Marine Mammal and Acoustical Monitoring of Missile Launches on San Nicolas Island, California, August 2001 – March 2008

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LGL LIMITED
environmental research associates

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Naval Air Warfare Center Weapons Division
Point Mugu, California

to

National Marine Fisheries Service
Silver Spring, Maryland, and Long Beach, California

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Marine Mammal and Acoustical Monitoring of Missile Launches on San Nicolas Island, California, August 2001 – March 2008

by

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ACRONYMS AND ABBREVIATIONS

3-D	3-dimensional
AGS	Advanced Gun System
AIC	Akaike's Information Criterion
~	approximately
ASCM	Anti-Ship Cruise Missile
ASL	above sea level
ATAR	Autonomous Terrestrial Acoustic Recorder
avg.	average
CFR	Code of Federal Regulations
cm	centimeters
CPA	closest point of approach
dB	decibels
dBA	decibel, A-weighted, to emphasize mid-frequencies and to de-emphasize low and high frequencies to which human (and pinniped) ears are less sensitive
DR	Ducted Rocket (pertains to GQM-163A "Coyote" Supersonic Sea-Skimming Target)
ft	feet
hr	hours
Hz	hertz
IHA	Incidental Harassment Authorization
in	inches
kg	kilograms
kHz	kilohertz
km	kilometers
kp	kilopond or kilogram-force
kt	knots
lb	pounds
LOA	Letter of Authorization
m	meters
mi	statute mile
min	minute
mm	millimeter
MMMP	Marine Mammal Monitoring Plan
MMPA	Marine Mammal Protection Act
M_{pa}	Frequency weighting appropriate for pinnipeds in air (see Gentry et al. 2004; Miller et al. 2005; Southall et al. 2007)
NAWCWD	Naval Air Warfare Center Weapons Division
NMFS	National Marine Fisheries Service
n.mi	nautical mile
PTS	Permanent Threshold Shift
RAM	Rolling Airframe Missile
rms	root mean square (a type of average)
s	seconds
SEL	sound exposure level, a measure of the energy content of a transient sound

SEL-A	A-weighted sound exposure level
SEL-f	flat-weighted sound exposure level
SEL-M	M_{pa}-weighted sound exposure level
SNI	San Nicolas Island
SPL	sound pressure level
SPL-A	A-weighted sound pressure level
SPL-f	flat-weighted sound pressure level
SPL-M	M_{pa}-weighted sound pressure level
SSST	Supersonic Sea-Skimming Target
TTS	Temporary Threshold Shift
USC	United States Code
V/μPa	volts per micropascal
μPa	micropascal
WOSA	Weighted Overlapped Segment Averaging

EXECUTIVE SUMMARY

From August 2001 to date, the Naval Air Warfare Center Weapons Division (NAWCWD) has held a series of incidental take authorizations issued by the National Marine Fisheries Service (NMFS) allowing non-lethal takes of pinnipeds incidental to the Navy's missile launch operations on San Nicolas Island (SNI), California. From August 2001 to July 2002, incidental "takes" were authorized under two annual Incidental Harassment Authorizations (IHAs) issued by NMFS to NAWCWD for the periods August 2001 to July 2002 (Year 1) and August 2002 to August 2003 (Year 2). Effective 2 October 2003, NMFS issued regulations pursuant to 50 Code of Federal Regulations (CFR) 216.107 and §101(a)(5)(A) of the Marine Mammal Protection Act (MMPA), 16 United States Code (USC) §1371(a)(5)(A) concerning the same types of non-lethal "takes". Those regulations, at 50 CFR 216.151–158, provide for NMFS to issue an annual Letter of Authorization (LOA) allowing 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. The regulations are effective for the 5-year period through 2 October 2008. NMFS has issued LOAs to NAWCWD for the periods October 2003 to October 2004 (Year 3), October 2004 to October 2005 (Year 4), February 2006 to February 2007 (Year 5), February 2007 to February 2008 (Year 6), and February 2008 to 2 October 2008 (Year 7).

In the Navy's Petition for Regulations that led to promulgation of 50 CFR 216.151–158, a Marine Mammal Monitoring Plan (MMMP) was proposed. This plan included provisions to monitor any effects of launch activities on pinnipeds hauled out at SNI in a manner similar to the monitoring that had already been done during 2001–2003. The MMMP was revised in 2005 (Holst et al. 2005a). The regulations and associated LOAs included requirements to submit annual reports on the results of the monitoring program. The regulations also required submission of a draft comprehensive technical report 180 days prior to the expiration of these regulations. This technical report is to provide "full documentation of methods, results, and interpretation of all monitoring tasks for launches during the first four LOAs, plus preliminary information for launches during the [initial portion of] the period covered by the final LOA."

The present comprehensive report provides results concerning the marine mammal and associated acoustic monitoring program for launches from SNI during the period August 2001 through March 2008. In order to be as complete as possible, this report includes results from the first 2 years of monitoring that were done under IHAs as well as the required information for the periods covered by the five LOAs. Previous related reports (all of which are included as PDF files in Appendix B on CD-ROM) have provided detailed results concerning

- 19 launches during August 2001 through July 2002 (Lawson et al. 2002),
- 12 launches during August 2002 through July 2003 (Holst and Greene 2003, 2004a),
- 13 launches during October 2003 to October 2004 (Holst and Greene 2004b; Holst et al. 2005b),
- 25 launches during October 2004 through October 2005 (Holst and Greene 2006a),
- 5 launches during February 2006 to February 2007 (Holst and Greene 2006b), and
- 3 launches during February 2007 to February 2008 (Holst and Greene 2007).

Holst et al. (2005b) reported on the results of all launches from August 2001 through May 2005; this report is a follow up to that document, now including the more recent launches. Here, we summarize and present the results for all launches during August 2001 through March 2008. The following subsections briefly summarize the monitoring program for August 2001–March 2008.

Description of Missile Launches and Monitoring Program Described

During the August 2001 to March 2008 period for which detailed data on launches are available, there were 77 launches of 83 vehicles from SNI on 53 different days. These launches involved either single vehicles, "dual" launches (two vehicles launched in quick succession within a span of ≤2 seconds [s]), or up to three vehicles launched separately on the same day. 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. Within the specific period of applicability of the 5-year regulations (2 October 2003 to date), there have been 46 launches of 49 vehicles on 27 different days. Up to two more Coyote launches are anticipated to occur in May 2008.

Vehicles were launched from one of two launch complexes on SNI. The Tomahawk and RAMs were launched from the Building 807 Launch Complex. This site is located close to shore on the western end of SNI, ~35 feet (ft) (11 meters [m]) above sea level (ASL). Vandals, Coyotes, Arrows, the Terrier-Orion, and the Falcon were launched from the Alpha Launch Complex. This launch site is 625 ft (190.5 m) ASL on the west-central part of SNI, 1.1 miles (mi) (1.8 kilometers [km]) inland from the closest part of the shoreline. From August 2001 through June 2004, AGS missiles and slugs were launched from the Alpha Launch Complex. Starting in July 2004, AGS vehicles were launched from the Building 807 Complex, to which the AGS launcher was relocated.

The vehicles launched from the Alpha Launch Complex had launch elevation angles ranging from 6.5 to 90º above horizontal (Arrows were launched vertically), and were directed generally westward (azimuths 232–305°). They crossed the west end of SNI at altitudes up to 17,300 ft (5273 m). From Building 807 Launch Complex, RAMs were launched at elevation angles of 8–10º and crossed the beach at an altitude of 50 ft (15 m). The Tactical Tomahawk was launched from the Building 807 Launch Complex at an elevation angle of 90º and crossed the beach at 1000 ft (305 m). AGS missiles and slugs were launched on azimuths of 235–305º and at elevation angles of 50–65°, crossing the beach at altitudes up to 5300 ft (1615 m).

Acoustic Measurements During Vehicle Launches

Vehicle flight sounds were measured as received at various locations on the periphery of SNI or near the launcher during many of the launches conducted throughout the monitoring period. Received sound levels were measured at as many as three different locations during many launches. At distances of 1640 ft (0.5 km) or more from the closest point of approach (CPA) of the vehicle, measures of sound level were typically higher for Vandals and Coyotes than for AGS and RAM vehicles. Although sounds from the AGS vehicles were weaker than those from Vandals and Coyotes at distances beyond 1640 ft (0.5 km), the levels recorded close to the AGS launcher were equal to or greater than those from the Vandal and Coyotes.

Multiple regression models for several sound measures showed that, after allowing for distance and other factors, Vandals and Coyotes had the highest average sound levels compared with all other vehicle types. Vandals produced flat-weighted sound pressure levels (SPL-f) as high as 137 decibels (dB) re 20 micropascals (μPa) near the launcher and 142 dB at a nearshore site located 1312 ft (400 m) from the CPA of the vehicle. Near the launcher, Coyotes produced SPL-f up to 126 dB, and at a site ~1 mi (1614 m) from the CPA, the SPL-f was 133 dB. AGS vehicles produced SPL-f of 156 dB near the launcher and 126 dB at a nearshore site 1500 ft (442 m) from the CPA. RAMs resulted in SPL-f up to 130 dB near the launcher and 99 dB at a nearshore site located ~1 mi (1555 m) from the CPA. Arrows produced SPL-f up to 90 dB at a site 1.1 mi (1821 m) from the CPA. A single Tomahawk was launched, and it produced an SPL-f of 93 dB 1735 ft (529 m) from the CPA. The only Terrier-Orion that was launched resulted in an SPL-f of 91 dB 1.5 mi (2433 m) from the CPA. In addition to these flat-weighted measurements, this report also presents results based on A-weighting (most appropriate for humans) and the new M-weighting procedure that has been developed for pinnipeds in air (M_{pa}) (Miller et al. 2005; Southall et al. 2007).

The regression models showed a statistically significant decrease in all measures of sound level with increasing CPA distance, as would be expected. There was also a significant increase in sound exposure level (SEL) with increasing elevation angle from the receiving location to CPA. The sound measures were not significantly related to the wind component along the CPA-to-receiver axis.

Behavior of Pinnipeds During Missile Launches

Behavior of pinnipeds around the periphery of western SNI during missile launches was monitored by unattended video cameras set up before each launch. The video data were supplemented by direct visual scans of the haul-out groups several hours prior to the launches and in some cases following the launches. Monitoring was typically attempted at up to three sites during each launch, with launch-to-launch variation in the specific locations monitored. Acoustic measurements were obtained at many of the same locations and times.

For each launch, the number, proportion, and (where determinable) ages of the individual pinnipeds that responded in various ways were extracted from the video, along with comparable data for those that did not respond overtly. The proportions of the animals on a given beach that moved, or that moved into the water, were examined in relation to distance from the CPA of the vehicle, and to various other variables characterizing conditions during the launch. A logistic regression approach was used for the latter analyses, which allowed examination of the simultaneous influences of a variety of variables (acoustic and otherwise) on the behavioral responses of the pinnipeds.

No evidence of injury or mortality to any pinniped species was observed during or immediately succeeding the launches. However, on three occasions, harbor seal pups were observed to be 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 seen knocking over sea lion pups when they moved along the beach, but no injuries were evident.

California Sea Lions

California sea lions were observed on 42 of 52 launch dates during the monitoring period, with observations at one to three sites during launches (total of 127 site–launch combinations monitored). Responses of sea lions to the launches varied by individual; some sea lions exhibited startle responses, whereas others hardly reacted to the launch. On 100 of 127 occasions, some sea lions reacted by moving along the beach (1–100%; avg. 56%). On 39 of 127 occasions, some but usually not all sea lions entered the water in response to the launch (1–100%; avg. 34%). Although sea lions that remained on the beach 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 time.

Responses of sea lions to launches were 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 responded (i.e., moved) in response to launches during the non-breeding season.

Northern Elephant Seals

Elephant seals were observed at one to three sites on 31 of 52 launch dates during the monitoring period, with a total of 53 monitored site–launch combinations. Most elephant seals exhibited little reaction to launch sounds; they merely raised their heads for a few seconds and then returned to their previous activity pattern (e.g., sleeping, resting). On 24 of 53 occasions, a small proportion (avg. 24%) of elephant seals on the beach repositioned or moved a small distance (<6 ft or <2 m) away from their resting site. The proportion of elephant seals that entered the water was typically zero, although 1–37% of elephant seals were seen to enter the water on 3 of 53 occasions.

Elephant seals tended to be more responsive (a greater proportion moved) when larger vehicles, such as Vandals and Coyotes, 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

Harbor seals were observed at one or two sites during 23 launch dates during the monitoring period, with a total of 48 site–launch combinations monitored. During the majority of these launches, most harbor seals left their haul-out sites and entered the water. Individuals that left the site typically did not return during the duration of the video-recording period, which lasted for an additional 1 to 2 hours (hr) after the launch. On 37 of 48 occasions, 7–100% (avg. 77%) of seals moved in response to the launch, and on 34 of 48 occasions, 7–100% (avg. 68%) entered the water.

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 much as 2.2 mi (3.5 km), commonly entered the water during launches.

Estimated Numbers of Pinnipeds Affected by Missile Launches

No evidence of pinniped injuries or fatalities related to missile launches was evident, nor was it expected. During all years of monitoring, few if any pinnipeds were exposed to sounds with energy levels above 129 dB re $(20\ \mu Pa)^2 \cdot s$ SEL on a flat-weighted basis (SEL-f), 122 dB SEL on an M_{pa}-weighted basis (SEL-M), or 118 dB SEL on an A-weighted basis (SEL-A). The maximum exposure levels (on an M_{pa} basis) were below the levels at which any of the three species would be expected to incur temporary or permanent hearing impairment (*cf.* Southall et al. 2007). However, small numbers of northern elephant seals and California sea lions may have been exposed to peak pressures as high as 150 dB re 20 µPa when Vandals flying over the beach created a sonic boom. That peak-pressure level would not be expected to elicit permanent threshold shift (PTS) in elephant seals or California sea lions, but might be near the minimum level that could elicit PTS in harbor seals if any harbor seals at SNI had been exposed to such high levels (which apparently did not occur). However, it is possible that some harbor seals, and perhaps elephant seals and California sea lions, did incur temporary threshold shift (TTS) during launches at SNI, as peak-pressure levels at haul-out sites sometimes reached ≥143 dB re 20 μPa when a sonic boom occurred. In the event that TTS did occur, it would typically be mild and reversible.

Pinniped groups generally extended farther along the beach than encompassed by the field of view of the video camera. In these cases, an estimate was made of the total number of individuals that were hauled out on the monitored beaches prior to the launch based on video pans of the area. The proportions of animals in the focal subgroups that were counted as affected during analysis of launch video records were extrapolated to the estimated total number of individuals hauled out in the area to derive a minimum estimate of the total number of pinnipeds affected. An attempt was also made to extrapolate the proportions of animals affected on the monitored beaches to unmonitored haul-out sites. However, this was not always possible, because it was generally unknown which beaches were used as haul-out sites on specific launch dates, and how many animals were hauled out. In addition, data from the previous launches were used to estimate the number of pinnipeds affected during launch days when no recordings were possible. We considered pinnipeds that left the haul-out site, or exhibited prolonged movement or prolonged behavioral changes, as being affected.

The greatest number of pinnipeds that was estimated to have been affected by launch sounds during any year of the 2001–2007 monitoring period was 2400 in Year 4 (Oct. 2004–Oct. 2005); this estimate included 1990 California sea lions, 15 northern elephant seals, and 193 harbor seals. These estimates include animals that left the haul-out site in response to the launch, or exhibited prolonged movement or behavioral changes relative to their behavior immediately prior to the launch. A greater number (99) of elephant seals was estimated to have been affected in Year 2 (Aug. 2002–Aug. 2003), but this estimate included all seals that moved any distance. The numbers may be underestimates, because not all pinniped beaches around western SNI could be monitored during any given launch, even though extrapolation of data for other potential haul-out sites was attempted.

Behavior of some pinnipeds occurring near the launch azimuths during the launch operations was affected. However, the results suggest that any effects of these launch operations were minor, short-term, and localized, with no consequences for local pinniped populations. Any localized displacement of pinnipeds was of short duration (although some harbor seals may have left their haul-out sites until the following low tide). Monitoring from August 2001 to July 2002 showed that numbers of pinnipeds occupying haul-out sites the day after a launch were similar to pre-launch levels. Thus, it is not likely that many (if any) of the pinnipeds on SNI were adversely impacted by the launches.

1. VEHICLE LAUNCHES AND MONITORING PROGRAM DESCRIBED

San Nicolas Island (SNI) is located ~62 miles (mi) (100 kilometers [km]) from the mainland coast of Southern California (Fig. 1.1). Missiles and other vehicles are launched from one of two land-based launch complexes on the western part of SNI (Fig. 1.2). The Building 807 Launch Complex is located on the west coast of SNI at ~35 feet (ft) (11 meters [m]) above sea level (ASL), and the Alpha Launch Complex is located 625 ft (190.5 m) ASL on the west-central part of SNI (Fig. 1.2). The vehicles pass over or near pinniped haul-out sites located around the periphery of SNI. The pinniped species that occur commonly on SNI are northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*).

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This report describes the vehicles and their launch processes, the associated monitoring program, and the monitoring results for the launches conducted by the Navy at SNI. It includes four chapters: Chapter 1 – background, introduction, and description of the Navy's missile launches during the overall monitoring period from 2001 to 2008 (this chapter); Chapter 2 – acoustical monitoring during the vehicle launches; Chapter 3 – visual monitoring of pinnipeds during those launches; and Chapter 4 – estimated numbers of pinnipeds affected by the vehicle sounds during these launches.

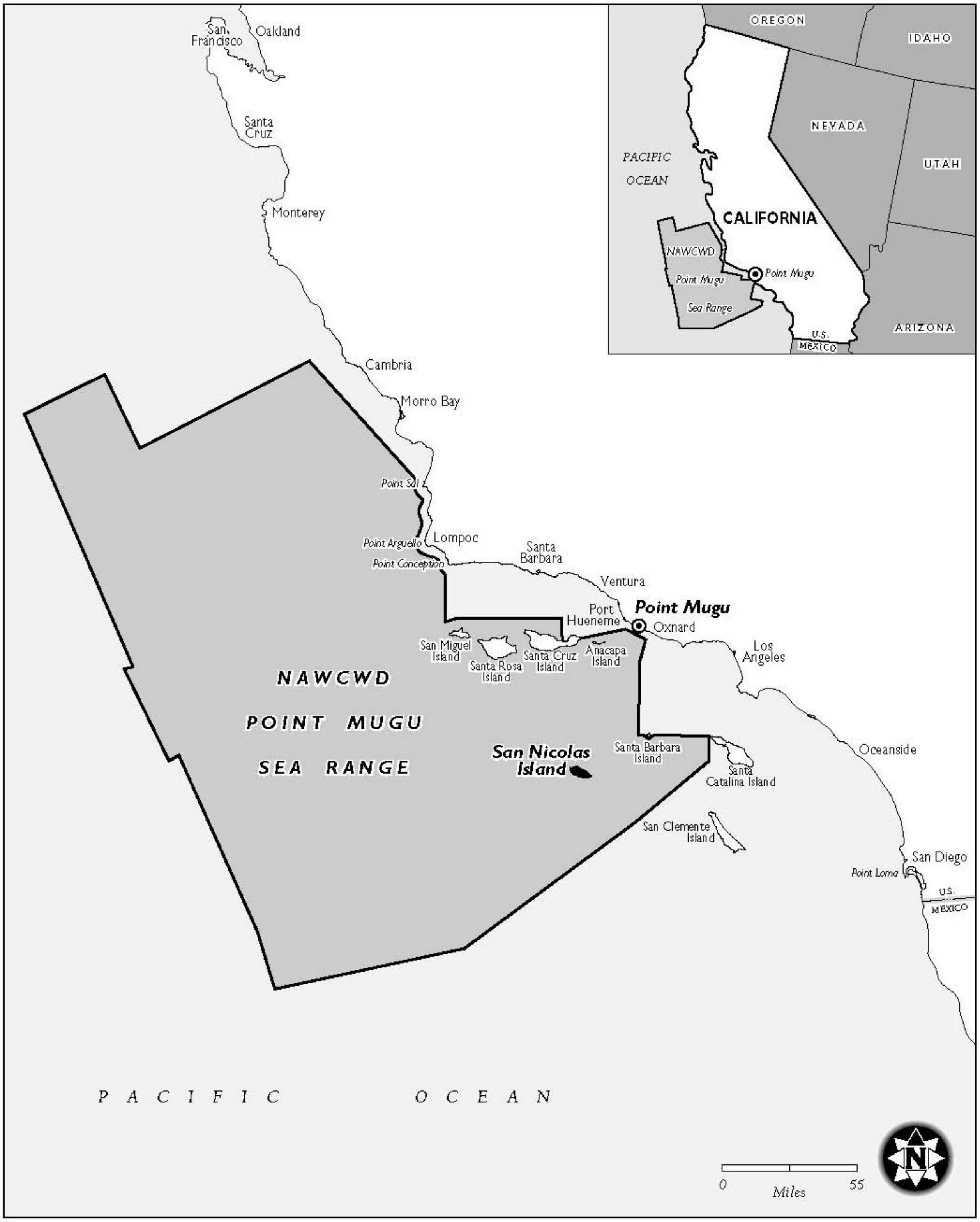

FIGURE 1.1. Regional site map of the Point Mugu Sea Range and San Nicolas Island.

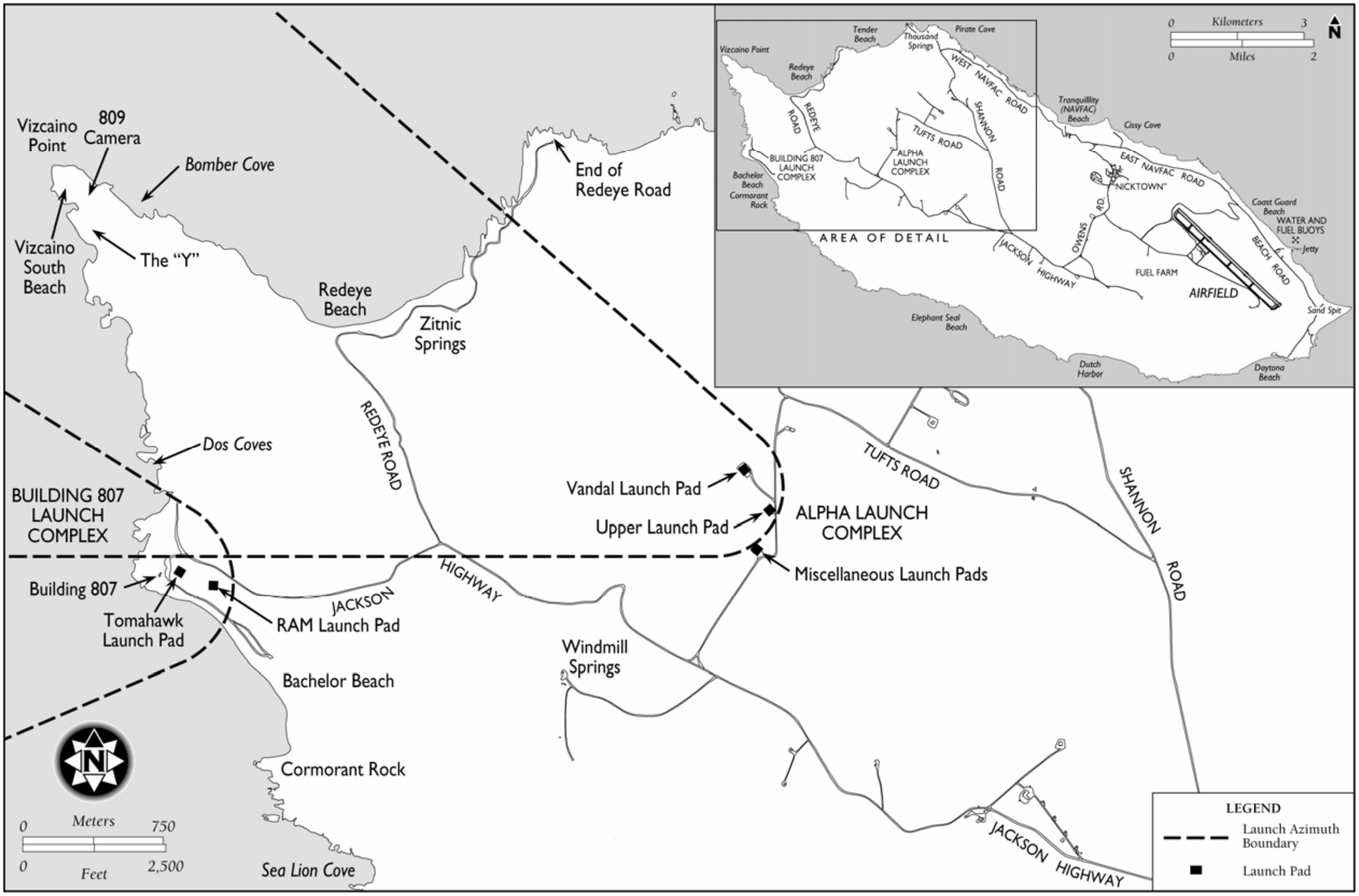

FIGURE 1.2. Map of San Nicolas Island, California, showing the Alpha Launch Complex, Building 807 Launch Complex, and the names of adjacent beaches on which pinnipeds are known to haul out. Also shown are the typical range of launch azimuths (dashed lines) for each launch complex. Occasionally launch paths could pass outside these boundaries, e.g., the Terrier Orion launch from the Alpha Complex at azimuth 232º (see § 1.4, below).

1.1 Vandal

The Vandal, designated MQM-8G, was a relatively large, air-breathing (ramjet) vehicle designed to provide a realistic simulation of the midcourse and terminal phase of a supersonic anti-ship missile (Fig. 1.3 and 1.4). The Vandal was an evolved version of the (former) Talos missile. The Vandal was 25.2 ft (7.7 m) long, excluding booster, and 28 in (71 cm) in diameter. There were three Vandal variants, the standard (retired before the monitoring study began), ER, and EER. The EER variant, including booster, weighed 8100 pounds (lb) (3674 kilograms [kg]). The variants differed primarily in their operational range. At SNI, Vandals were launched from the Alpha Launch Complex (Fig. 1.2) until July 2005, but they are no longer in use.

Vandals had no explosive warhead. At launch, the Vandal was accelerated for several seconds by a solid propellant rocket booster, to a speed sufficient for the ramjet engine to start. After several seconds of thrust, the booster was discarded, and the missile continued along its flight path at supersonic speed under ramjet power. The expended booster rocket dropped into the water west of SNI.

Vandals were remotely controlled, non-recoverable missiles. Vandal launch trajectories varied from high-elevation angles (up to 42º), crossing the west end of SNI at an altitude of up to 17, 277 ft (5266 m), to a nearly horizontal launch profile crossing the west end of SNI at an altitude of about 1300 ft (396 m). With a launch angle ≤13º, the Vandal could descend to a sea-skimming altitude several nautical miles out at sea, or it could continue offshore at higher altitude.

At SNI, the Vandal was often launched singly, but up to three Vandals were launched on a single day. On three occasions, two Vandals were launched sequentially, spaced closely in time ('dual' launch). If launched sequentially, the Vandals were launched in succession from the same pad (Fig. 1.4).

1.2 Coyote

The Coyote, designated GQM-163A, is an expendable supersonic sea-skimming target (SSST) powered by a ducted-rocket ramjet. It is capable of flying at low altitudes (13 ft or 4 m cruise altitude) and supersonic speeds (Mach 2.5) over a flight range of 45 nautical miles (n.mi or 83 km) (Fig. 1.5). This vehicle is designed to provide a ground launched aerial target system to simulate a supersonic, sea-skimming Anti-Ship Cruise Missile (ASCM) threat. The Coyote was developed to replace the Vandal.

The Coyote vehicle assembly consists of two primary subsystems: MK 70 solid propellant booster, and the GQM-163A target vehicle. The solid-rocket booster is about 18 inches (in) (46 centimeters [cm]) in diameter and is of the type used to launch the Navy's Terrier surface-to-air missile. The GQM-163A target vehicle is 18 ft (5.5 m) long and 14 in (36 cm) in diameter, exclusive of its air intakes. It consists of a solid-fuel Ducted Rocket (DR) ramjet subsystem, Control and Fairing Subassemblies, and the Front End Subsystem (FES). Included in the FES is an explosive destruct system to terminate flight if required.

The Coyote utilizes the unmodified Vandal launcher, currently installed at the Alpha Launch Complex on SNI, with a Launcher Interface Kit (Fig. 1.5). A modified AQM-37C Aerial Target Test Set is utilized for target checkout, mission programming, verification of the vehicle's ability to perform the entire mission, and homing updates while the vehicle is in flight.

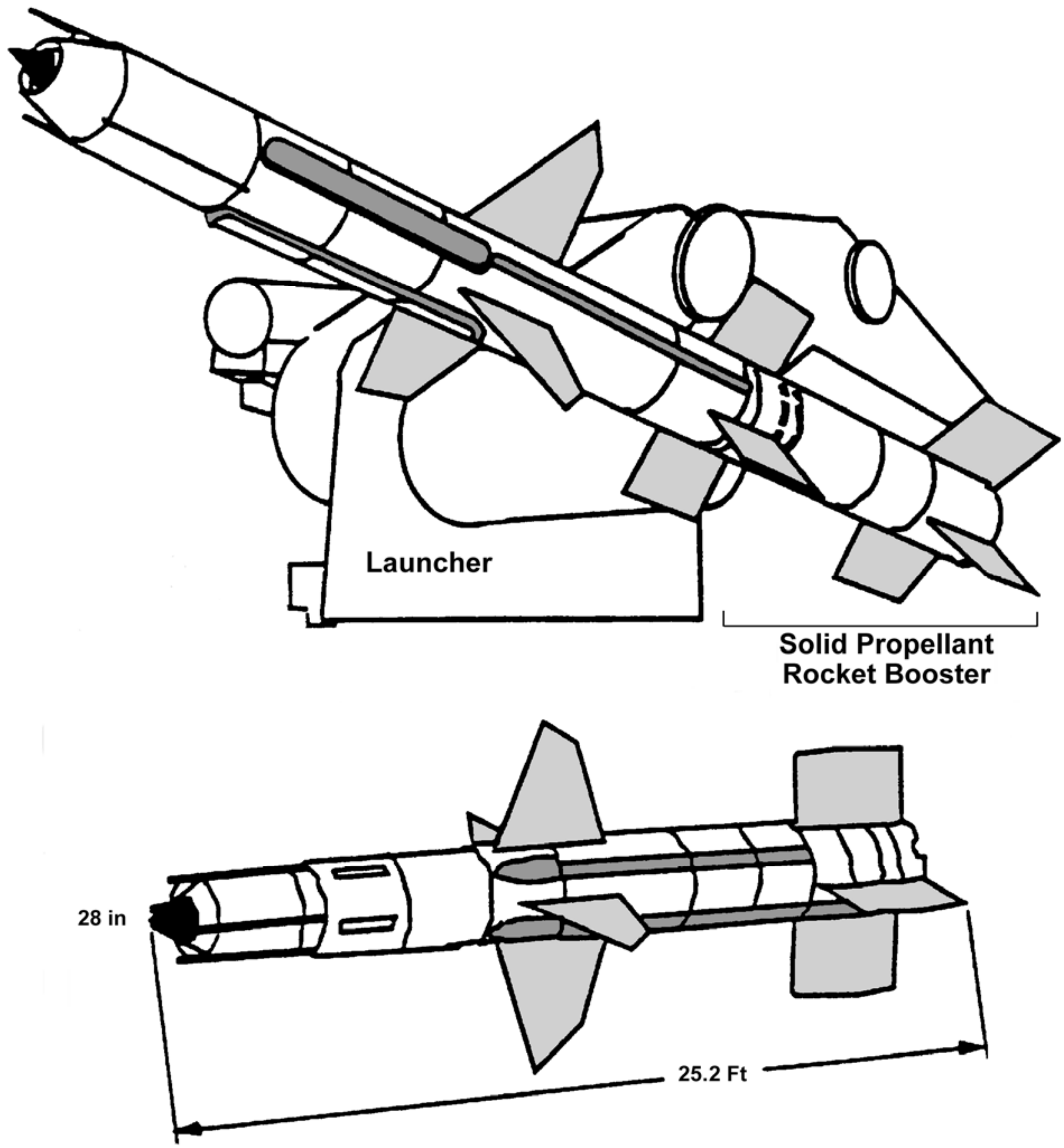

FIGURE 1.3. Vandal supersonic vehicle, which was accelerated to ramjet operational speed by a solid propellant rocket booster. ER (top) and EER (bottom) Vandal variants are identical in dimensions, with the EER having greater range and weight. Vandals were launched from a dedicated launcher system (Fig. 1.4) at the Alpha Launch Complex on SNI.

FIGURE 1.4. Two Vandals mounted on the launch pad at the Alpha Complex on SNI; solid rocket booster is visible at rear of closer Vandal (photograph by U.S. Navy).

FIGURE 1.5. Coyote with booster and launcher at the Alpha Launch Complex on SNI (photograph by U.S. Navy).

During a typical launch, booster separation would occur about 5.5 s after launch and about 1.4 n.mi (2.6 km) downrange, at which time the vehicle would have a speed of about Mach 2.35 (Orbital Sciences Corp; www.orbital.com). Following booster separation, the GQM-163A's DR ramjet ignites, the vehicle reaches its apogee, and then dives to 16 ft (5 m) altitude while maintaining a speed of Mach 2.5. During launches from SNI, the low-altitude phase occurs over water west of the island. The target performs pre-programmed maneuvers during the cruise and terminal phases, as dictated by the loaded mission profile, associated waypoints, and mission requirements. During the terminal phase, the Coyote settles down to an altitude of 13 ft (4 m) and Mach 2.3 until DR burnout.

1.3 Tactical Tomahawk

The Tactical Tomahawk is a long range, subsonic cruise missile (Fig. 1.6). It has a speed of about 550 mph (880 km/h) and a range of 870 n.mi (1609 km). It is designed to fly at extremely low altitudes at high subsonic speeds, and it is piloted by several mission-tailored guidance systems. Radar detection of this missile is extremely difficult because of the small radar cross-section and low altitude flight profile. Operational Tomahawks have one of two warhead configurations: a 1000-lb (454-kg) blast/ fragmentary unitary warhead, or a general-purpose submunition dispenser with combined effect bomblets. The Tactical Tomahawk can be reprogrammed in-flight to strike any of 15 pre-programmed alternate targets or to redirect the missile to any Global Positioning System (GPS) target coordinates. It can also loiter over a target area, and it has an on-board camera.

The Tactical Tomahawk is 18.25 ft (5.6 m) long with a 20.5 ft (6.3 m) long booster. It weighs 2900 lb (1315 kg) without the booster or 3500 lb (1588 kg) with the booster. It has a diameter of 20.4 in (51.8 cm) and a wing span of 8.75 ft (2.7 m). At SNI, one Tomahawk missile, with booster, has been launched vertically from the Building 807 Launch Complex (Fig. 1.6).

1.4 Terrier-Orion

As compared with the Vandal, the Terrier-Orion is a slightly smaller vehicle, and it flies ballistic trajectories. The Terrier-Orion is a two-stage, unguided, fin-stabilized, solid propellant rocket system designed to provide a realistic simulation of a medium-range ballistic missile (Fig. 1.7). The two-stage Terrier-Orion vehicle has an overall length of ~33 ft (10 m), body diameter of 18 in (45.7 cm; first stage) and 14 in (35.6 cm; second stage), and a total weight at lift off of 3976 lb (1804 kg).

The Navy launched one Terrier-Orion at SNI during Year 1, with no explosive warhead. At launch, the Terrier-Orion is accelerated for 6.4 s by a solid propellant rocket booster. After 13.6 s of coasting, the booster is discarded and the missile continues along its ballistic flight path at supersonic speed under second stage rocket power for 27 s. The expended booster rocket dropped into the water west of SNI, and the second stage and forebody impacted ~5 min after launch.

The Terrier-Orion is a non-recoverable missile that was launched from the same launch site (Alpha Launch Complex) on the western part of SNI as the Vandals and Coyotes. The Terrier-Orion's launch trajectory was near-vertical (64.6º), crossing the west end of SNI at an altitude of ~13,000 ft (3962 m).

FIGURE 1.6. Tactical Tomahawk missile and launcher at the Building 807 Launch Complex on SNI (photograph by U.S. Navy).

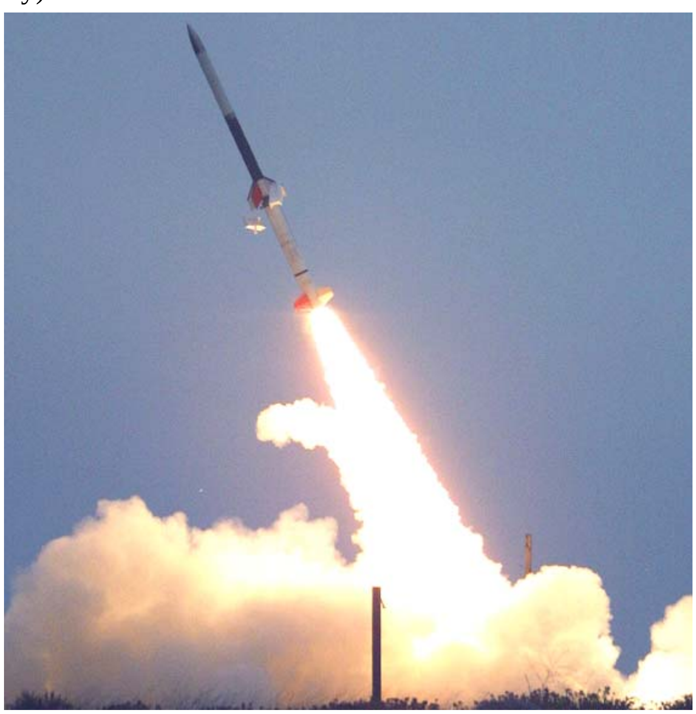

FIGURE 1.7. Terrier-Orion launch from the pad at the Alpha Complex on SNI (photograph by U.S. Navy).

1.5 Falcon Rocket

A rocket was launched on 6 April 2006 as part of the FalconLaunch IV Rocket Program. The purpose of the program is to provide "hands on" educational experience for cadets at the United States Air Force Academy, and to establish the capability to fly small Air Force scientific payloads. This is the first ever undergraduate sounding rocket program in the world and is designed to develop future Air Force officers technically and professionally. The three predecessors to FalconLaunch IV were built and tested to pioneer the technology needed to launch FalconLaunch IV.

The objectives of FalconLaunch IV are to reach an altitude of 62 mi (100 km) in steady flight while carrying a 5.1 lb (2.3 kg) payload that includes a camera with streaming video, camera housing, amplifier, transmitter, two antennas, battery, and bulkhead. The flight objectives will be validated by real-time data from the onboard avionics equipment, since the rocket will not include a recovery system.

The rocket that is launched during FalconLaunch IV is a single stage, solid-propellant, sounding rocket with four stabilizing fins (Fig. 1.8 and 1.9). The rocket is 10.5 ft (3.2 m) in length, with a gross mass of 159.6 lb (72.4 kg), and a propellant mass of 103.2 lb (46.8 kg). The rocket has a nominal burn time of 9.8 s and an average thrust of 1136 kilopond (kp).

The rocket launched at SNI on 6 April malfunctioned and did not clear the beach; it landed on the island ~0.6 mi (1 km) from the launch pad.

FIGURE 1.8. Setting up for the FalconLaunch IV at the Building 807 Launch Complex on SNI (photograph by U.S. Navy).

FIGURE 1.9. FalconLaunch IV at the Alpha Launch Complex on SNI (photograph by U.S. Navy).

1.6 Rolling Airframe Missile (RAM)

The Navy/Raytheon RAM is a supersonic, lightweight, quick-reaction missile. This relatively small missile, designated RIM 116, uses the infrared seeker of the Stinger missile and the warhead, rocket motor, and fuse from the Sidewinder missile. It has a high-tech radio-to-infrared frequency guidance system.

The RAM is a solid-propellant rocket 5 in (12.7 cm) in diameter and 9.2 ft (2.8 m) long. Its launch weight is 162 lb (73.5 kg), and operational versions have warheads that weigh 25 lb (11.4 kg). At SNI, RAMs are launched from the Building 807 Launch Complex (Fig. 1.10).

1.7 Advanced Gun System (AGS)

The AGS is a gun designed for a new class of Destroyer; it will launch both small missiles and ballistic shells. It is to be a fully integrated gun weapon system, including a 155-millimeter (-mm) gun, integrated control, an automated magazine, and a family of advanced guided and ballistic projectiles, propelling charges, and auxiliary equipment. The operational AGS will have a magazine with a capacity for 600 to 750 projectiles and associated propelling charges. The regular charge for the gun will replace the booster usually associated with a missile. The gun will get the missile up to speed, at which point the missile's propulsion will take over. The missile itself is relatively quiet, as it does not have a booster, and is fairly small. However, the gun blast is rather strong. Each AGS missile launch at SNI is preceded by one or two howitzer firings using a slug, to verify that the gun barrel is properly seated and aligned.

