Monitoring Plan for
Vehicle Launches on San Nicolas Island, California, 2010–2014

submitted by

LGL LIMITED
environmental research associates

and

GREENERIDGE SCIENCES

for

Naval Air Warfare Center Weapons Division

Point Mugu, California

and

National Marine Fisheries Service

Silver Spring, Maryland, and Long Beach, California

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Vehicle Launches on San Nicolas Island, California, 2010–2014

by

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ACRONYMS AND ABBREVIATIONS

~	approximately
ABL	Airborne Laser
AGS	Advanced Gun System
ATAR	Autonomous Terrestrial Acoustic Recorder
avg.	average
CFR	Code of Federal Regulations
CPA	closest point of approach
dB	decibel
hr	hour
Hz	hertz
IHA	Incidental Harassment Authorization
kHz	kilohertz
km	kilometer
LOA	Letter of Authorization
m	meter
min	minute
mm	millimeter
M_{pa}	frequency-weighting appropriate for pinnipeds in air (see Gentry et al. 2004; Southall et al. 2007)
NMFS	National Marine Fisheries Service
RAM	Rolling Airframe Missile
rms	root mean square
s	second
SEL	sound exposure level
SNI	San Nicolas Island
SPL	sound pressure level
V/μPa	volt per micropascal
μPa	micropascal

1. INTRODUCTION

Naval Air Warfare Center Weapons Division (NAWCWD) currently holds a Letter of Authorization (LOA) issued by the National Marine Fisheries Service (NMFS) allowing non-lethal takes of pinnipeds incidental to the Navy's vehicle launch operations on San Nicolas Island (SNI), California. The current LOA is valid from 4 June 2009 through 3 June 2010. The LOA was issued pursuant to 50 Code of Federal Regulations (CFR) 216.150–159 and §101(a)(5)(A) of the Marine Mammal Protection Act (MMPA), 16 United States Code (USC) §1371(a)(5)(A). Those regulations were initially issued for the period from 2 October 2003 through 2 October 2008 and were reissued in 2009 for the period 2 June 2009 through 2 June 2014. The regulations and associated LOAs allow for the 'take by harassment' of small numbers of northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*) during routine launch operations on Navy-owned SNI.

Previously, separate LOAs were issued for this purpose for the periods October 2003 to October 2004, October 2004 to October 2005, February 2006 to February 2007, February 2007 to February 2008, and February to October 2008. No launches took place during the February to October 2008 LOA period or during two intervals between expiry of one LOA and issuance of another (8 October 2005 to 2 February 2006 and 3 October 2008 through 3 June 2009). Before any LOAs were issued, two separate Incidental Harassment Authorizations (IHAs) were issued by NMFS; those provided similar incidental take authorization for the periods August 2001 to July 2002 and August 2002 to August 2003.

In the Navy's most recent Petition for Regulations that led to promulgation of 50 CFR 216.150–159, a Marine Mammal Monitoring Plan was proposed. This plan included provisions to monitor any effects of vehicle launch activities on pinnipeds hauled out at SNI in a manner similar to the monitoring that took place during 2001–2008. The Navy expected that the launches would cause disturbance reactions by some of the pinnipeds on the beaches, but no pinniped mortality and no significant long-term effect on the stocks of pinnipeds hauled out on SNI were anticipated. The possibility of some changes in the monitoring during the 2009–2014 period was considered in the previous monitoring plan, but in actuality no significant changes from the approach in 2001–2008 have been implemented to date.

During operations under the IHAs (2001–2003) and the initial regulations (2003–2008), the Navy monitored pinniped haul-out areas before, during, and after launch operations. The purpose of the monitoring was to document and characterize any observed responses and to detect (to the extent feasible) any instances of pinniped injuries or deaths if they occurred. More specifically, the monitoring program was designed to determine how common the disturbance reactions are, the nature of those reactions, the distances at which they occur, and their relationship to launch sounds.

From August 2001 to October 2008, there were a total of 77 launches of 83 vehicles from SNI on 53 different dates. These launches involved either single vehicles, "dual" launches, or up to three vehicles launched separately on the same day. Dual launches involved the launch of two vehicles within a span of ≤2 seconds (s) of one another; when counting the number of launches, a dual launch was treated as one launch. In total, 29 Vandals, 9 Coyotes, 11 Rolling Airframe Missiles (RAMs), 15 Advanced Gun System (AGS) slugs, 14 AGS missiles, 2 Arrows, 1 Falcon, 1 Tomahawk, and 1 Terrier-Orion were launched. Detailed information on these launches, the sounds they created, and pinniped behaviors during the launches can be found in Holst et al. (2008).

During 2009, three single vehicles were launched on three different dates, including one Terrier-Lynx and two Terrier-Black Brant vehicles (Holst and Greene 2010). These three launches occurred at night during the Airborne Laser (ABL) testing program. For that program, vehicles must be launched at night when the laser is visible.

The purpose of this document is to describe the monitoring approach planned for 2010–2011 in particular, and in a more general way for 2010–2014. All aspects of the planned monitoring are described, with emphasis on the few specific changes in monitoring that are proposed, and on the reasons for proposing those changes. Sections of the following text that contain changes from the monitoring approach used up to 2009 are denoted as underlined text. The monitoring that is proposed to occur during 2010–2014 launches is introduced briefly here and then described in more detail in subsequent subsections.

The Navy proposes to continue a standard, ongoing, land-based monitoring program to assess effects on harbor seals and sea lions but not elephant seals on SNI. During each launch, monitoring will occur at three sites at different distances from the launch site. By concentrating on the species that show the strongest reactions and types of vehicles that elicit the strongest reactions from pinnipeds, future monitoring will address the questions that remain open following the initial 8 years of monitoring (2001–2009). As in the past, the monitoring will be via autonomous video cameras, with enhancements to improve monitoring abilities at night. Pinniped behavior on the beach will be documented prior to the planned launch operations, during the launch, and following the launch.

During each monitored launch, the Navy will obtain calibrated recordings of the sounds of the launches as received at different distances from the vehicle's flightline. A variety of different recording sites will be used over the course of the year. These recordings, along with previously acquired acoustic data (Holst et al. 2008; Holst and Greene 2010), will allow a thorough description of launch sounds as received at different locations on western SNI, and the factors that affect received sound levels. Insofar as possible, the acoustic data will be obtained at the same sites as the video data on pinniped responses to the launches. By continued analysis of paired data on behavioral observations and received sound levels, their relationships will be further characterized, along with the influences of other variables that affect pinniped responses. Analyses planned for inclusion in the next comprehensive report (draft due in December 2013) will establish the "dose-response" relationship for species whose behavioral responses are related to received sound levels.

2. SUMMARY OF KEY RESULTS FROM PREVIOUS MONITORING

2.1 Comprehensive Study

From August 2001 to March 2008, there were a total of 77 launches of 83 vehicles from SNI on 53 different dates. During these launches, launch sounds and pinniped behavior were documented. Regression analyses were performed on the data to: (1) determine the relationship between the sound measures and various predictor variables, (2) examine the relationship between pinniped responses and several non-sound variables (such as distance, wind, season, etc.), and (3) determine the relationship between pinniped responses and various variables, including received sound level. For all analyses, data from 2001–2008 were combined.

The results of the Comprehensive Study covering launches from SNI during August 2001–March 2008 are briefly summarized below, and are summarized in somewhat more detail in the Appendix. Details regarding the data analysis methods, explanation of variables, and complete presentation of results can be found in Holst et al. (2008).

2.1.1 Acoustics

Peak pressure level, sound pressure level (SPL), and sound exposure level (SEL) decreased with increasing distances from the closest point of approach (CPA) of the vehicle. The relationship to the logarithm of CPA distance was slightly stronger than the relationship to linear distance. As expected, flat-weighted sound levels were generally stronger than A- and M-weighted (for pinnipeds in air, M_{pa}) levels at corresponding CPA distances. At longer CPA distances, the difference between the weighted sounds increased.

For all measures of sound (peak pressure, SPL, SEL), Vandals and Coyotes were the vehicles that produced the most sound. All other vehicles launched in 2001–2008 were generally quieter than Vandals or Coyotes. AGS and RAM vehicles were smaller and produced considerably less sound. The sound levels from the other vehicles were, on average, intermediate between those of Vandals and the small vehicles, but quite variable. The results also showed that, for higher angles above the horizon from the recording site to the vehicle CPA (CPA angle), the A- and M_{pa}-weighted received sound levels tended to be greater (other factors being equal).

The duration of the received sounds depended on the vehicle type and distance. From longest duration to the shortest duration, the order of the vehicles was “other large” vehicles (Terrier, Tomahawk, Arrow, and Falcon combined), RAMs, Vandals and Coyotes, and AGS vehicles. Duration of sound increased with increasing linear CPA distance. The wind component along the CPA-to-receiver axis was no more than a marginally significant predictor of sound duration, and it was not a significant predictor of the received sound level, other factors being equal.

2.1.2 Pinnipeds

From August 2001–March 2008, California sea lions were monitored during a total of 127 site-launch combinations during 42 launch dates, northern elephant seals were observed on 53 occasions during 31 launch dates, and harbor seals were monitored on 48 occasions during 23 launch dates. No evidence of injury or mortality was observed during or immediately succeeding the launches for any pinniped species. However, on three occasions, harbor seal pups were knocked over by adult seals as both pups and adults moved toward the water in response to the launch. Seal pups were momentarily startled, but did not appear to be injured and continued to move towards the water. On two occasions (not during launches), adult sea lions were observed knocking over sea lion pups when they moved along the beach; no injuries were evident.

California Sea Lions.—Generally, responses of sea lions to launches varied by individual. Some sea lions exhibited startle responses, whereas others hardly reacted to the launch. On 27 of 127 occasions, sea lions neither moved nor entered the water during the launch. On the remaining 100 occasions, 1–100% (average [avg.] 56%) of observed sea lions moved in response to the launch. Although sea lions showed increased vigilance for a short period after each launch, all age classes settled back to pre-launch behavior patterns within 1 or 2 minutes (min) after the launch. Also, during most launches, the proportion of sea lions that entered the water was generally low or zero. However, on 39 of 127 occasions, some but usually not all (1–100%; avg. 34%) sea lions entered the water in response to the launch.

Sea lion response was related to sound levels and CPA distance. More sea lions moved with increasing SELs, and a greater number entered the water with decreasing CPA distances. In addition, other factors being equal, a greater proportion of sea lions moved in response to launches during the non-breeding season.

Northern Elephant Seals.—During the majority of launches, most observed elephant seals exhibited little reaction to launches; they merely raised their heads for a few seconds and then returned to their previous activity pattern (e.g., sleeping, resting). During several launches (24 of 53 occasions), a small proportion (avg. 24%) of elephant seals on the beach repositioned or moved a small distance (<2 meters [m]) away from their resting site. The proportion of elephant seals that entered the water was typically zero, although 1–37% of elephant seals entered the water on three occasions.

Elephant seals tended to be more responsive (a greater proportion moved) when larger vehicles, such as Vandals, were launched. Elephant seal response was also related to CPA distance and SEL; a greater proportion of elephant seals moved with decreasing CPA distance and increasing SEL.

Harbor Seals.—During the majority of launches, most observed harbor seals left their haul-out sites, entered the water, and did not return during the duration of the video-recording period. On 37 of 48 occasions, 7–100% (avg. 77%) of seals moved in response to the launch. On 34 of 48 occasions, 7–100% (avg. 68%) entered the water in response to the launch.

