Appendix G: Statistical Probability Analysis for Estimating Direct Strike Impact and Number of Potential Exposures

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

There are no figures in this section.

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APPENDIX G STATISTICAL PROBABILITY ANALYSIS FOR ESTIMATING DIRECT STRIKE IMPACT AND NUMBER OF POTENTIAL EXPOSURES

This appendix discusses the methods and results for calculating the probability of a direct strike of an animal from any military items from the proposed training and testing activities falling toward (or directed at) the sea surface. For the purposes of this appendix, military items include non-explosive practice munitions (e.g., rounds from shipboard small-arms live-fire training), sonobuoys, acoustic countermeasures, and targets. 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 Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area). Furthermore, the analysis conducted here does not account for explosive munitions because impacts from explosives are analyzed within the United States (U.S.) Department of the Navy (Navy) Acoustic Effects Model.

G.1 DIRECT IMPACT ANALYSIS

A statistical probability was calculated to estimate the impact probability (P) and number of exposures (T) associated with direct impact of military items on marine animals on the sea surface within the specified training or testing area (R) in which the activities are occurring. The statistical probability analysis is based on probability theory and modified Venn diagrams with rectangular "footprint" areas for the individual animal (A) and total impact (I) inscribed inside the training or testing area (R). The analysis 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, and (2) that the animals are stationary, which does not account for any movement or any potential avoidance of the training or testing activity.

1. A = length*width, where the individual animal's width (breadth) is assumed to be 20 percent of its length for marine mammals and 112 percent of its length for sea turtles. This product for A is multiplied by the number of animals N_a in the specified training or testing area (i.e., product of the highest average seasonal animal density [D] and training or testing area [R]: $N_a = D*R$) to obtain the total animal footprint area ($A*N_a = A*D*R$) in the training or testing area. As a worst case scenario, the total animal footprint area is calculated for the species with the highest average seasonal density in the training or testing area with the highest use of military items within the entire Study Area.

2. $I = N_{mun}$*length*diameter, where N_{mun} = total annual number of military items for each type, and "length" and "diameter" refer to the individual military equipment dimensions. For each type, the individual impact footprint area is multiplied by the total annual number of military items to obtain the type-specific impact footprint area ($I = N_{mun}$*length*diameter). Each training or testing activity uses one or more different types of military items, each with a specific number and dimensions, and several training and testing activities occur in a given year. When integrating over the number of military items types for the given activity (and then over the number of activities in a year), these calculations are repeated (accounting for differences in dimensions and numbers) for all military items types used, to obtain the type-specific impact footprint area (I). These impact footprint areas are summed over all military items types for the given activity, and then summed (integrated) over all activities to obtain the total impact footprint area resulting from all activities occurring in the training or testing area in a given year.

As a worst case scenario, the total impact footprint area is calculated for the training or testing area with the highest use of military items within the entire Study Area.

Though marine mammals and sea turtles are not randomly distributed in the environment, a random point calculation was chosen due to the intensive data needs that would be required for a calculation that incorporated more detailed information on an animal's or military item's spatial occurrence.

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.

The likelihood of an impact is calculated as the probability (P) that the animal footprint (A) and the impact footprint (I) will intersect within the training or testing area (R). This is calculated as the area ratio A/R or I/R, respectively. Note that A (referring to an **individual** animal footprint) and I (referring to the impact footprint resulting from the **total** number of military items N_{mun}) are the relevant quantities used in the following calculations of single-animal impact probability [P], which is then multiplied by the number of animals to obtain the number of exposures (T). The probability that the random point in the training or testing area is within both types of footprints (i.e., A and I) depends on the degree of overlap of A and I. The probability that I overlaps A is calculated by adding a buffer distance around A based on one-half of the impact area (i.e., 0.5*I), such that an impact (center) occurring anywhere within the combined (overlapping) area would impact the animal. Thus, if L_i and W_i are the length and width of the impact footprint such that $L_i*W_i = 0.5*I$ and $W_i/L_i = L_a/W_a$ (i.e., similar geometry between the animal footprint and impact footprint), and if L_a and W_a are the length and width (breadth) of the individual animal such that $L_a*W_a = A$ (= individual animal footprint area), then, assuming a purely static, rectangular scenario (Scenario 1), the total area $A_{tot} = (L_a + 2*L_i)*(W_a + 2*W_i)$, and the buffer area $A_{buffer} = A_{tot} – L_a*W_a$.