FIGURE 1.10. RAM launcher at the Building 807 Launch Complex on SNI (photograph by U.S. Navy).

FIGURE 1.11. Howitzer used as AGS launcher at the Alpha Complex on SNI (photograph by U.S. Navy).

At SNI, a howitzer (Fig. 1.11) was used to launch test missiles while the AGS gun was being developed. The launcher was located at the Alpha Launch Complex until June 2004, and the launches there were at azimuths of 282–305°. In July 2004, the launcher was moved to the Building 807 Launch Complex, where vehicles were launched at azimuths of 240–300°. The initial AGS testing effort was completed in 2006 (Year 5), with the last launch occurring in May 2006.

1.8 Arrow Self-Defense Missile

The Arrow (Fig. 1.12) is a theater missile defense weapon, or anti-ballistic missile (ABM). It was developed in Israel and is designed to intercept tactical ballistic missiles. It is about 22.3 ft (6.8 m) long and 2 ft (0.6 m) in diameter. It travels at hypersonic speed, and it has high and low altitude interception capabilities. The Arrow consists of three main components: a phased array radar (known as Green Pine), a fire control center (called Citron Tree), and a high-altitude interceptor missile that contains a powerful fragmentation warhead and two solid propellant stages, including a booster and sustainer. The array radar is capable of detecting incoming missiles at a distance of 310 mi (500 km). Once a missile is detected, the fire control center launches the interceptor missile. The interceptor travels at nine times the speed of sound and reaches an altitude of 31 mi (50 km) in less than 3 min.

The first test of an Arrow in the United States was conducted at SNI on 29 July 2004, and another Arrow was launched on 26 August 2004. At SNI, Arrows have been launched near the Alpha Launch Complex, within the area labeled on Figure 1.2 as “Miscellaneous Launch Pads”, at an azimuth of 285°.

1.9 Vehicle Launches during the Monitoring Period

During the period from August 2001 to March 2008, there were a total of 77 launches of 83 vehicles from SNI on 53 different days (Table 1.1). These launches involved either single vehicles, “dual” launches (two vehicles launched in quick succession within a span of ≤2 s), or up to three vehicles on the same day. In total, 29 Vandals, 9 Coyotes, 11 RAMs, 15 AGS slugs, 14 AGS missiles, 2 Arrows, 1 Falcon, 1 Tomahawk, and 1 Terrier-Orion were launched. Within the specific period of applicability of the 5-year regulations (2 October 2003 to date), there were 46 launches of 49 vehicles on 27 different days (Table 1.1). All launches occurred during daylight hours (between 07:29 and 17:24 local time). Weather during the launches ranged from cool to warm, with variable winds, and skies ranging from clear and sunny to partly cloudy or overcast (Table 1.1). Up to two additional Coyotes are scheduled to be launched during the current “Year 7” monitoring period, in May 2008.

All RAM launches occurred from the Building 807 Launch Complex (Fig. 1.2 and 1.10); they had a launch azimuth of 240º and an elevation angle ranging from 8 to 10º. The Tomahawk was also launched from the Building 807 Launch Complex, at an elevation angle of 90°, transitioning to an azimuth of 285°. AGS vehicles were launched on azimuths of 282–305° from the Alpha Launch Complex (Fig. 1.2) until June 2004. In July 2004, the AGS launcher was moved to the Building 807 Launch Complex, where AGS vehicles were launched at azimuths of 235–300°. AGS slugs and missiles were launched at elevation angles of 50–65°.

All other vehicles were launched from the Alpha Launch Complex (Fig. 1.2). The Terrier-Orion was launched at an azimuth of 232º and an elevation angle of 64.6º. The Falcon was launched at an elevation angle of 80º at an azimuth of 280º. The Falcon malfunctioned and landed on the island ~0.6 mi (1 km) from the launch pad. Vandals were launched at azimuths of 270–285º, and at low (6.5–8º) to high

FIGURE 1.12. View of the Arrow interceptor and launcher at the Alpha Complex on SNI (photograph by U.S. Navy).

(42º) elevation angles. Coyotes (Fig. 1.5) were launched at azimuths of 270–300º, with elevation angles of 14–22º. The Arrows (Fig. 1.12) were launched at the Alpha Launch Complex at elevation angle of 90°, transitioning to an azimuth of 285°.

These launch azimuths caused the vehicles to pass over or near various acoustic measurement sites and pinniped monitoring sites where Autonomous Terrestrial Acoustic Recorders (ATARs) and video systems had been deployed. The latter consisted of several wagon- or tripod-mounted cameras, as well as a remotely-controlled fixed video camera ("809 Camera") near Building 809 (Fig. 1.2).

1.10 Acoustical Monitoring of the Missile Launches

Audio recordings were obtained to document launch sounds at several distances from the launch trajectories of the vehicles; details are given in Chapter 2. During most launches, audio recorders were placed near video cameras and recorders that were documenting pinniped reactions, thus obtaining paired acoustic and pinniped-response data. In addition to recording launch sounds, the audio recordings also documented the ambient noise levels to which the pinnipeds were exposed prior to and following launches. Objectives of the audio monitoring program included.

1. documenting the levels and characteristics of launch sounds at several distances from the azimuths of the vehicles;
2. documenting the levels and characteristics of ambient sounds at the same locations as for the launch sounds, as a measure of the background noise against which the pinnipeds will (or will not) detect the launch sounds; and
3. determining whether the sound levels from vehicle overflights were high enough to have the potential to induce Temporary Threshold Shift (TTS) in pinnipeds exposed to launch sounds.

Based on a review of the literature (Lawson et al. 1998) done prior to the start of the monitoring, it was evident that the sound levels that might cause notable disturbance for each pinniped species are variable and context-dependent. Lawson et al. et al. (1998) estimated the minimum received level, on an A-weighted Sound Exposure Level (SEL-A) basis, that might elicit substantial disturbance was 100 dBA re $(20\ \mu Pa)^2 \cdot s$ for all pinnipeds. The 100 dBA re $(20\ \mu Pa)^2 \cdot s$ SEL pertains to exposure to prolonged sounds, which were taken to last at least several seconds. It is arguable how many of the launch sounds should be considered to be “prolonged” from the perspective of a pinniped at a fixed location on a beach. Measured durations range from much less than 1 s up to ~21 s (see Chapter 2). In any event, the assumption that reactions might occur at distances up to those where received levels diminished to 100 dBA SEL (see Fig. 2.39 *in* Greene and Malme 2002) was one factor in selecting acoustic (and video) monitoring sites during Year 1. Sites at distances up to ~2.5 mi (4 km) from the launcher and/or launch trajectory were monitored in Year 1.

After reviewing video recordings of pinnipeds during launches at SNI during 2001–2002 (also see Holst and Lawson 2002), the 100-dBA SEL still seemed reasonable as a minimum received level that might elicit disturbance of California sea lions. However, 90 dBA SEL seemed more appropriate for harbor seals, as they showed a strong response to most launches, including a number of launches where received levels were <100 dBA SEL. In contrast, the majority of elephant seals usually exhibited little or no reaction to launch sounds. The received levels of sounds from the larger vehicles, as measured in Year 1, indicated that levels at or above 90 dBA SEL could be expected out to distances of ~2.5 mi (4 km) from the launch trajectory (see Fig. 2.39 *in* Greene and Malme 2002). Thus, monitoring at sites located up to ~2.5 mi (4 km) from the launcher and/or launch trajectory continued during subsequent years. Continuing monitoring work (Chapter 3) has shown that some behavioral responses may extend to received sound levels lower than 90 dBA SEL.

1.11 Visual Monitoring of Pinnipeds During Vehicle Launches

The Navy conducted video and visual monitoring of marine mammals during the vehicle launches from SNI throughout the Year 1–7 monitoring period, supplemented by the aforementioned simultaneous autonomous audio recording of launch sounds (see Chapter 2). The video and visual monitoring provided data on samples of the pinnipeds hauled out on western SNI during launches. The accumulation of such data across numerous launches was expected to provide the data required to characterize the extent and nature of disturbance effects. In particular, it would provide the information needed to document the nature, frequency, occurrence, and duration of any changes in pinniped behavior resulting from the vehicle launches, including the occurrence of stampedes from haul-out sites if they occur.

TABLE 1.1. Details of all missile launches at SNI from August 2001 through March 2008 (also see Appendix A). The weather data were collected at the SNI airport, which is located at an elevation of 500 ft (152 m) ASL toward the east end of SNI; therefore weather conditions at recording and haul-out sites may have differed somewhat from those listed here. Times are local.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
YEAR 1									
15 Aug. 2001	12:56	Vandal	Alpha	270°	8° / 1280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~328 ft	12:51	3 cameras good	2 of 3 ATARs overloaded
"	13:17	Vandal	Alpha	270°	8° / 1280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~328 ft	12:51	3 cameras good	2 of 3 ATARs overloaded
20 Sept. 2001	08:30	Vandal	Alpha	270°	8° / 1280 ft	14°C; winds 300° at 6 kt; overcast	06:03	3 cameras good	1 of 3 ATARs failed
"	17:02	Terrier-Orion	Alpha	232.3°	64.6° / 13,000 ft	14°C; winds 300° at 6 kt; overcast	06:03	4 cameras good	2 of 3 ATARs failed
5 Oct. 2001	13:37	Vandal	Alpha	273.3°	8° / 1300 ft	16°C; winds 290° at 9 kt; overcast with drizzle	18:09	3 cameras good	2 of 3 ATARs failed
19 Oct. 2001	09:00	Vandal	Alpha	270°	8° / 1280 ft	17°C; winds 320° at 10 kt; overcast	05:15	3 cameras good	2 of 3 ATARs overloaded
19 Dec. 2001	15:22	Vandal	Alpha	273°	8° / 1300 ft	15°C; clear and sunny	19:09	1 of 3 cameras good	1 of 3 ATARs failed
14 Feb. 2002	11:33	Vandal	Alpha	273°	8° / 1300 ft	20°C; winds 5 kt; overcast	17:03	2 of 3 cameras good	1 of 3 ATARs overloaded
22 Feb. 2002	12:13	Vandal	Alpha	270°	42° / 9600 ft	27°C; winds 3 kt; sunny and warm	12:44	1 of 3 cameras good	1 of 3 ATARs failed
"	14:56	Vandal	Alpha	270°	42° / 9600 ft	27°C; winds 3 kt; sunny and warm	12:44	1 of 3 cameras good	1of 3 ATARs failed
6 Mar. 2002	11:20	Vandal	Alpha	273.1°	8° / 1300 ft	17°C; winds 270° at 9 kt; overcast	11:03	3 cameras good	3 ATARs OK

TABLE 1.1 (continued).

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
1 May 2002	15:53	Vandal	Alpha	273°	6.5° / malfunctioned & hit land	18°C; winds 300° at 20 kt; windy but clear	07:09	2 of 3 cameras good	2 of 3 ATARs failed
"	17:00	Vandal	Alpha	273°	42° / 9600 ft	18°C; winds 300° at 20 kt; windy but clear	07:09	2 of 3 cameras good	1 of 3 ATARs failed
8 May 2002	14:54	Vandal	Alpha	273°	8° / 1300 ft	18°C; winds 270° at 10 kt; sunny and clear	13:15	4 cameras good	3 ATARs OK
19 June 2002	15:07	AGS Slug	Alpha	305°	63° / malfunctioned & hit land	15°C; winds 290° at 15 kt; overcast	11:42	2 of 2 cameras good	1 of 2 ATARs failed
21 June 2002	12:53	Dual RAM	Building 807	240°	8° / 50 ft	16°C; winds 270° at 12 kt; overcast	13:18	2 of 2 cameras good	1 ATAR used; OK
26 June 2002	11:20	AGS Slug	Alpha	300°	62.5° / 500 ft	17°C; winds 290° at 16 kt; foggy and overcast	05:50	2 of 2 cameras good	3 ATARs OK
"	12:51	AGS Missile	Alpha	300°	62.5° / 5300 ft	17°C; winds 290° at 16 kt; foggy and overcast	05:50	2 of 2 cameras good	3 ATARs OK
18 July 2002	11:54	Vandal	Alpha	273°	8° / 1300 ft	19°C; winds 340° at 4 kt; foggy and overcast	10:04	1 of 1 camera good	2 of 3 ATARs failed
YEAR 2									
23 Aug. 2002	14:09	Tactical Tomahawk	Building 807	305°	90° / 1000 ft	15.6°C; winds 285° at 8.7-13.0 kt; overcast and partly cloudy	16:31	2 of 2 cameras good	2 of 3 ATARs failed
18 Nov. 2002	11:03	Dual RAM	Building 807	240°	10° / 50 ft	23.9°C; winds 125° at 1.7 kt; clear and sunny	7:52	1 of 2 cameras good	1 of 3 ATARs failed
10 Dec. 2002	8:49	Vandal	Alpha	273°	8° / 1300 ft	18.3°C; winds 285° at 21.7 kt; clear	8:33	1 of 2 cameras good	1 of 3 ATARs failed

TABLE 1.1 (continued).

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
18 Dec. 2002	14:30	AGS Slug	Alpha	282°	50° / 4500 ft	12.8°C; winds 285° at 17.4 kt; overcast to partly cloudy	15:15	No videos could be obtained	2 ATARs used; OK
“	16:15	AGS Missile	Alpha	282°	50° / 4500 ft	12.8°C; winds 285° at 17.4 kt; overcast to partly cloudy	15:15	No videos could be obtained	1 of 2 ATARs failed
24 Jan. 2003	14:20	Coyote	Alpha	270°	20° / 3400 ft	18.3°C; winds 293° at 8.7-13.0 kt; clear and windy	20:09	2 of 3 cameras good	2 of 3 ATARs failed
14 Mar. 2003	09:13	Vandal	Alpha	273°	8° / 1300 ft	13.9°C; winds 225° at 3.5 kt; calm, overcast at shore, fog inland	13:34	1 of 2 cameras good	3 ATARs OK
16 Mar. 2003	13:04	Vandal	Alpha	273°	8° / 1300 ft	15°C; winds 315° at 13.9-20.0 kt; gusty, few clouds	14:36	2 of 2 cameras good	2 of 3 ATARs failed
4 Apr. 2003	15:20	Dual Vandal	Alpha	273°	8° / 1300 ft	12.8°C; winds 315° at 14.8 kt; clear	16:18	2 of 2 cameras good	3 ATARs OK
4 June 2003	12:35	Coyote	Alpha	270°	22° / 3500 ft	17.2°C; winds 210° at 7.0 kt; haze; few clouds	7:41	2 of 2 cameras good	3 ATARs OK
26 June 2003	13:27	Vandal	Alpha	285°	42° / 17,277 ft	23°C; winds 230° at 7.0 kt; clear but some haze; fog	13:37	3 cameras good	1 of 3 ATARs failed
28 July 2003	16:27	Vandal	Alpha	270°	8° / 1280 ft	20°C; winds 300° at 11kt; few clouds	15:16	3 cameras good	2 of 3 ATARs failed

TABLE 1.1 (continued).

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
YEAR 3									
5 May 2004	11:46	Dual RAM	Building 807	240°	8° / 50 ft	17°C; winds 315° at 6 kt; clear and sunny	16:02	2 of 3 cameras good	3 ATARs OK
18 May 2004	12:40	Coyote	Alpha	300°	18° / 3300 ft	18°C; winds 315° at 15 kt; sunny and windy	15:11	3 cameras good	2 of 3 ATARs overloaded
3 June 2004	11:31	AGS Slug	Alpha	282°	50° / 4500 ft	17°C; winds 270° at 6 kt; partly cloudy	15:40	1 of 3 cameras good	3 ATARs OK
"	13:22	AGS Slug	Alpha	282°	50° / 4500 ft	17°C; winds 270° at 6 kt; partly cloudy	15:40	2 of 3 cameras good	3 ATARs OK
"	15:08	AGS Missile	Alpha	282°	50° / 4500 ft	17°C; winds 270° at 6 kt; partly cloudy	15:40	2 of 3 cameras good	3 ATARs OK
26 July 2004	15:10	AGS Slug	Building 807	300°	50° / 4500 ft	19°C; winds 310° at 14 kt; scattered clouds	10:31	3 cameras good	3 ATARs OK
"	15:43	AGS Slug	Building 807	300°	50° / 4500 ft	19°C; winds 310° at 14 kt; scattered clouds	10:31	3 cameras good	3 ATARs OK
29 July 2004	10:20	Arrow	Alpha	285°	90°/ ~7000 ft	16°C; winds 320° at 7 kt; overcast	13:57	4 cameras good	3 ATARs OK
26 Aug. 2004	10:08	Arrow	Alpha	285°	90°/ ~7000 ft	18°C; winds 320° at 5 kt; overcast	13:10	3 cameras good	3 ATARs OK
27 Aug. 2004	16:30	Coyote	Alpha	300°	18° / 3300 ft	20°C; winds 4 kt; scattered clouds	20:05	2 of 3 cameras good	3 ATARs OK
22 Sept. 2004	09:56	RAM	Building 807	240°	10° / 50 ft	27°C; winds 60° at 8 kt; overcast	N/A	1 of 3 cameras good	3 ATARs OK
"	10:57	RAM	Building 807	240°	10° / 50 ft	27°C; winds 60° at 8 kt; overcast	N/A	2 of 3 cameras good	3 ATARs OK
"	11:19	RAM	Building 807	240°	10° / 50 ft	27°C; winds 60° at 8 kt; overcast	N/A	2 of 3 cameras good	3 ATARs OK

TABLE 1.1 (continued).

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
YEAR 4									
27 Jan. 2005	08:59	AGS Slug	Building 807	287°	50° / 4500 ft	10.6°C; winds 370° at 6 kt; broken clouds	3:57	3 cameras good	1 of 3 ATARs failed
"	11:41	AGS Slug	Building 807	287°	50° / 4500 ft	10.6°C; winds 370° at 6 kt; broken clouds	3:57	3 cameras good	1 of 3 ATARs failed
"	13:29	AGS Missile	Building 807	287°	50° / 4500 ft	10.6°C; winds 370° at 6 kt; broken clouds	3:57	3 cameras good	1 of 3 ATARs failed
24 Feb. 2005	09:05	AGS Slug	Building 807	240°	50° / 4500 ft	14.7°C; winds 130° at 3 kt	N/A	0 of 3 cameras good	3 ATARs OK
"	13:16	AGS Missile	Building 807	240°	50° / 4500 ft	16.6°C; winds 340° at 7 kt	N/A	3 cameras good	3 ATARs OK
11 Mar. 2005	09:30	Dual Vandal	Alpha	273°	8° / 1300 ft	winds 130° at 12 kt; overcast	3:54	3 cameras good	3 ATARs OK
24 Mar. 2005	08:35	Coyote	Alpha	270°	14° / 3000 ft	23°C; winds 203° at 8 kt; overcast	14:56	3 cameras good	1 of 3 ATARs failed
22 April 2005	16:43	Coyote	Alpha	270°	14° / 3000 ft	winds 315° at < 8kt; variable cloud cover	15:06	3 of 4 cameras good	3 ATARs OK
2 June 2005	07:29	Vandal	Alpha	273°	8° / 1300 ft	winds 270° at 6 kt; overcast	13:02	1 of 3 cameras good	3 ATARs OK
"	09:49	Vandal	Alpha	273°	8° / 1300 ft	winds 270° at 6 kt; overcast	13:02	2 of 3 cameras good	3 ATARs OK
16 June 2005	10:08	AGS Slug	Building 807	280°	62.5° / 5300 ft	15°C; winds 315° at 6 kt	11:25	2 of 2 cameras good	1 of 3 ATARs failed
"	14:00	AGS Missile	Building 807	280°	62.5° / 5300 ft	15°C; winds 315° at 6 kt	11:25	2 of 2 cameras good	1 of 3 ATARs failed

TABLE 1.1 (continued).

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
29 June 2005	08:56	AGS Slug	Building 807	280°	62.5° / 5300 ft	15°C; winds 310° at 15 kt; overcast	10:41	4 cameras good	3 ATARs OK
"	11:04	AGS Slug	Building 807	280°	62.5° / 5300 ft	16°C; winds 300° at 12 kt; overcast, vis. 5 mi	10:41	4 cameras good	1 of 3 ATARs failed
"	14:35	AGS Missile	Building 807	280°	62.5° / 5300 ft	16°C; winds 300° at 12 kt; overcast, vis. 5 mi	10:41	3 of 4 cameras good	2 of 3 ATARs failed
26 July 2005	12:56	AGS Slug	Building 807	280°	65° / 5500 ft	20°C; winds 210° at 4 kt; scattered clouds	08:09	3 cameras good	3 ATARs OK
"	14:53	AGS Missile	Building 807	280°	65° / 5500 ft	20°C; winds 210° at 4 kt; scattered clouds	08:09	3 cameras good	3 ATARs OK
27 July 2005	10:07	Vandal	Alpha	270°	8° / 1280 ft	16°C	08:52	3 cameras good	1 of 3 ATARs failed
28 July 2005	08:04	Vandal	Alpha	270°	8° / 1280 ft	17°C; winds 270° at 10 kt; overcast	09:41	3 cameras good	3 ATARs OK
"	11:20	Vandal	Alpha	270°	35° / 8500 ft	20°C; winds 270° at 10 kt; overcast	09:41	3 cameras good	1 of 3 ATARs failed
"	11:38	Vandal	Alpha	270°	35° / 8500 ft	20°C; winds 270° at 10 kt; overcast	09:41	2 of 3 cameras good	3 ATARs OK
25 Aug. 2005	09:03	AGS Slug	Building 807	280°	62.5° / 5300 ft	22°C; winds 320° at 9 kt; clear	07:48	3 cameras good	1 of 3 ATARs failed
"	11:30	AGS Missile	Building 807	280°	62.5° / 5300 ft	22°C; winds 320° at 9 kt; clear	07:48	3 cameras good	3 ATARs OK
"	13:30	AGS Missile	Building 807	280°	62.5° / 5300 ft	22°C; winds 320° at 9 kt; clear	07:48	3 cameras good	3 ATARs OK
6 Oct. 2005	09:30	Coyote	Alpha	270°	14° / 3000 ft	25°C; winds 350° at 2 kt; clear	04:55	1 of 3 cameras good	2 of 3 ATARs failed

TABLE 1.1 (continued).

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (ºTrue)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Time at Low Tide	Video Quality*	Audio Quality
YEAR 5									
14 Feb. 2006	11:14	AGS Slug	Building 807	235°	62.5° / 5300 ft	13.9°C; winds 338° at 7-10 kt	16:28	3 cameras good	1 of 3 ATARs failed
“	13:40	AGS Missile	Building 807	235°	62.5° / 5300 ft	15.6°C; winds 338° at 8-12 kt	16:28	3 cameras good	1 of 3 ATARs failed
6 April 2006	16:42	Falcon	Alpha	280°	80° / malfunctioned & hit land	13.9°C; winds 315° at 8-10 kt	12:56	3 cameras good	1 of 3 ATARs failed
15 May 2006	09:10	AGS Slug	Building 807	235°	62.5° / 5300 ft	17.8°C; winds 130° at 9 kt	07:25	3 cameras good	1 of 3 ATARs failed
“	15:30	AGS Missile	Building 807	235°	62.5° / 5300 ft	18.9°C; winds 170° at 8 kt	18:47	2 of 3 cameras good	1 of 3 ATARs failed
YEAR 6									
26 April 2007	10:26	Dual RAM	Building 807	240°	10° / 50 ft	21°C; winds 315° at 8 kt; clear	13:16	2 of 3 cameras good	All 3 ATARs failed
12 June 2007	09:30	Coyote	Alpha	270°	14° / 914 m	18°C; winds 90° at 4 kt; overcast	13:29	3 cameras good	All 3 ATARs failed
13 June 2007	17:24	Coyote	Alpha	270°	14° / 3000 ft	24°C; no wind; clear	14:17	1 of 3 cameras good	1 of 3 ATARs failed

Note: There were no additional launches after 13 June 2007 up to March 2008; N/A means not available or unknown.

*Some cameras malfunctioned, no pinnipeds were seen at the time of launch, or the video quality was poor (also see Appendix A).

The video records were to be used to document pinniped responses to the launches. The objectives included the following:

1. identify and document any change in behavior or movements that occurred at the time of the launch;
2. compare received levels of launch sound with pinniped responses, based on acoustic and behavioral data from monitoring sites at different distances from the launch site and flightline during each launch; from the data accumulated across a series of launches, establish the "dose-response" relationship for vehicle sounds under different launch conditions;
3. ascertain periods or launch conditions when pinnipeds are most and least responsive to launch activities, and
4. document numbers of pinnipeds affected by vehicle launch sounds and, although unlikely, any mortality or injury.

Data from all seven monitoring years were pooled in order to meet the objectives. Additional data are expected to be collected during future monitoring. A detailed description of the methods for the visual monitoring can be found in Section 3.2 of Chapter 3.

1.12 Estimated Numbers of Pinnipeds Affected

The monitoring programs for the Navy's vehicle launches were designed, in part, to provide the data needed to estimate the numbers of pinnipeds affected by the launches and the manner in which they were affected. Pinnipeds are assumed to be 'taken by harassment' if there is a reason to believe that auditory impairment (TTS) might have occurred as a result of a launch, or if biologically significant behavioral patterns of pinnipeds are disrupted. NMFS (2000) defined a biologically significant behavioral response as one "…that affects biologically important behavior[s], such as survival, breeding, feeding and migration, which have the potential to affect the reproductive success of the animal". As a corollary of that, NMFS (2002) stated that "…one or more pinnipeds blinking its eyes, lifting or turning its head, or moving a few feet along the beach as a result of a human activity are not considered a 'take' under the MMPA definition of harassment".

In this report, consistent with previous related reports, we have assumed that only those animals that met the following criteria would be counted as affected by launch sounds:

1. pinnipeds that were injured or killed during launches, if any (e.g., by stampedes);
2. pinnipeds exposed to launch sounds strong enough to cause permanent or temporary auditory impairment (PTS or TTS);
3. pinnipeds that left the haul-out site, or exhibited prolonged movement or prolonged behavioral changes (such as pups separated from mothers) relative to their behavior immediately prior to the launch.

In practice, no pinnipeds are known to have been injured or killed during the monitored launches (i.e., since August 2001), and few are believed to have received sounds strong enough to elicit TTS (see Chapter 4). Thus, the number of pinnipeds counted as potentially affected during the monitoring period was primarily based on criterion (3) – the number that left the haul-out site, or exhibited prolonged movement or other behavioral changes.

1.13 Summary

From August 2001 through March 2008, NAWCWD conducted a total of 77 launches from SNI, on 53 different days. Vehicles were launched from the Building 807 Launch Complex near the beach on the west-central part of SNI and from the Alpha Launch Complex farther inland on SNI. An acoustic and visual monitoring program was conducted during these launches to assess the effects of these operations on the pinniped species on the island. Monitoring procedures and results of the acoustic and visual monitoring during August 2001 to June 2007 are described in Chapters 2 and 3. Those chapters use the combined data from all monitoring years to characterize the launch sounds and pinniped responses. Those results are in turn used in Chapter 4 to estimate the numbers of pinnipeds potentially affected by the launches.

2. ACOUSTICAL MEASUREMENTS OF VEHICLE LAUNCHES, AUGUST 2001–MARCH 2008

2.1 Introduction

A total of 83 vehicles were launched from SNI during 77 launches that occurred from 15 August 2001 through 13 June 2007. (There were no launches subsequent to 13 June 2007 through 31 March 2008.) Of these, 19 launches (20 vehicles) occurred during the August 2001 through July 2002 period (Year 1), 12 launches (14 vehicles) took place during August 2002 through August 2003 (Year 2), 13 launches (14 vehicles) occurred from October 2003 to October 2004 (Year 3), 25 launches of 27 vehicles occurred during October 2004 to October 2005 (Year 4), 5 launches took place during February 2006 to February 2007 (Year 5), and 3 launches (4 vehicles) occurred February 2007 to February 2008 (Year 6) (Table 1.1). Launches involved either single vehicles, “dual” launches (one launch involving two vehicles launched in quick succession), or widely-separated launches of up to three vehicles on the same day. In total, 29 Vandals, 9 Coyotes, 11 RAMs, 15 AGS slugs, 14 AGS missiles, 2 Arrows, 1 Falcon, 1 Tomahawk, and 1 Terrier-Orion were launched. Table 2.1 lists the launch dates, times, and types of vehicles. Maps of the launch azimuths and monitoring locations for all launches can be found in Appendix A.

The acoustic measurement program was consistent throughout the monitoring period. The sounds of each vehicle, as well as background sounds, were recorded at up to three sites on the island during each vehicle flight. ATARs, described below, were used to record the launch sounds at places and times where launch safety considerations required that no operator could be present during launches. Of the 231 possible recordings over the period from August 2001 through March 2008 (77 launches × 3 recording sites per launch), 226 recordings were attempted and 166 recordings were obtained and analyzed; 60 ATARs did not operate successfully (Table 2.1).

2.2 Field Methods

2.2.1 Deployment of ATARs

During each vehicle launch within the monitoring period, up to three ATARs were positioned near pinniped haul out sites at varying distances from the planned launch azimuth. During each of these launches, at least one ATAR was within a horizontal distance of 1968 ft (600 m) of the planned azimuth or the launcher itself. The other ATARs were positioned to the sides of that azimuth at other locations where pinniped responses were to be monitored by video methods (see Chapter 3). The audio recordings were planned 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 were exposed during each flight, these acoustic data were to be combined with the pinniped behavioral data to determine if there is a “dose-response” relationship between received sound levels and pinniped behavioral reactions (see Chapter 3).

TABLE 2.1. Vehicle launches recorded at SNI from August 2001 to March 2008.

Date	Local Time	Vehicle	Elevation Angle (°)	Acoustic Recording Sites	Acoustic Data
Year 1					
15 Aug. 01	12:56	Vandal	8	3	1 OK*
“	13:17	Vandal	8	3	1 OK*
20 Sept. 01	08:30	Vandal	8	3	2 OK †
“	17:02	Terrier-Orion	64.6	3	1 OK †
5 Oct. 01	13:37	Vandal	8	3	1 OK †
19 Oct. 01	09:00	Vandal	8	3	1 OK*
19 Dec. 01	15:22	Vandal	8	3	2 OK †
14 Feb. 02	11:33	Vandal	8	3	2 OK*
22 Feb. 02	12:13	Vandal	42	3	2 OK †
“	14:56	Vandal	42	3	2 OK †
6 Mar. 02	11:20	Vandal	8	3	3 OK
1 May 02	15:53	Vandal	6.5	3	1 OK †
"	17:00	Vandal	42	3	2 OK †
8 May 02	14:54	Vandal	8	3	3 OK
19 June 02	15:07	AGS Slug	63	2	1 OK †
21 June 02	12:53	Dual RAM	8	1	1 OK
26 June 02	11:20	AGS Slug	62.5	3	3 OK
“	12:51	AGS Missile	62.5	3	3 OK
18 July 02	11:54	Vandal	8	3	1 OK †
Year 2					
23 Aug. 02	14:09	Tomahawk	90	3	1 OK †
18 Nov. 02	11:03	Dual RAM	10	3	2 OK †
10 Dec. 02	08:49	Vandal	8	3	2 OK †
18 Dec. 02	14:30	AGS Slug	50	2	2 OK
"	16:15	AGS Missile	50	2	1 OK †
24 Jan. 03	14:20	Coyote	20	3	1 OK †
14 Mar. 03	09:13	Vandal	8	3	3 OK
16 Mar. 03	13:04	Vandal	8	3	1 OK †
4 Apr. 03	15:20	Dual Vandal	8	3	3 OK
4 June 03	12:35	Coyote	22	3	3 OK
26 June 03	13:27	Vandal	42	3	2 OK †
28 July 03	16:27	Vandal	8	3	1 OK †
Year 3					
5 May 04 022004	11:46	Dual RAM	8	3	3 OK
18 May 04	12:40	Coyote	18	3	1 OK*
3 June 04	11:31	AGS Slug	50	3	3 OK
“	13:22	AGS Slug	50	3	3 OK
“	15:08	AGS Missile	50	3	3 OK
26 July 04	15:10	AGS Slug	50	3	3 OK
“	15:43	AGS Slug	50	3	3 OK
29 July 04	10:20	Arrow	90	3	3 OK
26 Aug. 04	10:08	Arrow	90	3	3 OK
27 Aug. 04	16:30	Coyote	18	3	3 OK
22 Sept. 04	09:56	RAM	10	3	3 OK
“	10:57	RAM	10	3	3 OK
“	11:19	RAM	10	3	3 OK

TABLE 2.1 (continued).

Date	Local Time	Vehicle	Elevation Angle (°)	Acoustic Recording Sites	Acoustic Data
Year 4					
27 Jan. 05	08:59	AGS Slug	50	3	2 OK †
"	11:41	AGS Slug	50	3	2 OK †
"	13:29	AGS Missile	50	3	2 OK †
24 Feb. 05	09:05	AGS Slug	50	3	3 OK
"	13:16	AGS Missile	50	3	3 OK
11 Mar. 05	09:30	Dual Vandal	8	3	3 OK
24 Mar. 05	08:35	Coyote	14	3	2 OK†
22 Apr. 05	16:43	Coyote	14	3	3 OK
2 June 05	07:29	Vandal	8	3	3 OK
"	09:49	Vandal	8	3	3 OK
16 June 05	10:08	AGS Slug	62.5	3	2 OK†
"	14:00	AGS Missile	62.5	3	2 OK†
29 June 05	08:56	AGS Slug	62.5	3	3 OK
"	11:04	AGS Slug	62.5	3	2 OK†
"	14:35	AGS Missile	62.5	3	1 OK†
26 July 05	12:56	AGS Slug	65	3	3 OK
"	14:53	AGS Missile	65	3	3 OK
27 July 05	10:07	Vandal	8	3	2 OK†
28 July 05	08:04	Vandal	8	3	3 OK
"	11:20	Vandal	35	3	2 OK†
"	11:30	Vandal	35	3	3 OK
25 Aug. 05	09:03	AGS Slug	62.5	3	2 OK†
"	11:30	AGS Missile	62.5	3	3 OK
"	13:30	AGS Missile	62.5	3	3 OK
6 Oct. 05	09:30	Coyote	14	3	1 OK†
Year 5					
14 Feb. 06	11:14	AGS Slug	62.5	3	2 OK†
"	13:40	AGS Missile	62.5	3	2 OK†
6 Apr. 06	16:42	Falcon	80	3	2 OK†
15 May 06	09:10	AGS Slug	62.5	3	2 OK†
"	15:30	AGS Missile	62.5	3	2 OK†
Year 6					
26 April	10:26	Dual RAM	10	3	0 OK†
12 June	09:30	Coyote	14	3	0 OK†
13 June	17:24	Coyote	14	3	2 OK†

* Other ATAR(s) overloaded. † Other ATAR(s) malfunctioned or data could not be interpreted.

ATARs were set up at the recording locations on the launch day well before the launch time and were retrieved later the same day. The ATAR units were deployed by Navy biologists, in most cases at sites as close as practical to three pinniped haul-out sites at various distances from the launch site and launch trajectory. The three (typically) ATAR sites for a given launch included the following locations: (1) as close as possible to the vehicle's planned flight path or to the launcher, (2) where the received sound levels were estimated to reach an SEL of ~90 to 100 dBA re (20 μPa)^2·s, as shown in Greene and Malme (2002), and (3) midway between sites 1 and 2. Over the period since monitoring started (August 2001), the Navy has distributed the ATARs such that, for types of vehicles launched commonly at SNI, recordings have been made at a variety of different distances and locations relative to the flight trajectories and relative to the launcher itself.

2.2.2 ATAR Design

The ATARs were designed to record continuously and unattended for up to 48 hr. It was necessary to use autonomous extended-duration recorders because safety considerations required all personnel to leave the monitoring sites 1 hr prior to the planned launch. With the 48-hr recording capability, an ATAR can still make recordings of flight sounds even if prolonged launch delays occur. The extended recording capabilities of the ATAR units, as compared with Digital Audio Tape (DAT) recording units used previously (e.g., Greene 1999), were important in accommodating any launch delays and periods between launches on the same day.

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 Hz. The principal components of an ATAR are two calibrated dissimilar microphones, two adjustable gain amplifiers (signal conditioners), a two-channel audio interface and analog-to-digital converter, and a laptop computer on whose hard disk the digitized sound samples are recorded. Figure 2.1 is a block diagram of an ATAR illustrating the types and arrangement of components.

Each ATAR includes two calibrated 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), were designed for transduction of strong signals with received sound levels up to 185 dB. 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 kHz and digitized to a 16-bit two-byte integer.

At each of the monitoring sites, the microphones were placed in hemispherical windscreens and positioned so they were 0.08–0.12 in (2–3 mm) from the flat side of the hemisphere. The windscreens were then each affixed to the center of an aluminum base plate 0.25 in (0.63 cm) thick and 22 in (55.9 cm) in diameter. The two base plates were set on the ground or sand in an area generally free of vegetation (Fig. 2.2). The purpose of the aluminum base plates was 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 required a PCB model 480E09 signal conditioner. These low-noise, unity-gain amplifiers apply the microphone polarizing voltage. The signal conditioners had calibrated gain selections of 1, 10 and 100 (corresponding to 0, 20 and 40 dB, respectively). These signal conditioners were mounted in waterproof Pelican cases with the remaining equipment, excluding the microphones and battery (Fig. 2.1 and 2.2).

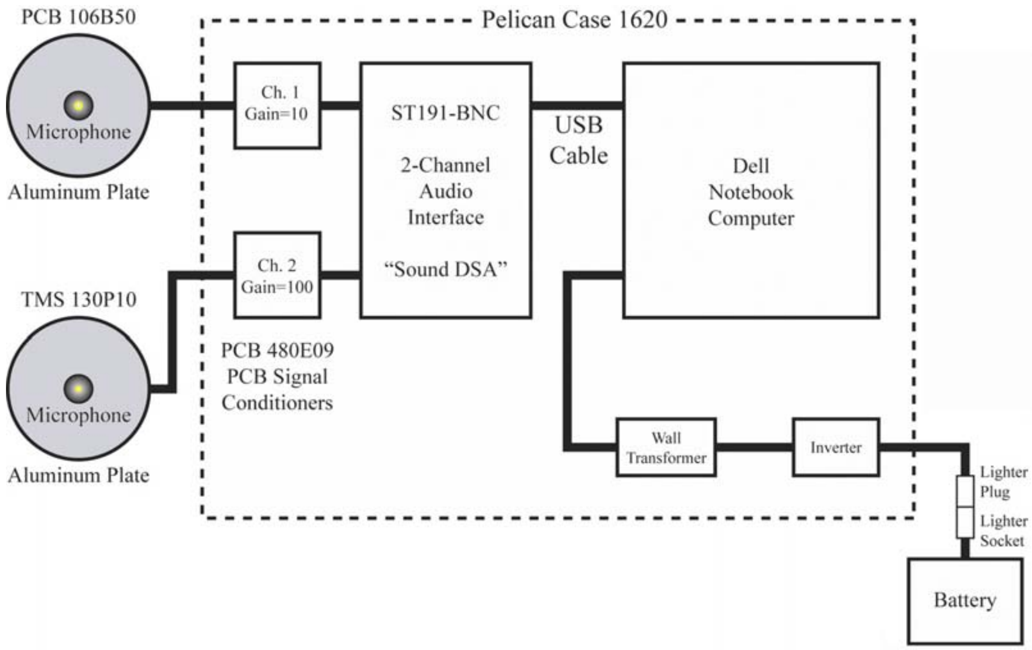

FIGURE 2.1. Block diagram of an Autonomous Terrestrial Acoustic Recorder (ATAR).