Harbor seals were more responsive to launches during the pupping/breeding season. Harbor seal response increased with increasing CPA angle, but was not strongly related to received sound level or CPA distance. Harbor seals at all monitored locations, including those with CPA distances as great as 3.5 kilometers (km), commonly entered the water during launches.

2.2 Launches in 2009

During 2009, three single vehicles were launched: a single Terrier-Lynx was launched on 6 and 13 June 2009, and a single Terrier-Black Brant was launched on 10 August 2009 (Holst and Greene 2010). As these were nighttime launches, details of behavior could not always be observed subsequent to these launches. Nonetheless, the behaviors of both species monitored (elephant seals and California sea lions) appeared similar to those recorded during previous launches. During all four recordings of sea lions in 2009, all animals observed exhibited startle responses and moved along the beach. Most elephant seals merely raised their heads during the launches, but during at least three of the five recordings, a small percentage (3–7%) of hauled out elephant seals moved short distances (0.5–3 m) away from their resting site in response to the launch.

3. RECOMMENDATIONS FOR FUTURE MONITORING

The Navy's Monitoring Plan in the Petition for Regulations submitted to NMFS in August 2008, suggests that monitoring plans for subsequent years would be proposed in the applications for subsequent LOAs, subject to further discussion with NMFS. The Navy anticipated that, if monitoring of certain types of launches during 2001–2008 showed that they cause no or minimal disturbance to pinnipeds, monitoring during subsequent launches of those types would either be terminated or scaled back, assuming concurrence from NMFS. The quotations in italics below, taken verbatim from the Monitoring Plan, describe the changes that were anticipated to occur in the monitoring effort over the 5-year period of applicability of the Regulations when they were originally requested during late 2008. Following each quoted paragraph is a discussion concerning whether these anticipated changes now seem appropriate, and whether they are included in the currently proposed 2010-2014 Monitoring Plan. Recommended changes are designated in underlined text. The recommendations are based on the data collected and analyzed for the period August 2001–August 2009.

"(1) *Monitoring may be reduced during launches of small or less noisy vehicles, depending on results from ongoing and future monitoring efforts. In particular, monitoring effort may be scaled back in the future for northern elephant seals, as this species has shown little if any reaction to most launches at SNI (see Holst et al. 2005a,b; 2008).*"

The Navy proposes to eliminate specific monitoring of ***elephant seals*** during all future launches of Vandal- or Coyote-size or smaller vehicles on SNI. During the majority of launches monitored during 2001–2009, elephant seals exhibited little reaction to launches. Most individuals merely raised their heads briefly during the launches, returning within seconds to their previous activity pattern (usually sleeping). During some launches, a small proportion of elephant seals on the beach repositioned or moved a small distance away from their resting site. On 29 of 53 occasions in 2001–2008 (during launches of various vehicle types), elephant seals neither moved nor entered the water during the launch. During the other occasions, generally a small proportion (avg. 24%) of elephant seals moved a short distance (<2 m) in response to the launch. The percent of elephant seals that entered the water was typically zero. However, on three occasions, 1–37% of elephant seals entered the water in response to the launch.

During future launches of Vandal- and Coyote-size or smaller vehicles, elephant seals will be monitored along with the other pinniped species if elephant seals happen to be in the field of view of the camera. However, the choice of sites to monitor would be made primarily on the presence of harbor seals and sea lions.

If NMFS does not approve the suggestion that all monitoring specifically for elephant seals can be eliminated during future launches of Vandal- or Coyote-size and smaller vehicles, the Navy proposes continued monitoring of this species only during launches of larger vehicles. Although elephant seals reacted little to launches, results show that they were generally more responsive when larger vehicles, such as Vandals and Coyotes, were launched. It is proposed that, at a minimum, monitoring of elephant seals during launches of AGS vehicles and RAMs should be discontinued. By ending or reducing dedicated monitoring of elephant seals, the continued monitoring effort at three sites per launch can focus on the other two species that are more responsive and where there are still some open questions about the frequency and extent of responses (see below).

Reactions of ***sea lions*** were variable and require further monitoring during all launches to better characterize any relationships between sea lion responses and vehicle types, distance, etc. Monitoring during launches of all types of vehicles should be continued, as even the smaller/quieter vehicles (e.g., RAMs) elicited responses from sea lions on SNI. For example, sea lion responses during RAM launches, which were monitored on 12 occasions, ranged from no reaction to movement along the beach (4–100% of sea lions moved in response to launches) and entering the water (1–35% of sea lions entered the water). It would also be desirable to monitor sea lions at greater distances (e.g., 2–4 km) from the CPA more often than has been done in the past. That would determine whether the responses diminish with increasing distance and at what rate.

Harbor seals showed variable responses to launches of AGS, Vandal, Coyote, and "other large" vehicles (Arrow and Falcon). Harbor seals were not monitored during RAM, Terrier, or Tomahawk launches. During launches of a given vehicle type, harbor seal responses ranged from no reaction to movement along the beach and into the water. For example, during AGS launches, harbor seals were monitored on 11 occasions. The seals either showed no reaction (on seven occasions at sites located ~1.5–1.8 km from the CPA) or 95–100% of seals responded by moving along the beach (on four occasions at sites located ~1.2–1.4 km from the CPA).

In general, monitoring of sea lions and harbor seals should be continued during launches of all types of vehicles, as even the smaller/quieter vehicles elicit responses, and the responses are quite variable. The factors associated with low vs. high responsiveness of those two species have not yet been characterized to the point that responses in a particular situation can be predicted. For elephant seals, on the other hand, responses are minor under all conditions, and it is proposed that additional specific monitoring of that species is no longer needed during launches of Vandal- or Coyote-size or smaller vehicles.

"(2) *Depending on results from ongoing and future monitoring efforts, monitoring for launches from Building 807 may eventually be terminated when only small and relatively quiet vehicles are launched from that location, during which "takes" are not expected. Monitoring at this location could cease, at least during launches of small vehicles, if ongoing and future monitoring shows no substantial effects on pinnipeds during launches of the small vehicles typically launched from Building 807. In addition, if large vehicles are launched from this location, they are expected to have a smaller area of influence as compared with launches from the Alpha Launch Complex. Monitoring during launches of larger vehicles from Building 807 may also be discontinued at some future date.*"

To date, monitoring of pinnipeds has continued during all launches from the Building 807 Launch Complex, contrary to what was discussed in the 2008 Petition for Regulations quoted above. Some relatively large vehicles (Terrier-Lynx and Terrier-Black Brant) have been launched there since 2009 (Holst and Greene 2010). Some of the launches that from the Building 807 Launch Complex have produced substantial sound levels near the launcher and nearby beaches. However, few if any pinnipeds haul out on the beach closest to the Building 807 Launch Complex.

Responses of pinnipeds to launches of smaller vehicles (RAMs and AGS vehicles) from the Building 807 Launch Complex ranged from no reaction to movement along the beach or into the water during the launches. Although the RAM is generally one of the quietest vehicles launched from SNI, RAMs launched from the Building 807 Launch Complex elicited variable responses from sea lions and elephant seals.

- Elephant seals were monitored during four dual RAM launches and responded during three of these launches. During one launch, two of seven seals moved 1–3 m, but none entered the water. On another occasion, 14 of 60 elephant seals moved a short distance along the beach, but none entered the water. During another dual launch, 5 of 76 seals moved a short distance and one entered the water. However, this individual was already within 1–2 m of the water.

- Sea lions were monitored on 11 occasions during seven RAM launches (including four dual launches). Responses ranged from no reaction on three occasions, to movement along the beach (12–100% of sea lions moved) on seven occasions. Sea lions (1–88%) entered the water on three occasions.

During the launch of a Tomahawk from Building 807 Launch Complex in August 2002, elephant seals did not move or enter the water. However, 96% of sea lions moved in response to the launch, and one individual entered the water.

During three separate launches of a single Terrier-Lynx and two Terrier-Black Brant vehicles from Building 807 Launch Complex in 2009, only elephant seals and California sea lions were monitored. As these launches occurred at night during the ABL testing program, low-light conditions sometimes made it difficult to determine the reaction of some animals to the launches.

- California sea lions were observed during all three launches (total of four site-date-launch combinations). During all four video recordings of sea lions, all animals observed exhibited startle responses and moved along the beach at sites 0.6–1.3 km from the CPA.

- Elephant seals were observed during all three launches (five site-date-launch combinations). At 0.2–1.7 km from the CPA, most elephant seals exhibited little reaction to launches; they merely raised their heads. During at least three of the five recordings, a small percentage (3–7%) of hauled out elephant seals moved short distances (0.5–3 m) away from their resting site in response to the launch.

During 2010–2014, the Navy plans to continue monitoring launch sounds, responses of sea lions, and responses of any harbor seals that might be present during launches of small and large vehicles from the Building 807 Launch Complex. <u>No specific effort will be made to monitor elephant seals</u>.

"(3) *Monitoring may be scaled back to include only the launches during sensitive seasons for pinnipeds (e.g., breeding/pupping period for harbor seals), as launches are expected to have the greatest impact on populations during these times.*"

The scaled-back monitoring suggested in the above quotation from the Petition for Regulations has not been implemented. However, ***elephant seals*** showed little reaction to most launches, and there is no evidence of increased responses during the pupping/breeding season (late December to first week of March). <u>Thus, it appears that future monitoring of elephant seals is not necessary during any season</u>.

Sea lions showed variable responses to vehicle launches. Generally, reactions of sea lions varied by individual. Some sea lions exhibited startle responses and increased vigilance for a short period after each launch, while others appeared to react more vigorously by moving along the beach or entering the water; some hardly reacted to the launch at all. Data from monitoring in 2001–2008 suggest that a greater proportion of sea lions moved in response to launches during the non-breeding season. Since sea lion responses to launches were quite variable, it is proposed that monitoring of this species continue during all seasons. As noted earlier, this should include all vehicle types and both launch locations (Building 807 and Alpha Launch Complexes), and more of the monitoring should be at longer distances (e.g., 2–4 km). With continued monitoring, it should be possible to better characterize the relationships between sea lion response, season, and other variables.

During the majority of the launches (whether in the pupping/breeding season or not), most ***harbor seals*** left their haul-out sites, entered the water, and did not return during the duration of the video-recording period. Therefore, it is not deemed appropriate at this time to reduce monitoring to the breeding season only. However, the regression analysis showed that harbor seals were more responsive to vehicles launched during pupping/breeding season (March to beginning of May). Where practicable, the Navy will attempt to limit the number of launches during the harbor seal pupping/breeding season, as seals appear to be more responsive at this time.

3.1 Summary

No evidence of injury or mortality was observed during or immediately succeeding any of the launches from SNI. Generally, elephant seals showed the least response to vehicle launches, sea lion response was variable, and harbor seals reacted strongly. As monitoring has shown that elephant seals show little reaction to vehicle launches on SNI, it is proposed that specific monitoring of elephant seal responses to launches of Vandal- or Coyote-size and smaller vehicles be discontinued. However, the Navy still plans to conduct pinniped observations at three different sites during each launch, focusing on California sea lions and harbor seals and it is likely that some elephant seals will be incidentally observed. Reactions of sea lions are variable and require further monitoring during all launches from both the Building 807 and the Alpha Launch Complexes. Also, harbor seals tend to react strongly to all types of vehicle launches, and monitoring for this species should be continued. Monitoring of sea lions and harbor seals during launches of all types of vehicles during all seasons should be continued, as even the smaller/quieter vehicles elicit responses from those species.