Four scenarios were examined with respect to defining and setting up the overlapping combined areas of A and I:

1. **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). Hence the impact footprint area (I) is assumed to be rectangular and given by the product of military items length and width (multiplied by the number of military items). $A_{tot} = (L_a + 2*L_i)*(W_a + 2*W_i)$ and $A_{buffer} = A_{tot} – L_a*W_a$.

2. **Scenario 2:** Dynamic scenario with end-on collision, in which the length of the impact footprint (Li) is enhanced by Rn = 5 military items lengths to reflect forward momentum. $A_{tot} = (L_a + (1 + R_n)*L_i)*(W_a + 2*W_i)$ and $A_{buffer} = A_{tot} – L_a*W_a$.

3. **Scenario 3:** Dynamic scenario with broadside collision, in which the width of the impact footprint (W_i) is enhanced by $R_n = 5$ military items lengths to reflect forward momentum. Atot = $(L_a + 2*W_i)*(W_a + (1 + R_n)*L_i)$ and $A_{buffer} = A_{tot} – L_a*W_a$.

4. **Scenario 4:** Purely static, radial scenario, in which the rectangular animal and impact footprints are replaced with circular footprints while conserving area. Define the radius (R_a) of the circular individual animal footprint such that $\pi*R_a^2 = L_a*W_a$, and define the radius (R_i) of the circular impact footprint such that $\pi *R_i^2 = 0.5*L_i*W_i = 0.5*I$. Then $A_{tot} = \pi *(R_a + R_i)^2$ and $A_{buffer} = A_{tot} - \pi *R_a^2$ (where $\pi = 3.1415927$).

Static impacts (Scenarios 1 and 4) assume no additional areal 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 five object lengths, resulting in a corresponding increase in impact area. Significantly different values may result from these two types of orientation. Both of these 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).

Impact probability P is the probability of impacting one animal with the given number, type, and dimensions of all military items used in training or testing activities occurring in the area per year, and is given by the ratio of total area (A_{tot}) to training or testing area (R): $P = A_{tot}/R$. Number of exposures is $T = N*P = N*A_{tot}/R$, where N = number of animals in the training or testing area per year (given as the product of the animal density [D] and range size [R]). Thus, $N = D*R$ and hence $T = N*P = N*A_{tot}/R = D*A_{tot}$. Using this procedure, P and T were calculated for each of the four scenarios, for Endangered Species Act (ESA)-listed marine mammals and the marine mammal and sea turtle species with the highest average seasonal 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.

G.2 PARAMETERS FOR ANALYSIS

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

1. **Three proposed alternatives:** No Action Alternative, Alternative 1, and Alternative 2. Animal densities, animal dimensions, and military item dimensions are the same for the three alternatives.

2. **Two Training or Testing Areas:** Hawaii Range Complex (HRC) and Southern California (SOCAL) Operating Areas (OPAREA). Areas are 235,000 square nautical miles (nm^2) and 120,000 nm^2, respectively. These two training areas were chosen because they constitute the areas with the highest estimated numbers and concentrations of military expended materials for each alternative, and would, thus, provide a reasonable comparison for all other areas with fewer expended materials.