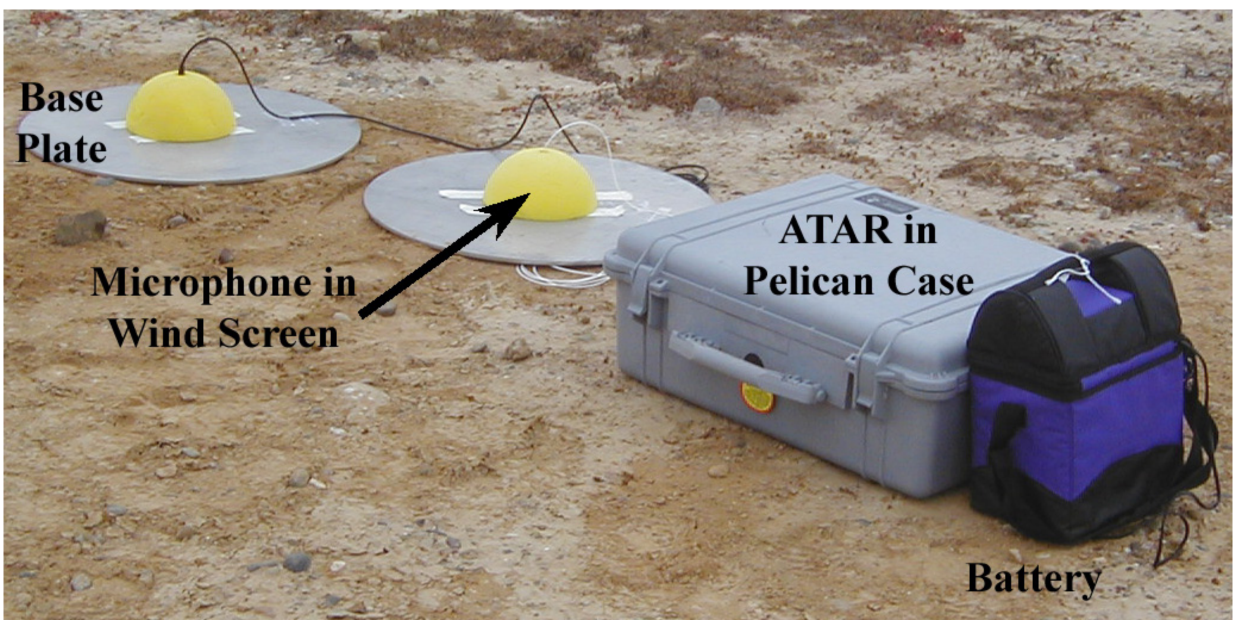

FIGURE 2.2. Typical field installation of an ATAR at the west end of SNI, California (photograph by J. Lawson, LGL).

Setting optimum recording levels was challenging as these had to be set before the launch, with no opportunity for adjustments based on initial results at that location. Setting recording levels too high results in clipping the signal; setting them too low would lose the signal beneath recorder self-noise; and setting them dynamically by automatic gain control would result in uncalibrated, and hence useless, data.

The ATARs did not record successfully during numerous (60) deployments (Table 2.1 and 2.2). During Years 1 and 2, the recording program aborted prematurely, sometimes before the vehicle was launched. The problem appeared to be associated with an input/output software driver, either between the sound card and the recording program, or between the recording program and hard disk. Evidence indicated a problem in the interaction of a manufacturer-supplied low-level software driver and the operating system (Windows 2000 Professional). The problem did not occur frequently in a laboratory environment, making it difficult to diagnose. The software driver was upgraded, and the operating system was replaced by Windows XP Professional just before the 4 April 2003 recordings. Although all three ATARs worked on that date, at one site an operator discovered a failure and corrected it before leaving for the launch. Additional failures occurred during several subsequent launches (Table 2.2).

In addition, a number of ATARs overloaded during launches, particularly during Year 1. The overloading occurred because the ATAR recording gains were inadvertently set higher than required. Thus, the overloading was not necessarily indicative of unusually high received levels, and the average received levels at the overloaded ATARs would not necessarily have been greater than those at non-overloaded ATARs.

During Year 2, it was observed that an ATAR would not operate at one site despite repeated attempts, but after being moved a fraction of a mile away, it operated successfully on the first try. It was suggested that microwave or other electromagnetic radiation on the island, from the numerous radar and telemetry systems present there, may produce sporadic but potentially intense electromagnetic interference and cause the ATARs to fail at some times and places. This observation is consistent with the fact that the ATARs do not fail when tested either in the lab at SNI or in Santa Barbara. Shielding and grounding was installed during subsequent launches, which seemed to alleviate this problem.

2.3 Audio and Data Analysis Methods

The ATARs recorded digital data directly onto a hard drive within the ATAR. The digital data on the hard drives were copied to a recordable CD-ROM after the recording period and returned to the acoustical contractor, Greeneridge Sciences Inc., for sound analysis.

Both time-series and frequency-domain analyses were performed on the acoustic data. Time-series results included signal waveform and duration, peak pressure level (peak), root mean square (rms) sound pressure level (SPL) and SEL. SPL and SEL were determined with three alternative frequency weightings: flat-weighted (SPL-f and SEL-f), A-weighted (SPL-A and SEL-A), and M_{pa}-weighted (SPL-M and SEL-M) basis. The recently-defined M_{pa}-weighting procedure, appropriate for pinnipeds in air, is described in Miller et al. (2005) and Southall et al. (2007) and in § 2.3.3 below. Frequency-domain results included estimation of sound pressure levels in one-third octave bands for center frequencies from 4 to 16,000 kHz. This section describes how these values are defined and calculated.

TABLE 2.2. Locations of ATAR recording devices (also see Appendix A).

Launch Date	Vehicle	ATAR Locations
Year 1		
15 Aug. 01	2 Vandals	End of Redeye Road; 809 Cameraº; Dos Covesº
20 Sep. 01	Vandal	809 Camera; Tender Beach; Dos Coves*
20 Sep. 01	Terrier-Orion	Alpha Launch Complex*; Building 807*; Cormorant Rock Blind
5 Oct. 01	Vandal	Phoca Reef; 809 Camera*; Vizcaino Point*
19 Oct. 01	Vandal	NAVFAC Beach; 809 Cameraº; Bachelor Beach Southº
19 Dec. 01	Vandal	809 Camera; Building 807; Dos Coves*
14 Feb. 02	Vandal	809 Camera; Bachelor Beach North; Alpha Launch Complexº
22 Feb. 02	Vandal	809 Camera; Redeye Beach; Dos Coves*
6 Mar. 02	Vandal	809 Camera; Dos Coves; Sheephead Ranch
1 May 02	Vandal	809 Camera†; Bachelor Beach South; Dos Coves*
8 May 02	Vandal	Pirates Cove; Sea Lion Cove; Vizcaino Point
19 June 02	AGS slug	Redeye II; Alpha Launch Complex*
21 June 02	Dual RAM	Building 807 Launch Complex
26 June 02	AGS slug and missile	809 Camera; Launch Pad; Redeye Beach
18 July 02	Vandal	809 Camera*; Dos Coves; Tender Beach*
Year 2		
23 Aug. 02	Tomahawk	Dos Coves, 50 ft from Launcher*, Bachelor Beach South*
18 Nov. 02	Dual RAM	75 ft from Launcher, Bachelor Beach North, Dos Coves*
10 Dec. 02	Vandal	Dos Coves, Bachelor Beach North, Launcher*
18 Dec. 02	AGS slug and missile	50 ft from Launcher, Near 809 Camera‡
24 Jan. 03	Coyote	Redeye I, Bachelor Beach South*, Dos Coves*
14 Mar. 03	Vandal	Pirates Cove, Sheephead Ranch, 100 ft from Launcher
16 Mar. 03	Vandal	Corral Harbor, Launcher*, Pirates Cove*
4 Apr. 03	Dual Vandal	NAVFAC Beach, No Name Cove, Phoca Point
4 June 03	Coyote	Sheephead Ranch, Near 809 Camera, 100 ft from Launcher
26 June 03	Vandal	The "Y", Near 809 Camera, Bomber Cove*
28 July 03	Vandal	Near 809 Camera, Bachelor Beach North*, Dos Coves*
Year 3		
5 May 04	Dual RAM	Dos Coves, Bachelor Beach North, Bachelor Beach South
18 May 04	Coyote	Pirates Cove, Harbor Seal Overlookº, Redeye Iº
3 June 04	AGS slugs (2) and missile	Dos Coves South, Harbor Seal Overlook, Near 809 Camera
26 July 04	AGS slugs (2)	Bachelor Beach North, Dos Coves South, Vizcaino Point
29 July 04	Arrow	Dos Coves South, Bachelor Beach North, Vizcaino Point
26 Aug. 04	Arrow	Dos Coves South, Phoca Reef, Vizcaino Point
27 Aug. 04	Coyote	Dos Coves South, Phoca Reef, Vizcaino Point
22 Sept. 04	3 RAMs	Dos Coves South, The “Y”, Vizcaino Point

º ATAR overloaded; * ATAR malfunctioned or recorded sound could not be analyzed; † ATAR malfunctioned at this location only during the first launch at 15:53:20; ‡ Sound recorded for AGS launch at 14:30 only.

TABLE 2.2 (continued).

Launch Date	Vehicle	ATAR Locations
Year 4		
27 Jan. 05	AGS slugs (2) and missile	Redeye I, Bachelor Beach North, Bachelor Beach South[*]
24 Feb. 05	AGS slug and missile	Vizcaino Point, Dos Coves South, Bachelor Beach South
11 Mar. 05	Dual Vandal	809 Camera, The "Y", Dos Coves South
24 Mar. 05	Coyote	809 Camera[*], The "Y", Dos Coves South
22 Apr. 05	Coyote	Harbor Seal Overlook, Phoca Reef, Phoca Point
2 June 05	2 Vandals	809 Camera, Bomber Cove, The "Y"
16 June 05	AGS slug and missile	Dos Coves South, Redeye I, Bachelor Beach North[*]
29 June 05	AGS slugs (2) and missile	The "Y"[†], Dos Coves Gate, Bachelor Beach [□]
26 July 05	AGS slug and missile	Bomber Cove, The "Y", Dos Coves South
27 July 05	Vandal	Bomber Cove, Harbor Seal Overlook[*], Phoca Reef
28 July 05	3 Vandals	Bomber Cove[‡], Harbor Seal Overlook, Phoca Reef
25 Aug. 05	AGS slug and 2 missiles	Bomber Cove, The "Y", Dos Coves South[§]
6 Oct. 05	Coyote	Bomber Cove, Dos Coves South[*], Phoca Reef[*]
Year 5		
14 Feb. 06	AGS slug and missile	Redeye I, Harbor Seal Overlook, The "Y"[*]
6 Apr. 06	Falcon	15 m from source, Harbor Seal Overlook, Dos Coves South[*]
15 May 06	AGS slug and missile	Phoca Reef[*], Harbor Seal Overlook, Vizcaino Point
Year 6		
26 Apr. 07	Dual RAM	Reef South of B807[*], Dos Coves South[*], The "Y"[*]
12 June 07	Coyote	Dos Coves South[*], The "Y"[*], Vizcaino Point[*]
13 June 07	Coyote	Dos Coves South[*], The "Y", Vizcaino Point

* ATAR malfunctioned or recorded sound could not be analyzed; [†] ATAR malfunctioned only during last launch at 14:35; [□] ATAR malfunctioned at 11:04 and 14:35; [‡] ATAR malfunctioned only during 11:20 launch; [§] ATAR malfunctioned during first launch at 09:03.

2.3.1 Time-Series Analysis

All analyses required 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, we first defined a "net energy" E. This measure of energy in excess of background was calculated as the cumulative signal energy above mean background energy:

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

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 was defined as the times associated with the accumulation of 5% and 95% of E.

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

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

Sound pressure was 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** was determined from 20·log (sound pressure).

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

2.3.2 Frequency-Domain Analysis

Frequency-domain analysis was used to estimate how signal power was distributed in frequency. Flat weighting was used for all frequency-domain analysis. The acoustical contractor used Welch's (1967) "Weighted Overlapped Segment Averaging" (WOSA) method to generate representative power spectral densities in each case. Power spectral densities were 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 were then summed into one-third octave bands.

For these analyses we defined the "signal" as consisting of the recorded data (vehicle signal plus background noise). This time series was 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 minimum three-term window (Harris 1978), 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 recorded on the high sensitivity channel, consisting of 4 s of data selected from before the vehicle signal, were 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 were integrated across standard one-third octave band frequencies to obtain summed sound pressure levels for each band. This analysis was 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 was broad, the lowest frequency one-third octave bands could not be computed. However, the cases of broad cell spacing correspond to cases of very short duration signals. Low frequencies are not important for short duration sounds.

2.3.3 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 were calculated for flat-, A-, and M_{pa}-weightings.

Flat-weighting leaves the signal spectrum unchanged. For instantaneous peak pressure, where the highest instantaneous pressure is of interest, it is not useful or appropriate 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 was used for frequency-domain analyses.

A-weighting shapes the signal's spectrum based on the standard A-weighting curve (Kinsler et al. 1982, p. 280; Richardson et al. 1995, p. 99). This 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 frequency response of the human ear to sounds at moderate levels. It is a standard method of presenting data on airborne sounds. The relative sensitivity of pinnipeds listening in air to different frequencies is somewhat similar to that of humans (Richardson et al. 1995), so A-weighting may, as a first approximation, be relevant to pinnipeds.

M_{pa}-weighting is a recent development that arose from the recent effort to develop science-based guidelines for regulating sound exposures (Gentry et al. 2004; Southall et al. 2007). During this process, separate weighting functions were 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; Miller et al. 2005; Southall et al. 2007). Two of these categories are pinnipeds listening 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 the potential effect of high-level sounds. With M_{pa}-weighting, the lower and upper "inflection points" are 75 Hz and 30 kHz.[1] For each launch whose sounds are reported here, we include the M_{pa}-weighted results as well as flat- and A-weighted results. Acoustic data based on M_{pa}-weighting are included because these values 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. Some of the analyses of pinniped responses relative to received sound levels included in Chapter 3 have been done using M_{pa}-weighted acoustic measures.

2.3.4 Data Analysis

From physical considerations, one expects the acoustic measures of a vehicle flight to be related to several potential predictor variables. The sound level is expected to diminish with increasing distance, but some other factors are also likely to affect the received sound. The primary measure of distance used here was the 3-dimensional (3-D) distance of the ATAR from the closest point of approach (CPA) of the vehicle. The simple bivariate relationships of various measures of sound to the 3-D CPA distance was first examined using scatter plots and Spearman Rank Order Correlations, separately by vehicle type.

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[1] The data obtained during the current monitoring period were only recorded at frequencies up to 20 kHz, so the (probably negligible) energy at 20–30 kHz is not included in calculating the M_{pa} (or other) measures.

One-sided *P*-values are appropriate, since the direction of the effect was predictable (i.e., sound levels were expected to diminish with increasing distance from the vehicle flight path). Then, a process of stepwise multiple linear regression was conducted to investigate the simultaneous relationships of received sound to several potential predictor variables.

For all analyses, data from August 2001 to June 2007 were used. (There were no additional launches during July 2007 through March 2008.) For each launch, several potential predictor variables were calculated. These included the 3-D distance from the ATAR recording site to the CPA of the vehicle (in km), the angle above the horizon from recording site to the 3-D CPA (in degrees), and the wind component along the axis from the CPA to the ATAR location (in knots). The wind component equaled the wind speed if the wind was blowing directly from the CPA location to the ATAR, – (wind speed) if blowing along that axis but in the opposite direction (ATAR to CPA), and zero if perpendicular to that axis. For these and other angles, the component was calculated as the cosine of the angle between wind direction and the CPA-to-ATAR axis, multiplied by the wind speed.

Multiple regression models were fitted to examine the relationships between 10 acoustic measures and the aforementioned potential predictor variables. The 10 measurements of received sound used as response variables included seven measures of received sound level (Peak level, SEL-f, SEL-A, SEL-M, SPL-f, SPL-A, SPL-M) and three measures of sound duration: the logarithm (base 10) of duration with flat-weighting (logDur-f), A-weighting (logDur-A), and M_{pa}-weighting (logDur-M).

The linear regression models were all of the form

$$y = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p + \varepsilon, \qquad [1]$$

where y was the acoustic measurement, $x_1, ..., x_p$ were a set of predictor variables, $\beta_0, \ldots, \beta_p$ were parameters to be estimated, and ε was a random error term that was assumed to follow a normal distribution with mean 0 and unknown variance σ^2 (Neter et al. 1996). The set of predictor variables to consider for inclusion in [1] was pre-determined based on hypothesized effects on received acoustic levels. This set of predictor variables included (1) vehicle type, (2) 3-D distance to the CPA (CPADist; in km), (3) the logarithm (base 10) of 3-D distance from recording site to CPA (logCPADist), (4) the angle above the horizon from the recorder to the vehicle CPA (CPA_Angle; in degrees), (5) the CPA-to-receiver wind component in kt, plus (6) whether or not a sonic boom occurred.

Vehicle type was incorporated as five variables representing whether (1) or not (0) the vehicle was (i) "other large" (Arrow, Tomahawk, Terrier-Orion), (ii) AGS missile, (iii) AGS slug, (iv) RAM, or (v) Coyote. Those five variables were all coded as zero for Vandal launches; i.e., the Vandal was treated as the reference vehicle in all regression models. For vehicles other than the Vandal, one of these five variables was coded as "1" and the others as "0". This is the standard method for handling categorical data in a multiple regression analysis. With this method, the coefficients derived by the multiple regression for each of the five vehicle type variables indicate the degree to which sounds from each of those vehicles differed from Vandal sounds.

A total of either 147 or 148 sets of launch sound measurements and associated predictor variables were available for analysis, depending upon the specific sound variable being considered.

Backward model selection, with forward looks for removed variables, was used to determine the "best" set of predictor variables to include in model [1]. From an initial model that included all predictor variables, variables were removed one-at-a-time based on a nominal significance criterion of 0.15.

Between removals, previously eliminated variables were inspected and added back to the model if their nominal significance values were less than 0.15. Backward steps with intervening forward looks were repeated until all variables in the model had significance values <0.15 and none could be added.

The coefficient of multiple determination (R^2) for each model, student's *t* statistic for each coefficient, and nominal *P*-values associated with the *t* statistics were also calculated. Estimation of the models was carried out using SAS Proc REG (SAS Institute 2000). Residual plots for all predictor variables in the final model were inspected for normality, homogeneity of variance across the range of the predictor, and any non-linear trend. The residual plot for the predicted values for the final model was inspected for possible outliers.

In general, sound propagation is characterized both by spreading loss, which is logarithmically related to distance, and by absorption/scattering loss, which is linear with distance. Therefore, both logarithmic (logCPADist) as well as a linear function of 3-D CPA distance were considered as potential predictors of the acoustic measures. Both 3-D distance variables (non-log and log) were allowed in the same model even though they were highly correlated (r = 0.75). As a result, slight multicolinearity (Neter et al. 1996) may exist in models containing both distance variables. To check for adversely high multicolinearity, coefficients of all predictor variables were inspected in models both with and without the 3D distance variables. If coefficients were similar, multicolinearity was deemed inconsequential and no corrections were made.

The results of the regressions, showing the best-fitting models, are presented in Table 2.6 (later). The nominal significance levels associated with each included predictor variable are also presented as an indication of its relative utility in predicting the acoustic measure.

2.4 Results

Measurements of the vehicle flight sounds are reported based on flat-, A-, and M_{pa}-weighting. The background sound levels are also reported based on each of these weighting methods.

2.4.1 Vehicle Flight Sounds

Four parameters are reported for the vehicle flight sounds: peak pressure level (peak), SPL, SEL, and duration. These parameters are explained in § 2.3. Table 2.3 shows the results based on flat-, A-, and M_{pa}-weighting.

It was to be expected that A- and M_{pa}-weighted levels would almost always be less than flat-weighted levels. Sonic boom noise is strong at frequencies below 1000 Hz, which are de-emphasized with A- and (to a lesser degree) M_{pa}-weighting. A-weighted values were typically lower than M_{pa}-weighted values (Table 2.3 and 2.4), consistent with the greater de-emphasis of low frequency components by A-weighting.

The flight sound durations, defined as the period during which 90% of the acoustic energy arrived (§ 2.3.1), are sometimes long because of rocket noise reverberation or because the launch was at a high elevation angle, resulting in a relatively prolonged period when the vehicle was well above the horizon. For launches of all vehicle types combined, A- and M_{pa}-weighted durations were typically shorter than flat-weighted durations, and A-weighted durations were usually shorter than M_{pa}-weighted durations (Table 2.3 and 2.4).

TABLE 2.3. Pulse parameters for flat-, A-, and Mpa-weighted sound from vehicle flights at SNI during August 2001 to March 2008. (No launches after June 2007.) The peak levels and SPLs are in dB relative to 20 µPa, the SELs (energy levels) are in dB re (20 µPa)2·s, and the durations (Dur.) are in s. The 3-D CPA distance of the vehicle from the monitoring site is given in m. Broadband (10–20,000 Hz) flat- and A-weighted sound levels recorded just before the launch are also given (in dB re 20 µPa) for each site, based on data from the high-sensitivity sensor designed to measure ambient sounds. See Appendix A for maps of monitoring locations relative to launch sites and launch azimuths.

				CPA	Flat-weighted sound				A-weighted sound			M-weighted sound		
Date	**Time**	**Vehicle**	**Site**	**(m)**	**Peak**	**SPL**	**SEL**	**Dur.**	**SPL**	**SEL**	**Dur.**	**SPL**	**SEL**	**Dur.**
2001														
15 Aug.	12:55	Vandal	End of Redeye Road	1763	109	94	99	3.2	82	87	3.3	90	94	2.7
"	12:55	Vandal	Dos Coves	N/A						Overloaded				
"	12:55	Vandal	809 Camera	N/A						Overloaded				
15 Aug.	13:16	Vandal	End of Redeye Road	1763	112	95	99	2.1	83	87	2.6	93	95	1.6
"	13:16	Vandal	Dos Coves	N/A						Overloaded				
"	13:16	Vandal	809 Camera	N/A						Overloaded				
20 Sept.	08:29	Vandal	Tender Beach	2256	116	101	108	5.2	89	96	4.3	98	104	4.4
"	08:29	Vandal	809 Camera †	1046	140	133	120	0.05	115	101	0.03	123	108	0.04
20 Sept.	17:00	Terrier-Orion	Building 807	N/A						N/A				
"	17:00	Terrier-Orion	100 ft from Launcher	N/A						N/A				
"	17:00	Terrier-Orion	Cormorant Rock Blind	2433	104	91	96	3.8	78	83	3.4	87	92	3.2
5 Oct.	13:36	Vandal	Phoca Reef	2424	111	93	96	2.4	56	63	4.6	65	72	4.7
19 Oct.	08:59	Vandal	Bachelor Beach South	N/A						Overloaded				
"	08:59	Vandal	809 Camera	N/A						Overloaded				
"	08:59	Vandal	NAVFAC Beach	3911	134	122	121	0.8	69	76	4.7	85	91	4.5
19 Dec.	15:20	Vandal	Building 807 †	823	145	137	124	0.05	111	106	0.3	120	112	0.2
"	15:20	Vandal	809 Camera †	897	142	135	121	0.04	110	102	0.2	121	109	0.07
2002														
14 Feb.	11:33	Vandal	150 ft from Launcher	N/A						Overloaded				
"	11:33	Vandal	809 Camera †	897	134	124	117	0.2	93	92	0.7	111	104	0.2
"	11:33	Vandal	Bachelor Beach North †	1206	145	136	124	0.05	121	107	0.04	129	115	0.04
22 Feb.	12:13	Vandal	809 Camera	2372	111	93	98	2.9	81	85	2.7	89	93	2.6
"	12:13	Vandal	Redeye Beach	1718	111	96	101	3.3	88	92	2.6	94	99	2.7
22 Feb.	14:56	Vandal	809 Camera	2372	109	92	99	4.6	82	88	3.8	89	95	4.2
"	14:56	Vandal	Redeye Beach	1718	111	96	102	3.6	87	92	2.9	94	99	3.2
6 March	11:20	Vandal	Dos Coves †	399	149	142	129	0.05	123	113	0.09	132	119	0.06
"	11:20	Vandal	Sheephead Ranch	2909	109	98	95	0.6	63	63	0.9	69	68	0.8
"	11:20	Vandal	809 Camera †	897	143	134	121	0.06	120	106	0.05	126	112	0.05

TABLE 2.3 (continued).

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	Flat-weighted sound SPL	Flat-weighted sound SEL	Flat-weighted sound Dur.	A-weighted sound SPL	A-weighted sound SEL	A-weighted sound Dur.	M-weighted sound SPL	M-weighted sound SEL	M-weighted sound Dur.
1 May	15:53	Vandal	Bachelor Beach South	N/A	114	108	104	0.3	58	55	0.6	68	65	0.5
“	17:00	Vandal	Bachelor Beach South	2318	115	95	103	6.7	85	92	4.7	90	98	5.8
“	17:00	Vandal	809 Camera	2312	112	96	104	6.8	85	90	3.5	90	97	4.9
8 May	14:54	Vandal	Vizcaino Point †	1121	144	135	122	0.05	117	104	0.05	126	113	0.05
“	14:54	Vandal	Sea Lion Cove	2139	104	85	92	5.8	74	81	4.9	80	88	5.4
“	14:54	Vandal	Pirates Cove	2388	111	96	96	1.2	60	63	41.7	71	74	1.9
19 June	15:07	AGSS	Redeye II	N/A	111	95	97	1.8	69	72	1.9	73	77	2.5
21 June	12:53	Dual RAM	50 ft from Launcher	2	147	126	131	3.2	125	130	3.2	125	130	3.2
26 June	11:20	AGSS	50 ft from Launcher	N/A	158	150	137	0.05	137	125	0.06	142	129	0.06
“	11:20	AGSS	Redeye Beach	N/A	110	100	96	0.4	61	60	0.7	75	73	0.6
“	11:20	AGSS	809 Camera	N/A	109	97	95	0.6	62	64	1.4	85	79	0.3
26 June	12:51	AGSM	50 ft from Launcher	22	157	148	136	0.06	133	122	0.07	139	127	0.06
“	12:51	AGSM	Redeye Beach	1536	108	103	93	0.1	57	48	0.1	73	64	0.1
“	12:51	AGSM	809 Camera	2115	107	97	94	0.4	82	64	0.02	80	75	0.3
18 July	11:54	Vandal	Dos Coves †	399	149	140	128	0.07	122	110	0.07	131	119	0.06
23 Aug.	14:09	Tomahawk ‡	Dos Coves	529	111	93	107	20.6	92	102	11.5	92	105	18.2
18 Nov.	11:03	Dual RAM	75 ft from Launcher	4	146	124	129	3.3	122	128	3.2	124	129	3.2
“	11:03	Dual RAM	Bachelor Beach North	693	112	90	97	5.1	84	92	5.8	89	96	5.6
10 Dec.	08:49	Vandal	Dos Coves †	421	150	140	128	0.06	131	118	0.05	135	122	0.05
“	08:49	Vandal	Bachelor Beach North †	1206	136	123	117	0.3	108	102	0.3	115	108	0.2
18 Dec.	14:30	AGSS	50 ft from Launcher	12	166	154	141	0.05	143	130	0.06	149	136	0.05
“	14:30	AGSS	Near 809 Camera	1196	131	109	119	9.0	78	88	8.1	97	100	1.8
“	16:15	AGSM	50 ft from Launcher	12	165	156	143	0.05	143	131	0.07	150	137	0.06
2003														
24 Jan.	14:20	Coyote	Redeye I †	1034	134	123	118	0.3	104	98	0.3	113	105	0.1
14 March	09:13	Vandal	Pirates Cove	2388	112	88	98	10.7	58	66	6.6	71	79	7.3
“	09:13	Vandal	Sheephead Ranch	2909	112	90	98	6.0	51	60	8.5	65	74	8.9
“	09:13	Vandal	100 ft from Launcher	27	156	137	136	0.8	119	118	0.8	129	128	0.9
16 March	13:04	Vandal	Corral Harbor	2590	115	98	100	1.6	64	71	4.7	72	78	4.7
4 April	15:20	Dual Vandal	NAVFAC Beach	3911	108	92	95	2.1	59	59	1.2	65	70	3.0
“	15:20	Dual Vandal	No Name Cove	3506	116	104	101	0.5	62	67	3.6	71	77	3.5
“	15:20	Dual Vandal	Phoca Point	3273	115	106	102	0.3	58	63	3.6	71	76	3.8
4 June	12:35	Coyote	Near 809 Camera	1397	136	115	116	1.4	99	99	0.9	104	106	1.4
“	12:35	Coyote	Sheephead Ranch †	2906	116	101	102	1.2	90	87	0.5	90	91	1.2
“	12:35	Coyote	100 ft from Launcher	72	142	126	128	1.5	113	115	1.5	122	123	1.4

TABLE 2.3 (continued).

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	Flat-weighted sound SPL	Flat-weighted sound SEL	Flat-weighted sound Dur.	A-weighted sound SPL	A-weighted sound SEL	A-weighted sound Dur.	M-weighted sound SPL	M-weighted sound SEL	M-weighted sound Dur.
26 June	13:27	Vandal	The “Y”	2948	112	93	101	7.2	80	89	7.3	87	96	8.3
“	13:27	Vandal	Near 809 Camera	2757	113	97	103	3.6	83	90	5.2	91	98	5.2
28 July	16:27	Vandal	Near 809 Camera †	1045	143	137	122	0.03	121	106	0.04	125	111	0.04
2004														
5 May	11:46	Dual RAM	Dos Coves	581	111	86	93	4.5	80	86	3.9	84	90	4.6
“	11:46	Dual RAM	Bachelor Beach North	693	116	90	97	4.2	85	91	3.7	89	95	3.8
“	11:46	Dual RAM	Bachelor Beach South	992	117	90	96	3.5	85	91	4.0	88	94	3.7
18 May	12:40	Coyote	Pirates Cove	2397	106	93	105	15.8	71	79	6.7	80	88	6.2
“	12:40	Coyote	Harbor Seal Overlook †	1292	>136	>128	>117	0.08	>106	>103	0.5	>112	>108	0.4
“	12:40	Coyote	Redeye I †	1061	>136	>130	>119	0.07	>111	>103	0.1	>117	>108	0.1
3 June	11:31	AGSS	Dos Coves South	1347	118	106	98	0.2	88	78	0.1	98	89	0.2
“	13:22	AGSS	Dos Coves South	1347	113	100	94	0.2	82	73	0.1	95	86	0.1
“	15:08	AGSM	Dos Coves South	1347	114	105	98	0.2	81	73	0.2	93	86	0.2
“	11:31	AGSS	Harbor Seal Overlook	1164	125	110	103	0.2	88	81	0.2	102	94	0.2
“	13:22	AGSS	Harbor Seal Overlook †	1164	115	101	95	0.3	85	76	0.1	94	86	0.1
“.	15:08	AGSM	Harbor Seal Overlook	1164	125	111	103	0.2	87	79	0.2	98	91	0.2
“	11:31	AGSS	Near 809 Camera	1268	127	110	103	0.2	107	89	0.02	114	99	0.03
“	13:22	AGSS	Near 809 Camera	1268	128	109	103	0.3	94	88	0.3	103	97	0.3
“	15:08	AGSM	Near 809 Camera	1268	120	108	102	0.2	82	76	0.2	94	87	0.2
26 July	15:10	AGSS	Bachelor Beach North	781	123	115	101	0.05	93	82	0.07	103	91	0.07
“	15:43	AGSS	Bachelor Beach North	773	125	116	103	0.05	94	82	0.08	106	94	0.05
“	15:10	AGSS	Dos Coves South	438	133	125	112	0.06	100	88	0.06	112	100	0.05
“	15:43	AGSS	Dos Coves South	442	135	126	114	0.05	102	90	0.07	114	101	0.06
“	15:10	AGSS	Vizcaino Point	1584	117	110	98	0.06	69	61	0.2	92	79	0.05
“	15:43	AGSS	Vizcaino Point	1589	116	110	98	0.07	65	58	0.2	86	76	0.1
29 July	10:20	Arrow	Dos Coves South	1780	105	89	100	12.2	78	87	9.0	86	96	9.8
“	10:20	Arrow	Bachelor Beach North	1820	107	90	102	14.3	83	92	8.5	90	99	0.3
“	10:20	Arrow	Vizcaino Point	2082	101	88	99	12.7	73	83	10.6	83	94	11.9
26 Aug.	10:08	Arrow	Dos Coves South	1779	103	88	98	11.0	78	87	8.8	85	95	10.2
“	10:08	Arrow	Phoca Reef	2656	101	86	98	15.7	72	82	10.3	82	92	10.5
“	10:08	Arrow	Vizcaino Point	2262	100	84	96	15.6	72	82	10.4	81	92	12.5
27 Aug.	16:30	Coyote	Dos Coves South †	1920	136	118	114	0.4	102	96	0.3	112	104	0.1
“	16:30	Coyote	Phoca Reef	2413	100	82	92	9.9	67	76	7.0	77	85	6.8
“	16:30	Coyote	Vizcaino Point †	1614	136	133	117	0.02	103	100	0.4	123	108	0.03

TABLE 2.3 (continued).

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	SPL	SEL	Dur.	A-weighted sound SPL	SEL	Dur.	M-weighted sound SPL	SEL	Dur.
22 Sept.	09:56	RAM	Dos Coves South	580	109	92	97	3.0	87	91	2.4	91	96	2.7
“	10:57	RAM	Dos Coves South	580	110	90	96	4.5	84	90	3.9	88	94	4.1
“	11:19	RAM	Dos Coves South	580	114	89	95	3.4	82	87	3.3	87	92	3.7
“	09:56	RAM	The “Y”	1555	116	99	95	0.4	83	82	0.8	93	91	0.7
“	10:57	RAM	The “Y”	1555	109	93	87	0.3	75	70	0.4	85	81	0.3
“	11:19	RAM	The “Y”	1554	111	97	89	0.1	79	71	0.2	83	83	0.1
“	09:56	RAM	Vizcaino Point	2013	105	92	87	0.4	77	73	0.4	85	81	0.4
“	10:57	RAM	Vizcaino Point	2013	104	94	84	0.1	73	65	0.2	83	76	0.2
“	11:19	RAM	Vizcaino Point	2013	107	93	84	0.1	72	64	0.2	85	77	0.2
2005														
27 Jan.	08:59	AGSS	Redeye I †	1492	108	103	91	0.05	65	56	0.1	79	69	0.1
“	11:41	AGSS	Redeye I †	1492	108	103	90	0.05		No signal		83	63	0.01
“	13:29	AGSM	Redeye I †	1492	108	103	90	0.05	53	50	0.5	71	68	0.4
“	08:59	AGSS	Bachelor Beach North †	753	125	116	103	0.05	84	80	0.4	105	93	0.05
“	11:41	AGSS	Bachelor Beach North †	753	123	114	101	0.06	79	77	0.5	103	90	0.05
“	13:29	AGSM	Bachelor Beach North †	753	123	112	101	0.07	78	76	0.7	102	90	0.07
“	08:59	AGSS	Bachelor Beach South	N/A						N/A				
“	11:41	AGSS	Bachelor Beach South	N/A						N/A				
“	13:29	AGSM	Bachelor Beach South	N/A						N/A				
24 Feb.	09:05	AGSS	Vizcaino Point	1897	114	108	95	0.06	67	55	0.07	87	73	0.04
“	13:16	AGSM	Vizcaino Point	1897	114	108	95	0.05	69	56	0.06	89	75	0.04
“	09:05	AGSS	Dos Coves South †	462	131	126	112	0.04	93	86	0.20	107	96	0.09
“	13:16	AGSM	Dos Coves South †	462	131	126	112	0.04	94	84	0.11	109	97	0.07
“	09:05	AGSS	Bachelor Beach South †	1203	125	119	104	0.03	96	84	0.07	105	93	0.05
“	13:16	AGSM	Bachelor Beach South †	1203	124	106	103	0.45	93	85	0.16	95	92	0.56
11 March	09:30	Dual Vandal	809 Camera †	906	143	134	122	0.07	119	106	0.06	125	113	0.06
“	09:30	Dual Vandal	The “Y” †	882	142	133	122	0.09	117	106	0.08	123	112	0.08
“	09:30	Dual Vandal	Dos Coves South †	420	148	137	127	0.09	122	111	0.08	130	119	0.08
24 March	08:35	Coyote	The “Y” †	1311	138	130	117	0.05	119	100	0.01	124	108	0.02
“	08:35	Coyote	Dos Coves South †	883	144	134	121	0.05	114	107	0.19	126	114	0.06
22 April	16:43	Coyote	Redeye I	1158	138	128	117	0.07	107	96	0.08	123	105	0.02
“	16:43	Coyote	Phoca Reef †	2446	103	82	90	6.20	56	65	7.88	66	74	7.40
“	16:43	Coyote	Phoca Point	3236	102	93	87	0.28	54	46	0.13	60	60	0.96
2 June	07:29	Vandal	809 Camera †	925	143	135	122	0.05	120	106	0.04	126	112	0.04
“	09:49	Vandal	809 Camera	925	135	128	123	0.30	88	84	0.43	104	99	0.35

TABLE 2.3 (continued).

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	Flat-weighted sound SPL	Flat-weighted sound SEL	Flat-weighted sound Dur.	A-weighted sound SPL	A-weighted sound SEL	A-weighted sound Dur.	M-weighted sound SPL	M-weighted sound SEL	M-weighted sound Dur.
2 June	07:29	Vandal	Bomber Cove [†]	1165	141	133	120	0.05	117	103	0.04	124	110	0.04
"	09:49	Vandal	Bomber Cove	1165	138	130	125	0.28	92	87	0.31	106	101	0.31
"	07:29	Vandal	The "Y" [†]	705	144	135	123	0.07	120	107	0.06	126	114	0.06
"	09:49	Vandal	The "Y"	705	134	126	120	0.28	83	78	0.35	100	96	0.33
16 June	10:08	AGSS	Dos Coves South [†]	461	133	126	112	0.04	95	89	0.27	112	100	0.06
"	14:00	AGSM	Dos Coves South [†]	461	132	125	112	0.05	99	88	0.08	111	99	0.07
"	10:08	AGSS	Redeye I	1459	111	106	93	0.05	56	50	0.25	84	70	0.04
"	14:00	AGSM	Redeye I	1459	110	104	92	0.06	58	48	0.09	81	67	0.05
29 June	08:56	AGSS	The "Y"	1222	138	133	120	0.05	92	83	0.12	113	100	0.05
"	11:04	AGSS	The "Y"	1222	139	133	120	0.05	95	85	0.08	117	103	0.04
"	14:35	AGSM	The "Y"	N/A						N/A				
"	08:56	AGSS	Dos Coves Gate	265	131	125	112	0.05	85	84	0.75	106	96	0.11
"	11:04	AGSS	Dos Coves Gate [†]	265	135	126	113	0.04	95	91	0.38	114	102	0.06
"	14:35	AGSM	Dos Coves Gate [†]	265	135	127	113	0.04	104	92	0.07	114	103	0.07
"	08:56	AGSS	Bachelor Beach [†]	925	125	117	105	0.06	96	86	0.09	104	93	0.08
"	11:04	AGSS	Bachelor Beach	N/A						N/A				
"	14:35	AGSM	Bachelor Beach	N/A						N/A				
26 July	12:56	AGSS	Bomber Cove	1707	119	113	99	0.05	65	65	0.93	95	81	0.04
"	14:53	AGSM	Bomber Cove	1707	117	111	98	0.05	70	60	0.09	91	78	0.05
"	12:56	AGSS	The "Y" [†]	1222	124	117	104	0.05	91	80	0.09	99	89	0.10
"	14:53	AGSM	The "Y"	1222	122	116	103	0.05	86	74	0.06	93	86	0.16
"	12:56	AGSS	Dos Coves South [†]	461	135	127	113	0.04	99	92	0.23	116	102	0.05
"	14:53	AGSM	Dos Coves South	461	134	126	113	0.05	104	91	0.06	114	102	0.06
27 July	10:07	Vandal	Bomber Cove [†]	1278	138	131	118	0.05	112	98	0.04	121	107	0.04
"	10:07	Vandal	Harbor Seal Overlook	N/A						N/A				
"	10:07	Vandal	Phoca Reef	2411	112	92	96	2.87	54	61	4.72	66	72	4.68
28 July	08:04	Vandal	Bomber Cove [†]	1287	140	131	119	0.05	116	101	0.03	123	109	0.04
"	11:20	Vandal	Bomber Cove	N/A						N/A				
"	11:30	Vandal	Bomber Cove	2489	126	122	113	0.13	82	81	0.93	92	92	0.93
"	08:04	Vandal	Harbor Seal Overlook [†]	964	138	120	119	0.79	107	101	0.27	109	108	0.71
"	11:20	Vandal	Harbor Seal Overlook	1915	111	93	101	5.42	81	89	5.81	87	95	6.73
"	11:30	Vandal	Harbor Seal Overlook	1915	113	93	101	5.76	82	90	6.09	88	96	7.25
"	08:04	Vandal	Phoca Reef	2411	112	107	96	0.07	58	48	0.10	78	67	0.08
"	11:20	Vandal	Phoca Reef	2411	110	104	93	0.08	61	52	0.14	74	65	0.12
"	11:30	Vandal	Phoca Reef	2411	110	104	93	0.09	60	51	0.12	73	64	0.13

TABLE 2.3 (continued).

