.736	0.301	3.902	11.447
VACAPES RC	0.000	0.000	6.806	3.714	0.084	0.000	7.078	0.111	0.390	14.659	32.842
Navy Cherry Point RC	0.000	0.000	1.067	0.018	0.098	0.000	1.297	0.082	0.136	1.122	3.819
Jacksonville RC	0.000	0.000	3.090	0.037	0.100	0.000	2.069	1.077	1.766	0.033	8.172
Key West RC	0.000	0.000	0.702	0.286	0.728	0.133	2.276	0.161	0.779	0.634	5.700
Gulf of Mexico RC	<0.001	0.000	2.051	0.596	0.112	0.000	2.330	0.117	0.181	0.259	5.648
NUWC Newport Testing Range[3]	<0.001	0.003	1.473	0.317	0.055	0.000	0.171	0.004	0.018	0.000	2.043
SFOMF	<0.001	0.000	0.019	<0.001	<0.001	0.015	0.084	0.030	0.341	0.022	0.512
NSWC Panama City Testing Range	<0.001	0.000	1.133	0.669	0.081	0.000	1.385	0.087	0.013	0.000	3.369
Other Locations											
Other AFTT Areas	0.000	0.000	0.000	0.000	0.000	0.000	<0.001	0.000	0.003	3.369	3.372
Total Impact	***<0.001***	*0.004*	*18.613*	*6.784*	*1.446*	*0.148*	*19.593*	*2.406*	*3.927*	*24.001*	***76.923***

[1] A habitat comprising "Submerged Aquatic Vegetation" (includes seagrass or benthic macroalgae habitat).
[2] A habitat comprising "Live Hard Bottom."
[3] Includes some overlap with other locations.
Notes: % = percent; < = less than; > = greater than; AFTT = Atlantic Fleet Training and Testing; EIS = Environmental Impact Statement; GOMEX = Gulf of Mexico; JAX = Jacksonville; m = meters; N/A = not applicable; NSWC = Naval Surface Warfare; NUWC = Naval Undersea Warfare; RC = Range Complex; SFOMF = South Florida Ocean Measurement Facility Testing Range; SINKEX = Sinking Exercise; VACAPES = Virginia Capes

Table I-4: Potential Impact to Bottom Habitat from Military Expended Materials for Military Readiness Activities Combined under Alternative 1 in a Single Year

EIS Locations	*Shallow Seafloor (0 to 95 m depths)*						*Deep Seafloor (95 to 2,500 m depths)*			*Bathyal/ Abyssal Zone (>2,500 m depths)*	*Total Impact (Acres)*
	Coastal Wetland[1]	*Seagrass Bed[1]*	*Mud/ Sand*	*Gravel/ Shell*	*Hard Bottom[2]*	*Coral Reef[2]*	*Mud/ Sand*	*Gravel/ Shell*	*Hard Bottom[2]*		
Range Complex/Testing Range											
Northeast RC[3]	<0.001	0.001	2.978	1.504	0.245	0.000	3.807	0.966	0.394	5.117	15.013
VACAPES RC	0.000	0.000	10.002	5.457	0.124	0.000	10.401	0.163	0.573	21.543	48.264
Navy Cherry Point RC	0.000	0.000	2.418	0.041	0.223	0.000	2.939	0.185	0.307	2.545	8.658
Jacksonville RC	0.000	0.000	16.199	0.193	0.527	0.000	10.847	5.648	9.257	0.174	42.846
Key West RC	0.000	0.000	0.759	0.309	0.787	0.144	2.460	0.174	0.842	0.686	6.160
Gulf of Mexico RC[3]	<0.001	0.000	2.706	0.787	0.148	0.000	3.075	0.154	0.239	0.342	7.452
NUWC Newport Testing Range[3]	<0.001	0.003	1.473	0.317	0.055	0.000	0.171	0.004	0.018	0.000	2.043
SFOMF	<0.001	0.000	0.019	<0.001	<0.001	0.015	0.084	0.030	0.341	0.022	0.512
NSWC Panama City Testing Range[3]	<0.001	0.000	1.133	0.669	0.081	0.000	1.385	0.087	0.013	0.000	3.369
Other Locations											
Other AFTT Areas	0.000	0.000	0.000	0.000	0.000	0.000	<0.001	0.000	0.003	3.855	3.858
SINKEX Box	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.264	7.264
VACAPES RC Inshore	<0.001	<0.001	0.019	0.001	<0.001	0.000	0.000	0.000	0.000	0.000	0.020
Jacksonville RC Inshore	<0.001	0.000	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	0.000	<0.001
Key West RC Inshore	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001
Gulf of Mexico RC Inshore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Total Impact	*0.000*	*0.005*	*37.709*	*9.279*	*2.189*	*0.159*	*35.170*	*7.412*	*11.989*	*41.548*	***145.459***