4. SPECIFIC MONITORING PROCEDURES

The Monitoring Plan for 2010–2014 under the new Regulations is described below. Other than the deletion of specific monitoring of elephant seals, the proposed monitoring is similar to that conducted under the two IHAs (2001–2003), the first Regulations (2003–2008), and the monitoring conducted under the LOA for 2009–2010 under the new Regulations. This will assure that the results from the ongoing work are consistent and can be combined with earlier results for overall analyses. The Monitoring Plan presented here is similar to the one included in the Petition for Regulations that was submitted in 2008, but now proposes the exclusion of monitoring for elephant seals during launches of Vandal- or Coyote-size or smaller vehicles. The Navy understands that this Monitoring Plan, together with the recommendations for changes, will be subject to further review, and that refinements may be required.

Insofar as possible, acoustic data will be obtained at the same sites as those where the Navy will acquire video data on pinniped responses to the launches. By analysis of the paired data on behavioral observations and received sound levels, data that can be used to examine whether there is a clear relationship between the two will be collected. If so such a relationship exists, the "dose-response" relationship will be determined, taking account of past and future monitoring data. However, it may be necessary to measure sounds near the launcher for vehicles that have not previously been launched or monitored on SNI, or for which no good near-launcher sound data exist. In some of those cases, especially for launches from the Alpha Launch Complex (which is located inland), there will be no matched video data on pinniped responses close to the location of the acoustic recorder.

4.1 Visual Monitoring of Pinnipeds during Launches

The Navy proposes to conduct marine mammal and acoustic monitoring during each daytime and nighttime launch from SNI during 2010–2014. This will include simultaneous autonomous audio recording of launch sounds and video recording of sea lion and harbor seal behavior, generally at three sites during each launch. This land-based monitoring will provide data required to characterize the extent and nature of "taking". In particular, it will provide the information needed to document the nature, frequency, occurrence, and duration of any changes in sea lion and harbor seal behavior resulting from vehicle launches, including the occurrence of stampedes (if any). These video and audio records will be used to further document sea lion and harbor seal responses to the launches. This will include the following components:

- identify and document any change in behavior or movement that may occur at the time of the launch;
- compare pre- and post-launch behavioral data on each launch day to quantify the interval required for pinniped numbers and behavior to return to normal[1] if there is a change as a result of launch activities;
- compare received levels of launch sound with pinniped responses, based on acoustic and behavioral data from up to three monitoring sites at different distances from the launch site and flightline during each launch; from the data accumulated across a series of previous and future

[1] If numbers and/or behavior have not returned to "normal" within the duration of the autonomous recording, the duration of the period with reduced numbers will be reported as "greater than *x* minutes".

launches, establish the "dose-response" relationship[2] for launch sounds under different launch conditions;
- ascertain periods or launch conditions when pinnipeds are most and least responsive to launch activities, and
- document take by harassment and, although unlikely, any mortality or injury.

4.1.1 Field Methods

The launch monitoring program is based primarily on remote video recordings. Observations will be obtained before, during, and after each vehicle launch. Because Navy safety rules prevent personnel from being present in many of the areas of interest, remote cameras will be used during vehicle launches. During the launches, use of video methods will theoretically allow observations of up to three pinniped species during the same launch, depending on how many species are hauled out within the presumed area of influence. However, specific monitoring for elephant seals will not take place from June 2010 onward unless a vehicle larger than a Vandal is launched.

For the combined pinniped and acoustic monitoring, the Navy will attempt to obtain video and audio records from three locations at different distances from the flight path of the vehicle during each launch from SNI. Video data will be obtained via three cameras that can be set up temporarily at any site. One monitoring location will likely be near the planned launch azimuth or the launcher itself; the other monitoring sites will be some distance from the launch azimuth. However, the monitoring locations may vary from launch to launch based on accessibility and presence of pinniped species.

Combined video and acoustic monitoring is important to ascertain the lateral extent of the disturbance effects and the "dose-response" relationship between sound levels and pinniped behavioral reactions. Given the variability in types of vehicles launched at SNI, in sound propagation, and in pinniped behavioral reactions, this analysis requires data from a relatively large number of otherwise comparable launches. To investigate the dose-response relationships, acoustic and video response data from all monitoring period years will be combined in the draft and final comprehensive report due in December 2013 and September 2014, respectively.

Mobile Cameras for Daytime Launches.—Prior to each launch, Navy personnel will place portable Sony DCR-SR100 digital video cameras on tripods that overlook haul-out sites. Camera placement may occur as much as 5 hours prior to the launch, depending on safety restrictions. Placement of the cameras will be such that pinniped disturbance will be minimized. The cameras will be set to record a focal subgroup within the haul-out aggregation for the maximum time permitted by the memory capacity and battery life of the cameras. The entire haul-out aggregation at a given site will not be recorded, as the wide-angle view that would be necessary to encompass an entire beach would not allow detailed behavioral analyses. It is more effective to obtain a higher-magnification view of a sample of the animals at the site. Microphones built into these cameras will also record (qualitatively) vehicle and other sounds. These audio data will be used during behavioral analyses (e.g., to confirm the exact time when the vehicle passed, etc.).

Thermal Imaging Cameras for Nighttime Launches.—Prior to each nighttime launch, Navy personnel will place FLIR HS-324 Command thermal imaging cameras to overlook haul-out sites.

[2] This is equivalent to estimating behavioral zones of influence by comparing pinnipeds' reactions to varying received levels of launch sounds.

Camera placement may occur as much as 6 hours prior to the launch, depending on safety restrictions. The thermal imaging cameras, made by FLIR Systems, Inc., have a field of view of 24°×18°. When a FLIR-HS-2X Extender 2X extender lens is used with the cameras, as is planned for some locations on SNI, the field of view is 12°×9°. The cameras record data internally onto a Secure Digital (SD) card and can store greater than 5 hours of video.

Placement of the cameras will be such that disturbance to pinnipeds will be minimized, and the cameras will be set to record a focal subgroup within the haul-out aggregation for the maximum time permitted by the memory capacity and battery life of the cameras. The entire haul-out aggregation at a given site will not be recorded, as the wide-angle view that would be necessary to encompass an entire beach would not allow detailed behavioral analyses. The thermal imaging cameras do not record sound, so no simultaneous audio recording separate from the acoustic monitoring data will be available.

Visual Observations.—Navy biologists will make direct visual observations of the pinniped groups prior to deployment of the cameras and Autonomous Terrestrial Acoustic Recorders (ATARs; see §4.2). Data from these visual observations will include local weather conditions, species, locations of any pinnipeds hauled out, and the type of launch activity planned.

4.1.2 Video and Data Analysis

Digital video data will be copied to DVD-ROMs to facilitate transport and playback, and for backup. Video records will then be reviewed by qualified Navy staff or transferred from the Navy to a qualified contractor for analysis. Biologists experienced in this type of analysis will review and code the video data on the DVD-ROMs as they are played back to a high-resolution monitor. The player will have a high-resolution freeze-frame capability. The videotaped data will be reviewed ~30 min before, during, and ~15 min after the launch in order to document the types and numbers of pinnipeds present, and the nature of any overt responses to the launch.

Proportions of Pinnipeds Responding.—The proportions of observed pinnipeds that (a) move or (b) enter the water will be determined from each video recording by observing the entire group of pinnipeds videotaped at the monitoring site during a launch. The percentage of pinnipeds that move will include all animals that travel along the beach, irrespective of how far or how long the movement lasts, and whether or not those pinnipeds enter the water. As a separate estimate, the (generally smaller) percentage of pinnipeds that enter the water will be determined, including all individuals that leave the haul-out site to enter the water during the launch.

Specific Behavioral Observations.—Quantitative behavioral observations of pinnipeds will be made based on two 1-min samples of each video recording from the day of each launch if possible (i.e., if light conditions allow). The objective is to determine whether behavioral changes attributable to the launches persist for more than a few minutes. (Following NMFS [2002], subtle behavioral reactions that persist for only a few minutes are considered unlikely to have biologically significant consequences for the pinnipeds.) Data will be recorded for the 1-min interval immediately preceding the launch and for a 1-min duration starting 10 min after the launch (i.e., from 10–11 min after the launch). A focal subgroup will be chosen from the group of clearly visible animals, and individuals will be observed. Only individuals that are easily seen throughout the entire sample period will be chosen as focal animals. More specifically, the variables that will be transcribed from the videotapes include

1. composition of the focal subgroup of pinnipeds (numbers by sex and age class);

2. description and timing of disruptive event (vehicle launch); this will include documenting the occurrence of the launch and whether launch noise was evident on the video record's audio channel (if present);
3. movements of pinnipeds, including number and proportion moving, direction and distance moved, pace of movement (slow or vigorous); and
4. interaction type: agonistic, mother/pup, play, or copulatory sequence types.

In addition, the following variables concerning the circumstances of the observations will also be extracted from the videotape or from direct observations at the site:

1. study location;
2. local time;
3. substratum type—a categorical description of the substratum upon which the focal group of pinnipeds was resting (sand, cobble, rock ledges, or water less than 1 m deep);
4. substratum slope (0–15º, >15º, or irregular), estimated from the video records;
5. weather, including an estimate of wind strength and direction, and presence of precipitation; these data are available from the Navy meteorological unit on SNI;
6. horizontal visibility—the average horizontal visibility (in meters) around the focal subgroup of pinnipeds, as determined by meteorological conditions and/or physical obstructions; this was estimated by determining what the farthest visible object was relative to the interacting pinnipeds, as evident from the known positions of local objects and accounting for obstructing terrain; and
7. tide state—exact time for local high tide as determined from relevant tide tables.

4.2 Acoustic Monitoring

4.2.1 Field Methods

Deployment of ATARs.—Acoustical recordings will be attempted at three to four locations during each launch, usually at locations near the three video records (see §4.1) and an additional "source" recording close to the launch pad. ATARs will be positioned so that, given the planned launch azimuth, at least one ATAR is near the launch azimuth (or the launch site itself). The other ATARs will be positioned close to the video recorders based on pinniped presence. These recordings are expected to be suitable for quantitative analysis of the levels and characteristics of the received flight sounds. In addition to providing information on the magnitude, characteristics, and duration of sounds to which pinnipeds are exposed during each launch, these acoustic data will be combined with the pinniped behavioral data to determine what the "dose-response" relationship is between received sound levels and pinniped behavioral reactions.

ATARs will be set up at the recording locations on the launch day well before the launch time and will be retrieved later the same day. ATAR units will be deployed by Navy personnel at sites as close as practical to three pinniped haul-out sites at various distances from the launch site and launch trajectory. ATAR placement will primarily be influenced by location of pinnipeds, though over the course of the monitoring period, it is expected that a variety of distances from the launch azimuth or launch pad will be recorded.

ATAR Design.—The ATARs are designed to record continuously and unattended for up to 13 hr. It is necessary to use autonomous extended-duration recorders because safety considerations require all personnel to leave the monitoring sites at least 1 hr prior to the planned launch.

The ATARs are designed to record both high-level sounds (e.g., from vehicle launches) and normal background sounds. The ATARs record two sensor channels, each with a bandwidth of 3 to 20,000 hertz (Hz). The principal components of an ATAR are two calibrated dissimilar microphones, two adjustable gain amplifiers (signal conditioners), and a Sound Devices 702 recorder that digitizes and records sound samples. In 2009, the Sound Devices 702 recorder replaced the notebook computer that was used to store the digital audio data previously, in order to improve the reliability of the system.