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	SPL	SEL	Dur.	A-weighted sound SPL	SEL	Dur.	M-weighted sound SPL	SEL	Dur.
25 Aug.	09:03	AGSS	Bomber Cove	1672	117	111	98	0.05	66	63	0.48	87	79	0.14
"	11:30	AGSM	Bomber Cove	1672	116	110	98	0.06	68	64	0.38	82	77	0.35
"	13:30	AGSM	Bomber Cove	1672	118	111	98	0.06	70	65	0.31	88	80	0.18
"	09:03	AGSS	The "Y"	1261	123	116	103	0.05	77	73	0.40	99	88	0.07
"	11:30	AGSM	The "Y"	1261	121	115	102	0.05	73	66	0.23	94	84	0.11
"	13:30	AGSM	The "Y"	1261	123	117	104	0.05	81	71	0.10	99	88	0.07
"	09:03	AGSS	Dos Coves South	N/A						N/A				
"	11:30	AGSM	Dos Coves South	460	133	126	112	0.04	101	89	0.06	113	100	0.05
"	13:30	AGSM	Dos Coves South	460	133	127	112	0.04	98	87	0.07	112	100	0.06
6 Oct.	09:30	Coyote	Bomber Cove †	1511	136	125	113	0.07	113	96	0.02	116	105	0.07
"	09:30	Coyote	Dos Coves South †	N/A						N/A				
2006														
14 Feb.	11:14	AGSS	Redeye I	1578	104.4	99.7	87.	0.0	53.4	43.0	0.09	74.9	61.5	0.05
"	11:14	AGSS	Harbor Seal Overlook †	1425	109.3	104.3	91.	0.06	61.4	51.0	0.09	82.8	69.3	0.05
"	11:14	AGSS	The "Y"	N/A						N/A				
"	13:40	AGSM	Redeye I	1578	108.4	103.5	90.	0.06	57.4	50.2	0.19	81.4	68.6	0.05
"	13:40	AGSM	Harbor Seal Overlook †	1425	114.2	108.7	95.	0.05	67.4	57.2	0.10	88.6	76.6	0.06
"	13:40	AGSM	The "Y"	N/A						N/A				
6 April	16:42	Falcon	15 m from source	N/A	142.0	127.6	126	0.76	126.6	123.6	0.49	127.6	124.9	0.54
"	16:42	Falcon	Harbor Seal Overlook	N/A	98.9	83.9	88.	2.83	71.2	75.3	2.57	77.2	81.5	2.65
"	16:42	Falcon	Dos Coves South	N/A						N/A				
15 May	09:10	AGSS	Phoca Reef	N/A						N/A				
"	09:10	AGSS	Harbor Seal Overlook	1416	113.6	109.0	95.	0.04	73.9	61.9	0.06	87.3	74.3	0.05
"	09:10	AGSS	Vizcaino Point †	1654	114.7	109.5	96.	0.05	85.9	72.8	0.05	93.8	80.2	0.04
15 May	15:30	AGSM	Phoca Reef	N/A						N/A				
"	15:30	AGSM	Harbor Seal Overlook †	1416	117.0	113.1	99.	0.04	78.6	66.0	0.06	93.5	79.3	0.04
"	15:30	AGSM	Vizcaino Point †	1654	119.0	112.6	99.	0.04	81.4	67.4	0.04	97.8	82.7	0.03
2007														
13 June	17:24	Coyote	Dos Coves †	N/A						N/A				
"	17:24	Coyote	Vizcaino Point †	1682	136.5	127.9	115	0.06	114.3	98.0	0.02	118.9	106.1	0.05
"	17:24	Coyote	The "Y" †	1217	139.7	129.9	117	0.05	114.9	101.5	0.05	123.8	109.0	0.03

Note: N/A = data not available (vehicle malfunctioned or ATAR malfunctioned or overloaded/clipped signal); AGSS = AGS Slug; AGSM = AGS Missile
†Sonic boom evident.
‡Chase planes preceded and followed the missile.

TABLE 2.4. Differences in sound measures with respect to A-, flat-, and Mpa-weighting.

	Differences in Sound Measures ± Standard Deviation								
	SPL (dB re 20 µPa)			**SEL (dB re (20 µPa)^2·s)**			**Duration (s)**		
Vehicle Type	**M_{pa} vs. A**	**Flat vs. M_{pa}**	**Flat vs. A**	**M_{pa} vs. A**	**Flat vs. M_{pa}**	**Flat vs. A**	**M_{pa} vs. A**	**Flat vs. M_{pa}**	**Flat vs. A**
Vandal (*n* = 54)	9.0 ±3.8	14.3 ±10.4	23.3 ±13.1	6.5 ±9.6	13.4 ±8.7	19.9 ±14.7	0.14 ±0.47	-0.34 ±1.24	-0.20 ±1.36
Coyote (*n* = 18)	8.2 ±4.5	10.8 ±6.6	19.1 ±7.1	2.6 ±8.9	11.2 ±5.0	13.8 ±11.3	-0.01 ±0.36	0.61 ±2.39	0.60 ±2.28
AGS* (*n* = 64)	26.2 ±10.6	15.8 ±6.6	32.0 ±14.1	5.2 ±9.7	15.3 ±5.6	20.5 ±13.5	-0.18 ± 0.81	0.10 ±0.92	-0.08 ±0.25
RAM (*n* = 15)	6.4 ±4.1	3.9 ±3.4	10.3 ±7.3	7.6 ±2.7	3.4 ±2.6	10.9 ±2.1	0.06 ±0.23	-0.01 ±0.25	0.04 ±0.39
Arrow (*n* = 6)	8.7 ±1.5	2.9 ±1.2	11.6 ±2.6	19.0 ±1.8	3.9 ±1.0	22.9 ±2.7	1.13 ±0.64	2.86 ±1.91	3.99 ±1.67
Terrier-Orion (*n* = 1)	9.4	3.2	12.6	14.5	3.9	18.4	-0.17	0.59	0.42
Tomahawk (*n* = 1)	0.7	1.2	1.9	13.3	1.7	15.0	6.71	2.37	9.07
Overall (*n* = 159)	11.48 ±8.28	12.96 ±8.77	24.44 ±14.26	6.19 ±9.30	12.47 ±7.53	18.66 ±13.06	0.07 ±0.85	0.12 ±1.42	0.18 ±1.57

Note: A-weighted values were typically < M_{pa}-weighted values which were < flat-weighted values. Negative values show where this trend was in the opposite direction. *AGS vehicles include slugs as well as missiles.

2.4.2 Spectral Composition of Launch Sounds

Graphs showing the pressure signature (pressure vs. time waveform) and flat-weighted SELs by one-third octave band for each individual launch can be found in the annual reports. Those reports are included (on CD-ROM) in Appendix B.

The one-third octave band-level spectra for the main vehicle types are summarized in Figures 2.3–2.7. The four panels in each Figure present the spectra as received at four categories of distance from CPA. For each type of vehicle, comparison of the spectra received in the various distance categories shows the expected tendency for diminishing levels with increasing distances. In general, the high-level sound components, most of which were found at the closer distances and low-to-moderate frequencies, are attributable to the launches. However, some of the lower-level data, particularly for the greater distances and higher frequencies, are likely confounded by self-noise from the recording system, with the vehicle sound components being weaker than shown.

For Vandals (Fig. 2.3), as well as AGS missiles (Fig. 2.5) and AGS slugs (Fig. 2.6), the highest ⅓-octave sound levels occurred at the lowest frequencies (<100 Hz). For the Coyotes (Fig. 2.4) and RAMs (Fig. 2.7), the highest ⅓-octave sound levels occurred at somewhat higher frequencies, from about 60 to

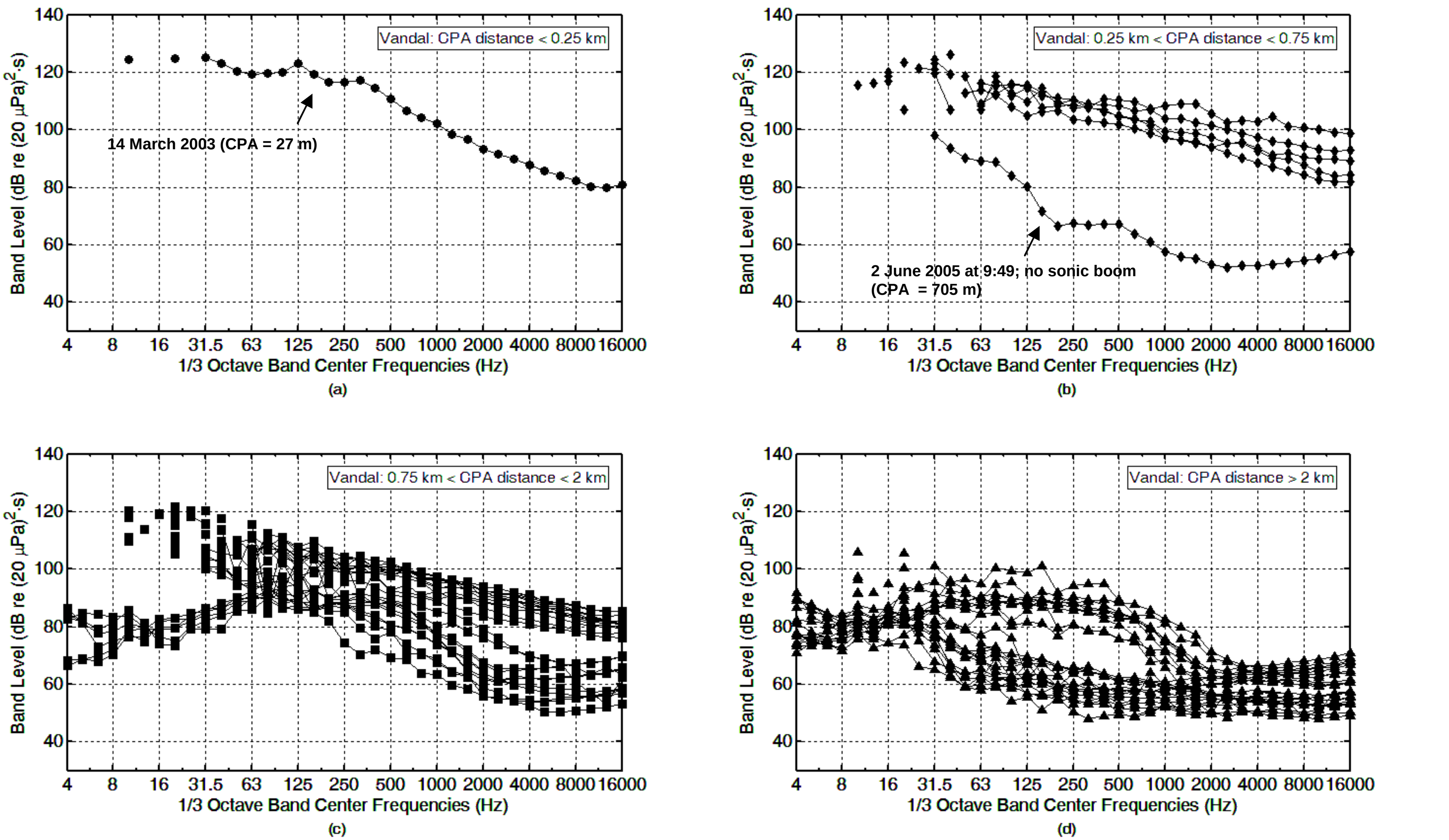

FIGURE 2.3. One-third octave band levels of ***Vandal*** launches for various 3-D CPA distances: (a) distance < 250 m, (b) 250 m < distance < 750 m, (c) 750 m < distance < 2000 m, and (d) distance > 2000 m.

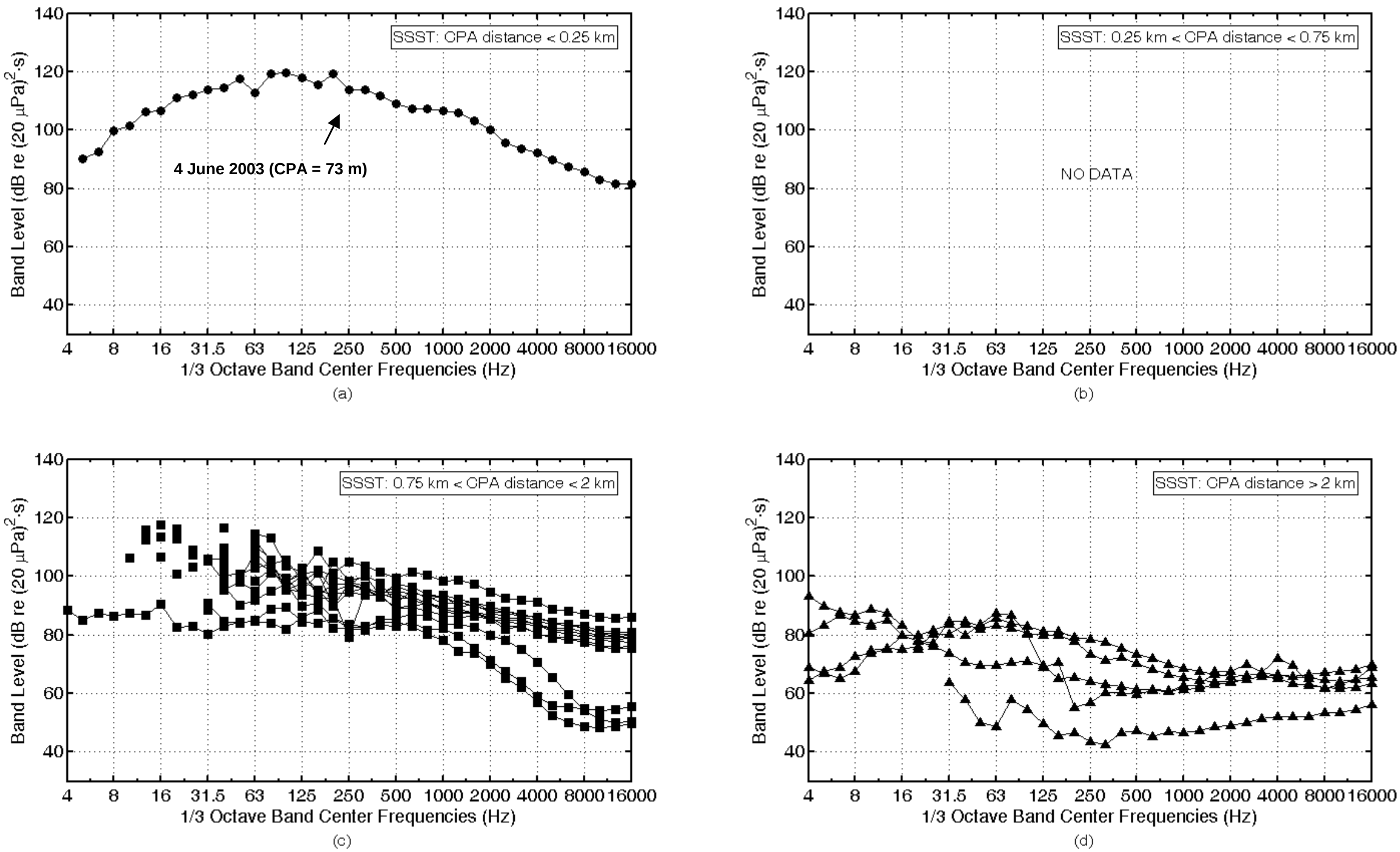

FIGURE 2.4. One-third octave band levels of GQM-163A ***Coyote*** SSST launches for various 3-D CPA distances: (a) distance < 250 m, (b) 250 m < distance < 750 m, (c) 750 m < distance < 2000 m, and (d) distance > 2000 m.

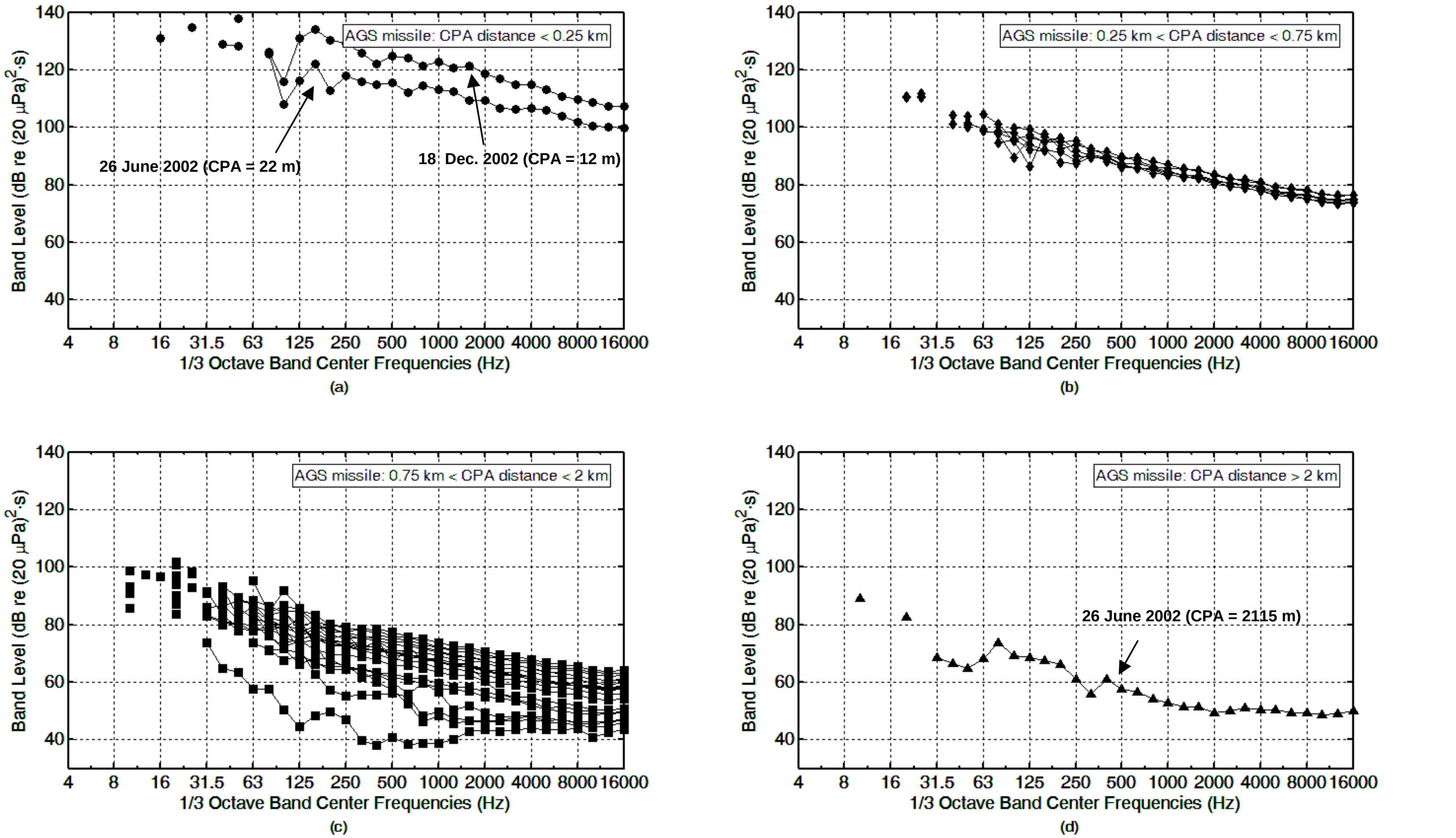

FIGURE 2.5. One-third octave band levels of ***AGS missile*** launches for various 3-D CPA distances: (a) distance < 250 m, (b) 250 m < distance < 750 m, (c) 750 m < distance < 2000 m, and (d) distance > 2000 m.

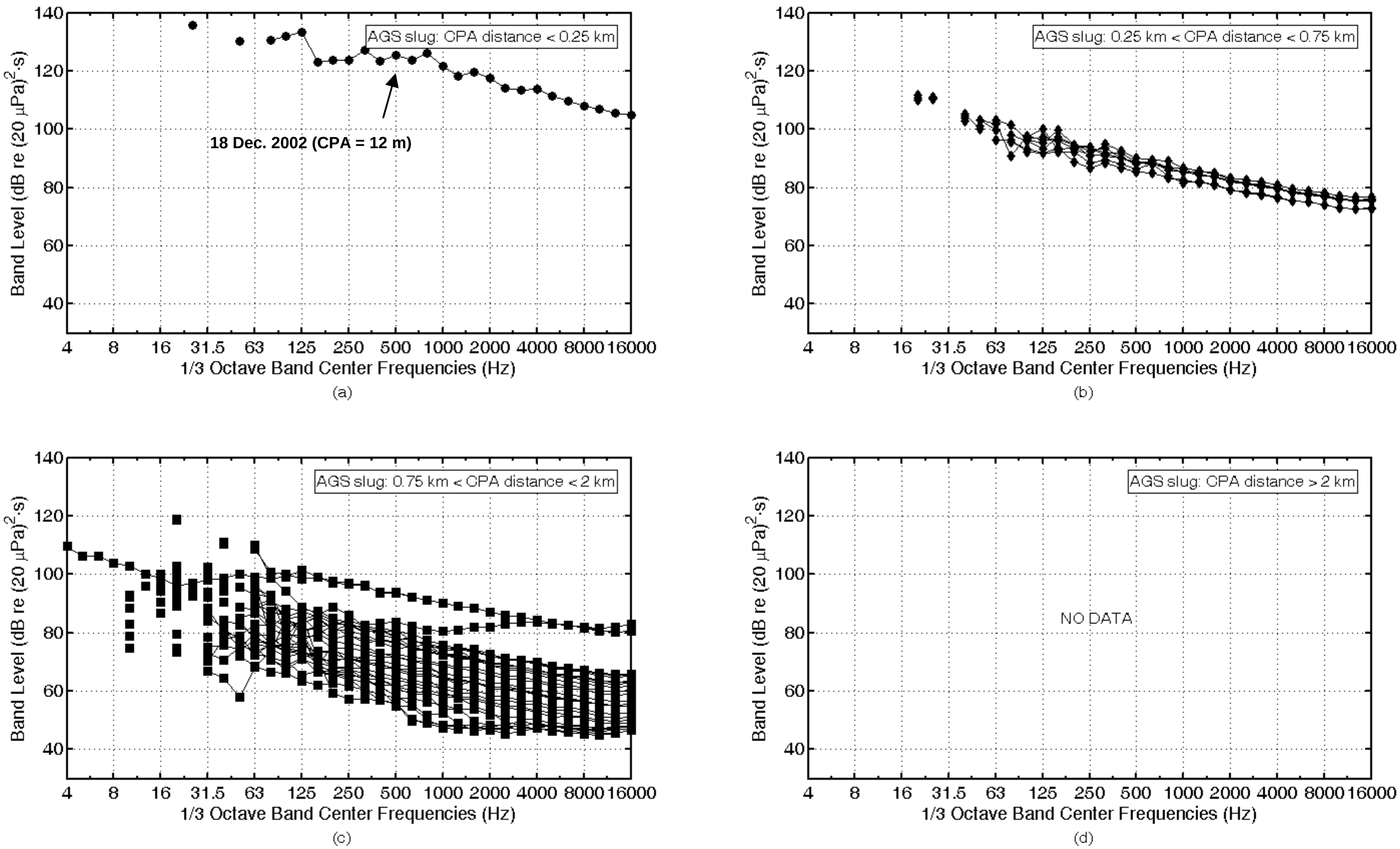

FIGURE 2.6. One-third octave band levels of ***AGS slug*** launches for various 3-D CPA distances: (a) distance < 250 m, (b) 250 m < distance < 750 m, (c) 750 m < distance < 2000 m, and (d) distance > 2000 m.

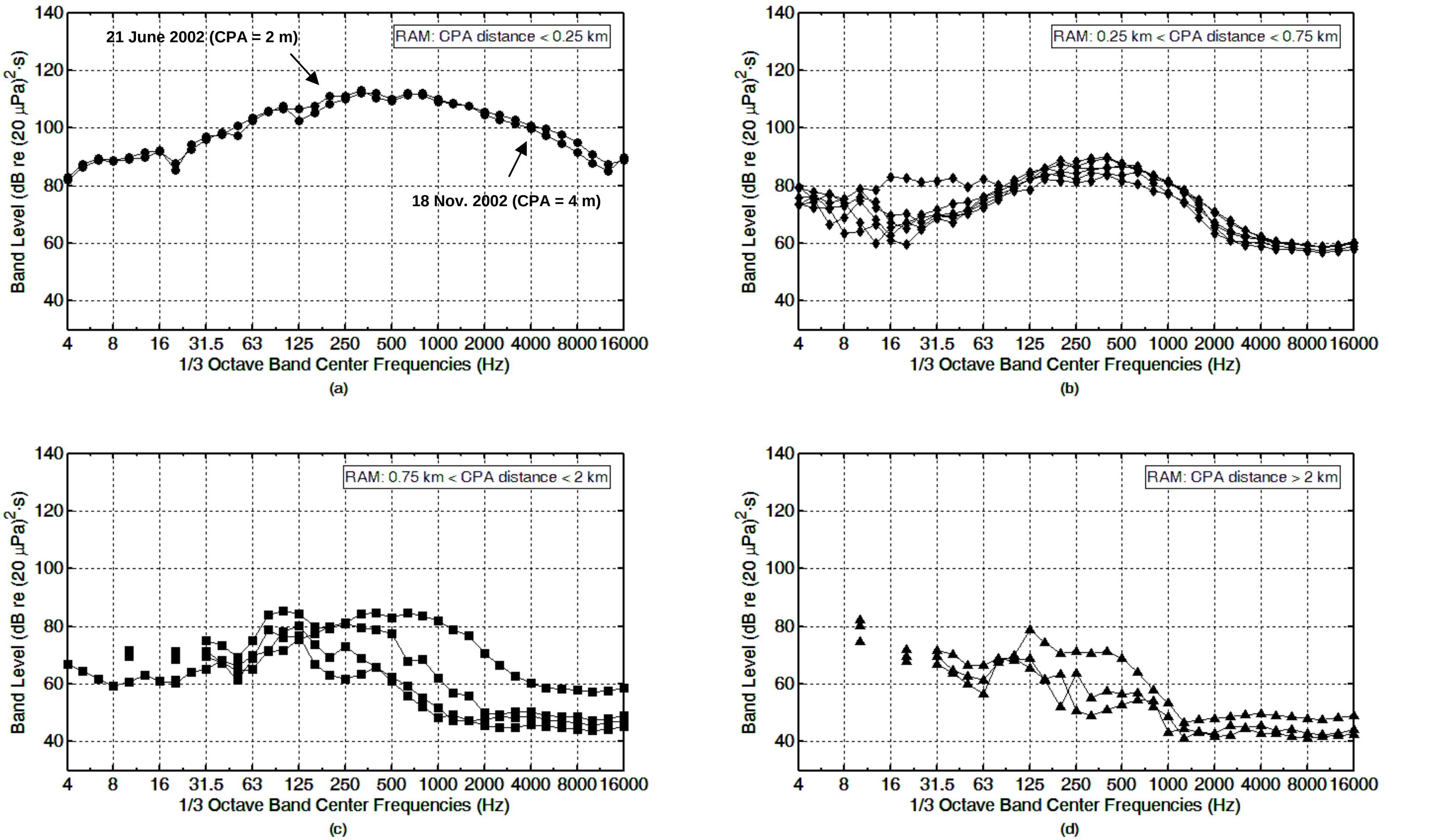

FIGURE 2.7. One-third octave band levels ***RAM*** launches for various 3-D CPA distances: (a) distance < 250 m, (b) 250 m < distance < 750 m, (c) 750 m < distance < 2000 m, and (d) distance > 2000 m.

1000 Hz. RAM launches, in particular, showed a predominance of mid- rather than low-frequency energy in their spectra (Fig. 2.7).

In Figure 2.3b, the spectrum with the lowest levels came from a missile flight that did not create a sonic boom, unlike the others. This Vandal launch (as recorded at The "Y" at 09:49 am on 2 June 2005) also had a lower peak pressure and longer duration compared to other Vandal launches. Similarly, in Figure 2.3c, the lower group of curves (comprising 6 recordings) consists of Vandal recordings for which no sonic boom was identified; the upper group of spectra was associated with sonic booms.

2.4.3 Vehicle Sounds in Relation to Distance

During the period August 2001 to March 2008, sounds from various vehicles were recorded at a variety of 3-D CPA distances (Table 2.3 and 2.5). Sounds recorded at nearshore locations are summarized below, whereas sounds recorded near the launcher are shown in Table 2.5.

- Vandal launches resulted in SPL-f values ranging from 85 dB re 20 µPa at Sea Lion Cove, located ~1.3 mi (2.1 km) from the CPA, to 140–142 dB recorded at Dos Coves ~1300 ft (400 m) from the CPA. Flat-weighted SEL ranged from 92 to 129 dB re (20 µPa)^2·s. Corresponding M_{pa}-weighted SELs (which are of more direct relevance to pinnipeds) ranged from 64 to 122 dB re (20 µPa)^2·s, and peak pressures ranged from 104 to 150 dB re 20 µPa.
- The Coyotes produced flat-weighted SPLs ranging from 82 dB re 20 µPa at Phoca Reef, 1.5 mi (2.4 km) from the CPA, to 134 dB at Dos Coves South, located 0.5 mi (883 m) from the CPA. SEL-f ranged from 87 to 119 dB re (20 µPa)^2·s. SEL-M ranged from 60 to 114 dB re (20 µPa)^2·s, and peak pressures ranged from 100 to 144 dB re 20 µPa.
- The Arrows produced flat-weighted SPLs ranging from 84 to 90 dB dB re 20 µPa at sites 1.1 mi (1.8 km) to 1.6 mi (2.7 km) from the CPA. SEL-f ranged from 96 to 102 dB re (20 µPa)^2·s, and SEL-M ranged from 92 to 99 dB re (20 µPa)^2·s. Peak pressures ranged from 100 to 107 dB re 20 µPa.
- As recorded at Cormorant Rock Blind, located 1.5 mi (2.4 km) from the CPA, the Terrier-Orion produced an SPL-f of 91 dB re 20 µPa, an SEL-f of 96 dB re (20 µPa)^2·s, and a SEL-M of 92 dB re (20 µPa)^2·s. The peak pressure was 104 dB re 20 µPa.
- At Dos Coves, located 1736 ft (529 m) from the CPA, the Tomahawk launch produced a flat-weighted SPL of 93 dB re 20 µPa, an SEL-f of 107 dB re (20 µPa)^2·s, and a SEL-M of 105 dB re (20 µPa)^2·s. The peak pressure was 111 dB re 20 µPa.
- The AGS missiles resulted in SPL-f values of 97–117 dB re 20 µPa, at nearshore sites located 0.5–1.2 mi (0.75–2 km) from the CPA and 125–127 dB at sites located <1516 ft (462 m) from the CPA. SEL-f levels ranged from 90 to 113 dB re (20 µPa)^2·s, and SEL-M ranged from 64 to 103 dB re (20 µPa)^2·s. The peak pressure ranged from 107 to 135 dB re 20 µPa.
- The AGS slugs produced flat-weighted SPL values of 100–133 dB re 20 µPa nearshore. SEL-f ranged from 88 to 120 dB re (20 µPa)^2·s, SEL-M ranged from 62 to 103 dB re (20 µPa)^2·s, and the peak pressures were 104 to 139 dB re 20 µPa.
- The RAM launches resulted in flat-weighted SPLs ranging from 86–99 dB at nearshore sites located ~0.4–1.2 mi (0.6–2.0 km) from the CPA. SEL-f ranged from 84 to 97 dB re (20 µPa)^2·s, and M_{pa}-weighted SELs were 76 to 96 dB re (20 µPa)^2·s. Peak pressure ranged from 104 to 117 dB re 20 µPa.

TABLE 2.5. The range of sound levels (maximum in bold) recorded near the launcher and at nearshore locations for all vehicle types launched at SNI from August 2001 through March 2008. Units for Peak and SPL are dB re 20 µPa; SEL is shown in dB re (20 µPa)2·s.

	CPA (m)	Peak (dB)	SPL-f (dB)	SPL-A (dB)	SPL-M (dB)	SEL-f (dB)	SEL-A (dB)	SEL-M (dB)
Launcher[1]								
AGS Slug	12	**166**	**154**	**143**	**149**	**142**	**130**	**136**
AGS Missile	12-22	157-**165**	148-**156**	133-**143**	139-**150**	136-**143**	122-**131**	127-**137**
RAM	2-4	146-**147**	124-**126**	122-**125**	124-**125**	129-**131**	128-**130**	129-**130**
Vandal	27	**156**	**137**	**119**	**129**	**136**	**118**	**128**
Coyote	72	**142**	**126**	**113**	**122**	**128**	**115**	**123**
Nearshore[2]								
AGS Slug								
Min	1578	104	100	53	75	88	43	62
Max	461-1268	**139**	**133**	**107**	**117**	**120**	**92**	**103**
AGS Missile								
Min	1492-2115	107	97	53	71	90	48	64
Max	265-462	**135**	**126**	**104**	**114**	**113**	**92**	**103**
RAM								
Min	581-2013	104	86	72	83	84	64	76
Max	580-1555	**117**	**99**	**87**	**93**	**97**	**92**	**96**
Vandal								
Min	2139-2909	104	85	51	65	92	48	64
Max	399-421	**150**	**142**	**131**	**135**	**129**	**118**	**122**
Coyote								
Min	2413-3236	100	82	54	60	87	46	60
Max	883-1311	**144**	**134**	**119**	**126**	**119**	**107**	**114**
Arrow								
Min	2262-2656	100	84	72	81	96	82	92
Max	1821	**107**	**90**	**83**	**90**	**102**	**92**	**99**
Terrier-Orion	2433	**104**	**91**	**78**	**87**	**96**	**83**	**92**
Tomahawk	529	**111**	**93**	**92**	**92**	**107**	**102**	**105**

Note: - means no launch sounds were recorded near the launcher.
[1] No acoustic data were recorded near the launcher during Arrow, Terrier-Orion, or Tomahawk launches.
[2] Acoustic data were only recorded at a single nearshore site during Terrier-Orion and Tomahawk launches.

The Tomahawk and RAM vehicles, and the AGS launches from July 2004 onward, were launched from the Building 807 Launch Complex near a beach (Fig. 1.2), so for those vehicles, it is possible that some pinnipeds could have been close to the launcher. For the Tomahawk, received level measurements close to the launcher are not available, but for the AGS and RAM launches, levels near the launcher were higher than those at any longer distance (Table 2.5; Fig. 2.8–2.13).

Scatter plots of broadband pulse parameters relative to 3-D CPA distance between the vehicles and the receiving location show that peak pressure level, SPL, and SEL generally decreased with increasing CPA distance from the vehicle (Fig. 2.8–2.13). The data from the Vandals spanned a wider range of distances (up to 2.5 mi or 4 km) than available for other vehicle types. The Vandal data showed that, at

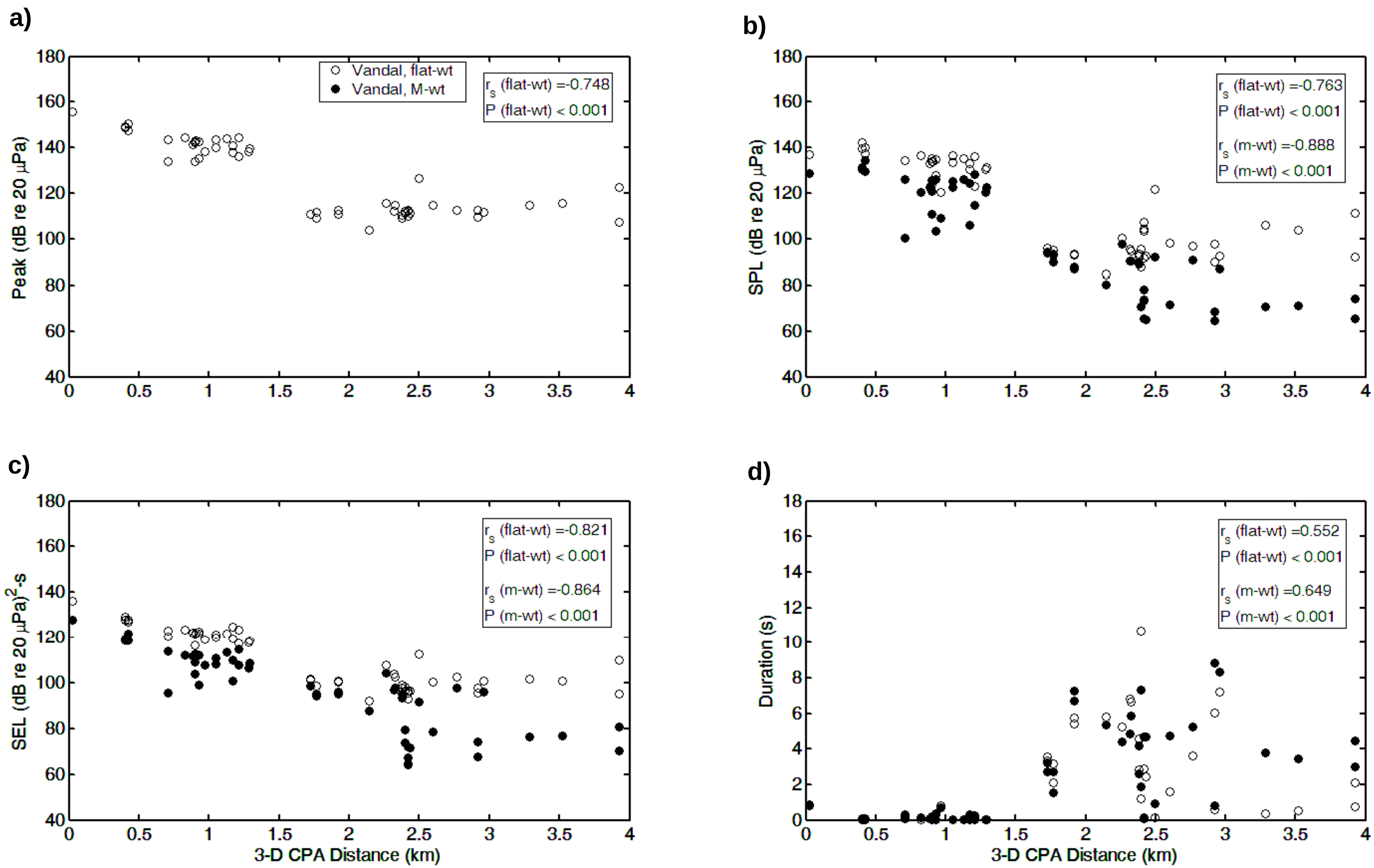

FIGURE 2.8. Sounds from launches of ***Vandal*** missiles relative to the 3-D CPA distance: (a) Peak sound pressure, (b) SPL, (c) SEL, and (d) Duration. For SPL, SEL, and Duration, both flat-weighted (open symbols) and Mpa-weighted (closed symbols) measurements are shown. Also shown are Spearman rank order correlation coefficients (rs) along with 1-sided *P*-values.

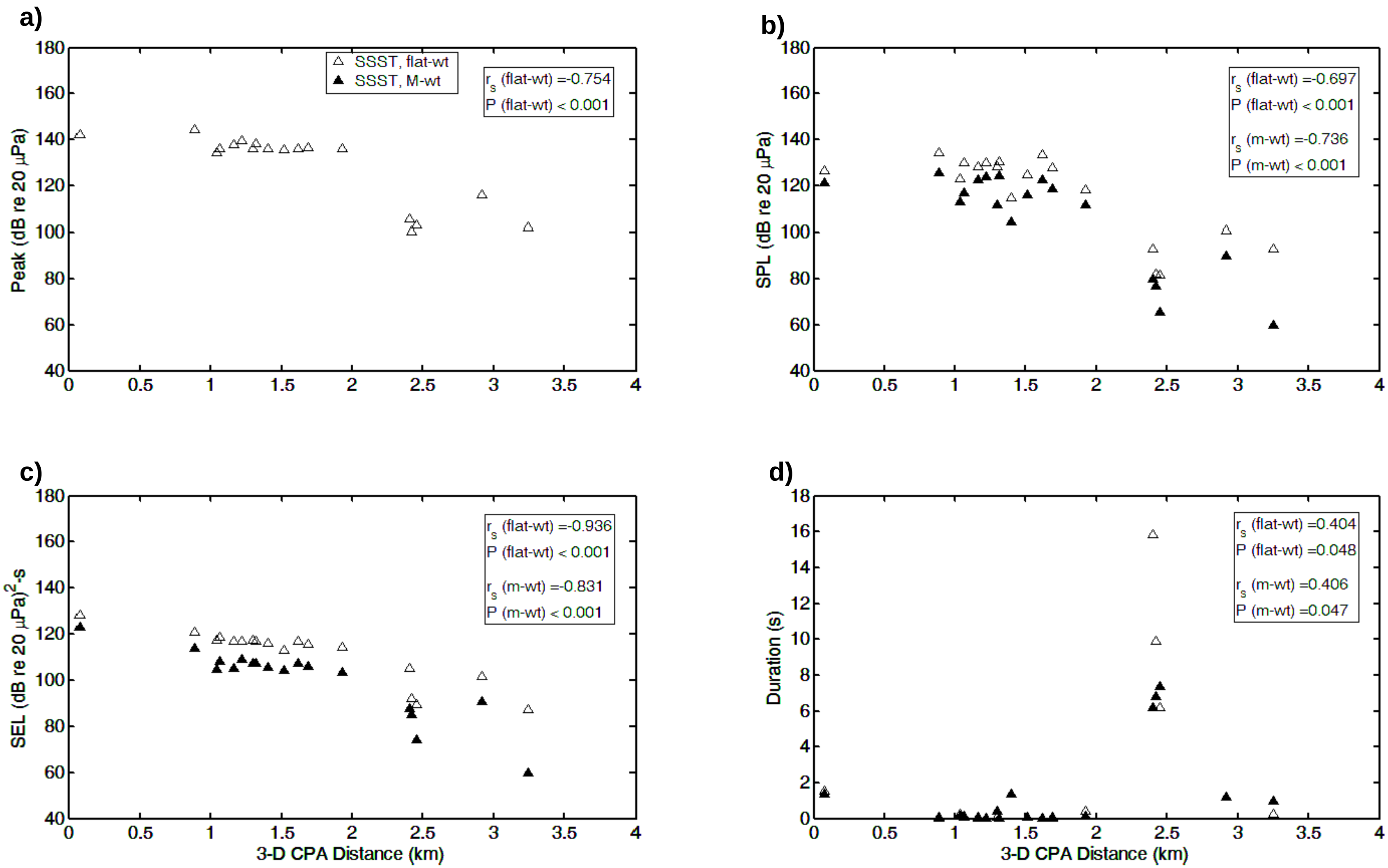

FIGURE 2.9. Sounds from GQM-163A ***Coyote*** SSST launches relative to the 3-D CPA distance: (a) Peak sound pressure, (b) SPL, (c) SEL, and (d) Duration. Plotted as in Figure 2.3.