Table I-4: Potential Impact to Bottom Habitat from Military Expended Materials for Military Readiness Activities Combined under Alternative 1 in a Single Year (continued)

EIS Locations	*Shallow Seafloor (0 to 95 m depths)*						*Deep Seafloor (95 to 2,500 m depths)*			*Bathyal/ Abyssal Zone (>2,500 m depths)*	*Total Impact (Acres)*
	Coastal Wetland[1]	*Seagrass Bed[1]*	*Mud/ Sand*	*Gravel/ Shell*	*Hard Bottom[2]*	*Coral Reef[2]*	*Mud/ Sand*	*Gravel/ Shell*	*Hard Bottom[2]*		

[1] A habitat comprising "Submerged Aquatic Vegetation" (includes seagrass or benthic macroalgae habitat).
[2] A habitat comprising "Live Hard Bottom."
[3] Includes some overlap with other locations.
Notes: % = percent; < = less than; > = greater than; AFTT = Atlantic Fleet Training and Testing; EIS = Environmental Impact Statement; GOMEX = Gulf of Mexico; JAX = Jacksonville; m = meters; N/A = not applicable; NSWC = Naval Surface Warfare; NUWC = Naval Undersea Warfare; RC = Range Complex; SFOMF = South Florida Ocean Measurement Facility Testing Range; SINKEX = Sinking Exercise; VACAPES = Virginia Capes

I.2 Statistical and Probability Analysis for Estimating Direct Strike Impact and Number of Potential Exposures from Military Expended Materials

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 materials include a variety of items including acoustic countermeasures, high-energy lasers, non-explosive practice munitions, sonobuoys, targets, and torpedoes. Only marine mammals and sea turtles will be analyzed using the methods presented in this section because animal densities are necessary to complete the calculations and density estimates are only available for these two species groups in the Study Area. The probability analysis included in this section does not consider that the high-energy laser systems used in military readiness activities that automatically shutdown when the locked target is lost. This means that if a high-energy laser beam aimed at a small boat on the water's surface, either from an aircraft or surface vessel moves off the target, the system ceases projecting laser light, preventing any energy from striking the water or a nearby animal. The analysis conducted here also 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 I-5 provides a list of symbols used in the equations located in the preceding sections.

Table I-5: 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

I.2.1 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 mammals and sea turtles on the sea surface in 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., 2011). 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_{Totl}), 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. This scenario assumes 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. This scenario assumes 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. 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 materials 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 percent 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 monthly 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 in the entire Study Area. For the remainder of the calculations, A_{TotS} was used to represent the presence of the species in 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 in 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). 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 (for consideration of mitigation during analysis, see Section 3.7.3.4, Marine Mammals, Physical Disturbance and Strike Stressors; and Section 3.8.3.4, Reptiles, Physical Disturbance and Strike Stressors).

I.2.2 PARAMETERS FOR ANALYSIS

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

- Two action alternatives: Alternatives 1 and 2. Animal densities, animal dimensions, and military item dimensions are the same for the two action alternatives.
- Two training or testing areas: Virginia Capes and Jacksonville Range Complexes. Areas are approximately 102,536 square kilometers (km^2) and 180,279 km^2, respectively. These two training and testing areas were chosen because they constitute the areas with the highest estimated numbers and concentrations of military expended materials for both alternatives, and would, thus, provide a reasonable comparison for all other areas with fewer expended materials.
    - To include Rice's whales in the analysis, the Gulf of Mexico Range Complex, Key West Range Complex, and the Naval Surface Warfare Center Panama City Testing Range were included in the analysis. The combined total area for these three locations is approximately 136,844 km^2.

- For high-energy lasers, two sites will be considered: Navy Cherry Point and Virginia Capes Range Complexes. Navy Cherry Point Range Complex has the highest number of high-energy lasers planned for training while Virginia Capes Range Complex has the highest number of high-energy lasers planned during testing. The area of the Navy Cherry Point Range is approximately 69,111 km^2.
- The following types of non-explosive munitions or other items were included in the analysis:
    - **Acoustic countermeasures:** includes aircraft deployed acoustic countermeasures
    - **Anchors:** includes blocks used to anchor mine shapes to the seafloor
    - **Bombs:** Non-explosive practice bombs and mine shapes, ranging from 10 to 2,000 pounds
    - **Expended bathythermographs**: small sensor deployed from ships
    - **High-energy lasers**: includes high-energy laser weapons that are directed at a surface target
    - **Large-caliber projectiles:** includes projectiles greater than or equal to a 57-millimeter projectile
    - **Lightweight torpedo accessories:** includes all accessories that are dropped along with the torpedo (nose cap, air stabilizer, etc.)
    - **Medium-caliber projectiles:** larger than 0.50-caliber rounds but smaller than 57-millimeters projectiles
    - **Small-caliber projectiles**: up to and including 0.50-caliber rounds
    - **Missiles:** includes rockets and jet-propelled munitions
    - **Sonobuoys:** includes all sonobuoys
    - **Targets:** includes expended airborne and surface targets, mine shapes, and aerial drones
    - **Torpedoes:** includes all lightweight torpedoes
- Animal species of interest: The five species of ESA-listed marine mammals expected in Virginia Capes, Jacksonville, or Cherry Point Range Complexes and the non-ESA-listed marine mammal and sea turtle species with the highest average month density in the training and testing areas of interest.
- Rice's whales were also considered in the analysis by including the following areas: Gulf of Mexico Range Complex, Key West Range Complex, and Naval Surface Warfare Center Panama City Testing Range. The analysis used the same method as previously described by incorporating the highest average monthly density in the training the testing areas of interest.