Each ATAR includes two microphones that differ in sensitivity. One microphone in each ATAR is a PCB 106B50 quartz microphone (PCB Piezotronics Inc., Depew, NY). These relatively insensitive microphones, with sensitivity –202 dB re 1 volt per micropascal (V/µPa), are designed for transduction of strong signals with received sound levels up to 185 dB re 20 µPa. To record ambient sounds concurrently, each ATAR includes a more sensitive microphone, the TMS 130P10 (–157 dB re 1 V/µPa). This, in conjunction with the PCB 106B50, provides additional dynamic range. Each microphone signal is sampled at 44.1 kilohertz (kHz) and digitized to a 16-bit two-byte integer.

At each of the monitoring sites, the microphones will be placed in hemispherical windscreens and positioned so they are 2–3 millimeters (mm) from the flat side of the hemisphere. The windscreens are then each affixed to the center of an aluminum base plate 6 mm thick and 56 centimeter in diameter. The two base plates are set on the ground or sand in an area generally free of vegetation. The purpose of the aluminum base plates is to provide a hard reflecting surface for high-frequency sounds. The ground itself is acoustically reflective at low frequencies. The combination of the base plates and the ground assures that the microphones sense the combined direct and reflected sound, just as an animal would near the ground (Greene 1999).

Each microphone requires a PCB model 480E09 signal conditioner. These low-noise amplifiers apply the microphone polarizing voltage. The signal conditioners have gain selections of 1, 10, and 100 (corresponding to 0, 20, and 40 dB, respectively). These signal conditioners are mounted in protective cases with the remaining equipment, excluding the microphones.

Setting optimum recording levels presents a challenge, given that these have to be set in advance of the launch, with no opportunity to make adjustments based on initial results at that location. Setting recording levels too high could result in clipping the desired signal, setting them too low could lose the signal beneath recorder self-noise, and setting them dynamically by automatic gain control would result in uncalibrated, and hence useless, data.

4.2.2 Audio and Data Analysis

The ATARs will record digital data onto CF Card within the ATAR. The digital data on CF cards will be copied to a recordable CD-ROM after the recording period and reviewed by qualified Navy staff or transferred to a qualified acoustical contractor for sound analysis.

Both time-series and frequency-domain analyses will be performed on the acoustic data. Time-series results will include signal waveform and duration, peak SPL, root mean square (rms) SPL, and SEL. Frequency-domain results will include estimation of sound pressure levels in 1/3rd octave bands for center frequencies from 4 to 16,000 kHz. This section describes how these values are defined and calculated. All values will be calculated in the same manner as during previous years (Holst et al. 2008) so that all results acquired since 2001 will be comparable and can be treated together in the analyses planned for the next Comprehensive Report.

Time-Series Analysis.—All analyses will require identification of a signal's beginning and termination. This identification can be complicated by background noise (whether instrumental or ambient), poorly defined signal onsets, and gradually diminishing signal "tails". To obtain a consistent measure of signal duration for each flight, a "net energy" E is defined. This measure of energy in excess of background is calculated as the cumulative signal energy above mean background energy:

$$E = \frac{1}{f_s}\sum_{i=1}^{N} \left(x_i^2 - \langle n^2 \rangle\right) \text{ Pa}^2 \text{ s}$$

where *x* represents all data points in an event file, *n* represents only background noise data points before the flight sound, N is the total number of samples in the event file, and f_s is the sampling rate.

Based on this consistent definition of net energy E, the beginning and end of a flight sound is defined as the times associated with the accumulation of 5% and 95% of E.

Duration is defined as the difference between these start and end times.

Sound exposure is defined as 90% of E, representing total sound exposure in units of $Pa^2 \cdot s$. **SEL** is determined from 10·log (sound exposure).

Sound pressure is defined as the square root of the sound exposure divided by the duration. Sound pressure is equivalent to the rms value of the signal, less background noise, over the duration. **SPL** is determined from 20·log (sound pressure).

The ***peak instantaneous pressure*** is defined as the largest sound pressure magnitude (positive or negative) exhibited by the signal, even if the signal reaches that level only momentarily. **Peak instantaneous pressure level** is determined from 20·log (peak instantaneous pressure).

Frequency-Domain Analysis.—Frequency-domain analysis will be used to estimate how signal power was distributed in frequency. Welch's (1967) "Weighted Overlapped Segment Averaging" (WOSA) method will be used to generate representative power spectral densities in each case. Power spectral densities will be calculated for the signal and pre-signal background noise on the low-sensitivity channel, and for background noise on the high-sensitivity channel. These spectral density values will then be summed into 1/3rd octave bands. We will continue to report flat-weighted and A-weighted data, as well as SPL and SEL values weighted by the "M_{pa}" weighting function that NMFS is expected to adopt for use in studies of pinnipeds in air exposed to strong man-made sounds (Gentry et al. 2004; Southall et al. 2007).

For these analyses, the "signal" will be defined as consisting of the recorded data (vehicle signal plus background noise). This time series will be segmented according to duration (determined from the broad-band time series analysis) as follows:

- for duration >1 s, use 32,768-sample blocks of total length 0.74 s with Blackman-Harris (Harris 1978) minimum three-term window, overlapped by 50%. This results in frequency cells spaced by 1.35 Hz and an effective cell width (resolution) of 2.3 Hz.
- for 0.0929 < duration < 1 s, use 4096-sample blocks of total length 0.0929 s with Blackman-Harris minimum three-term window, overlapped by 50%. This results in frequency cells spaced by 10.77 Hz and an effective cell width (resolution) of 18.3 Hz.

- for duration <0.0929 s, use the samples spanning the signal duration and apply a uniform window. This results in cell spacing in Hz given by the reciprocal of the record length in seconds. The cell width (resolution) is the same as the cell spacing.

Background noise data that will be recorded on the high sensitivity channel, consisting of 4 s of data selected from before the vehicle signal, will be segmented into 44,100-sample blocks overlapped by 50% and weighted by the Blackman-Harris minimum three-term window, resulting in 1-Hz cell spacing and 1.7 Hz cell width, or resolution.

The spectral density values will be integrated across standard $1/3^{rd}$ octave band frequencies to obtain summed sound pressure levels for each band. This analysis will be performed for the signal, the noise on the signal channel (low-sensitivity channel), and the background noise (high-sensitivity channel). Note that when the cell spacing is broad, the lowest frequency $1/3^{rd}$ octave bands cannot be computed. However, the cases of broad cell spacing usually correspond to cases of very short duration signals. Low frequencies are not important for short duration sounds.

Frequency Weighting.—Frequency weighting is a form of filtering that serves to measure sounds over a broad frequency band with various schemes for de-emphasizing sounds at frequencies not heard well and retaining sounds at frequencies that animals hear well. The concept is that sound at frequencies not heard by animals is less likely to injure or disturb them, and therefore such sounds should not be included in measurements relevant to those animals. Time-series results for the full 3 to 20,000 Hz bandwidth will be calculated for flat-, A-, and M_{pa}-weightings. Instantaneous peak pressure, SPL, SEL and duration will be calculated with flat weighting. Three of these four measures (not peak pressure) will also be calculated with A- and M_{pa}-weighting.

Flat-weighting leaves the signal spectrum unchanged. For instantaneous peak pressure, where the highest instantaneous pressure is of interest, it is not useful to diminish the level with filtering, so only the flat-weighted instantaneous peak pressure is relevant. Also, non-uniform weighting is not useful when reporting results for specific frequencies or narrow frequency bands. Therefore, only flat-weighting will be used for frequency-domain analyses.

With ***A-weighting***, the signal's spectrum is multiplied by the standard A-weighting spectrum (Kinsler et al. 1982:280; Richardson et al. 1995:99). This multiplication slightly amplifies signal energy at frequencies between 1 and 5 kHz and attenuates signal energy at frequencies outside this band. This process is designed to mimic the weighting applied by the human ear and is a standard method of presenting data on airborne sounds. The relative sensitivity of pinnipeds listening in air to different frequencies is generally similar to that of humans (Richardson et al. 1995), so A-weighting may, as a first approximation, be relevant to pinnipeds listening to moderate-level sounds. SPL, SEL, and duration will be calculated with A-weighting but instantaneous peak pressure will not.

M_{pa}-weighting is a recent development that arose from the ongoing effort to develop science-based guidelines for regulating sound exposures. During this process, separate weighting functions have been developed for five categories of marine mammals, with these functions being appropriate in relation to the hearing abilities of those groups of mammals (Gentry et al. 2004; Southall et al. 2007). Two of these categories are pinnipeds hearing in water and in air, for which the weighting functions have been designated M_{pw} and M_{pa}, respectively. The five "M-weighting" functions are almost flat between the known or inferred limits of functional hearing for the species in each group, but down-weight ("attenuate") sounds at higher and lower frequencies. As such, they are analogous to the C-weighting function that is often applied in human noise exposure analyses where the concern is about potential effects of high-level sounds. With M_{pa}-weighting, the lower and upper "inflection points" are 75 Hz and

30 kHz. Acoustic data based on M_{pa}-weighting are likely to be needed in the future for purposes of assessing impacts on pinnipeds of sounds with high received levels, such as those during some vehicle overflights. SPL, SEL, and duration will be calculated with M_{pa}-weighting but instantaneous peak pressure will not.

5. REPORTING PLAN

5.1 Annual Reports

An interim technical report will be submitted to NMFS 60 days prior to the expiry of the LOA issued under the Regulations (or at such other interval as may be negotiated between NMFS and the Navy and specified in the LOA), along with a request for a follow-on LOA. This interim technical report will provide full documentation of methods, results, and interpretation pertaining to all monitoring tasks for launches during the period covered by the LOA. However, only preliminary information would be included for any launches during the 60-day period immediately preceding submission of the interim report to NMFS. Also included would be full documentation for any previously-unreported launches that occurred too late in the preceding year to have been included in that year’s report. In the unanticipated event that any cases of pinniped mortality or serious injury are judged to result from launch activities at any time during the period covered by the Regulations, this will be reported to NMFS immediately.

5.2 Comprehensive Report

A draft Comprehensive Report, covering all launches from 2001 through 2013 will be submitted to NMFS in December 2013, 180 days before the expiry of the Regulations on 2 June 2014, as called for in the Regulations (50 CFR § 216.155). The draft report will provide full documentation of methods, results, and interpretation pertaining to all monitoring tasks for launches during the August 2001 through June 2013 period, and preliminary information about launches in the July–December 2013 period. A final Comprehensive Report, including all monitoring results through to the expiry of the Regulations, will be submitted 90 days after the end of the period of effectiveness of the Regulations. This final report will be an update of the Comprehensive Report submitted to NMFS in April 2008.