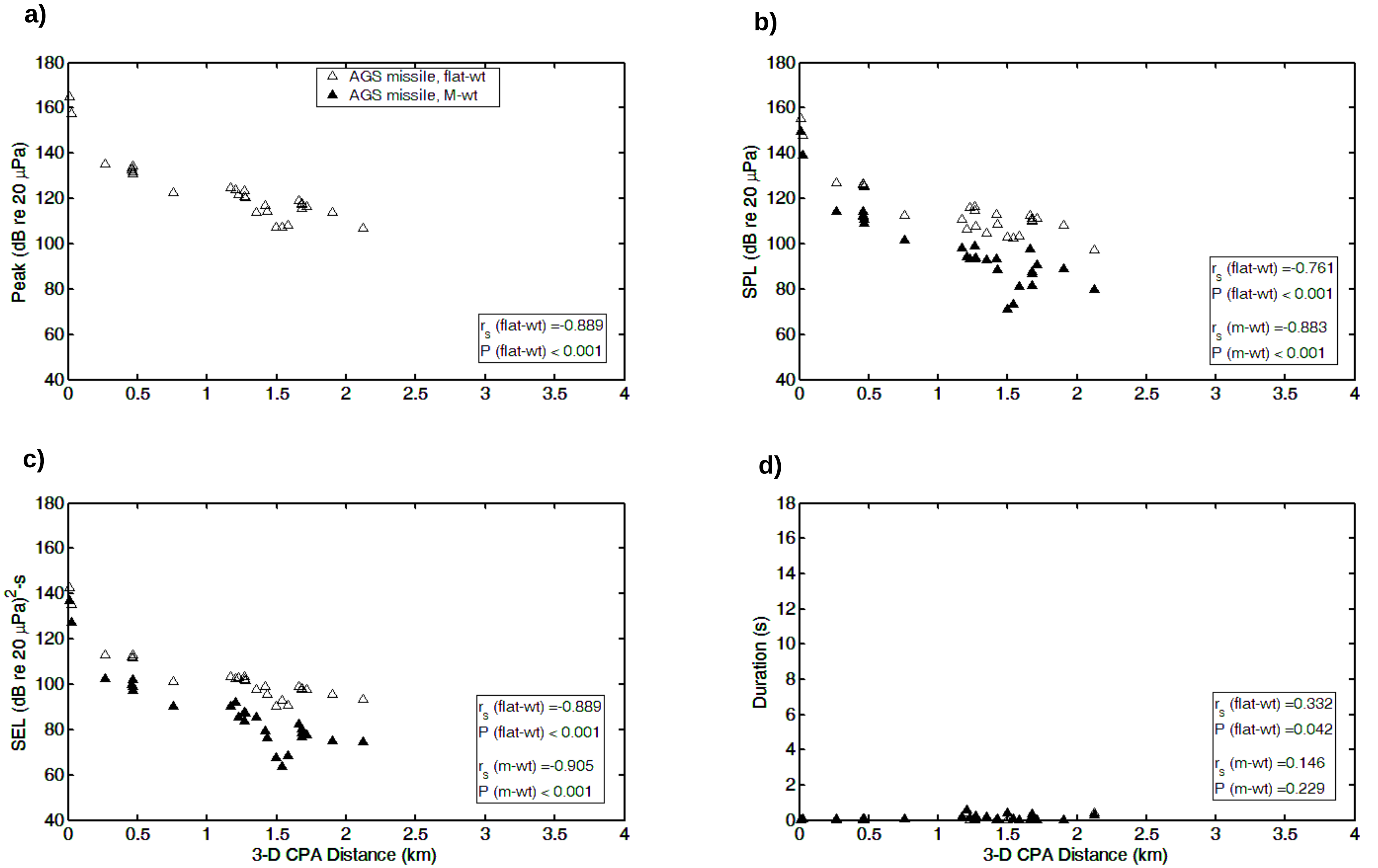

FIGURE 2.10. Sounds from ***other large vehicle*** (Terrier-Orion, Tomahawk, Arrow) launches relative to the 3-D CPA distance: (a) Peak sound pressure, (b) SPL, (c) SEL, and (d) Duration. Plotted as in Figure 2.3.

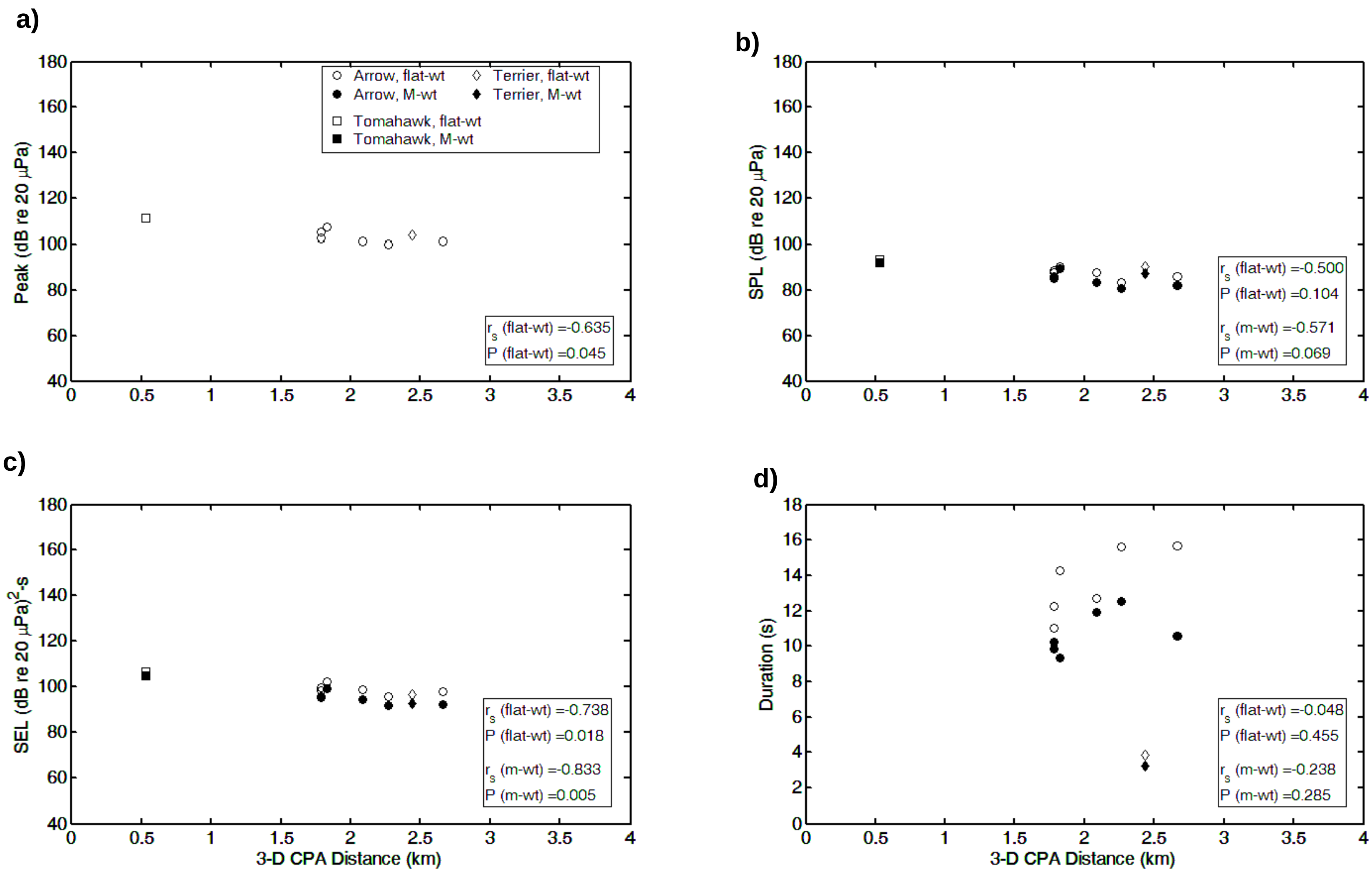

FIGURE 2.11. Sounds from launches of ***AGS missiles*** relative to the 3-D CPA distance: (a) Peak sound pressure, (b) SPL, (c) SEL, and (d) Duration. Plotted as in Figure 2.3.

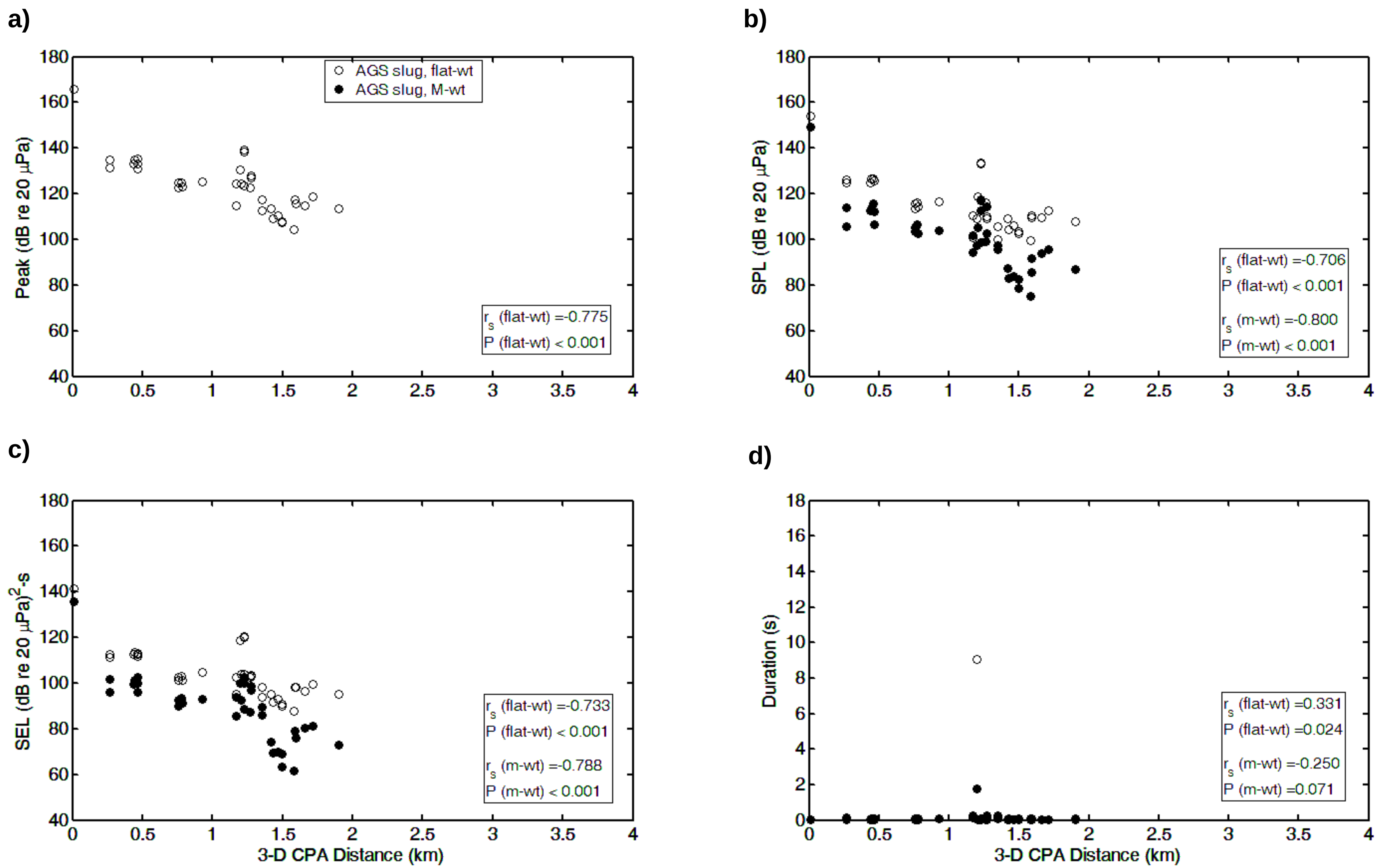

FIGURE 2.12. Sounds from launches of ***AGS slugs*** relative to the 3-D CPA distance: (a) Peak sound pressure, (b) SPL, (c) SEL, and (d) Duration. Plotted as in Figure 2.3.

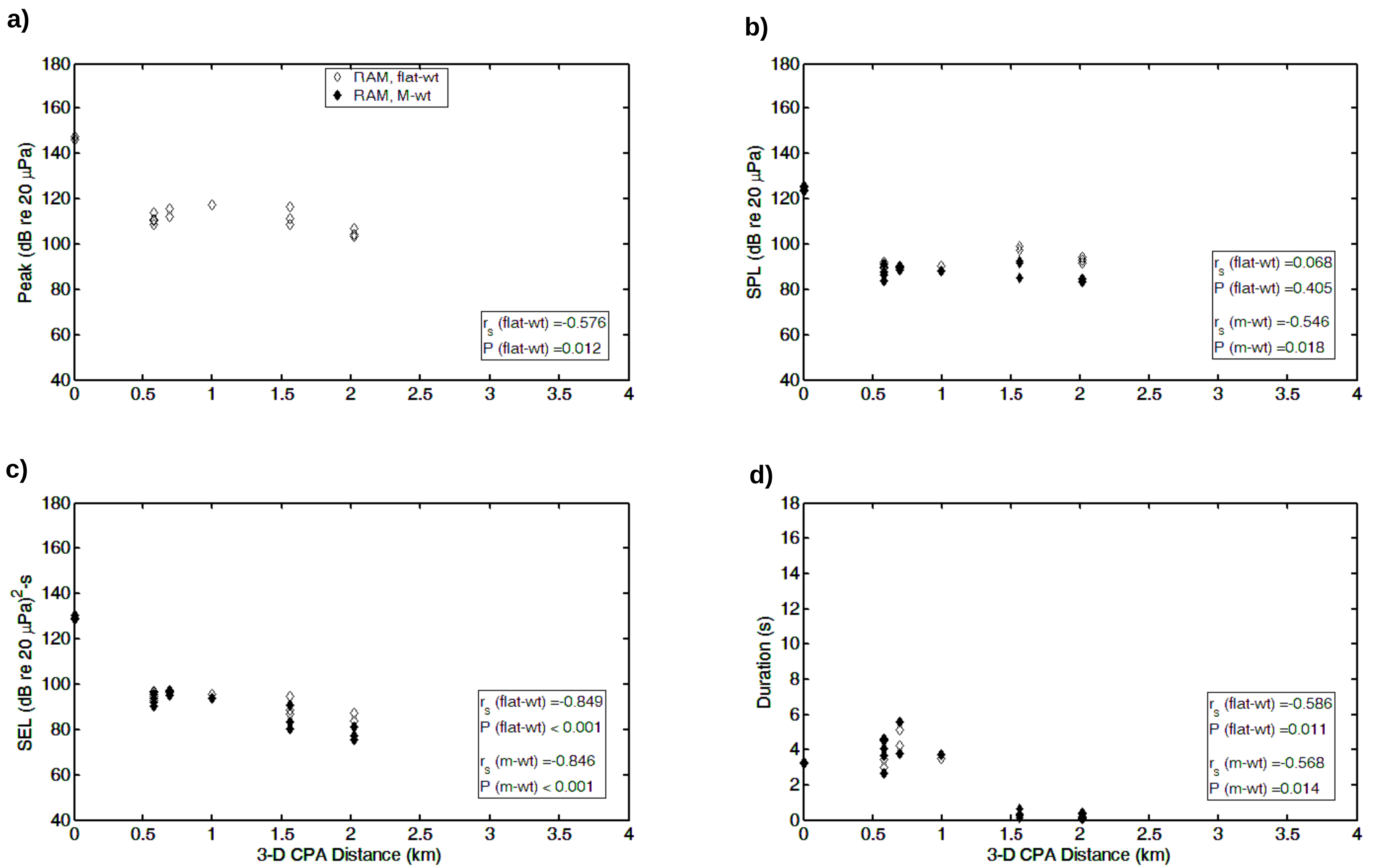

FIGURE 2.13. Sounds from ***RAM*** launches relative to the 3-D CPA distance: (a) Peak sound pressure, (b) SPL, c) SEL, and (d) Duration. Plotted as in Figure 2.3.

the longer distances (>1.25 mi or >2 km), the loss rate when plotted against a linear distance scale tended to "flatten out" in the case of peak pressure, SPL, and SEL (Fig. 2.8). This was expected, given that attenuation of sound tends to be logarithmically related to distance.

The scatter diagrams for the various received level measurements vs. distance reveal several additional patterns:

- As expected, flat-weighted levels were stronger than M_{pa}-weighted levels at corresponding CPA distances, with increasing divergence between the two at the longer CPA distances.
- Peak pressures were necessarily higher than SPLs. SEL is measured on a different scale than peak pressure or SPL, so direct comparisons of SEL values with other values are of limited relevance.
- At locations distant from the launcher (distances ≥1312 ft or 400 m), received sound levels were typically higher for Vandals and Coyotes (Fig. 2.8–2.9) than for AGS vehicles and (especially) the RAMs (Fig. 2.11–2.13; see also Table 2.5). Those were the commonly-launched types of vehicles for which most data were obtained. Vandals produced the highest received sound levels, and Coyotes produced the second highest sound levels, at receiver locations away from the launcher (Table 2.5).
- At locations close to the launcher, AGS vehicles produced strong sounds. Sounds from the AGS vehicles were typically weaker than those from Vandals and Coyotes at distances beyond 1312 ft (400 m), but the levels recorded close to the AGS launcher were as high or higher than those near the Vandal or Coyote launcher (Table 2.5). The Vandals and Coyotes, and until June 2004 also the AGS vehicles, were launched at an inland location, not close to any pinnipeds. However, the AGS launcher has subsequently been at the Building 807 launch site near the coast. Peak pressure measured near the AGS launcher (12 m or 39 ft away) has been 165–166 dB re 20 µPa for the AGS launches; the corresponding SEL-M was 149–150 dB re $(20\ \mu Pa)^2 \cdot s$.
- Duration generally increased with increasing CPA distance for Vandals and Coyotes. In contrast, the duration decreased with increasing CPA distances for RAMs. There was no strong relationship between duration and distance for AGS vehicles (for which durations were almost always very short regardless of distance) or for the heterogeneous "other large vehicles" group.

Vandal, Coyote, Arrow, Terrier-Orion, and (until June 2004) AGS vehicles were launched from a location in the interior of western SNI, about 1.2 mi (2 km) from the closest shoreline. They were at altitudes of at least 1280 ft (390 m) ASL when they crossed the beach at the western end of the island. Thus, for those launches, the sounds measured at the closest distance (e.g., launcher) would be expected to be higher than those that would have been received by any pinnipeds on the beaches. However, for Vandals and Coyotes launched from the inland location, levels near the launcher were not much higher than those at 3-D CPA distances up to at least 0.6 mi or 1 km (Fig. 2.8–2.9).

2.4.4 Other Factors Related to Missile Sound Levels and Durations

Multiple regression equations were fitted to the acoustic measurements and to potential predictor variables to determine the extent and manner in which sound measurements were related to each factor after allowance for the effects of other simultaneously-varying factors. The coefficients for the best-fit models are given in Table 2.6.

TABLE 2.6. Coefficients and nominal significance levels (P-values) of the best-fit regression models of sound measures vs. predictor variables; n = sample size; RMSE = root mean square error (units same as for sound measure examined); AIC = Akaike's Information Criterion; R2 = coefficient of multiple determination; Intercept = y-intercept of the regression equation.

Variable	**Peak n = 148**	**SPL-f n = 148**	**SPL-A n = 147**	**SPL-M n = 148**	**SEL-f n = 148**	**SEL-A n = 147**	**SEL-M n = 148**	**logDur-f n = 148**	**logDur-A n = 147**	**logDur-M n = 148**
Intercept	139.397	128.627	107.302	119.694	121.881	101.662	113.690	-0.676	-0.622	-0.764
Other Large	-19.716	-21.106	-8.029	-9.393	-9.740	2.590	0.506	1.241	1.085	1.057
P-value	***	***	(*)	*	***	ns	ns	***	***	***
AGS Missile	-10.337	-6.045	-14.806	-10.123	-12.734	-20.533	-16.340	-0.752	-0.627	-0.590
P-value	***	**	***	***	***	***	***	***	***	***
AGS Slug	-10.133	-7.017	-14.610	-8.534	-12.802	-18.636	-15.631	-0.634	-0.429	-0.683
P-value	***	**	***	***	***	***	***	***	**	***
RAM	-20.660	-27.105	-14.004	-17.409	-23.292	-10.961	-14.646	0.322	0.273	0.357
P-value	***	***	***	***	***	***	***	(*)	ns	*
Coyotes	-0.501	-0.121	1.867	1.460	-0.582	0.447	0.644	-0.053	-0.166	-0.118
P-value	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sonic Boom	3.232	5.693	8.727	6.277	-	4.188	-	-0.449	-0.391	-0.455
P-value	*	**	***	**		*		***	**	***
CPADistkm	-7.464	-8.488	-12.544	-13.589	-5.906	-9.481	-10.164	0.300	0.354	0.407
P-value	***	***	***	***	***	***	***	**	**	***
logCPADist	-13.092	-11.228	-14.230	-10.669	-13.211	-16.861	-13.395	-0.275	-0.333	-0.332
P-value	***	***	***	***	***	***	***	(*)	*	*
CPA_Angle	0.049	-	0.159	0.105	0.044	0.138	0.108	-	-0.004	-
P-value	(*)		**	**	*	***	***		ns	
Wind	-	-	-	-	-	-	-	-0.014	-0.017	-
P-value								(*)	(*)	
R^2	0.791	0.730	0.757	0.767	0.807	0.782	0.781	0.608	0.523	0.626
RMSE	6.918	8.939	10.717	9.454	5.659	9.148	7.790	0.554	0.575	0.540
AIC	582.129	657.071	706.970	674.599	521.778	660.437	616.362	-165.423	-152.107	-173.934

Notes: The Vandal was used as the reference vehicle against which sound measurements for other vehicle types were compared. Nominal significance levels are coded as *** for $P \leq 0.001$, ** for $0.001 < P \leq 0.01$, * for $0.01 < P \leq 0.05$, (*) for $0.05 < P \leq 0.1$, and ns for $P > 0.1$ and not significant. "-" means that this variable was not included in the model, i.e., nominal $P > 0.15$.

Sound Level.—*Vehicle type* had a strong influence on received sound level after allowance for other factors. For all seven of the sound level measures, the coefficients for three small vehicle types (RAM, AGS Missile, AGS Slug) were negative and statistically significant, indicating that, other factors being equal, those three vehicle types tend to be quieter than Vandals (Table 2.6). "Other large" vehicles also tended to be quieter than Vandals according to most measures, though not based on SEL-A and SEL-M. The SEL values for "other large" vehicles were closer to those for Vandals than were the SEL values for the three small vehicles. Sound levels from Coyotes were similar to those from Vandals based on all measures that were considered.

The *sonic boom* coefficients were positive and statistically significant for 5 of 7 sound level measures, including peak pressure, the three SPL measures, and one of three SEL measures (Table 2.6). This indicates that, after allowance for the influences of several other factors, sound pressure levels tended to be greater when a sonic boom occurred. However, the energy in the received sound (as represented by the SEL measures) was not as consistently related to presence or absence of a sonic boom.

The fitted models confirmed that all seven measures of received sound level were strongly and negatively related to both *logarithm of CPA distance* and *linear CPA distance* (nominal $P \leq 0.001$ in all cases). The strong relationship to log CPA distance is consistent with the "flattening out" of the level vs. range data at longer distances, as evident in Figure 2.8. The coefficient for logCPADist ranged from –10.7 to –16.9, slightly less than the –20 expected with simple spherical spreading in an (artificial) unbounded situation. The coefficients for CPADist are the dB losses per km and correspond to a linear loss with distance such as is expected from absorption and scattering losses.

The fitted coefficients for *CPA angle* (unnormalized) showed that, for vehicles whose CPA occurred at higher angles above the horizontal, most sound level measures (6 of 7) were stronger, other factors being equal. This effect was most clear-cut (nominal $P \leq 0.001$) when received acoustic energy (SEL), either A-weighted or M_{pa}-weighted, was considered (Table 2.6).

The coefficient for *wind component* along the CPA-to-receiver axis is in the units dB/kt. *Wind component* was not a statistically significant predictor of any of the seven measures of received sound level (Table 2.6). We had expected that, after other factors were taken into account by the model, received level would be positively related to this wind component. The available evidence indicates there was no such relationship.

Sound Duration.—Sound duration, whether based on flat-, A-, or M_{pa}-weighted data, was more strongly related to linear CPA distance than to logCPADist (Table 2.6). Duration tended to increase as CPA distance increased. Vehicle type was also a predictor of duration. From longest to shortest duration, the order of the vehicles was "other large" vehicles (Terrier-Orion, Tomahawk, Arrow), RAMs, Vandals, Coyotes, and AGS vehicles. The positive coefficients for "other large" and (to a lesser degree) RAM missiles show that, after allowance for the distance effect, their sounds tended to persist longer than those for the "reference" vehicle, the Vandal. The negative and highly significant coefficients for AGS vehicles show that AGS sounds were notably shorter-lasting than those of the Vandal. Sounds from Coyotes had a similar duration to those from Vandals. The negative coefficients for *sonic boom* indicate that durations of periods with substantial received sound were shorter during a launch associated with a sonic boom. The *wind component* along the CPA-to-receiver axis was no more than a marginally significant predictor of sound duration, and duration was unrelated to CPA_Angle.

2.4.5 Ambient Noise Levels

Background sounds were recorded on the second channel of each ATAR using a higher sensitivity microphone. As expected, this channel overloaded during the brief time while the missile flight sounds were received, but at other times recorded the background sounds reliably, i.e., at levels above the self-noise (instrumentation noise) of the sensing and recording electronics. The sound levels for the 10–20,000 Hz band are tabulated in Table 2.7.

Ambient levels averaged 66 dB re 20 μPa flat-weighted (range 23–91 dB), 52 dB M_{pa}-weighted (range 21–80 dB), and 46 dB A-weighted (range 22–72 dB) (Table 2.7). The measured ambient levels were generally quite low, with the average being comparable to sound levels expected in quiet residential areas. The considerable effect of A- and M_{pa}-weighting as compared to flat-weighting is evident. A-weighted levels of ambient sound averaged 20 dB less (range 1–42 dB less) than flat-weighted levels and 6 dB less (range 1–16 dB less) than M_{pa}-weighted levels. M_{pa}-weighted levels averaged 13 dB less (range 1–35 dB less) than flat-weighted levels. Much of the background sound was infrasonic energy in the 10–20 Hz band, probably mainly attributable to wind noise. When the 10–20 Hz components were excluded, broadband levels were typically 10 dB lower than those for the 10–20,000 Hz band.

2.5 Discussion and Summary

Seventy-seven launches of 83 vehicles occurred from SNI from August 2001 to March 2008, and each vehicle's sounds were measured at up to three separate sites. Of the sounds recorded near pinniped haul-out sites, none exceeded 129 dB re 20 $\mu Pa^2 \cdot s$ SEL-M, the energy level at which TTS onset may occur in the harbor seal (Southall et al. 2007). The harbor seal is the most sensitive of the three pinniped species present regularly at SNI. Higher SELs were, for some vehicles, recorded close to the launcher (far from any pinnipeds). However, peak levels near pinniped haul-out sites were as high as 150 dB re 20 μPa; this measurement exceeds the peak pressure level (143 dB) at which TTS onset may occur in the harbor seal, and it also exceeds the level (149 dB) at which a slight PTS may occur (Southall et al. 2007). The possibility of TTS and PTS occurring in pinnipeds hauled out on SNI during vehicle launches is further discussed in Chapter 4.

The sound results showed that Vandals and Coyotes produced more sound than RAM and AGS vehicles, and on average tended to produce more sound than "other large" vehicles launched from SNI. The levels from Coyotes were similar to those from Vandals after allowance for other confounding factors. Received levels decreased significantly with increasing logCPADist and linear CPADist, as expected.

Most sound level measurements increased with an increase in the angle above the horizon from recording site to the CPA. The CPA angle was included in the regression to account for possible differences in sound radiation depending on the elevation angle to the vehicle at its CPA.

For the sound-level variables, the coefficient of the logCPADist term is the dB loss per tenfold increase in distance, and was calculated to be –10.7 to –16.8 in the "best" models. The coefficient would be –20 for pure spherical spreading (inverse square law spreading, as expected for unbounded space free of boundaries, absorption, or scattering). The "less-negative" coefficients for the sound level measures indicate that there were contributions to the received level from refraction, reflections, or multipath arrivals. The ground is a boundary as well as a medium for sound conduction. The sound probably travels to the microphone both in air and as a boundary wave along the earth-air interface.

TABLE 2.7. Broadband (10–20,000 Hz) sound levels (in dB re 20 µPa) as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds.

Date	Time	Vehicle	Site	Flat-weighted	A-weighted	M_{pa}-weighted
2001						
15 Aug.	12:55	Vandal	End of Redeye Road	69.3	44.7	52.6
"	12:55	Vandal	Dos Coves		N/A	
"	12:55	Vandal	809 Camera		N/A	
15 Aug.	13:16	Vandal	End of Redeye Road	75.3	44.0	51.3
"	13:16	Vandal	Dos Coves		N/A	
"	13:16	Vandal	809 Camera		N/A	
20 Sept.	08:29	Vandal	Tender Beach	64.3	53.1	60.5
"	08:29	Vandal	809 Camera	57.2	42.1	46.2
20 Sept.	17:00	Terrier-Orion	Building 807		N/A	
"	17:00	Terrier-Orion	100 ft from Launcher		N/A	
"	17:00	Terrier-Orion	Cormorant Rock Blind	64.0	41.8	51.7
5 Oct.	13:36	Vandal	Phoca Reef	49.6	44.3	48.0
19 Oct.	08:59	Vandal	Bachelor Beach South		N/A	
"	08:59	Vandal	809 Camera		N/A	
"	08:59	Vandal	NAVFAC Beach	33.0	21.6	24.6
19 Dec.	15:20	Vandal	Building 807	74.4	50.7	58.5
"	15:20	Vandal	809 Camera	77.4	46.9	53.2
2002						
14 Feb.	11:33	Vandal	150 ft from Launcher		N/A	
"	11:33	Vandal	809 Camera	64.6	53.7	59.6
"	11:33	Vandal	Bachelor Beach North	63.9	46.7	52.3
22 Feb.	12:13	Vandal	809 Camera	61.4	37.2	43.1
"	12:13	Vandal	Redeye Beach	55.5	46.1	51.2
22 Feb.	14:56	Vandal	809 Camera	64.2	41.0	46.2
"	14:56	Vandal	Redeye Beach	53.5	43.7	48.7
6 March	11:20	Vandal	Dos Coves	63.4	38.9	44.8
"	11:20	Vandal	Sheephead Ranch	55.6	30.7	36.2
"	11:20	Vandal	809 Camera	71.5	43.0	45.4
1 May	15:53	Vandal	Bachelor Beach South	79.6	46.1	50.8
"	17:00	Vandal	Bachelor Beach South	82.2	46.8	52.5
"	17:00	Vandal	809 Camera	79.7	44.5	51.3
8 May	14:54	Vandal	Vizcaino Point	72.2	40.7	50.6
"	14:54	Vandal	Sea Lion Cove	62.5	33.1	45.3
"	14:54	Vandal	Pirates Cove	71.7	40.8	47.7
19 June	15:07	AGSS	Redeye II	76.0	54.5	62.4
21 June	12:53	Dual RAM	50 ft from Launcher	67.4	53.6	63.1
26 June	11:20	AGSS	50 ft from Launcher	62.0	27.2	35.4
"	11:20	AGSS	Redeye Beach	67.2	50.1	56.0
"	11:20	AGSS	809 Camera	66.2	46.9	49.2
26 June	12:51	AGSM	50 ft from Launcher	82.2	41.0	48.1
"	12:51	AGSM	Redeye Beach	69.1	47.2	52.2
"	12:51	AGSM	809 Camera	66.4	45.3	48.8
18 July	11:54	Vandal	Dos Coves	55.1	42.6	47.9
23 Aug.	14:09	Tomahawk ‡	Dos Coves	70.1	58.4	64.0
18 Nov.	11:03	Dual RAM	75 ft from Launcher	68.2	60.7	64.3
"	11:03	Dual RAM	Bachelor Beach North	70.9	53.8	60.6

TABLE 2.7 (continued).

Date	Time	Vehicle	Site	Flat-weighted	A-weighted	M_{pa}-weighted
10 Dec.	08:49	Vandal	Dos Coves	91.1	60.5	64.3
"	08:49	Vandal	Bachelor Beach North	86.0	53.8	60.6
18 Dec.	14:30	AGSS	50 ft from Launcher	81.9	71.6	79.4
"	14:30	AGSS	Near 809 Camera	70.6	44.5	52.0
"	16:15	AGSM	50 ft from Launcher	79.7	70.9	77.5
2003						
24 Jan.	14:20	Coyote	Redeye I	74.3	55.2	61.9
14 March	09:13	Vandal	Pirates Cove	50.6	34.9	44.1
"	09:13	Vandal	Sheephead Ranch	52.4	42.5	48.7
"	09:13	Vandal	100 ft from Launcher	61.3	28.2	34.7
16 March	13:04	Vandal	Corral Harbor	60.7	41.0	50.8
4 April	15:20	Dual Vandal	NAVFAC Beach	61.7	41.3	43.9
"	15:20	Dual Vandal	No Name Cove	47.1	35.3	42.2
"	15:20	Dual Vandal	Phoca Point	68.9	36.4	41.9
4 June	12:35	Coyote	Near 809 Camera	69.1	41.2	48.7
"	12:35	Coyote	Sheephead Ranch	59.1	42.3	45.7
"	12:35	Coyote	100 ft from Launcher	59.8	31.7	48.0
26 June	13:27	Vandal	The "Y"	62.2	51.2	54.3
"	13:27	Vandal	Near 809 Camera	69.6	41.5	45.5
28 July	16:27	Vandal	Near 809 Camera	77.6	43.0	45.4
2004						
5 May	11:46	Dual RAM	Dos Coves	64.2	47.3	55.3
"	11:46	Dual RAM	Bachelor Beach North	67.2	57.0	61.8
"	11:46	Dual RAM	Bachelor Beach South	77.5	67.3	72.5
18 May	12:40	Coyote	Pirates Cove		N/A	
"	12:40	Coyote	Harbor Seal Overlook	79.3	36.9	46.0
"	12:40	Coyote	Redeye I	77.9	44.6	51.5
3 June	11:31	AGSS	Dos Coves South	71.1	52.6	58.7
"	13:22	AGSS	Dos Coves South	75.6	54.0	59.5
"	15:08	AGSM	Dos Coves South	71.5	55.9	60.7
"	11:31	AGSS	Harbor Seal Overlook		N/A	
"	13:22	AGSS	Harbor Seal Overlook		N/A	
"	15:08	AGSM	Harbor Seal Overlook		N/A	
"	11:31	AGSS	Near 809 Camera	65.6	40.4	45.5
"	13:22	AGSS	Near 809 Camera	64.0	41.0	46.7
"	15:08	AGSM	Near 809 Camera	73.4	41.8	47.4
26 July	15:10	AGSS	Bachelor Beach North	64.2	53.7	58.1
"	15:43	AGSS	Bachelor Beach North	61.3	53.2	56.7
"	15:10	AGSS	Dos Coves South	66.4	55.9	58.8
"	15:43	AGSS	Dos Coves South	74.4	61.3	63.8
"	15:10	AGSS	Vizcaino Point	78.2	46.9	57.8
"	15:43	AGSS	Vizcaino Point	71.7	38.1	45.8
29 July	10:20	Arrow	Dos Coves South	67.4	56.4	61.1
"	10:20	Arrow	Bachelor Beach North	70.7	48.3	53.1
"	10:20	Arrow	Vizcaino Point	64.5	40.5	46.5
26 Aug.	10:08	Arrow	Dos Coves South	72.4	57.8	64.7
"	10:08	Arrow	Phoca Reef	22.9	21.9	21.4
"	10:08	Arrow	Vizcaino Point	56.8	40.4	49.6
27 Aug.	16:30	Coyote	Dos Coves South	61.7	51.9	56.7
"	16:30	Coyote	Phoca Reef	55.2	38.4	50.3
"	16:30	Coyote	Vizcaino Point	59.1	39.2	50.3

TABLE 2.7 (continued).

Date	Time	Vehicle	Site	Flat-weighted	A-weighted	M_{pa}-weighted
22 Sept.	09:56	RAM	Dos Coves South	67.7	52.0	56.3
“	10:57	RAM	Dos Coves South	62.4	46.5	52.2
“	11:19	RAM	Dos Coves South	60.8	50.3	54.4
“	09:56	RAM	The “Y”	69.3	39.0	50.4
“	10:57	RAM	The “Y”	70.0	40.7	51.9
“	11:19	RAM	The “Y”	74.4	39.2	48.0
“	09:56	RAM	Vizcaino Point	62.2	39.7	52.4
“	10:57	RAM	Vizcaino Point	59.6	35.7	49.5
“	11:19	RAM	Vizcaino Point	64.7	36.5	52.5
2005						
27 Jan.	08:59	AGSS	Redeye I	73.2	64.8	69.1
“	11:41	AGSS	Redeye I	72.3	N/A	68.9
“	13:29	AGSM	Redeye I	69.6	60.0	64.8
“	08:59	AGSS	Bachelor Beach North	65.2	54.1	60.3
“	11:41	AGSS	Bachelor Beach North	68.1	55.4	62.2
“	13:29	AGSM	Bachelor Beach North	65.4	53.7	60.0
24 Feb.	09:05	AGSS	Vizcaino Point	76.3	47.5	55.7
“	13:16	AGSM	Vizcaino Point	61.5	43.4	51.2
“	09:05	AGSS	Dos Coves South	70.5	63.3	64.6
“	13:16	AGSM	Dos Coves South	78.2	57.6	61.1
“	09:05	AGSS	Bachelor Beach South	68.9	59.3	65.0
“	13:16	AGSM	Bachelor Beach South	66.1	54.8	60.4
11 March	09:30:00	Dual Vandal	809 Camera	64.7	40.1	49.5
“	09:30:00	Dual Vandal	The “Y”	62.3	37.5	51.2
“	09:30:00	Dual Vandal	Dos Coves South	81.9	53.1	59.3
24 March	08:35	Coyote	The “Y”	54.5	36.9	47.0
“	08:35	Coyote	Dos Coves South	68.9	56.8	62.2
22 April	16:43	Coyote	Harbor Seal Overlook	52.2	35.8	45.1
“	16:43	Coyote	Phoca Reef	55.7	47.7	51.4
“	16:43	Coyote	Phoca Point	47.7	37.6	43.0
2 June	07:29	Vandal	809 Camera	56.7	40.4	46.4
“	09:49	Vandal	809 Camera	63.7	40.5	47.5
“	07:29	Vandal	Bomber Cove	60.7	41.8	50.5
“	09:49	Vandal	Bomber Cove	69.1	41.5	50.9
“	07:29	Vandal	The “Y”	62.1	49.3	55.3
“	09:49	Vandal	The “Y”	67.7	50.9	57.7
16 June	10:08	AGSS	Dos Coves South	76.5	72.0	75.8
“	14:00	AGSM	Dos Coves South	73.4	57.1	60.5
“	10:08	AGSS	Redeye I	62.2	45.0	51.0
“	14:00	AGSM	Redeye I	68.8	41.5	53.2
29 June	08:56	AGSS	The “Y”	67.1	46.8	49.7
“	11:04	AGSS	The “Y”	64.0	44.4	47.3
“	14:35	AGSM	The “Y”		N/A	
“	08:56	AGSS	Dos Coves Gate	67.9	56.4	59.9
“	11:04	AGSS	Dos Coves Gate	71.1	51.5	56.0
“	14:35	AGSM	Dos Coves Gate	73.3	55.1	58.5
“	08:56	AGSS	Bachelor Beach	61.8	52.4	57.7
“	11:04	AGSS	Bachelor Beach		N/A	
“	14:35	AGSM	Bachelor Beach		N/A	
26 July	12:56	AGSS	Bomber Cove	68.4	55.2	60.6
“	14:53	AGSM	Bomber Cove	68.9	46.1	50.3
“	12:56	AGSS	The “Y”	66.9	60.5	62.8

TABLE 2.7 (continued).