I.2.3 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 I-6 through Table I-9.

Table I-6: Estimated Representative Marine Mammal Exposures from Direct Strike of a High-Energy Laser by Area and Alternative in a Single Year

Species	*Training*		*Testing*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
VACAPES RC				
Blue whale	0.000000011	0.000000011	0.000000028	0.000000028
Fin whale	0.000048736	0.000048736	0.000051917	0.000051917
North Atlantic right whale	0.000000495	0.000000495	0.000000717	0.000000717
Sei whale	0.000001259	0.000001259	0.000001647	0.000001647
Short beaked common dolphin	0.010210021	0.010210021	0.010692757	0.010692757
Sperm whale	0.000686559	0.000686559	0.000709483	0.000709483
Cherry Point RC				
Blue whale	0.000000001	0.000000001	0.000000001	0.000000001
Bottlenose dolphin	0.002028441	0.002028441	0.001978733	0.001978733
Fin whale	0.000000226	0.000000226	0.000000201	0.000000201
North Atlantic right whale	0.000000008	0.000000008	0.000000005	0.000000005
Sei whale	0.000000080	0.000000080	0.000000065	0.000000065
Sperm whale	0.000157765	0.000157765	0.000154860	0.000154860
GOMEX RC, Key West RC, and Naval Surface Warfare Center Panama City Testing Range				
Rice's whale	0.000012165	0.000012165	0.000012448	0.000004000

Notes: GOMEX = Gulf of Mexico; RC = Range Complex; VACAPES = Virginia Capes

Table I-7: Estimated Representative Sea Turtle Exposures from Direct Strike of a High-Energy Laser by Area and Alternative in a Single Year

Species	*Training*		*Testing*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
VACAPES RC				
Green sea turtle	0.025458068	0.025458068	0.026529168	0.026529168
Cherry Point RC				
Loggerhead sea turtle	0.008734298	0.008734298	0.008558060	0.008558060

Notes: RC = Range Complex; VACAPES = Virginia Capes

Table I-8: Estimated Representative Marine Mammal Exposures from Direct Strike of Military Expended Materials by Area and Alternative in a Single Year

Species	*Training*		*Testing*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
VACAPES RC				
Blue whale	0.0000022	0.0000022	0.0000013	0.0000013
Fin whale	0.0002577	0.0002577	0.0001765	0.0001815
North Atlantic right whale	0.0000246	0.0000246	0.0000148	0.0000154

Table I 8: Estimated Representative Marine Mammal Exposures from Direct Strike of Military Expended Materials by Area and Alternative in a Single Year (continued)

Species	*Training*		*Testing*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
Sei whale	0.0000406	0.0000406	0.0000247	0.0000256
Short beaked common dolphin	0.0383024	0.0383024	0.0275588	0.0282200
Sperm whale	0.0018468	0.0018468	0.0014124	0.0014393
JAX RC				
Blue whale	0.0000006	0.0000006	0.0000001	0.0000001
Bottlenose dolphin	0.0106540	0.0106540	0.0045509	0.0047142
Fin whale	0.0000036	0.0000036	0.0000007	0.0000008
North Atlantic right whale	0.0000117	0.0000117	0.0000025	0.0000028
Sei whale	0.0000086	0.0000086	0.0000018	0.0000020
Sperm whale	0.0001394	0.0001394	0.0000489	0.0000513
GOMEX RC, Key West RC, and Naval Surface Warfare Center Panama City Testing Range				
Rice's whale	0.0000306	0.0000332	0.0000967	0.0000998

Notes: GOMEX = Gulf of Mexico; JAX = Jacksonville; RC = Range Complex; VACAPES = Virginia Capes

Table I-9: Estimated Representative Sea Turtle Exposures from Direct Strike of Military Expended Materials by Area and Alternative in a Single Year

Species	*Training*		*Testing*	
	Alternative 1	*Alternative 2*	*Alternative 1*	*Alternative 2*
VACAPES RC				
Green sea turtle	0.0849936	0.0849936	0.0623745	0.0637685
JAX RC				
Loggerhead sea turtle	0.1508685	0.1508685	0.0968295	0.0983556

Notes: JAX = Jacksonville; RC = Range Complex; VACAPES = Virginia Capes

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