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Appendix: Responses of Pinnipeds to Navy Missile Launches at San Nicolas Island, California

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Abstract

To document the responses of pinnipeds to launches of missiles and similar aerial vehicles, three species of pinnipeds were observed during 77 launches from a Navy-owned island off California from August 2001 to June 2007. Pinniped behavior and flight sounds during each launch were recorded by unattended video cameras and acoustic recorders set up around the island's periphery, usually in pairs, as vehicles flew over or near haul-out sites. Multiple logistic regression was used to assess dependence of pinniped responses on received sound, distance from flight path, type of vehicle, and natural factors. The majority of California sea lions (*Zalophus californianus*) startled and showed increased vigilance up to 2 min after each launch; responses often included movement on the beach or into the water, and were significantly related to received sound level and distance from the vehicle's closest point of approach. Most northern elephant seals (*Mirounga angustirostris*) showed little reaction to launches and merely raised their heads briefly. Nonetheless, their responses were also related to received sound level and distance from the trajectory. The harbor seal (*Phoca vitulina*) was the most responsive species. During the majority of launches, most (average 68%) seals within ~4 km of the launch trajectory left their haul-out site by entering the water; seals started hauling out again at the same site several hours after the launch. Within the range of conditions studied, there was no clear correlation between harbor seal response and received sound level or distance from the closest point of approach of the vehicle. Despite these short-term behavioral reactions, the effects of launch operations are likely to have been minor and localized, with no consequences for local pinniped populations.

Key Words: disturbance, launch sounds, missiles, response, California sea lion, harbor seal, northern elephant seal

Introduction

The responses of pinnipeds to human activities vary widely (Richardson et al., 1995), with the degree of disturbance depending on species, disturbance type and intensity, and other factors. The literature on pinniped responses to missile launches and related activities is limited and includes a wide variety of vehicle types. Several species of pinnipeds have been documented to enter the water in response to vehicle launches, aircraft overflights, and sonic booms, but they generally hauled out again within several hours after the disturbance or the next day (e.g., Bowles & Stewart, 1980; Stewart, 1982, 1993; Stewart et al., 1994a; Holst et al., 2005; ManTech SRS Technologies [MSRS], 2008). Although the primary effect of occasional missile launches on pinnipeds is likely to be short-term disturbance, there is also concern about stampedes and the crushing or abandonment of pups. Several studies have noted pup mortality due to abandonment by female pinnipeds during disturbance events, including overflights (e.g., Johnson, 1977; Wickens et al., 1992). However, direct mortality during disturbance-induced stampedes is rare (Richardson et al., 1995). Nonetheless, Lewis (1987) noted mortality of Steller sea lions (*Eumetopias jubatus*) due to human disturbance events. Also, walruses (*Odobenus rosmarus*) stampeding from haul-out sites during aircraft overflights have been reported to crush other individuals, especially calves (e.g., Loughrey, 1959; D. Fisher *in* Johnson et al., 1989; Ovsyanikov et al., 1994). However, no pup mortality has been observed during aerial vehicle launches at Navy-owned San Nicolas Island (SNI; Holst et al., 2005), large missile launches at Vandenberg Air Force Base (MSRS, 2008, 2009), or in response to simulated sonic boom sounds in California (Stewart, 1981, 1982). As existing knowledge is limited, there is a need to examine pinniped responses to launches of small- and moderate-sized vehicles, as launch facilities are often situated along coastlines where pinnipeds haul out.

The U.S. Navy has been launching missiles, aerial targets, and other similar vehicles from SNI for over 50 years. The vehicles often fly over or near beaches around the periphery of SNI where pinnipeds are hauled out; some vehicles produce a sonic boom. Under the Marine Mammal Protection Act, the National Marine Fisheries Service (NMFS) issues authorizations to the Navy for disturbance of pinnipeds during launches from SNI. These authorizations allow the 'take by harassment' of small numbers of northern elephant seals, harbor seals, and California sea lions during routine launches of small and moderate-sized vehicles from SNI. Two separate 1-year Incidental Harassment Authorizations (IHAs) were held by the Navy from 2001 to 2003, and from October 2003 to October 2008, launch operations were conducted under Regulations (NMFS, 2003) and associated Letters of Authorization (LOA). A total of 77 launches of 83 vehicles took place from SNI on 53 days from 2001 through 2008 (Table 1). Acoustic and pinniped monitoring took place in conjunction with these vehicle launches.

Pinniped responses were documented by unattended video cameras set up before each launch at haul-out sites. Video data were supplemented by direct visual observations of the hauled out pinniped groups prior to and occasionally following the launches. Launch sounds were also monitored near pinniped haul-out sites by Autonomous Terrestrial Acoustic Recorders (ATARs). The monitoring effort was intended to provide the information needed to document the nature, frequency, and duration of changes in pinniped behavior resulting from the vehicle launches, including the occurrence of stampedes or injuries if they occurred.

The specific objectives of the monitoring program were (1) to identify and document changes in behavior or movements that occurred during the launches, (2) to relate pinniped responses to distance from the launch azimuth and received sound levels, with allowance for other factors influencing responses, and (3) to compare the responses of the three pinniped species. Previously, we reported on the responses of pinnipeds to 31 launches of small and moderate-sized vehicles from SNI during 2001 to 2003 (Holst et al., 2005). Since 2003, numerous additional vehicles have been launched from SNI. This has allowed a more detailed analysis of pinniped responses, including use of a multivariate approach to evaluate whether various additional factors affected the strength of pinniped responses to the launches. Here we present the results from monitoring during the 2001–2008 period.

Materials and Methods

Vehicle Launches

The launches involved either single vehicles, "dual" launches (two vehicles launched in quick succession within a span of ≤2 seconds), or up to three vehicles launched separately on the same day. In total, the Navy launched 29 Vandal target missiles, nine Coyote Supersonic Sea-Skimming Targets (SSSTs), 17 Advanced Gun System (AGS) slugs, 12 AGS missiles, 11 Rolling Airframe Missiles (RAM), and occasionally other missiles (two Arrows, one Falcon, one Tactical Tomahawk, and one Terrier Orion). Most of these vehicles are medium-sized missiles (1000–4000 kg at launch), but the RAM and AGS missiles are small (~70 kg). Vehicles were launched from one of two launch complexes on SNI. The Tomahawk and RAMs were launched from the Building 807 Launch Complex on the west coast of SNI (Figure 1), close to shore and 11 m above sea level. Until June 2004, AGS vehicles were launched from the Alpha Launch Complex, located 190 m above sea level on the west–central part of SNI (Figure 1); starting in July 2004, these vehicles were launched from the Building 807 Launch Complex. All other vehicles were launched from the Alpha Launch Complex. All launches occurred during daylight. Conditions ranged from clear and sunny to overcast and partly cloudy, with variable winds.

Acoustic Monitoring

During each vehicle launch, up to three ATARs were positioned near pinniped haul-out sites at varying distances from the planned launch azimuth to record received sound levels during launches. The ATARs were designed with separate channels to record both high-level sounds (e.g., from vehicle launches) and normal background sounds. The ATARs recorded each sensor channel with a bandwidth of 3 to 20,000 Hz. The principal components of the ATARs included two calibrated dissimilar microphones (PCB 106B50 and TMS 130P10), two adjustable gain amplifiers (signal conditioners—PCB model 480E09), and a two-channel digital audio recorder. Microphones were placed in hemispherical windscreens and each was affixed to an aluminum base plate (56 cm diameter, 6 mm thick) set on the ground.

Acoustic Analysis

From the recorded data for each launch, peak pressure, sound duration, rms sound pressure level (SPL) averaged over the duration, and M_{pa}-weighted sound exposure levels (SEL-M) were determined. Duration of transient launch sounds was defined as period during which 90% of the launch sound energy was received. The recently-defined M_{pa}-weighting procedure, appropriate for pinnipeds receiving strong airborne sound, is described in Southall et al. (2007). The M-weighting function is almost flat between the known or inferred limits of functional hearing for pinnipeds, but down-weights (attenuates) sounds at higher and lower frequencies. With M_{pa}-weighting, the lower and upper "inflection points" are at 75 Hz and 30 kHz. More details on the measurement procedures and other parameters measured can be found in Greene et al. (in prep.).

Visual Monitoring of Pinnipeds

Video recordings by remote cameras were made before, during, and after each launch; remote cameras were essential because of safety rules associated with launches. Use of three video cameras allowed observations of up to three pinniped species during the same launch at up to three locations, depending on how many species were hauled out at each site. Monitoring locations varied from launch to launch, depending on seasonal abundance of pinnipeds and logistics of equipment deployment. Navy environmental personnel also observed the pinniped groups directly prior to camera deployment, and (sometimes) during retrieval, of the cameras. Details of the field procedures were described by Holst et al. (2005).

Video Analysis

Digital video data were reviewed using a high-resolution monitor, and the following variables were transcribed: (1) composition of each haul-out aggregation, i.e., species, sex and age class; (2) description and timing of the launch; and (3) number and proportion of pinnipeds that moved and entered the water during and immediately after the launch. The proportion of the monitored pinnipeds that moved or entered the water in response to the launch were determined by noting the total number of animals that reacted in relation to the total number of pinnipeds hauled out at the monitored site. Wind strength and direction were measured at the SNI airport, located 152 m above sea level toward the east end of the island. To relate pinniped behavior (e.g., percent of pinnipeds that moved or entered the water) to the proximity of the launch, the 3-dimensional (3-D) distance from the recording site to the closest point of approach (CPA) of the vehicle was calculated for each launch and monitoring site.

Data Analysis

To determine basic relationships between pinniped behavior and either proximity to the vehicle or SEL-M, Spearman Rank Order Correlations were calculated. The two response variables analyzed were "% that moved" and "% that entered water". One-sided *p*-values were derived because the direction of the effect was predictable. The analyses included data from all launches on all dates during all years of monitoring. To further investigate the effects of launches on pinniped behavior while allowing for various potentially confounding factors, we fitted logistic regression models (Ramsey & Schafer, 2002) to the two measures of behavioral responses, separately for the three pinniped species. All logistic regression equations were of the form

$$\pi = \frac{\exp(\beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \ldots + \beta_k\chi_k)}{1 + \exp(\beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \ldots + \beta_k\chi_k)}$$

where π was the proportion of a given pinniped species (harbor seal, sea lion, elephant seal) that moved or entered the water after a launch, $\chi_1, \ldots, \chi_p$ were a set of predictor variables, and $\beta_0, \ldots, \beta_p$ were parameters to be estimated. The proportions, π, were calculated by dividing the number of individuals that moved or entered the water after a launch by the number of individuals that were on the beach at the time. Basic sample size was the number of launches, not number of individuals, and proportions observed when larger numbers were present on the beach were treated as having more precision than proportions obtained when few individuals were present.

Predictor variables considered for inclusion were pre-determined based on their hypothesized effects on pinniped behavior after a launch. From this pool of predictor variables, backward model selection, with forward looks at the significance of previously removed variables, was used to determine the "best" set of predictor variables. From an initial model with all predictor variables, predictors were removed one-at-a-time based on a significance value of 0.15. Between removals, previously eliminated variables were inspected and added back to the model if their significance value had become <0.15.

The χ^2 statistic for each coefficient and *p*-values associated with the χ^2 statistics were also calculated. A multiplicative change in variance over and above that predicted by the binomial distribution (i.e., overdispersion) was estimated and used to adjust coefficient *p*-values (SAS Institute, 2000). Overdispersion parameters were estimated by including all predictor variables except measured sound levels in the model, and computing the resulting Pearson χ^2 goodness-of-fit statistic. If χ^2 was >1, the estimated overdispersion parameter was set equal to the square root of Pearson's χ^2 for all models involving that species. If χ^2 was <1, the overdispersion was set to 1.0. All subsequent model runs for a particular species, including model selection, included the species' estimated overdispersion parameter. Probability values for individual parameters were calculated by dropping the variable from the model, observing the change in total model fit (i.e., deviance), dividing the change in model fit by the overdispersion parameter, and comparing the result to a χ^2 distribution (McCullagh & Nelder, 1989). All calculations were carried out using *SAS* Proc Logistic and *SAS* Proc GENMOD (SAS Institute, 2000).