3. **The following types of munitions or other items:**

    a) **Small-caliber projectiles:** up to and including 0.50 caliber rounds
    b) **Medium-caliber projectiles:** larger than 0.50 caliber rounds but smaller than 57 millimeter (mm) projectiles
    c) **Large-caliber projectiles:** includes projectiles greater than or equal to a 57 mm projectile

d) **Missiles:** includes rockets and jet-propelled munitions
e) **Bombs:** Non-explosive practice bombs and mine shapes, ranging from 10 to 2,000 pounds (lb.) (4.5 to 907.2 kilograms [kg])
f) **Torpedoes:** includes aircraft deployed torpedoes
g) **Sonobuoys:** includes aircraft deployed sonobuoys

4. **Animal species of interest:** the six species of ESA-listed marine mammals and the non-ESA listed marine mammal species with the highest average seasonal density in the training and testing areas of interest. The sea turtle species with the highest average seasonal density in the training and testing areas of interest.

G.3 INPUT DATA

Input data for the direct strike analysis include animal species likely to be in the area and military items proposed for use under each of the three alternatives. Animal species data include: (1) species ID and status (i.e., threatened, endangered, or neither), (2) highest average seasonal density estimate for the species of interest, and (3) adult animal dimensions (length and width) for the species with the highest density. The animal's dimensions are used to calculate individual animal footprint areas (A = length*width), and animal densities are used to calculate the number of exposures (T) from the impact probability (P): T = N*P. Military items data include: (1) military items category (e.g., projectile, bomb, rocket, target), (2) military items dimensions (length and width), and (3) total number of military items used annually.

Military items input data, specifically the quantity (e.g., numbers of guns, bombs, and rockets), are different in magnitude among the three proposed alternatives (No Action Alternative, Alternative 1, and Alternative 2). All animal species input data, the military items identification and category, and military items dimensions, are the same for the three alternatives, only the quantities (i.e., total number of military items) are different.

G.4 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 three 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 among the alternatives arise from different numbers of events (and therefore military items) for the three alternatives.

Results for marine mammals and sea turtles are presented in Table G-1 and Table G-2.

Table G-1: Estimated Annual Marine Mammal Exposures from Direct Strike of Munitions and Other Items by Area and Alternative

Pacific Marine Ecosystem						
HAWAII Operating Area						
Species	**Training**			**Testing**		
	No Action	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**
Humpback	0.00011	0.00015	0.00015	<0.00001	0.00003	0.00003
Blue Whale	<0.00001	0.00001	0.00001	<0.00001	<0.00001	<0.00001
Fin Whale	<0.00001	0.00001	0.00001	<0.00001	<0.00001	<0.00001
Sei Whale	<0.00001	0.00001	0.00001	<0.00001	<0.00001	<0.00001
Sperm Whale	0.00015	0.00028	0.00028	0.00001	<0.00001	<0.00001
Hawaiian Monk Seal	<0.00001	0.00001	0.00001	<0.00001	<0.00001	<0.00001
Southwest Coast United States Continental Shelf Large Marine Ecosystem						
SOUTHERN CALIFORNIA Operating Area						
Species	**Training**			**Testing**		
	No Action	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**
Humpback Whale	0.00032	0.00060	0.00060	0.00001	0.00005	0.00006
Blue Whale	0.00001	0.00002	0.00002	<0.00001	<0.00001	<0.00001
Fin Whale	0.00001	0.00002	0.00002	<0.00001	<0.00001	<0.00001
Sei Whale	0.00001	0.00003	0.00003	<0.00001	<0.00001	<0.00001
Sperm Whale	0.00044	0.00082	0.00082	0.00002	0.00007	0.00008
Guadalupe Fur Seal	0.00006	0.00006	0.00006	<0.00001	0.00001	0.00001

Table G-2: Estimated Sea Turtle Exposures from Direct Strike of Military Expended Materials by Area and Alternative

Pacific Marine Ecosystem						
HAWAII Operating Area						
Species	**Training**			**Testing**		
	No Action	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**
Pacific Sea Turtle Guild	0.01361	0.02011	0.01937	0.00049	0.00432	0.00457

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