Date	Time	Vehicle	Site	Flat-weighted	A-weighted	M_{pa}-weighted
"	14:53	AGSM	The "Y"	67.1	57.3	60.3
26 July	12:56	AGSS	Dos Coves South	60.7	54.0	57.2
"	14:53	AGSM	Dos Coves South	64.3	59.2	62.0
27 July	10:07	Vandal	Bomber Cove	53.3	40.0	45.2
"	10:07	Vandal	Harbor Seal Overlook		N/A	
"	10:07	Vandal	Phoca Reef	49.9	42.1	46.5
28 July	08:04	Vandal	Bomber Cove	50.3	39.1	42.8
"	11:20	Vandal	Bomber Cove		N/A	
"	11:30	Vandal	Bomber Cove	59.8	46.0	48.2
"	08:04	Vandal	Harbor Seal Overlook	52.2	37.3	43.4
"	11:20	Vandal	Harbor Seal Overlook	59.4	33.3	40.6
"	11:30	Vandal	Harbor Seal Overlook	59.3	31.2	39.6
"	08:04	Vandal	Phoca Reef	59.8	39.6	43.1
"	11:20	Vandal	Phoca Reef	71.2	39.4	44.5
"	11:30	Vandal	Phoca Reef	68.5	36.2	40.5
25 Aug.	09:03	AGSS	Bomber Cove	55.3	36.1	41.4
"	11:30	AGSM	Bomber Cove	55.1	36.1	45.1
"	13:30	AGSM	Bomber Cove	56.6	37.4	46.4
"	09:03	AGSS	The "Y"	59.5	49.7	53.0
"	11:30	AGSM	The "Y"	62.8	46.2	52.0
"	13:30	AGSM	The "Y"	60.2	53.3	56.1
"	09:03	AGSS	Dos Coves South		N/A	
"	11:30	AGSM	Dos Coves South	58.1	49.1	52.8
"	13:30	AGSM	Dos Coves South	64.8	46.4	50.9
6 Oct.	09:30	Coyote	Bomber Cove	61.6	39.9	47.9
"	09:30	Coyote	Dos Coves South	64.3	54.0	57.5
2006						
14 Feb.	11:14	AGSS	Redeye I	66.6	52.4	60.2
"	11:14	AGSS	Harbor Seal Overlook	71.9	41.0	52.1
"	11:14	AGSS	The "Y"		N/A	
"	13:40	AGSM	Redeye I	69.2	54.4	63.3
"	13:40	AGSM	Harbor Seal Overlook	67.6	42.7	54.6
"	13:40	AGSM	The "Y"		N/A	
6 April	16:42	Falcon	15 m from source	68.5	28.7	34.0
"	16:42	Falcon	Harbor Seal Overlook	74.4	37.2	45.5
"	16:42	Falcon	Dos Coves South		N/A	
15 May	09:10	AGSS	Phoca Reef		N/A	
"	09:10	AGSS	Harbor Seal Overlook	71.2	31.6	39.3
"	09:10	AGSS	Vizcaino Point	68.1	37.5	45.3
"	15:30	AGSM	Phoca Reef		N/A	
"	15:30	AGSM	Harbor Seal Overlook	51.7	30.3	37.8
"	15:30	AGSM	Vizcaino Point	50.9	35.2	43.3
2007						
13 June	17:24	Coyote	Dos Coves		N/A	
"	17:24	Coyote	Vizcaino Point	67.6	43.4	48.3
"	17:24	Coyote	The "Y"	57.8	36.0	44.0

Note: AGSS = AGS Slug; AGSM = AGS Missile; N/A = not available.

It is important to note that there is considerable variability in the measurements for situations that are supposedly similar. This is represented by rms error terms, in the regression models for sound level; the rms error was between 6 and 11 dB (Table 2.6). The coefficients of determination, which indicate how much of the variability in the acoustic data is accounted for by the regression models, ranged from 0.73 to 0.81 (73% to 81 %). Although this indicates that a reasonably high percentage of variability is understandable based on the factors that were hypothesized to affect received sound levels, there was some unexplained residual variability. The conditions of every flight, especially meteorological, would need to be better documented in order to obtain better predictability. Atmospheric temperature-humidity profiles, which influence sound speed profiles, along with wind speed and direction as a function of altitude, are all known to have important influences on in-air acoustic propagation based on theory and other studies. Temperature inversions, in which temperature increases with increasing altitude, cause downward refraction of sound. Above a certain altitude, such inversions reverse, and at higher altitudes, sound waves are refracted upward and away from ground-based detectors. The development of temperature inversions is typically related to time of day, existing late at night and in the early morning, and then disappearing as the sun angle increases; marine fog layers are capped by temperature inversions.

In addition to the lack of data on vertical profiles of sound speed, various additional factors for which we have incomplete or no data are suspected to contribute to the variability in the measured data. For example, the available information about the vehicle trajectories is limited; we do not have specific information about the exact altitude of each vehicle at each point along its trajectory. Thus, our estimates of 3-D CPA distance and CPA angle are approximations. Also, for vehicles that employ a booster for the first brief period of flight, our analysis does not allow for the timing of booster burnout relative to the CPA time. Whether or not the booster is still operating when the missile is at its CPA location is likely to affect the received sounds.

Nonetheless, the results obtained to date provide much information about the levels and other characteristics of the sounds from the various types of missiles and targets launched from SNI, and about some of the factors that influence those sounds. This information is valuable in interpreting pinniped reactions, and as a basis for developing models of factors related to the variability in pinniped responses (see Chapter 3).

3. BEHAVIOR OF PINNIPEDS DURING MISSILE LAUNCHES

3.1 Introduction

Three species of pinnipeds are common on the beaches of SNI: California sea lion, harbor seal, and northern elephant seal. These three species were monitored during 77 launches from SNI on 53 separate dates during 2001–2007; no other pinniped species were recorded. This chapter documents the behavioral reactions of pinnipeds exposed to the launch sounds. Specific information about each launch is given in Chapter 1. Chapter 2 documents the sounds measured at various sites on western SNI during each launch.

The vehicles launched from SNI fly over or near haul-out sites that may be occupied by breeding/pupping or molting seals and/or sea lions. In January, vehicles launched from the western end of SNI fly over haul-out sites occupied by breeding/pupping northern elephant seals and non-breeding California sea lions and harbor seals. Northern elephant seals continue to pup and breed through February and early March and haul out to molt during March and April. Harbor seals also start to pup/breed at the end of February and continue to do so through early May. From May to June, vehicles fly over haul-out sites occupied by molting harbor and elephant seals. California sea lions start to pup/breed in June and continue to do so through July. In July, adult male elephant seals are hauled out to molt, but harbor seals have finished molting. During August and September, there are relatively few pinnipeds ashore; that period does not coincide with the pupping season for any of the three pinniped species. However, molting adult male elephant seals are still hauled out in August, and molting California sea lions are hauled out in September. During October and November, hauled out pinnipeds of all three species are neither breeding/pupping nor molting. In late December, elephant seals begin breeding/pupping.

All three species showed some response to launches, with the responses generally being strongest for harbor seals, intermediate and variable for sea lions, and least for elephant seals. In most cases, sea lion and elephant seal behavior returned to pre-launch states within minutes following the launches. In fact, most elephant seals demonstrated little or no reaction to the vehicle launches. Behavior as well as numbers of sea lions and elephant seals hauled out several hours after the launches appeared similar to the behavior and numbers observed before launches. In contrast, harbor seals commonly left their haul-out sites to enter the water and did not return during the duration of the video-recording period. However, data from monitoring during Year 1 showed that the behavior and numbers of harbor seals hauled out on the day following a launch were similar to those on the day of the launch (Holst and Lawson 2002).

No evidence of injury or mortality was observed on the day of any launch during the monitoring period. However, on three occasions in Year 2 (prior to the 5-yr period covered by the current Regulations), adult harbor seals were observed (on the videotape) to travel over pups when the adults were moving toward the water in response to a launch. These pups were momentarily startled, but then continued to move toward the water; they did not appear to be injured. On two occasions during Year 3, adult sea lions were seen moving over sea lion pups, but not in relation to the launches. No obvious injuries were noted.

3.2 Field Methods

The launch monitoring program was based primarily on remote video recordings. Observations were obtained before, during, and after each vehicle launch. Remote cameras were essential because, during vehicle launches, safety rules prevent personnel from being present in many of the areas of interest. During the launches described in this report, use of video methods theoretically allowed observations of up to three pinniped species during the same launch. The actual number of species studied per launch depended on the number of video systems deployed during each launch (usually three) and on the number of species hauled out at those sampling sites (Table 3.1). During most launches, two species were monitored.

For the combined pinniped and acoustic monitoring, the Navy usually attempted 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 were generally obtained via two or three portable cameras that could be set up temporarily at any site, plus a permanent ("fixed") camera that is installed near Building 809. The latter fixed camera was not operational during the Year 2 launches, but was used occasionally again from Year 3 onward. During most launches, one monitoring location was near the planned launch azimuth or the launcher itself; the other monitoring sites were some distance from the launch azimuth. Appendix A shows the monitoring locations relative to the launch azimuths; the monitoring locations varied from launch to launch.

Combined pinniped 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 launches. Acoustic and pinniped response data from the entire 2001–2007 monitoring period have been used in the current analysis of the dose-response relationships.

3.2.1 Fixed Camera

A permanent, fixed camera is installed in an elevated position at Building 809 at the west end of SNI (see Appendix A). This camera, designated "809 Camera", is situated on a metal tower overlooking Vizcaino Point (Fig. 3.1). The camera can be remotely zoomed, tilted, and panned by an observer stationed in a remote blockhouse (Building 127). Digital video data from this camera can be sent back to the blockhouse where they can be viewed on a large video monitor and recorded on large-format digital videotape. Video data from this camera can be recorded for any desired duration. This camera does not include a built-in microphone. The "809 Camera" was not operational during Year 2 launches, but was used again during Year 3 and onward.

3.2.2 Mobile Cameras

During the day of each launch, Navy biologists placed up to two portable Sony Hi-8 digital video cameras on tripods that overlooked haul-out sites (see Appendix A). Placement of the cameras was such that disturbance to the pinnipeds was minimal, and the cameras were set to record a focal subgroup within the haul-out aggregation for the maximum 4 hr permitted by the videotape capacity of the mobile cameras. The entire haul-out aggregation at a given site was not recorded, as the wide-angle view that would have been necessary to encompass an entire beach would not have allowed detailed behavioral analyses. It was more effective to obtain a higher-magnification view of a sample of the animals at the site. Vehicle and other sounds detected by the microphones built into these cameras were also recorded. These audio data were used during behavioral analyses (e.g., to confirm the exact time when the vehicle passed), but were uncalibrated and not of sufficient quality to provide launch sound information.

3.2.3 Wagoncam

A "wagoncam" (or Camera Cart) was also used on several occasions (Fig. 3.2). A wagoncam, unlike the "mobile cameras", can transmit its signal back to a centralized location where it is recorded. In this case, the signal from the wagoncam was recorded at Building 127. The wagoncam does not

TABLE 3.1. Video data collected for California sea lions, northern elephant seals, and harbor seals during vehicle launches at SNI, from 2001–2007. Multiple launches separated by minutes or hours are indicated by (x2) or (x3); dual launches separated by seconds are indicated by (d).

	Launch Date (month/day)																								
	2001					2002													2003						
Video Recording Location	08/ 15 (x2)	09/ 20 (x2)[a]	10/ 05	10/ 19	12/ 19	02/ 14	02/ 22 (x2)	03/ 06	05/ 01 (x2)	05/ 08	06/ 19	06/ 21 (d)	06/ 26 (x2)	07/ 18	08/ 23	11/ 18 (d)	12/ 10	12/ 18 (x2)[b]	01/ 24	03/ 14	03/ 16	04/ 04 (d)	06/ 04[c]	06/ 26	07/ 28
California Sea Lion																									
Dos Coves North	x	x	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
Dos Coves South	x	x	-	-	-	-	-	-	-	-	-	x	-	-	x	x	x[p]	-	-	-	-	-	-	-	x
At or near 809 Camera	x	x[p]	x	x	x	x[m]	-	x	x	x	x	-	x	-	-	-	-	-	-	-	-	-	x	x	x
The "Y"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-
Bomber Cove	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-
Bachelor Beach North	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	x
Redeye Beach	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Sea Lion Cove	-	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vizcaino Point	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Elephant Seal																									
Bachelor Beach North	-	x	-	-	x[m]	x	x	-	-	-	-	x	-	-	x	x[p]	x	-	-	-	-	-	-	-	x
Bachelor Beach South	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Dos Coves South	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	-	-	-
Pirates Cove	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redeye Beach	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redeye I	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x[p]	-	-	-	-	-	-
Sea Lion Cove	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harbor Seal																									
At or near 809 Camera	x	x	x	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phoca Reef	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redeye Beach	-	-	-	-	-	-	x[o]	x	x[o]	x	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Sea Lion Cove	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corral Harbor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
Pirates Cove	-	-	-	-	x[o]	-	x[o]	x	x	x	-	-	-	-	-	-	-	-	-	x[o]	x	-	-	-	-
Phoca Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
No Name Cove	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
Sheephead Ranch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	-	-

[a] Vandal launch monitored at 3 sites (Dos Coves North & South, 809 Camera); Terrier-Orion launch monitored at 4 sites (Bachelor Beach North & South, Sea Lion Cove, 809 Camera); incidental observations of sea lions via 809 Camera at harbor seal haul out were unclear.
[b] Two locations monitored, but both videos failed. [c] Two separate sites were monitored at Sheephead Ranch.
[m] Video malfunctioned. [o] No pinnipeds hauled out at time of launch. [p] Poor video quality.

TABLE 3.1 (continued).

Video Recording Location	2004								2005													2006			2007		
Launch Date (month/day)	05/05 (d)	05/18	06/03 (x3)[d]	07/26 (x2)	07/29	08/26	08/27	09/22 (x3)[e]	01/27 (x3)	02/24 (x2)[f]	03/11 (d)	03/24	04/22	06/02 (x2)[g]	06/16 (x3)	06/29 (x3)[h]	07/26 (x2)	07/27	07/28 (x3)[i]	08/25 (x3)	10/06	02/14 (x2)	04/06	05/15 (x2)[j]	04/26 (d)	06/12	06/13
California Sea Lion																											
Dos Coves South	x	-	x	x	x	x	x	x	-	x[p]	x	x	-	-	x	x[m]	x	-	-	x	x	-	x	-	x	x	x
At or near 809 Camera	-	-	x[p]	x	x	-	-	x[p]	-	-	x	x	x	x[p]	-	x	x	x	x	x	x	x	x	x[m]	x	x	x[p]
The "Y"	-	-	-	-	-	-	-	-	-	-	x	x	-	x	-	-	x	-	-	x		-	-	-	-	x	x[m]
Bomber Cove	-	-	-	-	-	-	-	-	-	-	-	-	-	x[p]	-	x	-	-	-	-	-	-	-	-	-	-	-
Bachelor Beach North	-	-	-	x	x	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-
Vizcaino Point	-	-	-	-	-	x	x	x[o]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harbor Seal Overlook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x[o]	-	-	-	-	-	-	-	-
Northern Elephant Seal																											
Bachelor Beach North	x	-	-	x	x	-	-	-	x	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-
Bachelor Beach South	x	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
The "Y"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	x[m]
Dos Coves South	-	-	x[p]	-	-	-	-	-	-	-	x	x	-	-	x	-	-	-	-	-	x	-	x	-	x	-	x
Redeye I	-	x	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Phoca Point	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reef South of B807	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Harbor Seal Overlook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Harbor Seal																											
Bomber Cove	-	-	-	-	-	-	-	-	-	x	-	-	-	x[p]	-	-	-	-	-	-	-	-	-	-	-	-	-
Harbor Seal Overlook	-	x	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x[o]	-	-	x	x	x	-	-	-
Phoca Reef	-	-	-	-	x	x	x[o]	-	-	-	-	-	x	-	-	-	-	x	x	-	x	-	-	x	-	-	-
Pirates Cove	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phoca Point	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[d] Video quality only poor during first launch at 11:31.
[e] The first launch was monitored at a slightly different location from the other two launches; only during the second launch was the video quality poor.
[f] Bomber Cove and Bachelor Beach only monitored during second launch; poor video quality at Dos Coves South only during first launch.
[g] Poor video quality at Bomber cove during both launches and at 809 Camera during first launch. [h] Video malfunctioned during third launch only.
[i] No pinnipeds hauled out during second launch only. [j] Video malfunctioned during second launch only.
[m] Video malfunctioned only during third launch [o] No pinnipeds hauled out at time of launch. [p] Poor video quality.

FIGURE 3.1. View of the permanent fixed video camera at Building 809. This camera can be remotely zoomed, tilted, and panned. (Photograph by U.S. Navy).

FIGURE 3.2. View of a wagoncam. Unlike other portable video cameras, a wagoncam can transmit its signal back to a centralized location where it is recorded. (Photograph by U.S. Navy).

include a built-in microphone. During the day of each launch, Navy biologists placed up to two wagoncams at locations overlooking haul-out sites. Placement was such that disturbance to pinnipeds was minimal. The entire haul-out aggregation at a given site could not be recorded, as the wide-angle view necessary to encompass an entire beach would not allow detailed behavioral analyses.

3.2.4 Visual Observations

Navy biologists from NAWCWD, Point Mugu, Range Department, made direct visual observations of the pinniped groups prior to deployment of the cameras and ATARs. Records from these visual observations included the local weather conditions, types and locations of any pinnipeds hauled out, and the type of launch activity planned. The time (to the second) was shown superimposed on the video. The video continued recording for 1–2 hr after the launch, and the observers typically returned to the monitoring sites for follow-up monitoring several hours after the launch. These observations helped determine whether the numbers of pinnipeds at the haul-out site had changed, and if there was obvious evidence of recent injury or mortality.

3.3 Video and Data Analysis

Digital video data were copied to DVD-ROMs to facilitate transport and playback, and for backup. Video records were then transferred from the Navy to LGL Ltd. for analysis.

Subsequent to the launch, an experienced biologist (MH) reviewed and coded the video data on the DVD-ROMs as they were played back to a high-resolution color monitor. The DVD player was connected to the monitor using a high-quality S-video output lead. The player had a high-resolution freeze-frame capability. A jog shuttle was used to facilitate distance estimation, launch timing, and characterization of behavior.

The videotaped data covering several hours before, during, and up to 2 hr after each launch were reviewed in order to document the types and numbers of pinnipeds present, and the nature of any overt responses to the launch.

3.3.1 Proportions of Pinnipeds Responding

The proportions of pinnipeds that moved and entered the water were determined from each video recording by observing the entire group of animals hauled out at the monitoring site during a launch. The percentage of animals that moved included all animals that traveled along the beach or entered the water, irrespective of how far or how long the movement lasted. The percentage of pinnipeds that entered the water included all individuals that left the haul-out site to enter the water during the launch.

3.3.2 Specific Behavioral Observations

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

1. composition of the focal subgroup of pinnipeds (numbers by sex and age class);
2. description and timing of disruptive event (vehicle launch); this included 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);
4. interaction type: agonistic, mother/pup, play, or copulatory sequence types; and
5. interaction distance: an estimate of the minimum distance [cm] between interacting pinnipeds' bodies, based on the known size of morphological features [body or head length] or comparison with adjacent substratum features of known size.

3.3.3 Circumstances of Observations

The following variables concerning the circumstances of the observations were also extracted from the videotape or from direct observations at the site:

1. study location;
2. local time;
3. composition of the focal subgroup of pinnipeds (numbers by sex and age class);
4. vehicle type (e.g., Vandal, AGS, RAM);
5. launch type (dual, single, double, triple);
6. season (e.g., breeding, molting, pupping);
7. 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);
8. substratum slope (0–15º, >15º, or irregular), estimated from the video records;
9. weather, including an estimate of wind strength and direction, and presence of precipitation; these data were made available by the Navy meteorological unit;
10. 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
11. tide state—exact time for local high tide was determined from relevant tide tables.

For each pinniped monitoring site, several parameters were calculated for each vehicle launch: the 3-D distance from the monitoring site to the CPA of the vehicle (in km), the angle above the horizon from recording site to the CPA (in degrees), and the wind component along the axis from the CPA to the monitoring site (in kt).

3.3.4 Statistical Analyses

For all analyses, combined data from August 2001 to March 2008 were used; there were no launches after June 2007. The two response variables analyzed were "% that moved" and "% that entered water" (% water). Scatter plots and Spearman Rank Order Correlations were used to examine the relationships of these variables to 3-D CPA distance and the measured vehicle sound (SEL), separately by vehicle type and pinniped species. One-sided *P*-values are appropriate, since the direction of the effect was predictable.

To further investigate the effects of vehicle launches on pinniped behavior while allowing for various potentially confounding factors, we fitted logistic regression models (Ramsey and Schafer 2002) to the same two measures of behavioral response, separately for the three pinniped species. All logistic regression equations were of the form

$$\pi = \frac{\exp\left(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k\right)}{1 + \exp\left(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k\right)} \quad [2]$$

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, $x_1, ..., x_p$ 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.

A set of predictor variables to consider for inclusion in [2] was pre-determined based on their hypothesized effects on pinniped behavior after a missile 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 to include in model [2]. From an initial model that included all predictor variables, predictor variables 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 was less than 0.15. Backward steps with intervening forward looks were repeated until all variables in the model had significance values <0.15 and none could be added. The χ^2 statistic for each coefficient, and *P*-values associated with the χ^2 statistics, were also calculated and reported.

In standard logistic regression analysis, individual "successes" (here, movement or entering the water) and "failures" (here, no movement or not entering the water) are assumed to be independent of one another and follow a binomial distribution. We, however, could not assume that an individual animal's response to the launch was independent of other animals in the same field of view. For the data, it was reasonable to assume that the lack of independence in behavior displayed by individual animals within a group manifested itself as a multiplicative increase in variance. In other words, it was reasonable to assume that non-independence increased the underlying variance of our proportions over that predicted by the binomial distribution. This assumption was reasonable because such an increase would occur if, for example, animals reacted in clusters (McCullagh and Nelder 1989). We envision animals reacting similarly within clusters, but dissimilarly between clusters. Under this assumption, 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. Overdispersion parameters for our logistic models were estimated by including all predictor variables except measured sound levels in the model [2], and computing the resulting Pearson χ^2 goodness-of-fit statistic. Assuming χ^2 was >1, the estimated overdispersion parameter was then set equal to the square root of Pearson's χ^2 for all models involving that species. If χ^2 was <1, the overdispersion parameter was set equal to 1.0. All subsequent model runs for a particular species, including model selection, included the species' estimated overdispersion parameter. *P*-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 and Nelder 1989). All calculations were carried out using SAS Proc Logistic and SAS Proc GENMOD (SAS Institute 2000).

The total number of observations available for modeling varied depending on response (% moved vs. % water) and pinniped species. Two separate analyses were completed for each combination of response variable (moved and entered water) and pinniped species, one considering SEL-M and one that did not consider SEL-M. The sample size was smaller when SEL was considered, as sound measurements were not available for all times and locations where pinniped responses were observed In all, 2 (responses) x 3 (species) x 2 (variable sets) = 12 models were fitted. 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], (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) measured SEL-M near the pinnipeds. 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). The other predictor variables were defined as in Chapter 2 (§ 2.3.4). Thus, vehicle type was categorized as (a) Vandal; (b) Coyote; (c) "other large" vehicle, including Falcon, Terrier-Orion, Tomahawk, Arrow; (d) AGS slug, (e) AGS missile, and (f) RAM. The 3-D CPA distance, CPA_Angle, and wind component were calculated as for the acoustic data (see § 2.3.4).

Vehicle type was incorporated as five variables representing whether (1) or not (0) the vehicle was (i) "other large" (Arrow, Tomahawk, Terrier-Orion), (ii) AGS missile, (iii) AGS slug, (iv) RAM, or (v) Coyote. Those five variables were all coded as zero for Vandal launches; i.e., the Vandal was treated as the reference vehicle in all regression models. For vehicles other than the Vandal, one of these five variables was coded as "1" and the others as "0".

All models 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 to multiple vehicle flights that all occurred under 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 not a result of inadequate data or modeling, but was largely caused by low sample sizes. In cases when incomplete separation prevented estimation, the model was reduced (variables were eliminated) until separation of responses was achieved and the models converged.

3.4 Results

3.4.1 Summary of Pinniped Responses to Launches, August 2001–March 2008

This section provides a short summary for each pinniped species, giving the general proportion of animals that responded to launches by moving or entering the water. This summary is based on all launches monitored at SNI during the August 2001–March 2008 period. (There were no launches after June 2007.) Detailed information on responses of pinnipeds to each launch can be found in the annual reports, which are included in Appendix B on CD-ROM.

California Sea Lions.—California sea lions were observed on 127 occasions (site–launch combinations) on 42 dates from August 2001 to June 2007. Responses of California sea lions to the launches varied by individual. Some sea lions exhibited brief startle responses, whereas others hardly reacted to the launch. Other sea lions, particularly pups that were previously playing in groups along the margin of the haul-out beaches, appeared to react more vigorously by moving around on the beach. On 100 of 127 occasions, some sea lions (1–100%; avg. 56%) reacted by moving along the beach; on the other 27 occasions, no hauled out sea lions that were being observed moved in response to the launch. On 39 of 127 occasions, some sea lions but usually not all were observed to enter the water in response to the launch. Less than 50% of the observed sea lions entered the water on 27 of those 39 occasions, and 52–100% entered the water on the remaining 12 occasions. 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 min after the launch time. On two occasions, adult sea lions moving around on the beach moved over sea lion pups; this movement was not in response to any launches. No injuries could be detected.

Elephant Seals.—Elephant seals were observed on 53 occasions on 31 dates from August 2001 to June 2007. Most elephant seals exhibited little reaction to launch sounds; they merely raised their heads for a few seconds and then returned to their previous activity pattern (e.g., sleeping, resting). During less than half of all occasions (24 of 53 occasions), a small proportion (avg. 24%) of the northern elephant seals under observation on the beach repositioned or moved a small distance (<6 ft or <2 m) away from their resting site. The proportion of elephant seals that entered the water was typically zero. A single elephant seal was seen to enter the water on two occasions (a Vandal launch on 10 Dec. 2002 and a dual RAM launch on 5 May 2004), and 13 of 35 elephant seals entered the water during a Coyote launch on 6 Oct. 2005. However, the move into the water by these animals was slow and gradual; it took 5 min for the 13 seals to enter the water. California sea lions were also hauled out at the site; 54% of them entered the water.

Harbor Seals.—Harbor seals were observed on a total of 48 occasions during 23 dates in the August 2001 to June 2007 period. During the majority of launches, most of the observed harbor seals left their haul-out sites and entered the water within seconds of the launch (few seals took >30 s). Individuals that left the site typically did not return during the duration of the video-recording period, which usually lasted for an additional 1 to 2 hr. On 37 of 48 occasions, 7–100% (avg. 77%) of the observed seals moved in response to the launch, and on 34 of 48 occasions, 7–100% (avg. 68%) entered the water. On three occasions, harbor seal pups were 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 towards the water.

3.4.2 Pinniped Responses in Relation to Distance and Launch Sounds

Scatter plots of pinniped response relative to 3-D CPA distance and SEL for each vehicle type are shown in Figures 3.3–3.8. “Other large” vehicles (Terrier-Orion, Tomahawk, Arrow) were grouped together for the scatter plots, as only limited data were available for each of those vehicle types.

The scatter plots show that a greater percentage of ***California sea lions*** responded to launches with low CPA distances (i.e., when the sea lions were closer to the launch azimuth; Fig. 3.3a and 3.4a) than to launches with greater CPA distances. However, there was much scatter in the relationships to distance.

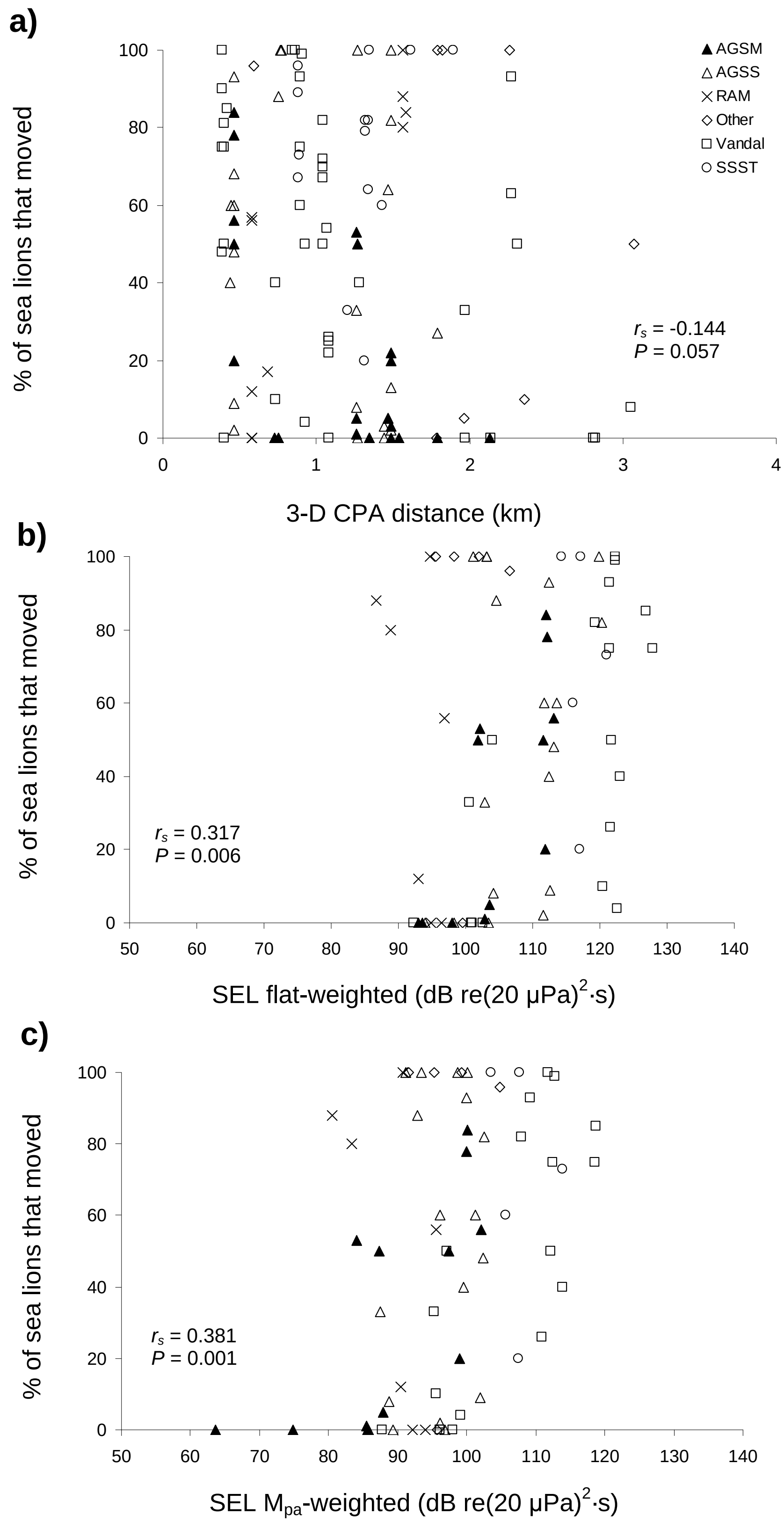

FIGURE 3.3. Percent of ***California sea lions*** that moved in relation to (a) 3-D CPA distance, (b) SEL flat-weighted, and (c) SEL Mpa-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (rs) and their 1-sided significance levels (P).

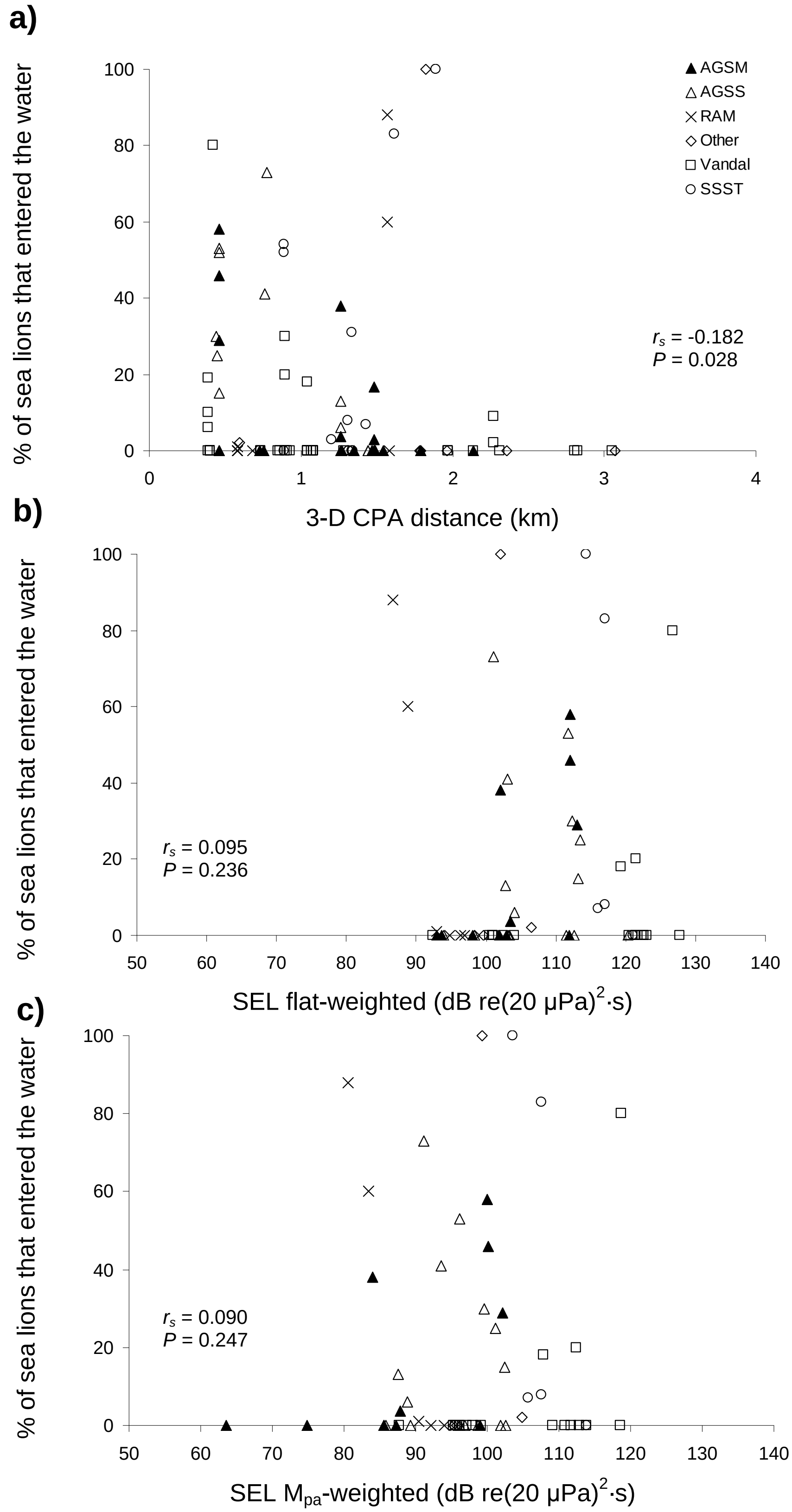

FIGURE 3.4. Percent of ***California sea lions*** that entered the water in relation to (a) 3-D CPA distance, (b) SEL flat-weighted, and (c) SEL Mpa-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (rs) and their 1-sided significance levels (P).

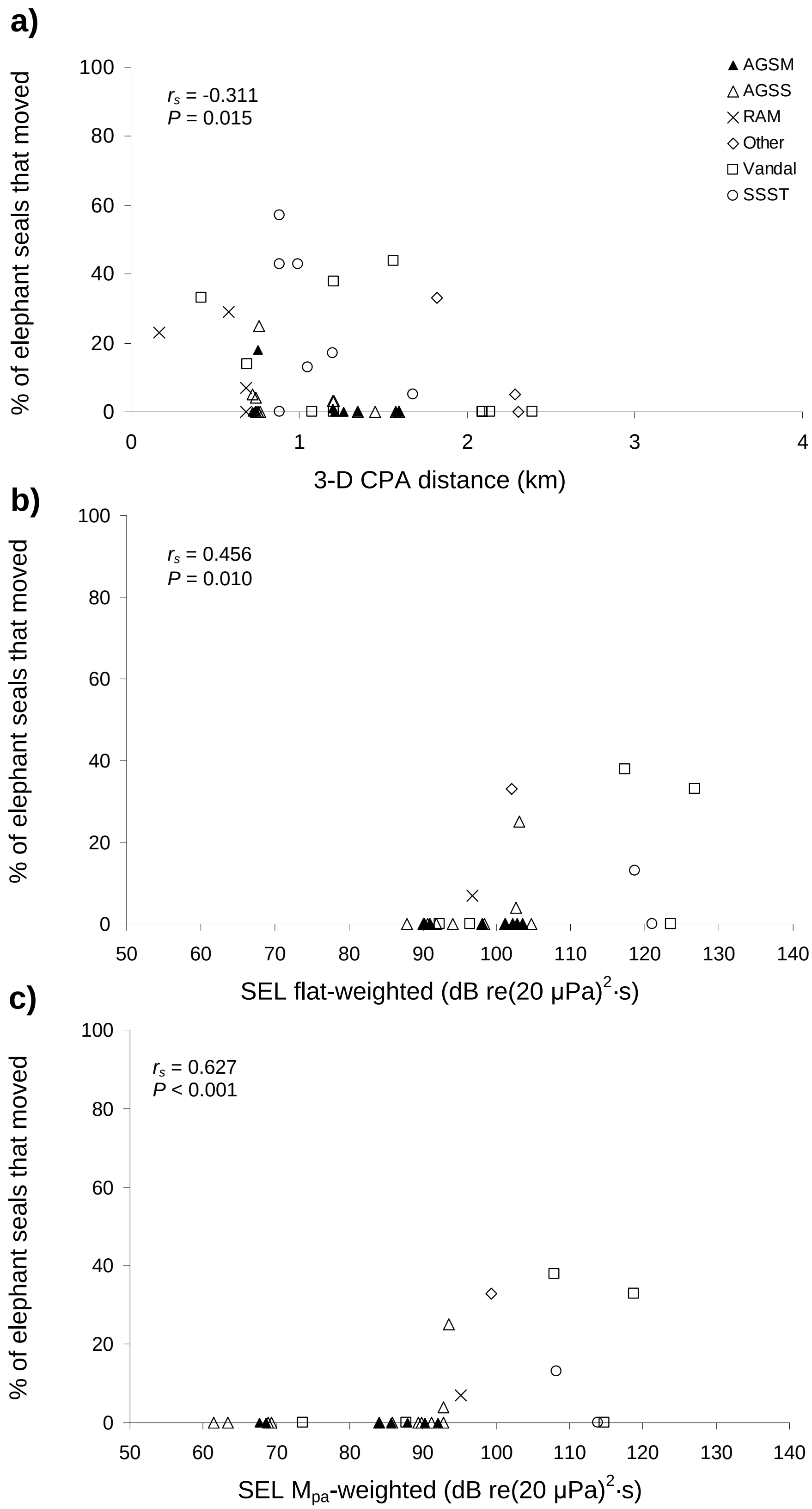

FIGURE 3.5. Percent of ***northern elephant seals*** that moved in relation to ***(a)*** 3-D CPA distance, ***(b)*** SEL flat-weighted, and ***(c)*** SEL M_{pa}-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (*P*).