Two separate analyses were completed for each combination of response variable (moved and entered water) and pinniped species, one of which included the measured M-weighted sound exposure level (SEL-M) and one that did not. In all, 12 models were fitted for the 2 response variables x 3 (species) x 2 variable sets (with and without SEL-M).

Predictor variables considered in the analysis were as follows: (1) vehicle type, (2) $\log_{10}$ of 3-D distance from recording site to CPA [logCPADist; km], (3) angle above horizon from recording site to CPA of vehicle [CPA_Angle; in degrees], (4) wind component along CPA-to-pinnipeds axis [Wind; calculated as the cosine of angle between wind direction and CPA-to-pinniped axis, multiplied by wind speed], (5) whether or not a previous launch had occurred the same day [Launch], (6) whether or not the launch occurred during pupping/breeding season [Season], (7) whether the launch produced a sonic boom [Sonic Boom], and (8) SEL-M. Season was designated by codes "1" for pupping/breeding and "0" for non-pupping/breeding. Launch was coded as either "0" for a single or dual launch, or the first launch in a multiple-launch series), or "1" for a launch preceded by another on the same day (i.e., the second or third launches in a widely-spaced series). Vehicle type was incorporated as five variables representing whether (1) or not (0) the vehicle was an (i) AGS missile, (ii) AGS slug, (iii) RAM, (iv) Coyote, or (v) "other large" (Falcon, Arrow, Tomahawk, Terrier-Orion). Those five variables were all coded as zero for Vandal launches; i.e., the Vandal was treated as the reference vehicle. For vehicles other than the Vandal, one of these five variables was coded as "1" and the others as "0".

Results

Video recordings of pinniped behavior during launches were obtained on 42 dates and nine different sites for California sea lions (n = 127 site–date combinations), on 31 days and seven sites for northern elephant seals (n = 53), and 23 days and nine sites for harbor seals (n = 48). For each of these site-date combinations, the video recordings provided data on the responses of a sample of the total number of pinnipeds hauled out at each monitored site.

California Sea Lion

Although most sea lions appeared startled and showed increased vigilance for a short period (< 2 min) after each launch, other sea lions hardly responded to the launch (Figure 2). On 100 of 127 occasions, some sea lions (1–100%; avg. 56%) reacted by moving around vigorously on the beach. On 39 occasions, up to 100% (avg. 34%) of sea lions entered the water in response to the launch. Sea lions within 2 km of the CPA often entered the water in response to launches (Figure 2c). All sea lions that remained on the beach resumed their pre-launch behaviors within 2 min of the launch.

Responses of sea lions to launches were related to SEL-M and CPA distance. Bivariate analysis showed that a greater percentage of sea lions entered the water with decreasing 3-D CPA distance from the vehicle (r_s = –0.182, p = 0.028, n = 112; Figure 2c). The relationship between decreasing CPA distance and percentage of sea lions that moved was only marginally significant (r_s = –0.144, p = 0.057, n = 121; Figure 2a).

Similarly, the logistic regressions that did not consider received sound level showed that the proportions moving and entering the water were highly significantly and inversely related to logCPADist ($p \leq 0.001$; Table 2). The proportion that moved also depended on the type of vehicle launched. Compared to proportions that moved during launches of the relatively large Vandal targets, the proportion moving was significantly higher during Coyote target launches and lower during launches of small AGS missiles.

When the measured sound (SEL-M) was included in the regression, the proportion of sea lions that moved was strongly and positively related to sound level ($p \leq 0.001$; Figure 2b and Table 3). After consideration of measured sound level, CPA distance no longer had much additional effect on proportion moving. However, even after allowance for sound level, there were significant differences in the proportions of sea lions that moved in response to the different vehicle types (Table 3). For a given received sound level, responses were similar for the Coyote SSST and Vandal targets (p >0.1), but responses to other vehicles (both small and large) tended to be greater ($p \leq 0.01$ in each case; Table 3). In addition, a greater proportion of sea lions moved in response to launches during the non-breeding season (Table 2, 3).

Northern Elephant Seal

The majority of elephant seals exhibited little reaction to launch sounds. On most occasions, elephant seals merely raised their heads briefly during the launch and then quickly returned to their previous activity (e.g., sleeping). However, on 24 of 53 occasions, a small proportion (avg. 24%) of elephant seals on the beach repositioned or moved a small distance (<2 m) away from their resting site, but settled within 30 s. The proportion of elephant seals that entered the water was typically zero, although up to 37% of elephant seals were seen to enter the water on three occasions.

Responses of elephant seals to launches, although limited, were related to SEL-M and CPA distance. The percentage of elephant seals that moved increased with decreasing 3-D CPA distance (r_s = –0.311, p = 0.015, n = 50; Figure 3a) and increasing SEL (r_s = 0.627, p < 0.001, n = 27; Figure 3b). Similarly, the logistic regression without SEL-M showed that response of elephant seals was significantly related to LogCPADist and to vehicle type ($p \leq 0.05$, Table 2). Elephant seals tended to be more responsive when larger vehicles, such as Vandals and to a lesser degree Coyotes, were launched (Table 2). When sound was considered, SEL-M was a better predictor ($p \leq 0.001$) of elephant seal response than CPA both in a simple bivariate sense (Figure 3b vs. 3a) and in a multivariate sense (Table 3). Once SEL-M was considered, there was no residual effect of vehicle type on proportion moving (Table 3). Although elephant seals entered the water on only three occasions, the tendency to enter the water was marginally higher with increasing SEL-M (r_s = 0.292, p = 0.068, n = 27; Figure 3d).

Harbor Seal

During the majority of launches, most harbor seals left their haul-out sites and entered the water, including those hauled out at sites as much as 3.5 km from the CPA. On 34 of 48 occasions, up to 100% (avg. 68%) of harbor seals entered the water. Harbor seals that left their haul-out site generally did not return during the duration of the video-recording period, which typically continued for 1–2 h after the launch.

Harbor seal responses (proportions moving and entering water) were not strongly related to either

CPA distance or measured SEL-M within the range of distances and received sound levels encountered at the study sites (Figure 4; Tables 2, 3). The proportion that moved was weakly related to decreasing CPA distance in a bivariate sense ($r_s = -0.231$, $p = 0.062$; $n = 45$; Figure 4a), but this trend was not significant after other variables were considered (Table 2). LogCPADist was a significant predictor ($p \leq 0.05$) of the proportion that entered the water only for the logistic regression that included sound (Table 3). Some harbor seals entered the water when received sound levels were as low as 64 dB re 20 μPa$^2 \cdot$s SEL-M, but others remained on their haul-out sites with SEL-M as high as 112 dB (Figure 4d).

Harbor seal response did increase significantly with increasing CPA angle, i.e., with increasing elevation angle from the haul-out site to the vehicle when the vehicle was at CPA (Table 2, 3). There was also a tendency for more seals to move into the water when the wind was directed from the vehicle's CPA location toward the haul-out site ($p < 0.01$, Table 3). When sound level was not considered, harbor seals were significantly more responsive ($p < 0.01$) to launches during the pupping/breeding season (Table 2), but that trend was not evident after allowance for sound (Table 3). Unlike the situation for the other two species, there was no tendency for consistent differences in responsiveness to the various vehicle types.

No evidence of injury or mortality was evident during or immediately succeeding the launches. However, on three occasions, harbor seal pups were observed to be knocked over by adult seals as the adults and pups moved toward the water in response to the launch. Seal pups were momentarily startled, but did not appear to be injured, and continued to move toward the water.

Discussion

In general, pinniped behavioral responses to launches were, with the exception of some harbor seals, usually brief. Northern elephant seals exhibited little reaction to the launches, even when exposed to sound levels as high as 119 dB re 20 μPa$^2 \cdot$s SEL-M (Figure 3). California sea lions showed stronger but variable responses. Harbor seals were the most responsive and frequently moved into the water during launches, even when the closest point of approach of the aerial vehicle was as much as 3.5 km away and SEL-M was as low as 64 dB re 20 μPa$^2 \cdot$s.

These results are consistent with those obtained with smaller samples from the first two years of monitoring (Holst et al., 2005). Similarly, several studies have noted that elephant seals generally showed no more than a momentary alert reaction when exposed to sounds that caused nearby harbor seals and California sea lions to flee (Stewart, 1981; Stewart et al., 1994a; MSRS, 2008). Harbor seals have also been shown to respond to some sonic booms, overflights by light aircraft, and space vehicle launches by flushing into the water (Bowles & Stewart, 1980; MSRS, 2008). Although MSRS (2008) noted that California sea lions and harbor seals were more responsive during launches that produced a sonic boom, this was not the case in our study.

All measured SEL-M values near pinniped beaches during vehicle launches were below the level (129 dB re 20 μPa$^2 \cdot$s) thought to induce mild temporary threshold shift (TTS) in harbor seals (Southall et al., 2007), and few (if any) of the pinnipeds that we monitored were exposed to sound levels above 122 dB SEL-M. However, several launches that produced a sonic boom (impulse) had peak pressure levels exceeding 143 dB re 20 μPa, the peak pressure level estimated to elicit onset of TTS in harbor seals. During three Vandal launches, measured peak pressure levels near a sea lion and harbor seal haul-out site reached 149–150 dB re 20 μPa (Greene et al., in prep), i.e., slightly exceeding the 149 dB re 20 μPa, a level that might induce slight permanent threshold shift or PTS in harbor seals (Southall et al., 2007). TTS and PTS thresholds appear to be higher for California sea lions and northern elephant seals than for harbor seals (Kastak et al., 2005; Southall et al., 2007). Thus, it is possible that a few pinnipeds, particularly harbor seals, may have incurred TTS during the launches of larger (Vandal and Coyote) vehicles. However, there was little potential for PTS, as harbor seals were not hauled out on beaches where sound levels were ≥149 dB re 20 μPa.

In evaluating factors influencing pinniped responses to launches, it was not possible to consider all potential predictor variables. Most of the logistic regression models, especially those that considered SEL-M in the pool of potential predictor variables, suffered from low sample sizes. In addition, several models, particularly those involving elephant seals, suffered from partial incomplete separation and would not converge. Partial incomplete separation occurred when none of the animals responded during two or more vehicle flights that occurred with similar values of the predictor variables. For example, if no elephant seals ever responded to any launches of an AGS missile or slug, the model would suffer from partial incomplete separation. Partial incomplete separation was largely caused by low sample size. In cases when incomplete separation prevented estimation, the model was reduced (variables were eliminated) until separation of responses was achieved and the models converged.

The analyses showed that responses of pinnipeds were affected by several factors, including proximity of the animals to the vehicle flight path, sound exposure level, or both, along with (for some situations) vehicle type, elevation angle from haul-out site to the vehicle's CPA position, season, and wind conditions. Besides the variables that were examined here, other factors such as weather, tide state, and time of day are also expected to play a part in determining pinniped behavior and responsiveness (e.g., Bowles & Stewart, 1980). Although pinnipeds are known to habituate to some human disturbance, including frequent overflights (Richardson et al., 1995), harbor seals and California sea lions continue to respond to the launches at SNI despite occasional exposures over many years. However, the number of pinnipeds that were disturbed during the launches was small, and any effects appeared to be minor, short-term, and localized, with no consequences for local pinniped populations. In fact, pinniped populations on SNI have been relatively stable (harbor seals) or growing (elephant seals, California sea lions) despite ongoing vehicle launches (Lowry et al., 1992; Stewart et al., 1994b; Hanan, 1996; Lowry, 2002). Similarly, Stewart (1981) reported that habitat use, population growth, and pup survival of northern elephant seals and California sea lions did not appear to be affected by periodic exposure to impulse noise, and Perry et al. (2002) noted no significant differences in beach counts of gray or harbor seals following sonic booms. Nonetheless, behavioral observations of California sea lions and harbor seals during launches from SNI will continue to meet regulatory requirements and to obtain a better understanding of factors that affect their responses.

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Table 1. Vehicles launched from San Nicolas Island from August 2001 through June 2007

Launch Dates	Number and Types of Vehicles Launched	Launch Azimuth (ºTrue)	Elevation Angle	Launch Complex	Altitude Over Beach (m)
Year 1					
Aug. 2001-July 2002	14 Vandals	270-273.3°	8-42°	Alpha	390-2926
	1 Terrier-Orion	232.3°	64.6°	Alpha	3962
	2 AGS Slugs	300-305°	62.5-63°	Alpha	152
	1 AGS Missile	300°	62.5°	Alpha	1615
	1 Dual RAM	240°	8°	Building 807	15
Year 2					
Aug. 2002-July 2003	5 Vandals	270-285°	8-42°	Alpha	396-5266
	1 Dual Vandal	273°	8°	Alpha	396
	2 Coyote SSSTs	270°	20-22°	Alpha	1036-1067
	1 Tactical	305°	90°	Building 807	30
	1 AGS Slug	282°	50°	Alpha	1372
	1 AGS Missile	282°	50°	Alpha	1372
	1 Dual RAM	240°	10°	Building 807	15
Year 3					
May-Sept. 2004	2 Coyote SSSTs	300°	18°	Alpha	1006
	2 Arrows	285°	90°	Alpha	2134
	4 AGS Slugs	282-300°	50°	2 at Building	1372
	1 AGS Missile	282°	50°	Alpha	1372
	3 RAMs	240°	10°	Building 807	15
	1 Dual RAM	240°	8°	Building 807	15
Year 4					
Jan.-Oct. 2005	6 Vandals	270-273°	8-35°	Alpha	396-2591
	1 Dual Vandal	273°	8°	Alpha	396
	3 Coyote SSSTs	270°	14°	Alpha	914
	8 AGS Slugs	280-287°	50-65°	Building 807	1372-1676
	7 AGS Missiles	240-287°	50-65°	Building 807	1372-1676
Year 5					
Feb.-May 2006	1 Falcon	280°	80°	Alpha	hit land
	2 AGS Slugs	235°	62.5°	Building 807	1615
	2 AGS Missiles	235°	62.5°	Building 807	1615
Year 6					
April-June 2007	2 Coyote SSSTs	270°	14°	Alpha	914
	1 Dual RAM	240°	10°	Building 807	15
Year 7					
	0 Missiles				

Table 2. Coefficients and nominal significance levels for best-fit regression models relating pinniped response (proportion that moved, proportion that entered the water) to non-sound predictor variables. n = number of monitoring occasions (i.e., site–launch combinations); Intercept = y-intercept of the regression equation

	Sea Lion		**Elephant Seal**	**Harbor Seal**	
	moved (*n* = 118)	**water (*n* = 118)**	**moved (*n* = 46)**	**moved (*n* = 45)**	**water (*n* = 45)**
AGS Missile	-1.264	–	-3.414	–	–
p-value	**		***		
AGS Slug	-0.661	–	-2.214	–	–
p-value	(*)		***		
RAM	-0.281	–	-2.123	–	–
p-value	ns		*		
Coyote SSST	1.225	–	-1.458	–	–
p-value	**		*		
Other Large	0.953	–	-2.063	–	–
p-value	ns		*		
Sonic Boom	–	0.650	–	–	–
p-value		ns			
LogCPADist	-2.765	-2.988	-2.282	–	–
p-value	***	***	*		
CPA_Angle	–	–	0.046	0.074	0.038
p-value			**	***	**
Season	-0.791	-0.575	–	1.978	1.707
p-value	**	ns		**	***
Wind	–	–	0.223	0.110	–
p-value			**	(*)	
Launch	–	–	–	–	-0.934
p-value					*
Intercept	0.390	-2.114	-2.512	-0.891	-0.740

Note: *** means nominal $p \leq 0.001$, ** for $0.001 < p \leq 0.01$, * for $0.01 < p \leq 0.05$, (*) for $0.05 < p \leq 0.1$, and ns (not-significant) means $p > 0.1$.

Table 3. Coefficients and nominal significance levels for best-fit regression models relating pinniped response (proportion that moved, proportion that entered the water) to sound and non-sound variables; *n* = number of monitoring occasions (i.e., site–launch combinations); Intercept = y-intercept of the regression equation

	Sea Lion		**Elephant Seal**	**Harbor Seal**	
	moved (*n* = 62)	**water (*n* = 55)**	**moved (*n* = 26)**	**moved (*n* = 31)**	**water (*n* = 31)**
SEL-M	0.235	–	0.268	–	0.043
p-value	***		***		ns
AGS Missile	3.232	–	–	–	–
p-value	**				
AGS Slug	3.304	–	–	–	–
p-value	**				
RAM	4.229	–	–	–	–
p-value	**				
Coyote SSST	-1.134	–	–	–	–
p-value	ns				
Other Large	3.346		–	–	–
p-value	**				
Sonic Boom	–	–	–	–	–
p-value					
LogCPADist	2.675	-3.119	–	–	6.992
p-value	(*)	**			*
CPA_Angle	–	–	-0.063	0.095	0.041
p-value			**	***	*
Season	-1.344	-0.759	–	–	–
p-value	**	ns			
Wind	–	–	–	0.260	–
p-value				**	
Launch	–	–	–	–	–
p-value					
Intercept	-24.983	-1.637	-28.288	-1.534	-6.556

Note: *** means nominal $p \leq 0.001$, ** for $0.001 < p \leq 0.01$, * for $0.01 < p \leq 0.05$, (*) for $0.05 < p \leq 0.1$, and ns (not-significant) means $p > 0.1$.

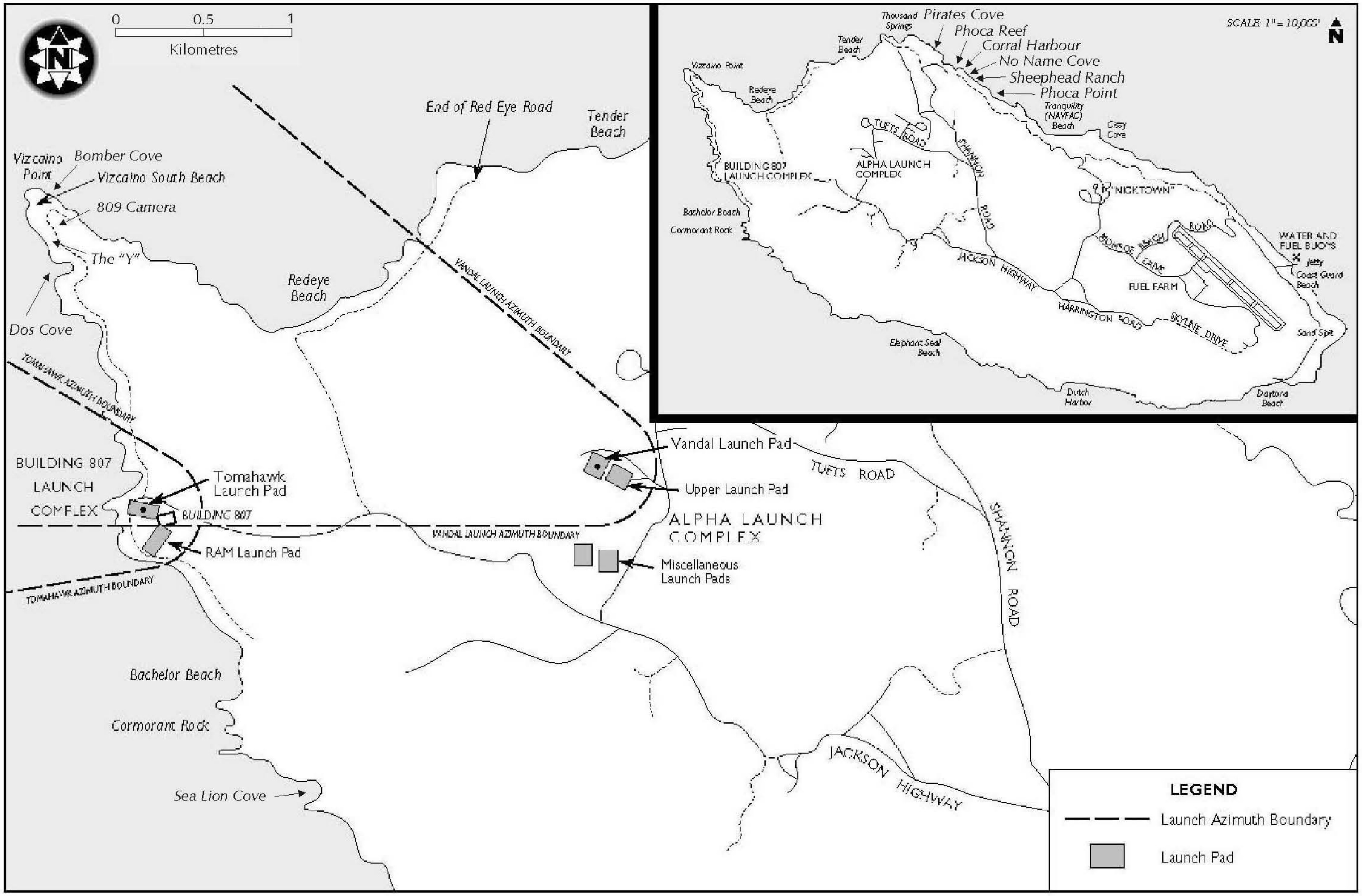

Figure 1. Map of San Nicolas Island, California, showing the vehicle launch sites (Alpha Launch Complex, Building 807 Launch Complex) and the names of the beaches where pinnipeds were monitored. The typical range of launch azimuths for vehicles leaving the two launch sites is indicated.