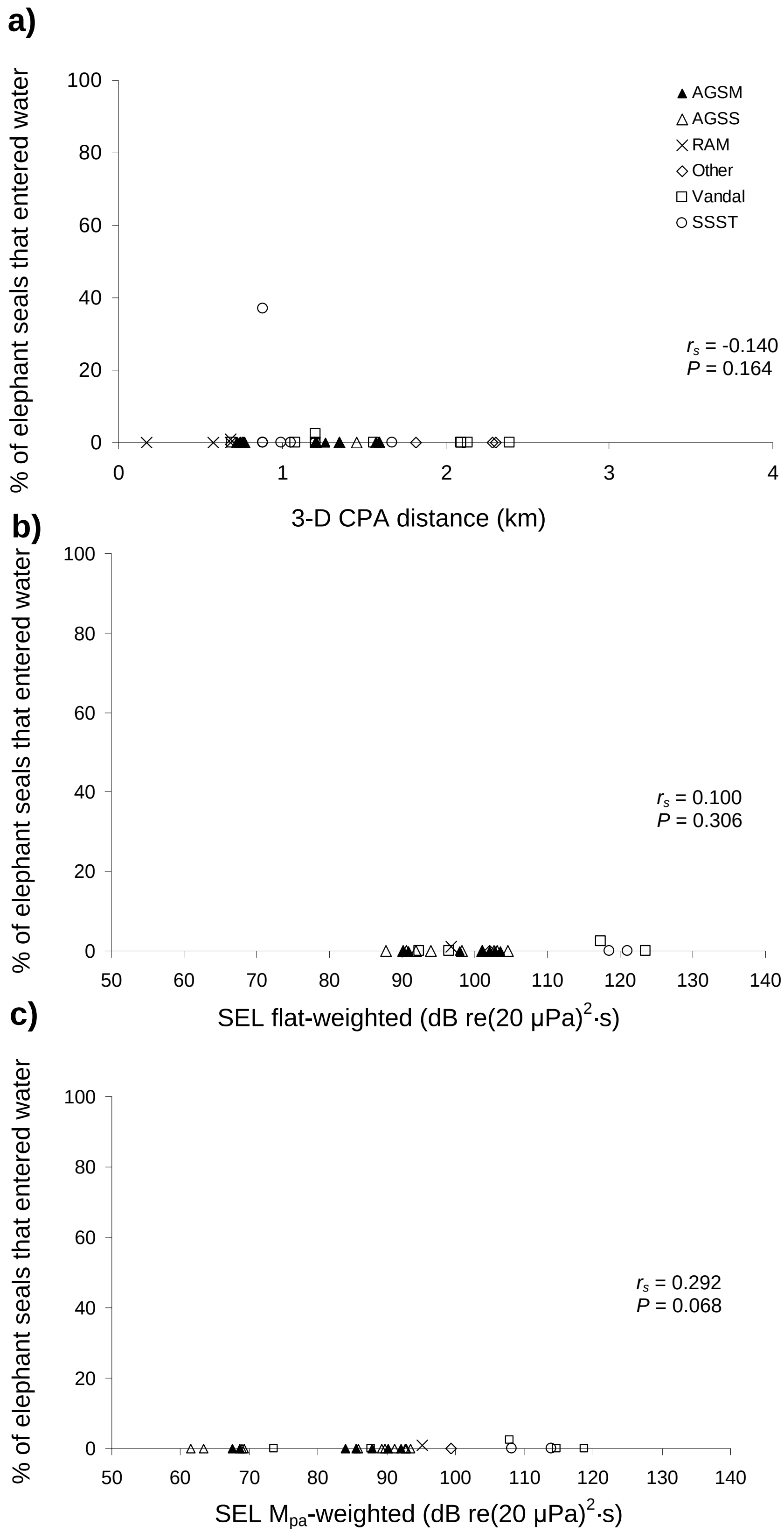

FIGURE 3.6. Percent of ***northern elephant seals*** that entered the water in relation to (a) 3-D CPA distance, (b) SEL flat-weighted, and (c) SEL Mpa-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (rs) and their 1-sided significance levels (P).

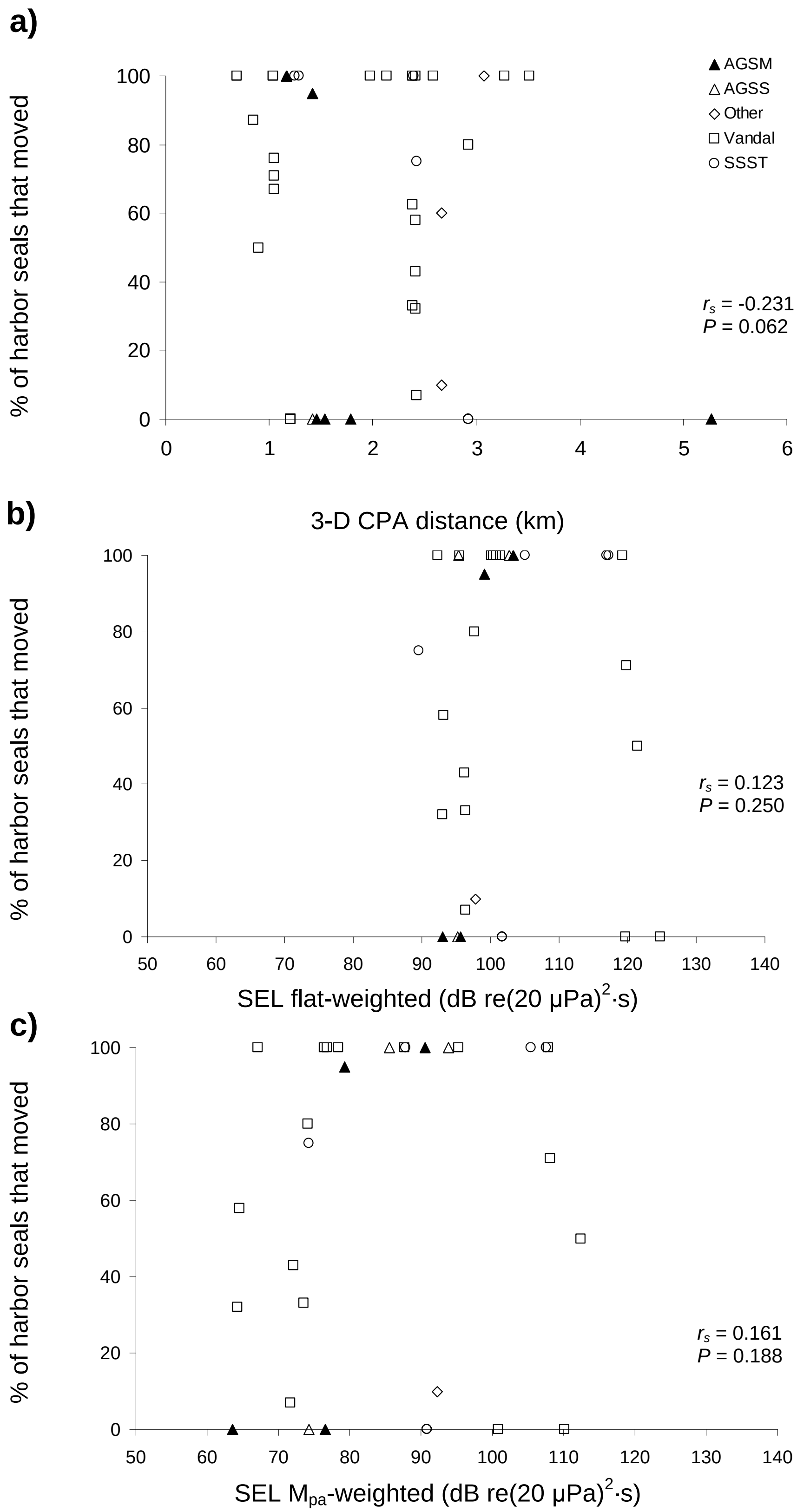

FIGURE 3.7. Percent of ***harbor seals*** that moved in relation to (a) 3-D CPA distance, (b) SEL flat-weighted, and (c) SEL Mpa-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (rs) and their 1-sided significance levels (P).

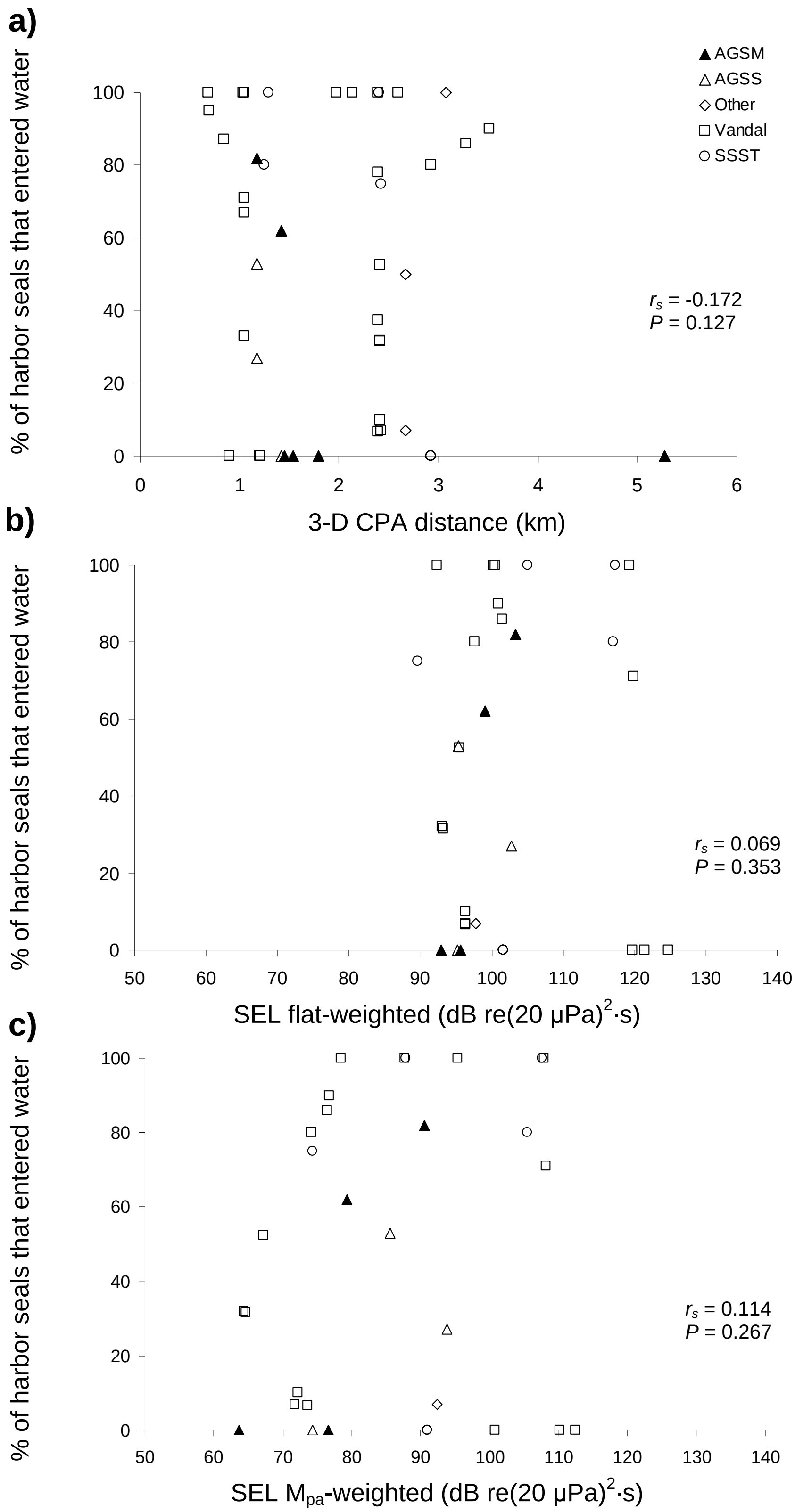

FIGURE 3.8. Percent of ***harbor seals*** that entered the water in relation to (a) 3-D CPA distance, (b) SEL flat-weighted, and (c) SEL Mpa-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (rs) and their 1-sided significance levels (P).

The percentage of sea lions that moved was more closely and significantly related to SEL than distance, regardless whether flat- or M_{pa}-weighting was applied to the sound data (Fig. 3.3b,c). The proportion of sea lions that entered the water was most commonly low or zero and, though weakly and negatively related to CPA distance, was not related to SEL (Fig. 3.4b,c).

It is evident from the scatter plots that the percentage of ***elephant seals*** that moved was generally low, even rather close to the launch azimuth (Fig. 3.5a). Nonetheless, elephant seals were even less responsive (fewer moved) at the greater CPA distances ($P \le 0.05$; Fig. 3.5a). Similarly, responsiveness was low with any received sound level, but nonetheless the proportion of elephant seals that moved was significantly greater with increasing SEL ($P \le 0.01$; Fig. 3.5b,c), and particularly with SEL-M. Elephant seals entered the water on only three occasions, so there was little ability to test for a relationship between that response and either distance or received sound level. Even so, the tendency to enter the water was marginally higher with increasing SEL-M (Fig. 3.6).

The scatter plots indicate that moderate to high proportions of ***harbor seals*** moved during launches, even in the case of some vehicles whose 3-D CPA distances were >1.9 mi or 3 km (Fig. 3.7a). The tendency for a greater proportion of harbor seals to move with decreasing CPA distance was only marginally significant ($P = 0.06$) given that harbor seals often moved even at the longer distances. Harbor seals also commonly entered the water during launches with CPA distances 0.4–2.2 mi or 0.7–3.5 km (Fig. 3.8a). Similarly, harbor seal responses showed only slight positive correlations with SEL; these trends were not statistically significant (Fig. 3.7 and 3.8).

3.4.3 Pinniped Responses Relative to Hypothesized Predictors

Results of the logistic regression analyses of pinniped responses in relation to various potential predictor variables are summarized in Tables 3.2 and 3.3. The best-fit models for regressions that included sound (SEL) may be affected adversely by strong correlation between some predictor variables (e.g., SEL and CPA Distance), or multicolinearity. In addition, there is strong likelihood of fairly severe overfitting in some of these models where sample sizes are small (as they are for harbor and elephant seals) when dealing with so many potential predictors. These models should be interpreted with caution.

California Sea Lions.—The best-fit regression model relating the proportion of sea lions that responded during a launch to non-sound variables indicated that, after allowing for other factors, the proportions moving and entering the water were both highly significantly related to logCPADist ($P \le 0.001$; Table 3.2). As would be expected, the relationships of the proportions moving and entering the water to logCPADist, after allowance for the influences of other variables (Table 3.2), were much stronger than the relationship to CPA distance before other variables were taken into account (Fig. 3.3a, 3.4a). Compared to the response to Vandals, a significantly greater proportion of sea lions moved in response to Coyotes, but significantly fewer moved during AGS launches (especially AGS missiles). The negative relationship between season and proportion moving indicates that sea lions tended to be more responsive (more moved) during the non-breeding season. CPA_Angle, wind component, and “first vs. subsequent launch” did not enter the model as significant predictors of either proportion moving or the proportion entering the water.

When a measure of received sound (SEL-M) was considered for inclusion in the regression models, along with the same non-sound variables, the proportion of sea lions that moved was strongly and positively related to SEL-M (Table 3.3). After allowance for SEL-M, consideration of logCPADist

TABLE 3.2. Coefficients and nominal significance levels (*P*-values) 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.

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

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

TABLE 3.3. 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.

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

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

did not have much additional ability to predict proportion moving, given the close relationship between SEL-M and logCPADist. However, the proportion moving was again higher in the non-breeding season, and still depended significantly on vehicle type. A given received level of sound was more likely to elicit movement if the vehicle was something other than a Vandal or Coyote. The proportion entering the water was more directly related to logCPADist ($P \leq 0.01$) than to received sound level (Table 3.3). Once distance was taken into account, none of the other variables was a significant predictor of proportion entering the water.

Elephant Seals.—When only non-sound variables were considered, the proportion of elephant seals that moved in response to the launch was significantly related to logCPADist, CPA_Angle, wind, and vehicle type (Table 3.2). As expected, a significantly greater proportion moved as CPA distances decreased ($P < 0.05$; Table 3.2). Also, significantly more elephant seals responded with increasing CPA_Angle. Wind affected the response significantly; there was a greater tendency to move when the wind included a component blowing from the CPA position toward the seals. Other factors being equal, a significantly greater proportion of elephant seals moved in response to Vandals as compared with any of the other vehicle types. An intermediate proportion moved during launches of Coyotes, and lower proportions moved during all other vehicle launches.

When sound as well as non-sound variables were considered in the analysis of the proportion of elephant seals that moved, the response was most strongly related to SEL-M. As expected, the proportion that moved increased significantly ($P \leq 0.001$) with increasing sound levels. After allowance for received sound level, response was no longer related to vehicle type, CPA distance, or wind. The number of seals that moved was again significantly related to CPA_Angle, but after allowance for sound level, more elephant seals moved with *decreasing* CPA_Angle (Table 3.3). The change in the direction of the relationship to CPA_Angle after SEL-M was considered was related to intercorrelations amongst the predictor variables.

Elephant seals moved into the water too rarely to allow a meaningful analysis of factors affecting that response.

Harbor Seals.—The logistic regression analyses confirmed that, even after allowance for other variables, there was no strong relationship of harbor seal responses to either CPA distance or to received SEL-M. When only non-sound variables were included in the regression analyses, the best-fitting models indicated that the responses of harbor seals were positively related to CPA_Angle and season (Table 3.2). Harbor seal responses increased significantly with increasing CPA_Angle ($P \leq 0.01$) and, other things being equal, were stronger during the pupping/breeding season. A significantly greater proportion of harbor seals entered the water during the first launch in a series compared with subsequent launches on the same day ($P \leq 0.05$; Table 3.2).

When SEL-M was considered as a potential predictor, it was found not to be significantly related to the proportions moving or entering the water (Table 3.3). That result is consistent with the low simple correlations evident in Figures 3.5b,c and 3.6b,c. The relationships to other variables are presumably better documented in the analysis excluding SEL-M (Table 3.2), for which the sample size was larger. (Data on SEL-M were not available for all launches and locations where pinnipeds were observed.)

3.4.4 Pinniped Behavior and Distribution Prior to and Following Launches

The "units of observation" were individual pinnipeds within the focal subgroups. Individuals were chosen that were clearly visible on the video recordings for the entire 1-min sampling period of interest (either pre- or post-launch). The individuals included in the focal subgroups before and after a given launch were not necessarily the same animals, especially in the situation where pinnipeds moved or left the haul-out site in response to the launch (e.g., harbor seals). In the case of northern elephant seals, the focal animals were often the same individuals that were observed prior to the launch. Table 3.4 presents means and standard deviations for inter-individual spacing, total distance moved, and number of position changes before and after launches, separately by species. In general, all three species moved more frequently and longer distances after than before launches, and were located closer to their nearest neighbor before launches compared with afterwards. Because the individuals within a focal group are likely to respond to one another, they should not be assumed to be independent. Therefore, it is not appropriate to apply simple statistical analysis approaches to these data as presently organized.

TABLE 3.4. Description of pinniped behavior and distribution prior to and after launches, August 2001–June 2007; n = number of animals; SD = standard deviation.

	Before Launch			**After Launch**		
Behavior Analyzed	Mean	SD	*n*	Mean	SD	*n*
Number of Position Changes						
California Sea Lions	0.18	0.59	1188	0.35	0.82	1047
Northern Elephant Seals	0.12	0.46	424	0.17	0.52	403
Harbor Seals	0.06	0.35	481	0.16	0.51	279
Total Distance Moved (m)						
California Sea Lions	0.33	1.58	1188	0.83	2.90	1047
Northern Elephant Seals	0.09	0.46	424	0.13	0.56	403
Harbor Seals	0.06	0.35	481	0.08	0.27	279
Distance to Neighbor (m)						
California Sea Lions	0.46	1.14	1187	0.48	1.41	1046
Northern Elephant Seals	0.22	0.53	425	0.27	1.35	403
Harbor Seals	0.91	1.16	480	1.19	2.11	276

3.5 Summary

Pinniped behavioral responses to launch sounds during the August 2001–March 2008 period were, with the exception of some responses by harbor seal seals, usually brief and not severe. In general, northern elephant seals usually exhibited little reaction to the launches, California sea lions showed variable responses, and harbor seals were the most responsive.

Northern elephant seals exhibited little reaction to launch sounds. M_{pa}-weighted SELs as high as 119 dB re $(20\mu Pa)^2 \cdot s$ did not elicit a strong reaction from northern elephant seals. Most individuals merely raised their heads briefly in response to the launch and then quickly returned to their previous activity pattern (usually sleeping). However, during several launches, a small proportion of northern elephant seals on the beach moved a short distance away from their resting site. A greater proportion of elephant seals moved with increasing SELs and with decreasing CPA distances. Elephant seals were observed to enter the water on only 3 of 53 occasions. Elephant seals appear to be more responsive (a greater proportion moved) when Vandals and Coyotes, as compared to other vehicles, were launched, and numbers moving were negatively related to distance from CPA and positively related to received sound level (SEL-M).

Responses of California sea lions to the vehicle launches varied by individual. Some sea lions exhibited brief startle responses and increased vigilance for a short period (1–2 min) after each launch. Other sea lions, particularly pups that were previously playing in groups along the margin of the haul-out beaches, appeared to react more vigorously by moving around on the beach. Responses of sea lions to launches were related to CPA distance and received sound levels; other factors being equal, more sea lions moved with decreasing distance and increasing SELs, among other factors. Movement into the water was uncommon.

During the majority of launches, most harbor seals rushed from their haul-out sites on rocky ledges to enter the water within seconds of the launch (few seals took >30 s), and did not return during the duration of the video-recording period (which sometimes extended 1 to 2 hr after the launch time). Observations during the 2001–2002 monitoring period showed that harbor seals were usually hauled out again at these sites the following day (Holst and Lawson 2002). Harbor seals appear to be more responsive during the pupping/breeding season and with increasing CPA angle, but their response was not related to vehicle type or sound level, and not strongly related to distance either. In general, harbor seals are comparatively sensitive to vehicle launches, and harbor seals hauled out on beaches far from the launch azimuth may react to the launches by moving or entering the water.

No evidence of injury or mortality was observed during or immediately succeeding the launches. However, on three occasions, harbor seal pups were 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 towards the water. On two other occasions, adult sea lions moving around on the beach moved over sea lion pups; this movement was not in response to any launches. No injuries could be detected.

4. ESTIMATED NUMBERS OF PINNIPEDS AFFECTED BY MISSILE LAUNCHES, AUGUST 2001–MARCH 2008

This chapter provides estimates of the numbers of pinnipeds affected by the Navy's missile launches on SNI from August 2001 through June 2007.

4.1 Pinniped Behavioral Reactions to Noise and Disturbance

Some of the pinnipeds on the beaches at SNI show disturbance reactions to vehicle launches, but others do not. The levels, frequencies, and types of noise that elicit a response are known or expected to vary between and within species, individuals, locations, and seasons. Also, it is possible that pinnipeds hauled out on land may react to the sight, or the combined sight plus sound, of a vehicle launch. Furthermore, pinnipeds may, at times, react to the sight and sound of seabirds reacting to a launch. Thus, responses were not expected to be a direct function of received sound level. However, some correlation between pinniped responses and received sound level (or distance as a surrogate for sound level) was expected. Results from correlation analyses performed on 2001–2003 data provided the first direct evidence for such relationships at SNI, at least for California sea lions and (weakly) for elephant seals (Holst and Greene 2004a; Holst et al. 2005c. The analyses performed on 2001–2004 data (Holst and Greene 2005b) and the current analyses using 2001–2007 data showed similar results, based on larger sample sizes with some allowance for additional factors influencing received sound levels.

For pinnipeds hauled out on land, behavioral changes range from a momentary alert reaction or an upright posture to movement – either deliberate or abrupt – into the water. Previous studies indicate that the reaction threshold and degree of response are related to the activity of the pinniped at the time of the disturbance. In general, there is much variability. Pinnipeds often show considerable tolerance of noise and other forms of human-induced disturbance, though at other times certain pinnipeds can be quite responsive (Richardson et al. 1995; Reeves et al. 1996; Lawson et al. 1998).

Although it is possible that pinnipeds exposed to launch noise might "stampede" from the haul-out sites in a manner that causes injury or mortality, this was judged unlikely prior to the monitoring program. Review of video records of pinnipeds during the launches indicates that this assumption was generally correct. However, monitoring conducted during 2002–2003 showed that, 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 (Holst et al. 2005b; Holst and Greene 2006a). On two occasions (not during launches), adult sea lions were seen knocking over sea lion pups when they moved along the beach, but no injuries were evident.

Since no injuries or deaths were observed during the monitored launches from August 2001 to June 2007, disturbance rather than injury or mortality is the primary concern in this project. The minimum numbers of pinnipeds on the monitored beaches that might have been affected significantly by the launch sounds were estimated. In this report, consistent with previous related reports, we have assumed that only those animals that met the following criteria would be counted as affected by launch sounds:

1. pinnipeds that were injured or killed during launches, if any (e.g., by stampedes);
2. pinnipeds exposed to launch sounds strong enough to cause TTS; and
3. pinnipeds that left the haul-out site, or exhibited prolonged movement or prolonged behavioral changes (such as pups separated from mothers) relative to their behavior immediately prior to the launch.

Consistent with NMFS (2002), "…one or more pinnipeds blinking its eyes, lifting or turning its head, or moving a few feet along the beach as a result of a human activity [were] not considered [affected] under the MMPA definition of harassment".

In practice, no pinnipeds are known or suspected to have been injured or killed during the monitored launches (i.e., since August 2001), and few are believed to have received sounds strong enough to elicit TTS (see § 4.2, below). Thus, the number of pinnipeds counted as potentially affected during the monitoring period was primarily based on criterion (3) – the number that left the haul-out site, or exhibited prolonged movement or other behavioral changes.

The numbers of such affected pinnipeds were calculated for the periods during and immediately following the 77 launches during the August 2001 through March 2008 period. Disturbance reactions (if any) were short-lived for northern elephant seals and California sea lions and did not appear to extend into subsequent hours or days. Harbor seals typically left their haul-out site during a launch, but seals often started to haul out again at the same site within 1–2 hr after the launch.

4.2 Possible Effects on Pinniped Hearing Sensitivity

Temporary or perhaps permanent hearing impairment is a possibility when pinnipeds are exposed to very strong sounds in air. Based on data from terrestrial mammals, the minimum sound level necessary to cause PTS is presumed to be higher than the level that induces barely-detectable TTS. Given what is known about the thresholds for TTS and PTS in terrestrial mammals and humans, the PTS threshold is expected to be well above the TTS threshold for non-impulsive sounds. For impulsive sounds, such as sonic booms and nearby artillery shots, the difference may be smaller (Kryter 1985; Southall et al. 2007).

4.2.1 Temporary Threshold Shift?

There are few published data on TTS thresholds for pinnipeds in air exposed to impulsive or brief non-impulsive sounds. J. Francine, quoted in NMFS (2001: 41837), has mentioned evidence of mild TTS in captive California sea lions exposed to a 0.3-sec transient sound with an SEL of 135 dB re $(20\ \mu Pa)^2 \cdot s$ (see also Bowles et al. 1999). However, mild TTS may occur in harbor seals exposed to received levels lower than 135 dB SEL (A. Bowles, pers. comm., 2003). Unpublished data indicate that the TTS threshold on an SEL basis may actually be around 129–131 dB re $(20\ \mu Pa)^2 \cdot s$ for harbor seals, within their frequency range of good hearing (Kastak et al. 2004; Southall et al. 2007). The same research teams have found that the TTS thresholds of California sea lions and elephant seals exposed to strong sounds are higher as compared to harbor seals (Kastak et al. 2005). Based on these studies and other available data, Southall et al. (2007) propose that pulses may induce mild TTS if the received peak pressure is approx. 143 dB re 20 μPa (peak) or if received SEL-M is approx. 129 dB re $(20\ \mu Pa)^2 \cdot s$. Those levels apply specifically to harbor seals; those levels are not expected to elicit TTS in elephant seals or California sea lions (Southall et al. 2007).

The sounds received from missile and target launches on SNI were sometimes impulse sounds (when there was a sonic boom or near the AGS launcher). At other times and locations they were non-impulsive.

- SEL-M measurements near launchers were greatest for RAM and AGS vehicle launches, reaching levels as high as 137 dB re $(20\ \mu Pa)^2 \cdot s$. Although the AGS and RAM launchers were located close to the shore at the Building 807 Launch Complex, pinnipeds generally do not haul out close to those launchers. The measured SEL-M values near pinniped beaches during vehicle launches on SNI in August 2001–March 2008 were below the 129-dB level, and few if any pinnipeds were exposed to sound levels above 122 dB SEL-M, 129 dB re (20 μPa)^2·s SEL-F, or 118 dBA SEL. The maximum SEL-M values measured at nearshore locations during Vandal, Coyote, AGS, and RAM launches were 122, 114, 103, and 96 dB re (20 μPa)^2·s, respectively (Tables 2.3–2.4).

- Peak pressure levels received near pinniped beaches close to the missile trajectory were generally <143 dB re 20 μPa. However, during 11 launches (1 Coyote and 10 Vandals) that produced a sonic boom (impulse), peak pressure levels were ≥143 dB at nearshore sites located 1308–3955 ft (399–1205 m) from the CPA. All three species haul out at such distances from the CPA. Thus, it is possible that a few pinnipeds, particularly harbor seals, may have incurred TTS during some larger-vehicle launches. Because of their higher TTS thresholds, it is likely that fewer California sea lions and elephant seals would have incurred TTS as compared to harbor seals.

4.2.2 Permanent Threshold Shift?

Southall et al. (2007) estimate that received sound exposure levels would need to exceed the TTS threshold by at least 15 dB for there to be risk of PTS. In the harbor seal, the SEL-M that is estimated to result in onset of PTS is 144 dB re (20 μPa)^2·s (Southall et al. 2007). As already noted above, the SEL-M measurements nearshore did not exceed the SEL-based TTS threshold let alone the PTS threshold. Even measurements taken close to the launcher were <144 dB re (20 μPa)^2·s.

However, there is some possibility that a few pinnipeds at SNI might receive peak pressures exceeding those that elicit onset of TTS or perhaps even PTS. In animals (or humans) exposed to strong impulsive sound, e.g., close to an artillery shot, there is a possibility of PTS as a result of the high peak pressure even if the received energy did not exceed the SEL criterion for PTS onset. When considering peak pressures rather than energy levels, PTS onset may occur when the received level is as little as 6 dB higher than the TTS threshold, or 149 dB re 20 μPa in the case of the harbor seal (Southall et al. 2007). Peak pressure levels received near pinniped beaches close to the missile trajectory were generally less than 149 dB re 20 μPa. However, during three launches involving Vandals that produced a sonic boom (impulse), peak pressure levels were 149–150 dB at Dos Coves (where California sea lions and elephant seals are known to haul out), located approx. 1300 ft or 400 m from the CPA. However, given the higher TTS thresholds in elephant seals and California sea lions than in harbor seals, PTS thresholds in those other species are also expected to be higher than in the harbor seal. Thus, it is unlikely that PTS occurred in sea lions or elephant seals during those launches. Harbor seals were not seen to haul out at Dos Coves during the 2001–2007 monitoring. The harbor seal haul-out site closest to the CPA of any vehicle launched during the period was Redeye Beach (with a distance to CPA of 2261 ft or 689 m), where peak levels would have been lower. Thus, harbor seals are also unlikely to have incurred PTS during launches at SNI.

4.2.3 Conclusions re Auditory Effects

Overall, the results indicate that there is some potential for TTS in pinnipeds hauled out near the vehicle launch azimuths during the launch operations at SNI, but little potential for PTS. This conclusion is necessarily speculative given the limited TTS data (and lack of PTS data) for pinnipeds in air exposed to strong sounds for brief periods. In the event that levels are occasionally sufficiently high to cause TTS, these levels probably would be only slightly above the presumed thresholds for mild TTS. Thus, in the event that TTS did occur, it would typically be mild and reversible (i.e., no PTS). Given the relatively infrequent launches from SNI, the low probability of TTS during any one launch, and the fact that a given pinniped is not always present on land, there appears to be very little likelihood of PTS from the cumulative effects of multiple launches.

If there is any reason to be concerned about auditory effects, it would be during either of two types of launches: (1) When artillery shots (i.e., AGS launches) occur at beach locations and pinnipeds are present nearby, should this ever occur. (2) When a Vandal, Coyote, or perhaps some “other large” vehicle travels at supersonic speed over a pinniped beach at relatively low altitude (i.e., when the elevation angle at launch was low).

4.3 Conclusions Regarding Effects on Pinnipeds

Disturbance is the main concern during the Navy’s missile launch program. Responses of pinnipeds to acoustic disturbance are highly variable, with the most conspicuous changes in behavior occurring when pinnipeds are hauled out on land when exposed to strong sounds. Vehicle launch activities conducted during August 2001–March 2008 appeared to cause no more than limited, short-term, and localized disturbance of California sea lions and especially elephant seals. In the case of harbor seals, a substantial fraction moved into the water in response to launches. The majority of the California sea lions and most if not all elephant seals remained in the haul-out areas (see Chapter 3). There was no evidence that pinniped reactions to launches resulted in any pup mortality or injuries.

Levels of vehicle sounds recorded near pinniped haul-out locations around western SNI during launch operations were up to 122 dB re 20 $\mu Pa^2 \cdot s$ on an M_{pa}-weighted basis, 129 dB on a flat-weighted SEL basis, and 118 dBA. These values represent substantial levels of transient noise, and probably underestimated the maximum values occurring at certain unmonitored nearshore locations. Nonetheless, they are below the levels expected to be necessary to cause temporary or permanent hearing impairment. However, some pinnipeds, particularly harbor seals, within 0.7 mi (1.2 km) of the CPA of a launched vehicle may incur mild TTS due to high peak levels. Nonetheless, for pinnipeds at most locations on SNI, the potential for TTS is low. Although peak levels close to the CPA can be high and may occasionally exceed the TTS and even the PTS thresholds, auditory injury in pinnipeds hauled out on SNI seems unlikely, One reason for that is that the quoted TTS and PTS thresholds (from Southall et al. 2007) are based on data for the most sensitive species, the harbor seal. That species does not tend to haul out as close to the launch azimuths as do sea lions and elephant seals.

4.4 Estimated Numbers of Pinnipeds Affected by Launches

The approach to estimating the numbers of pinnipeds affected by launch sounds during August 2001 through March 2008 was based on video observations of pinnipeds, combined with estimates of the numbers of hauled out pinnipeds not videotaped but exposed to the same launch sounds. The latter animals are presumed to have reacted in the same manner as those whose responses were videotaped. The total numbers of such affected pinnipeds were determined only for the periods during and immediately following the 77 launches. Disturbance reactions (if any) for northern elephant seals and California sea lions were short-lived and did not appear to extend into subsequent hours or days. Harbor seals typically left their haul-out sites during a launch; some harbor seals were observed to haul out at the same site again during follow-up monitoring (i.e., within 2 hr after the launch), but others did not return during post-monitoring periods.

For pinniped groups that extended farther along the beach than encompassed by the field of view of the video camera, an estimate of the total number of individuals that were hauled out at the monitored site was made based on a pre-launch video pan of the area. The proportions of animals in the focal subgroups that were affected during each launch (based on the disturbance criteria listed in § 4.1) were then extrapolated to the estimated total number of individuals hauled out in this area. An attempt was also made to extrapolate the proportions of animals affected on the monitored beaches to unmonitored haul-out sites. However, this was not always possible, because it was generally unknown which beaches were used as haul-out sites on specific launch dates, and how many animals may have been hauled out. For pinniped species that were not monitored on certain launch dates, the number of animals affected by launch sounds was estimated based on data from previous launches. That is, the number of affected animals for the corresponding season and vehicle type was used, if possible. Despite these extrapolations, the estimates of the numbers of pinnipeds affected by launch sounds on each day are likely underestimates.

The estimated numbers of pinnipeds affected during each monitoring year are shown in Table 4.1 below. However, these numbers are likely overestimates, as the numbers of seals and sea lions affected on each launch day were added over the entire year, and many pinnipeds may have been affected more than once during the course of a year. Thus, the numbers in Table 4.1 are thought to more accurately reflect the number of exposures of pinnipeds during a monitoring year rather than the number of individuals affected.

TABLE 4.1. Estimated numbers of California sea lions, northern elephant seals, and harbor seals potentially affected each monitoring year by launch sounds from the Navy's missile launch program on SNI, August 2001–March 2008. The Regulations under which the present report was prepared pertain to the period from October 2003 to date.

Year	# of Monitored Launches	Total # Potentially Affected in Area		
		California sea lions	**Northern elephant seals**	**Harbor seals**
1 (Aug. 01-July 02)*	19	1042	50	204
2 (Aug. 02-Aug. 03)*	12	635	99	189
3 (Oct. 03-Oct. 04)	13	610	13	193
4 (Oct. 04-Oct. 05)	25	1990	15	395
5 (Feb. 06-Feb. 07)	5	295	0	13
6 (Feb. 07-Feb. 08)	3	567	0	40

* During Years 1 and 2, the numbers of potentially affected animals included all animals that moved, regardless of how far or for how long. During subsequent years, only animals that moved more than '… a few feet along the beach…' or > approx. 26 ft or 8 m, were included in these estimates.

4.5 Summary

No evidence of pinniped injuries or fatalities related to launch noises was evident, nor was it expected. However, on three occasions, harbor seal pups were knocked over by adult seals as 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 towards the water. There appeared to be no increase in aggressive interactions as a result of the reactions to the launches.

Few if any pinnipeds were exposed to received levels of sound energy above 122 dB re (20 µPa)^2·s M_{pa}-weighted. The specific received levels of transient airborne sound that cause the onset of TTS in pinnipeds are not well documented. However, some of the recorded peak levels exceeded the estimated peak pressure at which mild TTS may occur in the harbor seal (143 dB re 20 µPa) and thus had the potential to induce TTS. However, any TTS would presumably be mild and quickly recoverable. Although occasionally peak levels close to the CPA may rise above the presumed PTS threshold for the harbor seal, PTS is considered to be unlikely given the distributions of the three species of pinnipeds on SNI.

The greatest numbers of pinnipeds estimated to have been affected (i.e., disturbed) by launch sounds occurred in Year 4 of the August 2001–June 2007 period; this monitoring year had the greatest number of launches. An estimated 1990 California sea lions, 15 northern elephant seals, and 395 harbor seals were affected in Year 4. The greatest number of elephant seals (99) was estimated to have been affected in Year 2 (although a slightly different, more conservative, method was used to make estimates during the first two years as compared to the following years – see Table 4.1). These figures are very approximate, because they (a) include extrapolations for pinnipeds on beaches that were not monitored on any given launch day, (b) very likely count some of the same individuals more than once, and (c) also exclude pinnipeds on some beaches that were not monitored. The pinnipeds included in these estimates left the haul-out site in response to the launch, or exhibited prolonged movement or behavioral changes relative to their behavior immediately prior to the launch.

The results suggest that any effects of the launch operations were minor, short-term, and localized, at least for California sea lions and especially elephant seals. In the case of harbor seals, a substantial fraction moved into the water in response to launches. Some harbor seals may have left their haul-out site until the following low tide; however, numbers occupying haul-out sites shortly after a launch, or the next day, were similar to pre-launch levels. However, it is not likely that any of the pinnipeds on SNI were adversely impacted by such behavioral reactions. Although some pinnipeds, particularly harbor seals, may have incurred TTS, this would have presumably been mild and recoverable.