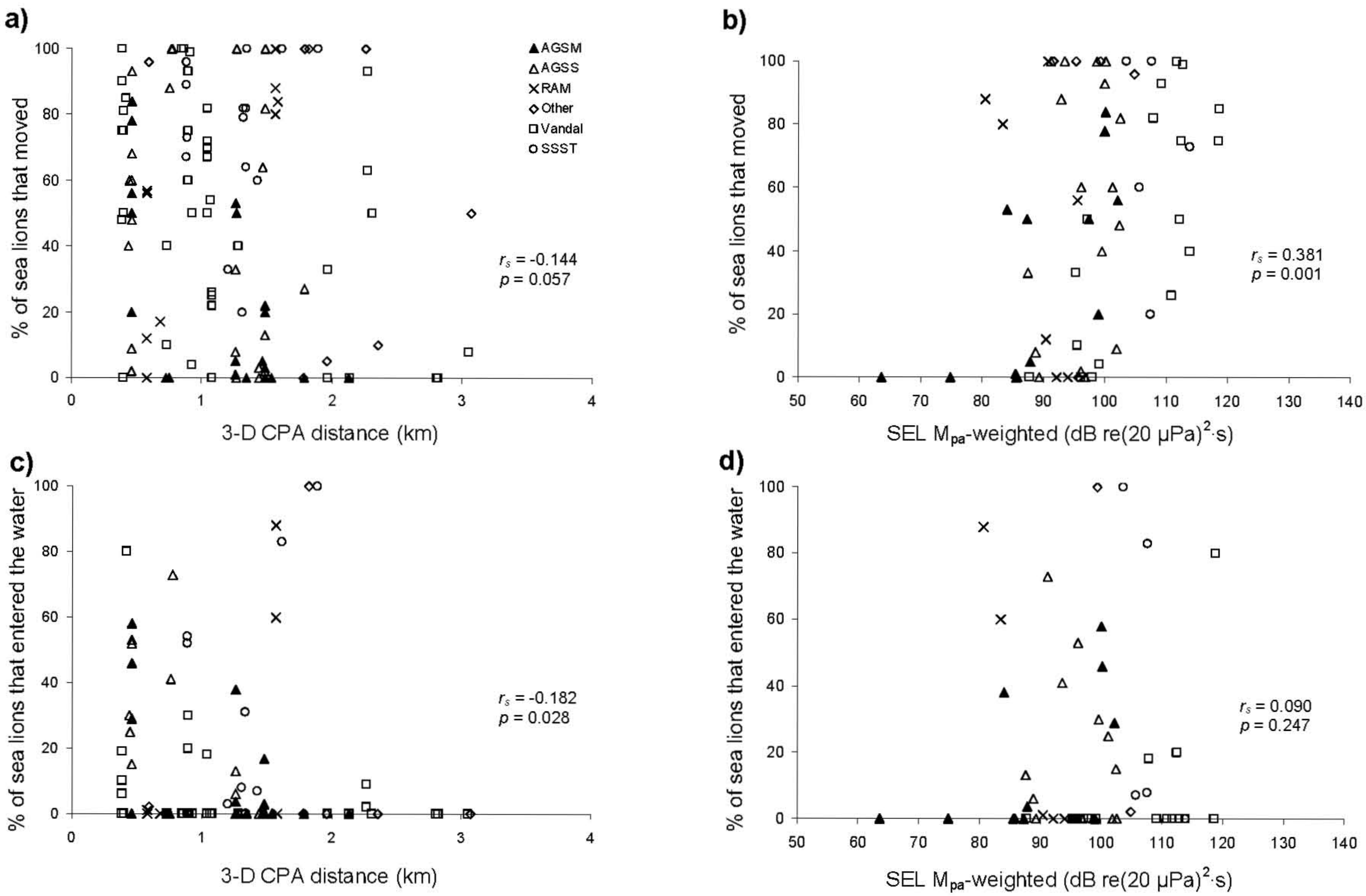

Figure 2. Percent of California sea lions that moved in relation to ***(a)*** 3-D CPA distance and ***(b)*** SEL M_{pa}-weighted for vehicles launched at SNI, and percent of California sea lions that entered the water in relation to ***(c)*** 3-D CPA distance and ***(d)*** SEL M_{pa}-weighted. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (p).

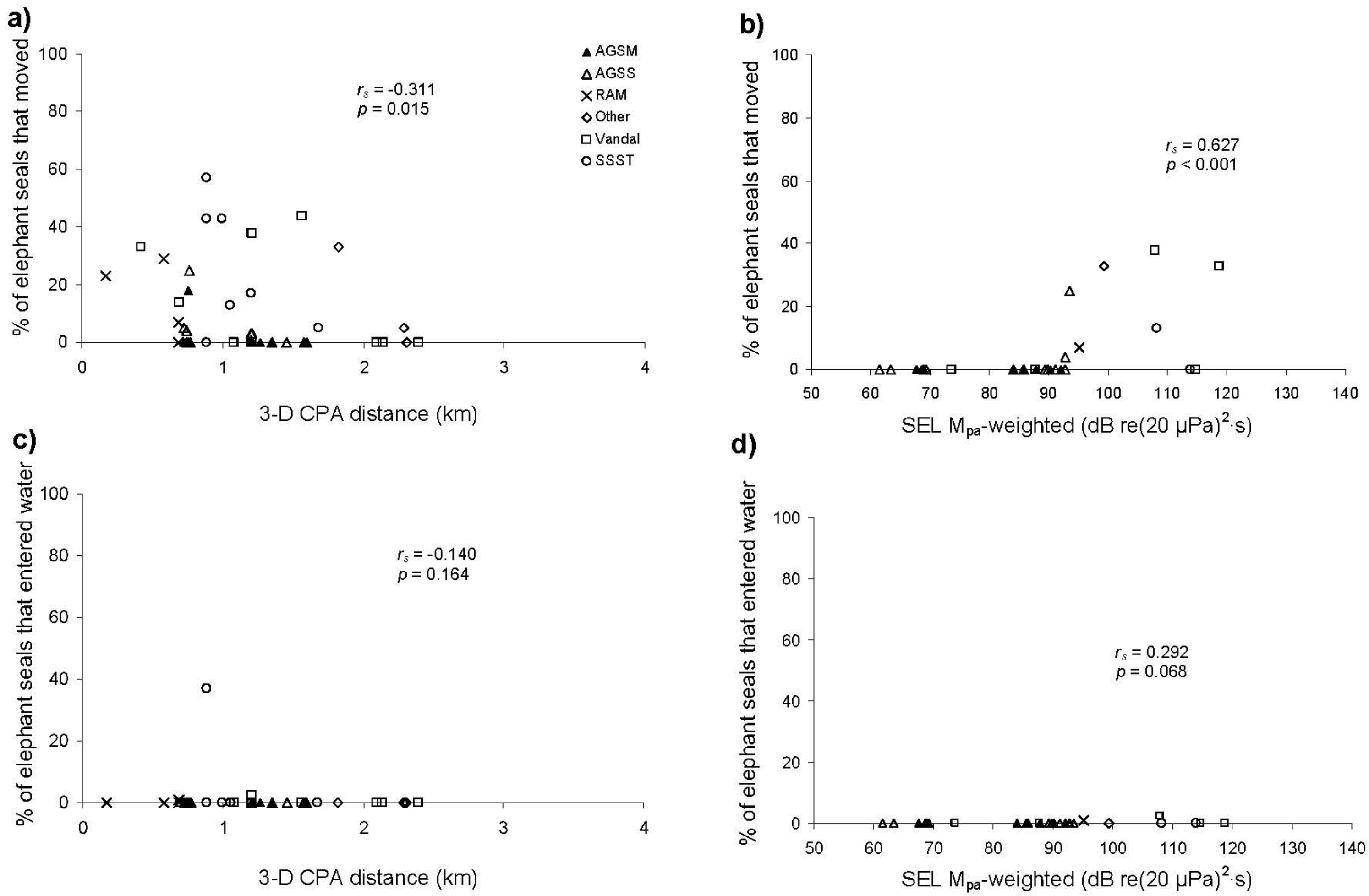

Figure 3. Percent of northern elephant seals that moved in relation to ***(a)*** 3-D CPA distance and ***(b)*** SEL M_{pa}-weighted for vehicles launched at SNI, and percent of elephant seals that entered the water in relation to ***(c)*** 3-D CPA distance and ***(d)*** SEL M_{pa}-weighted. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (p).

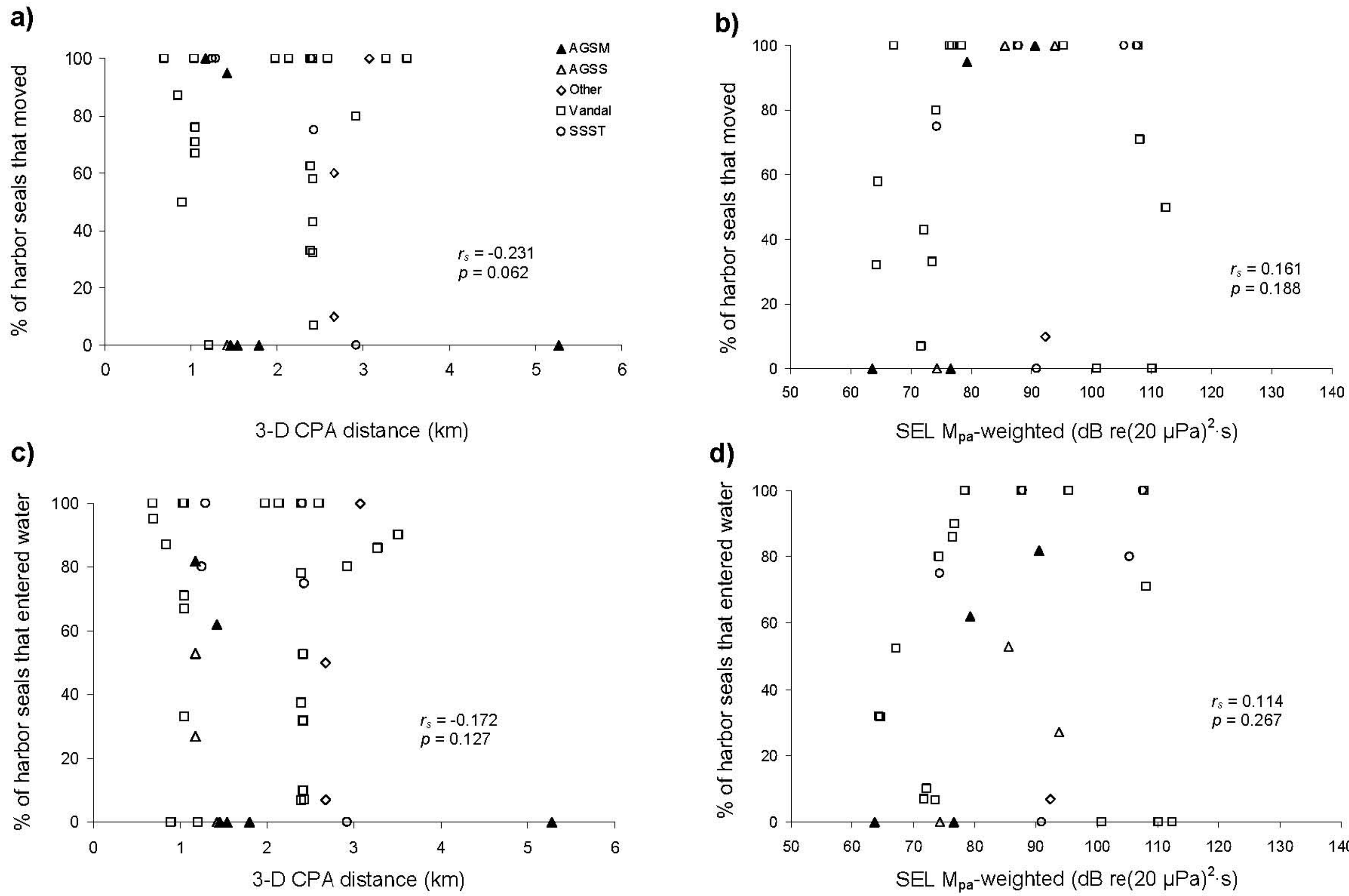

Figure 4. Percent of harbor seals that moved in relation to ***(a)*** 3-D CPA distance and ***(b)*** SEL M_{pa}-weighted for vehicles launched at SNI, and percent of harbor seals that entered the water in relation to ***(c)*** 3-D CPA distance and ***(d)*** SEL M_{pa}-weighted. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (p).