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APPENDIX A: MAPS OF LAUNCH AZIMUTHS AND MONITORING SITES

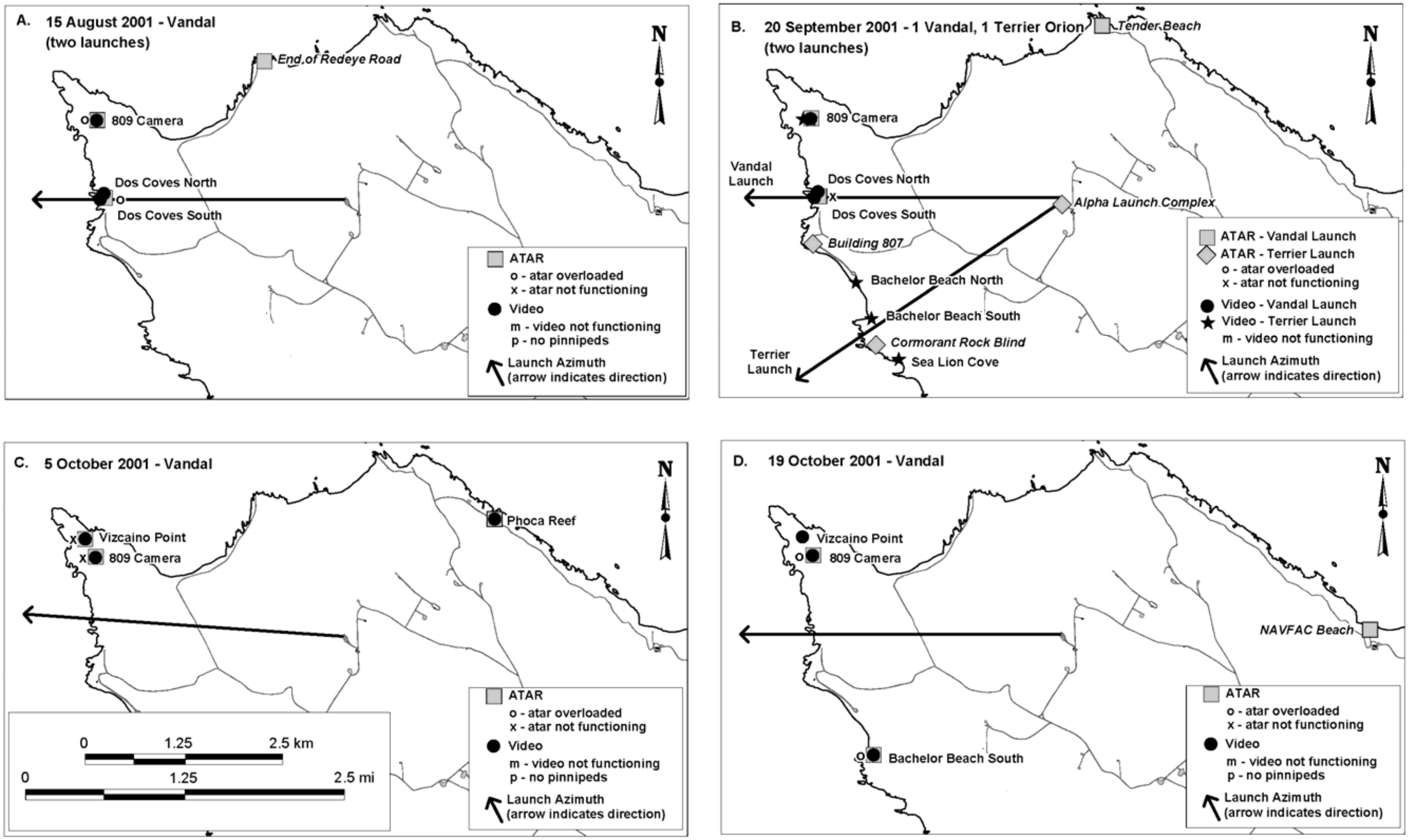

FIGURE A-1. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island in Year 1.

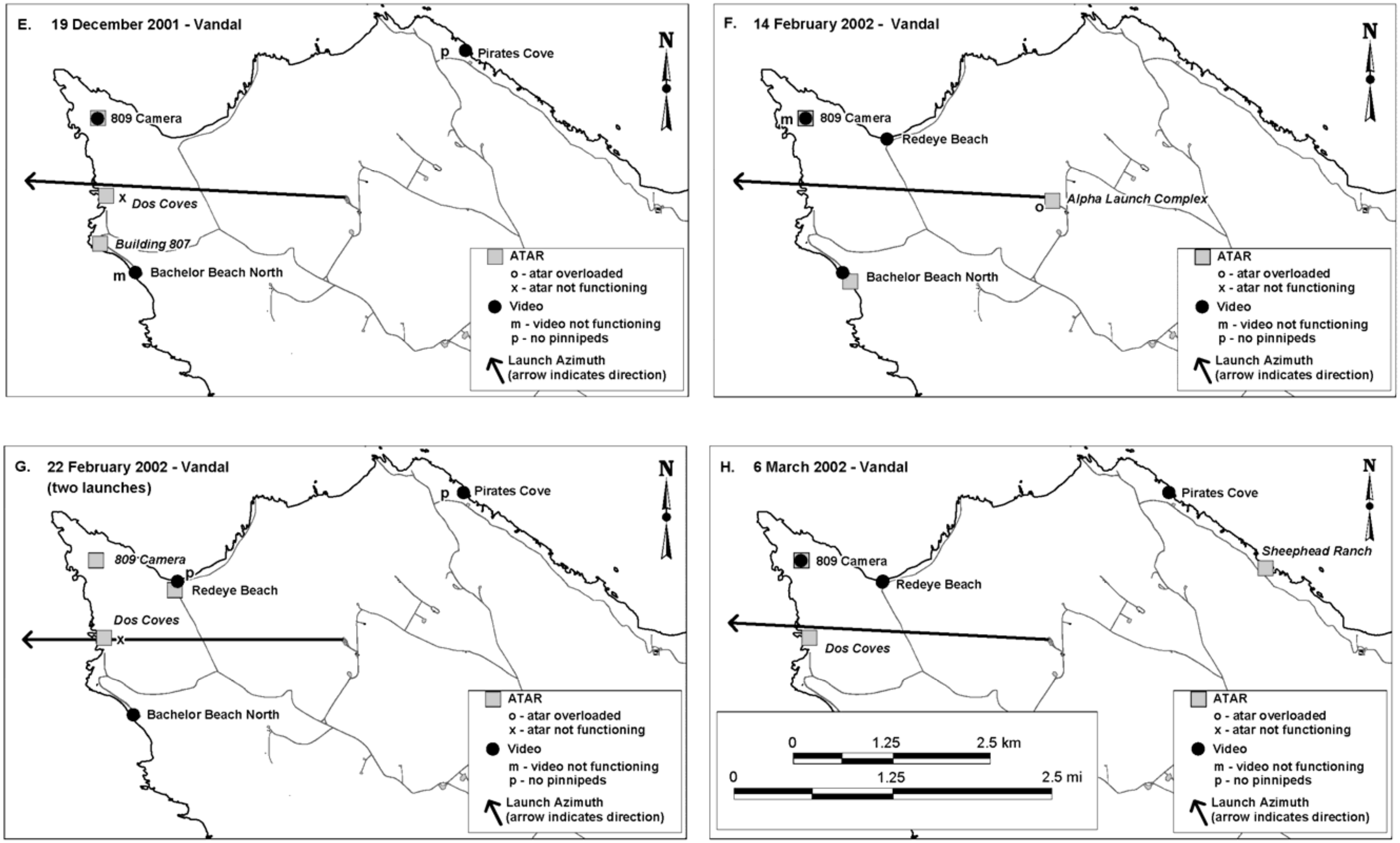

FIGURE 1 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island in Year 1.

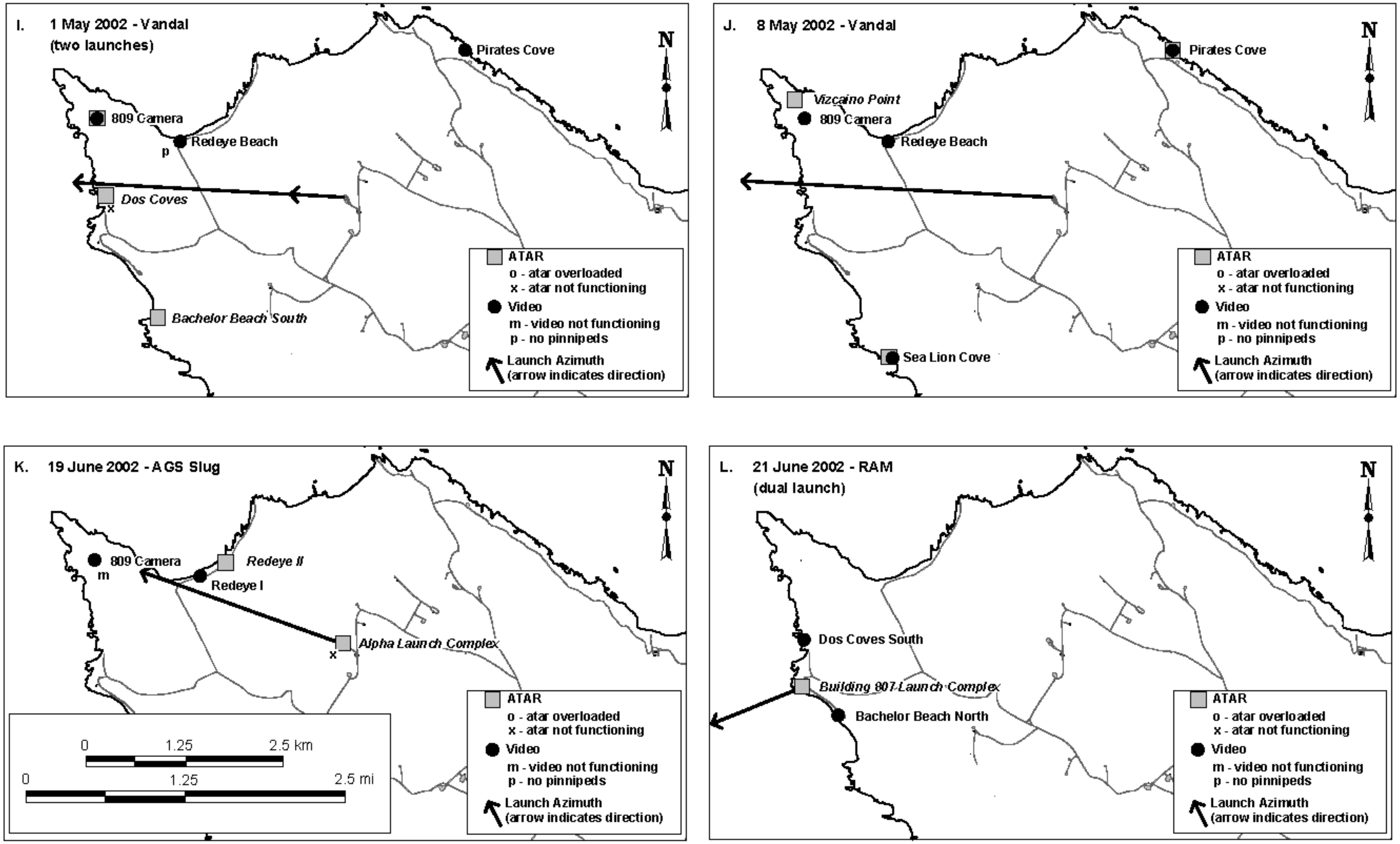

FIGURE A-1 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island in Year 1.

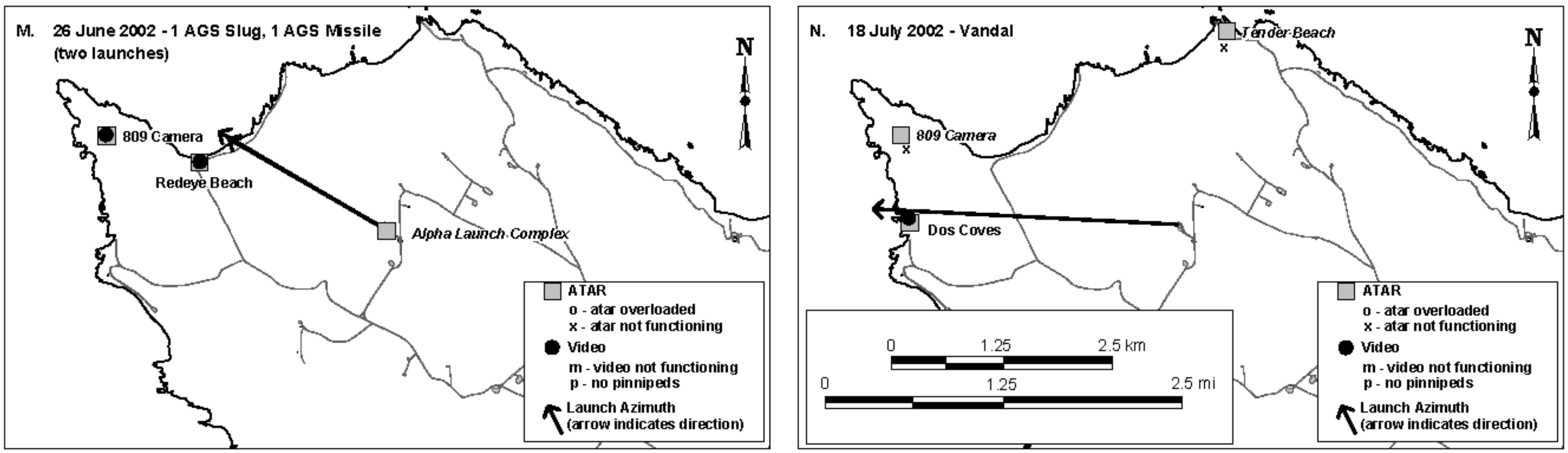

FIGURE A-1 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island in Year 1.

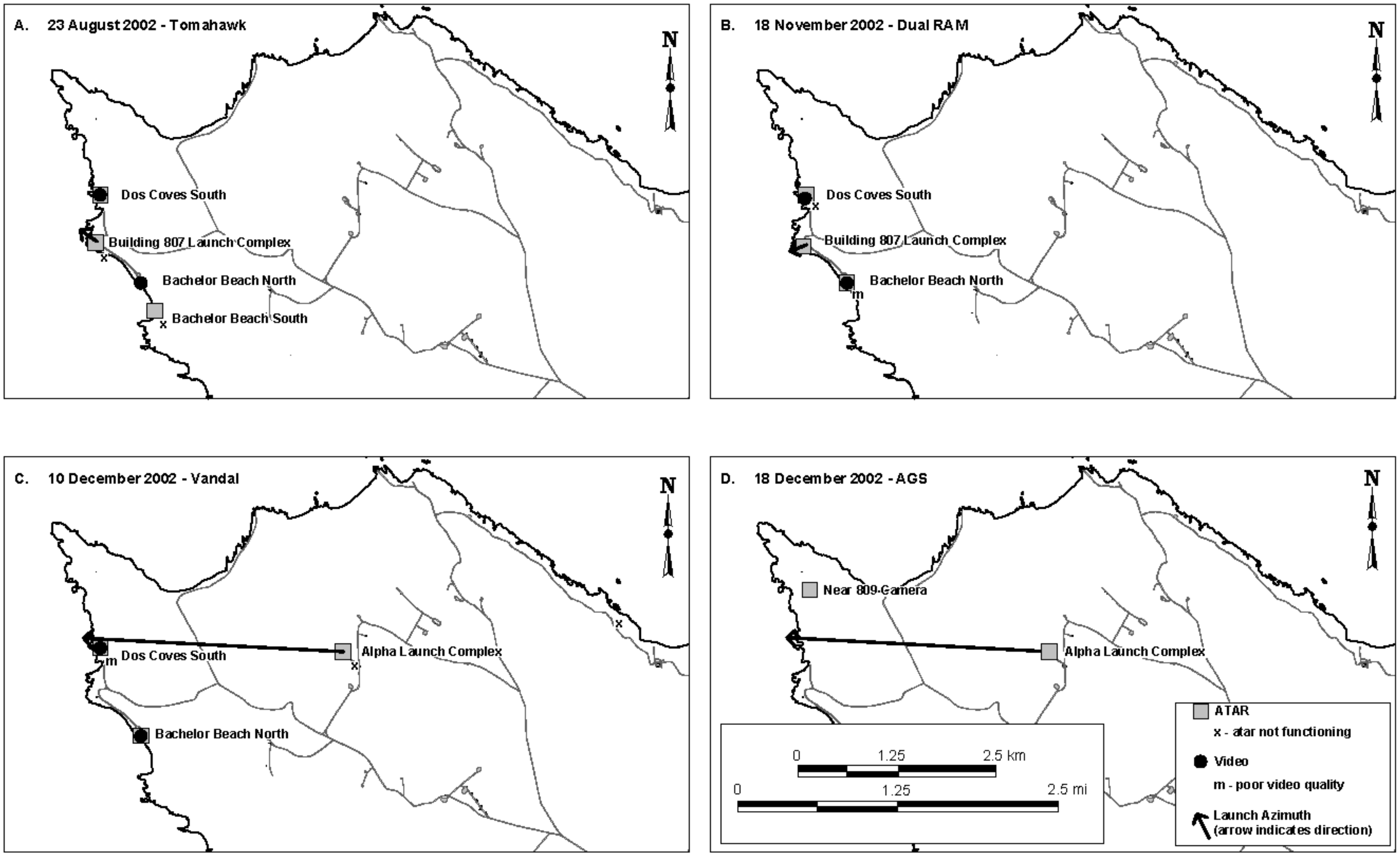

FIGURE A-2. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 2. GQM-163A = Coyote launch.

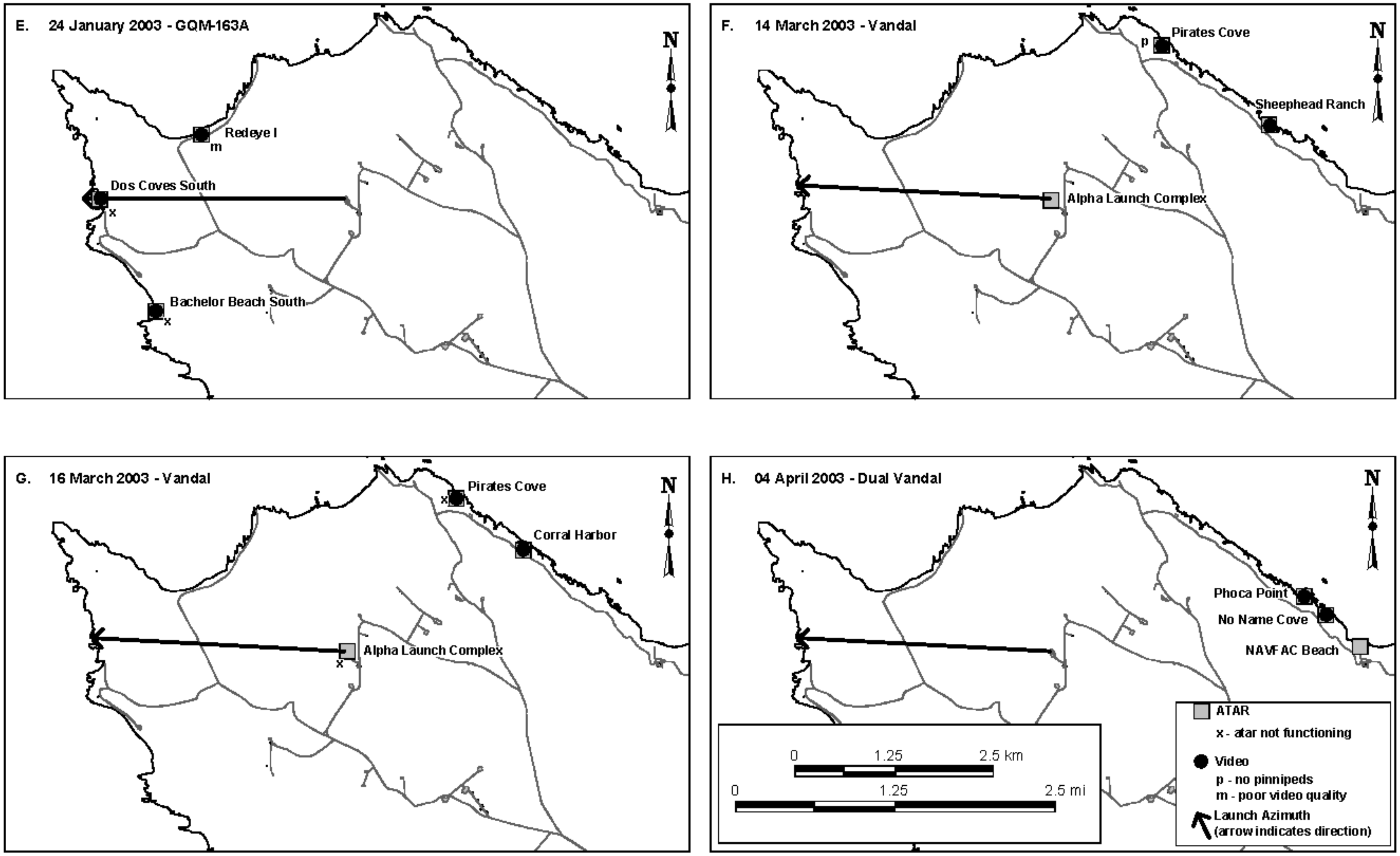

FIGURE A-2 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 2.

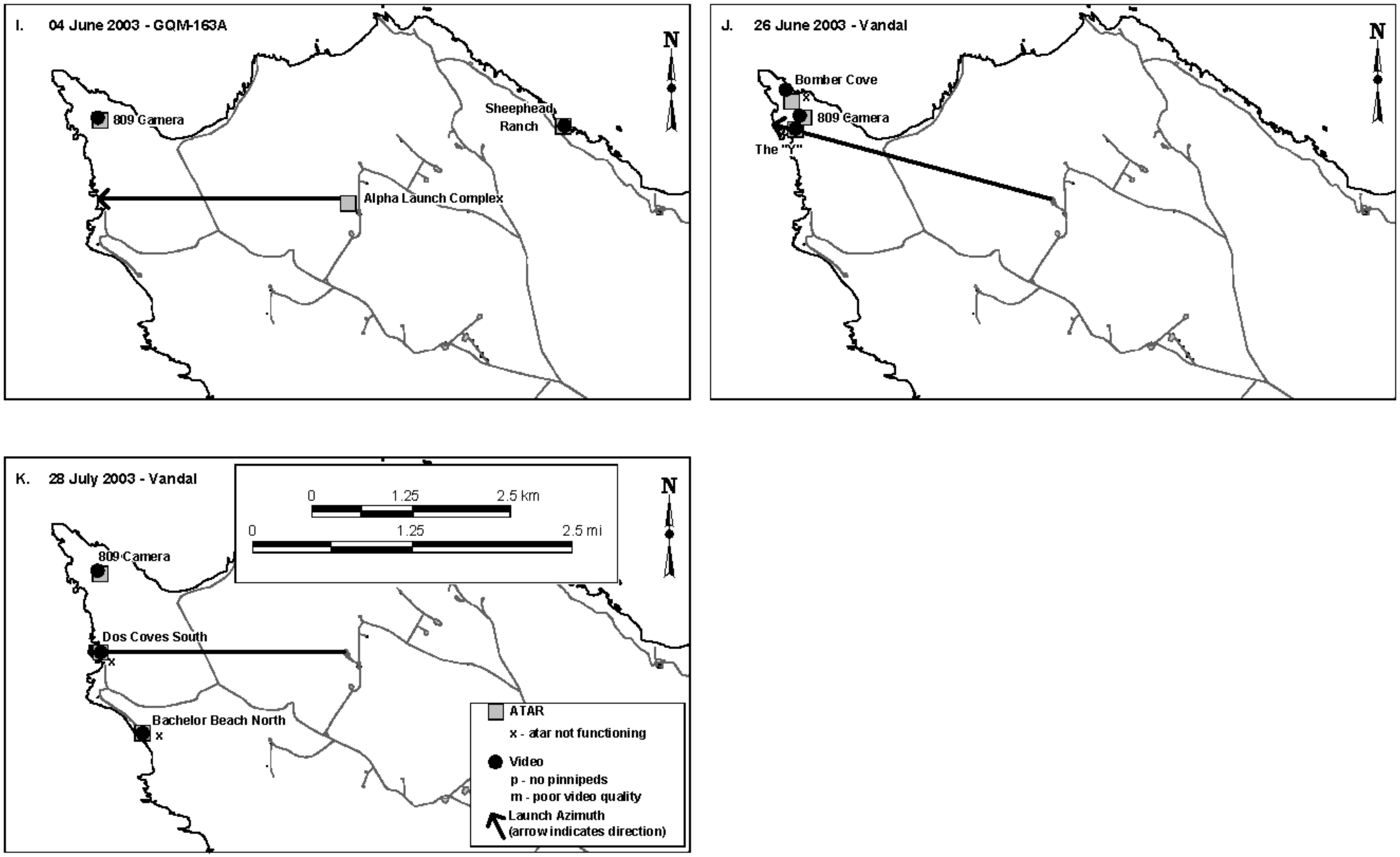

FIGURE A-2 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 2.

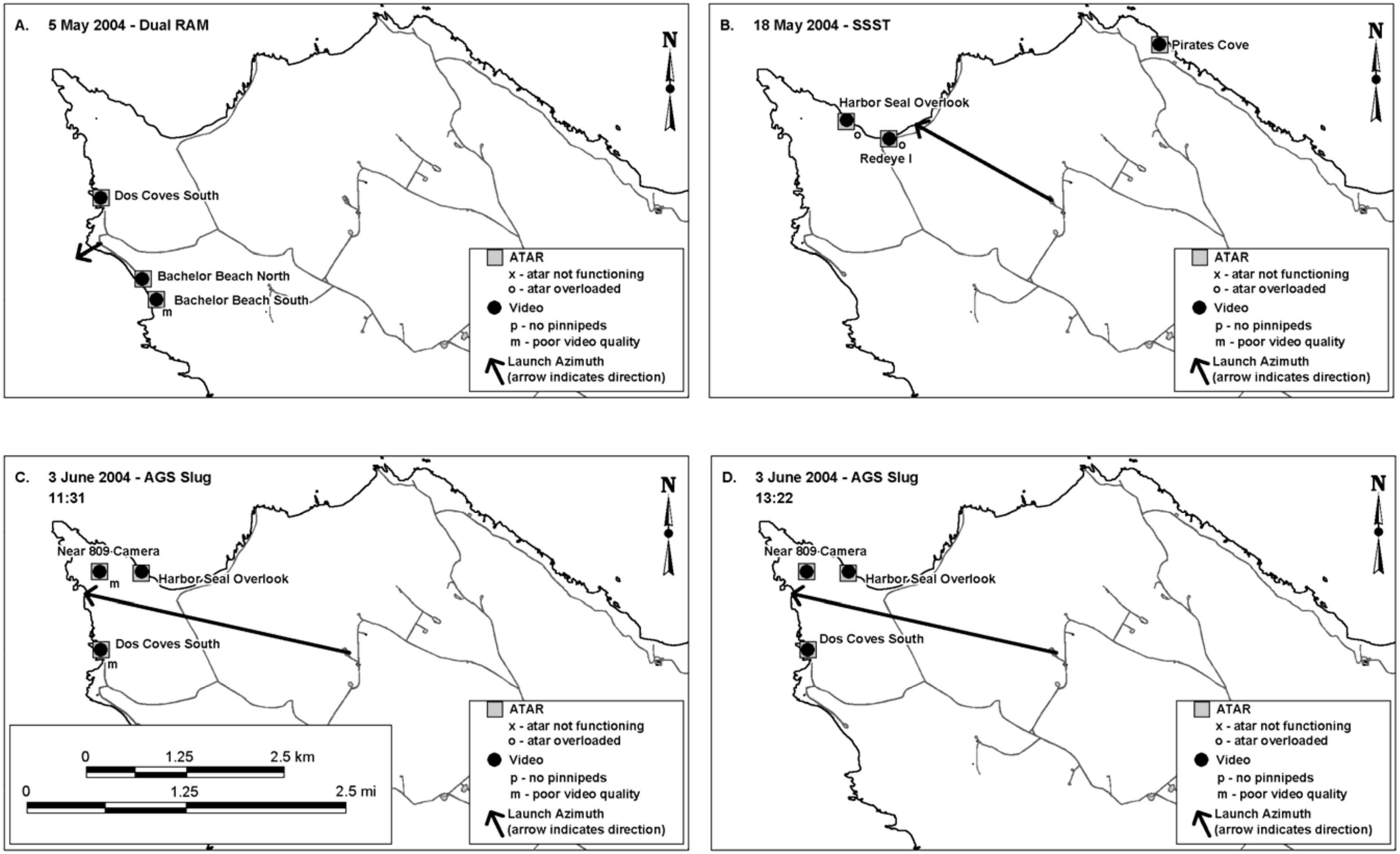

FIGURE A-3. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 3. SSST = Coyote launch.

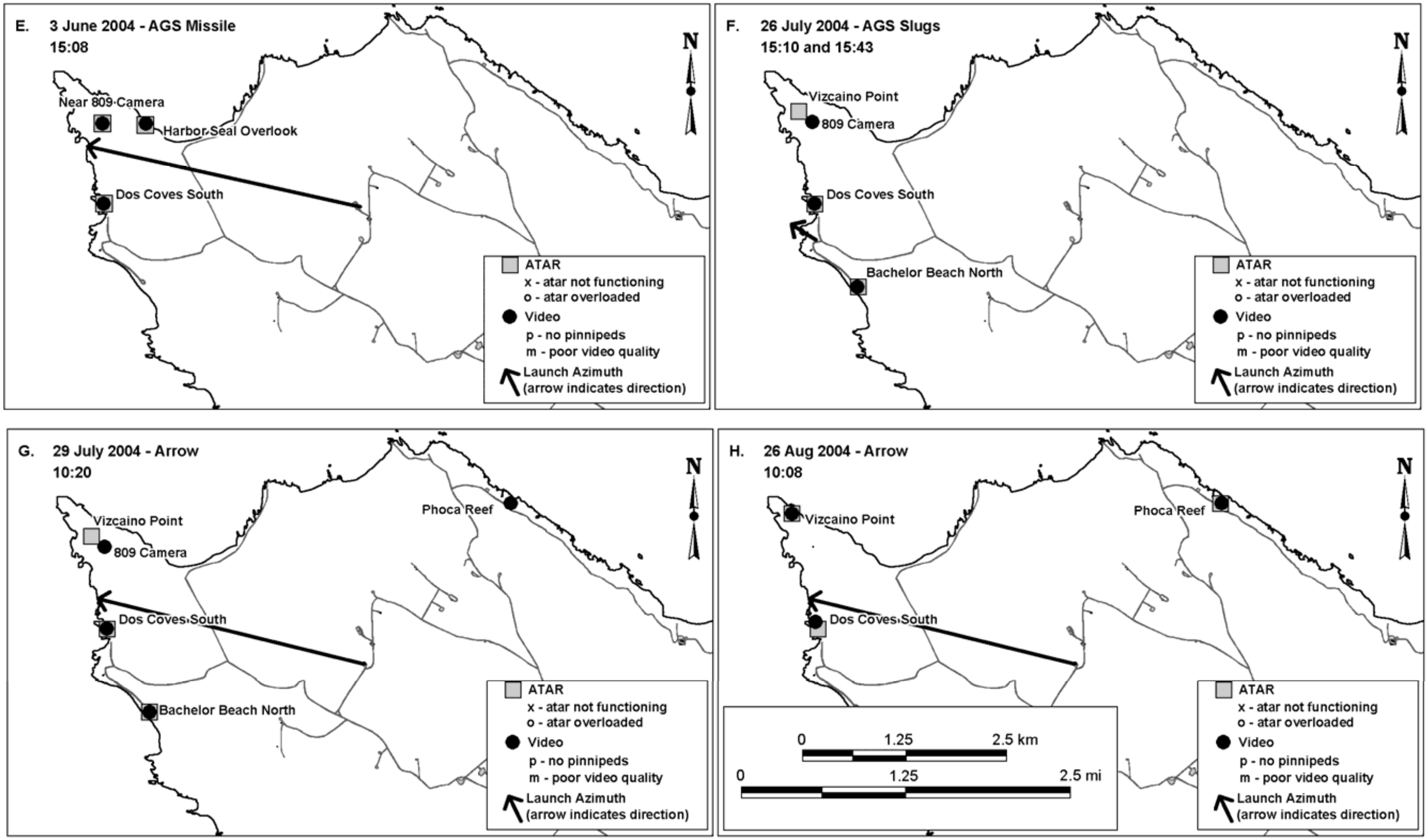

FIGURE A-3 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 3.

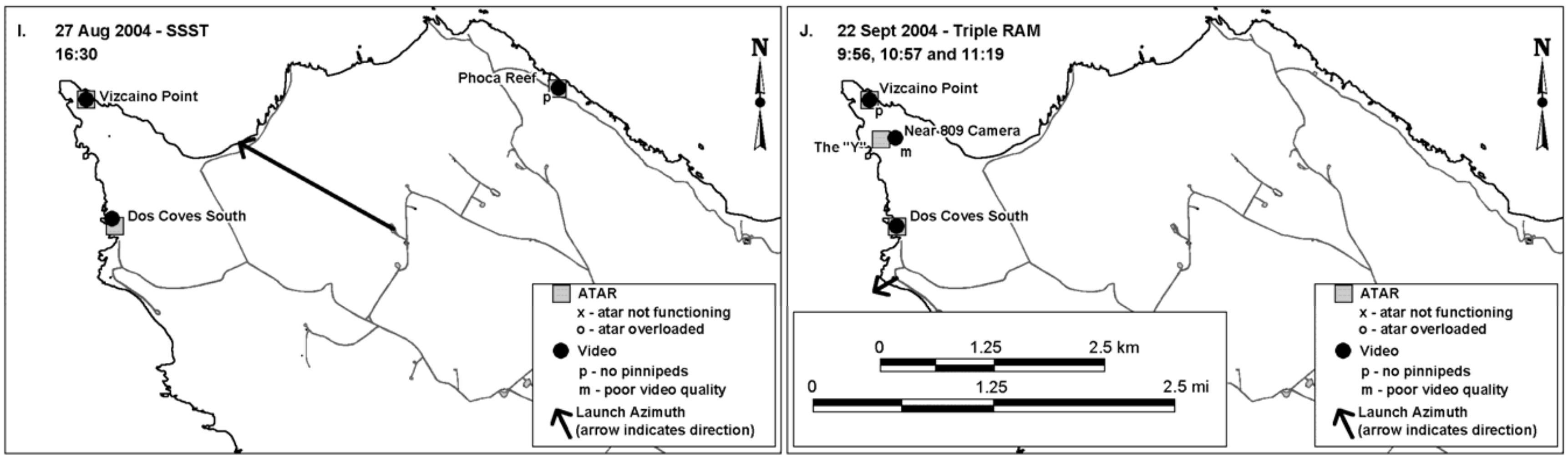

FIGURE A-3 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 3.

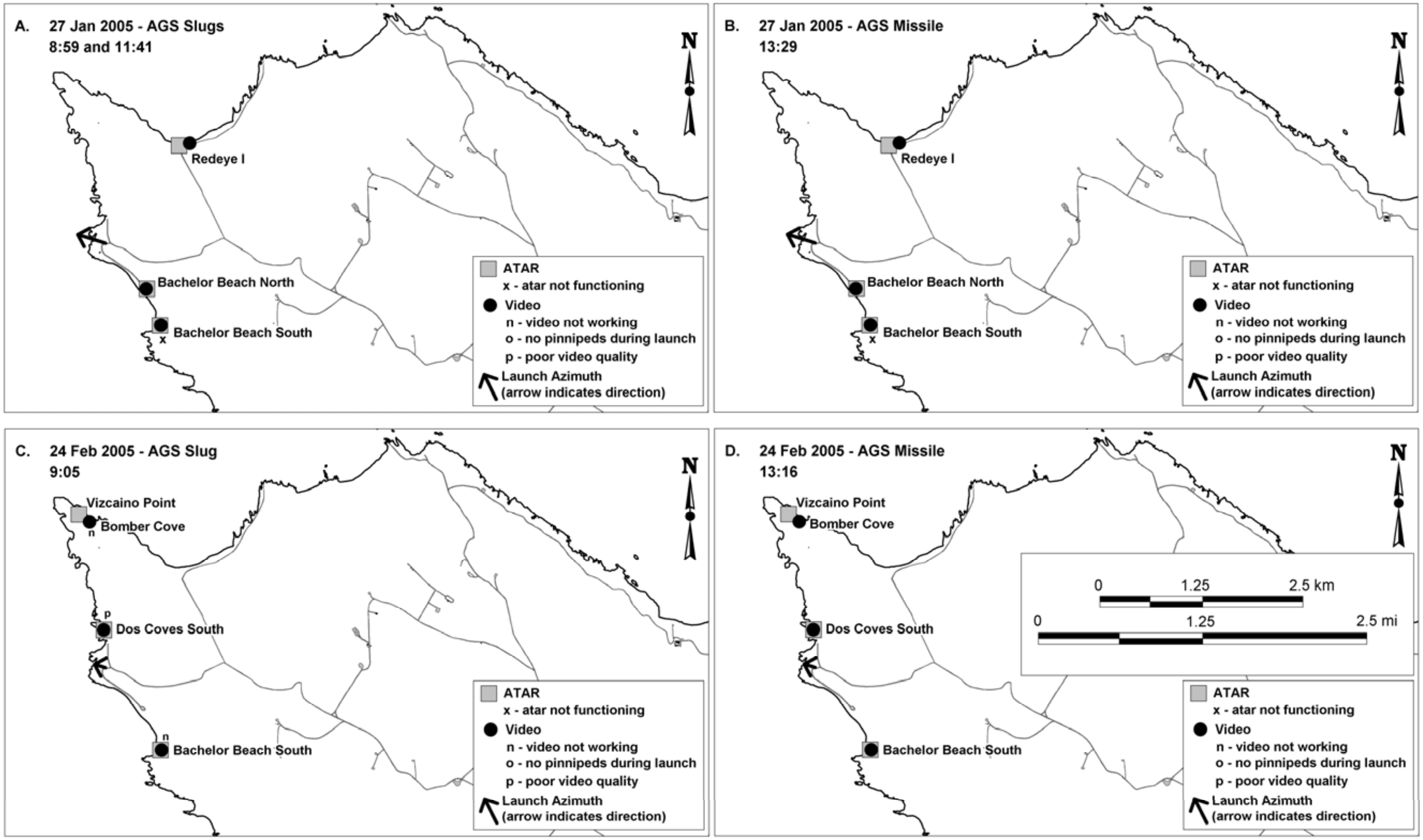

FIGURE A-4. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 4. SSST = Coyote launch.

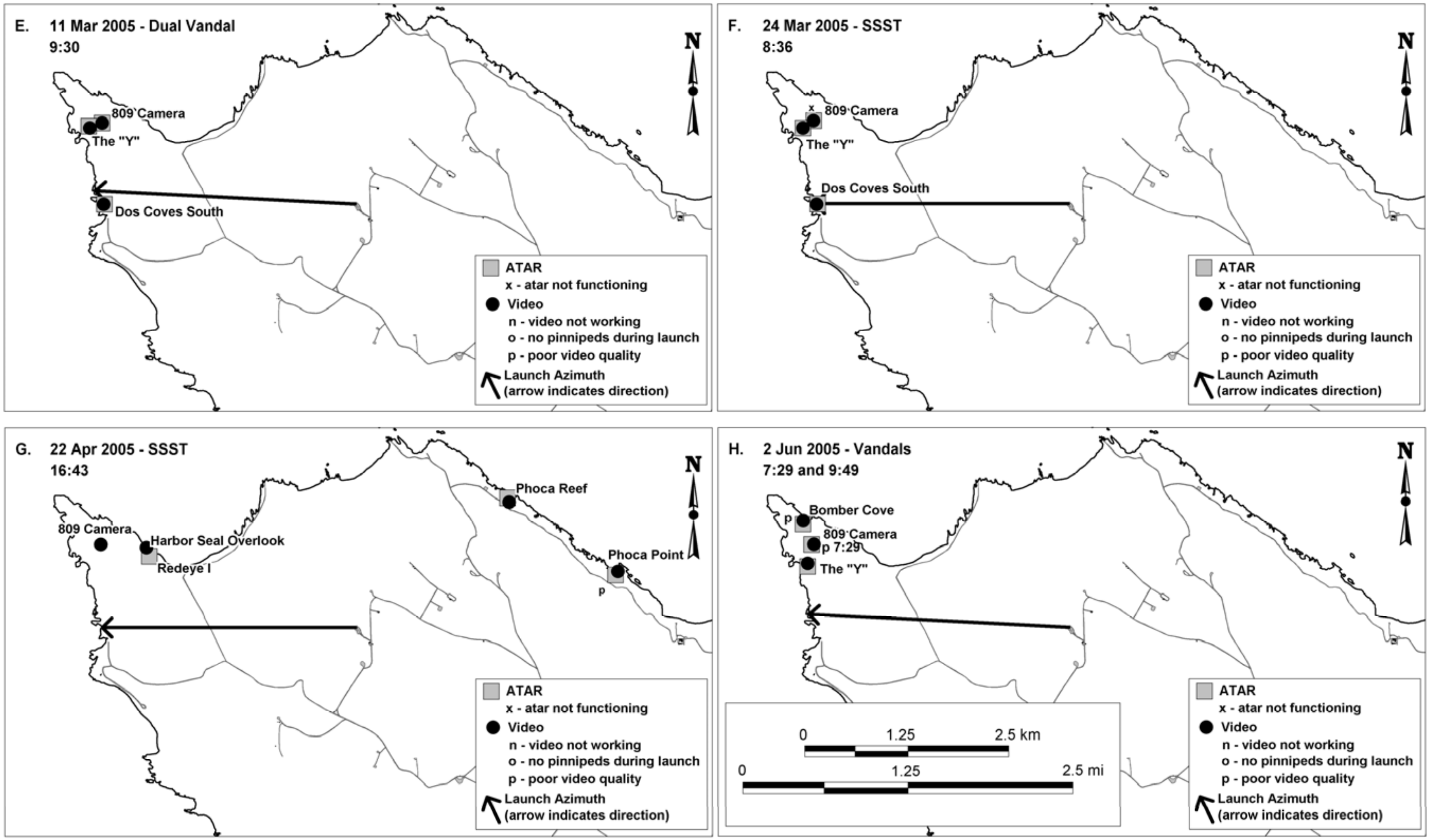

FIGURE A-4 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 4.

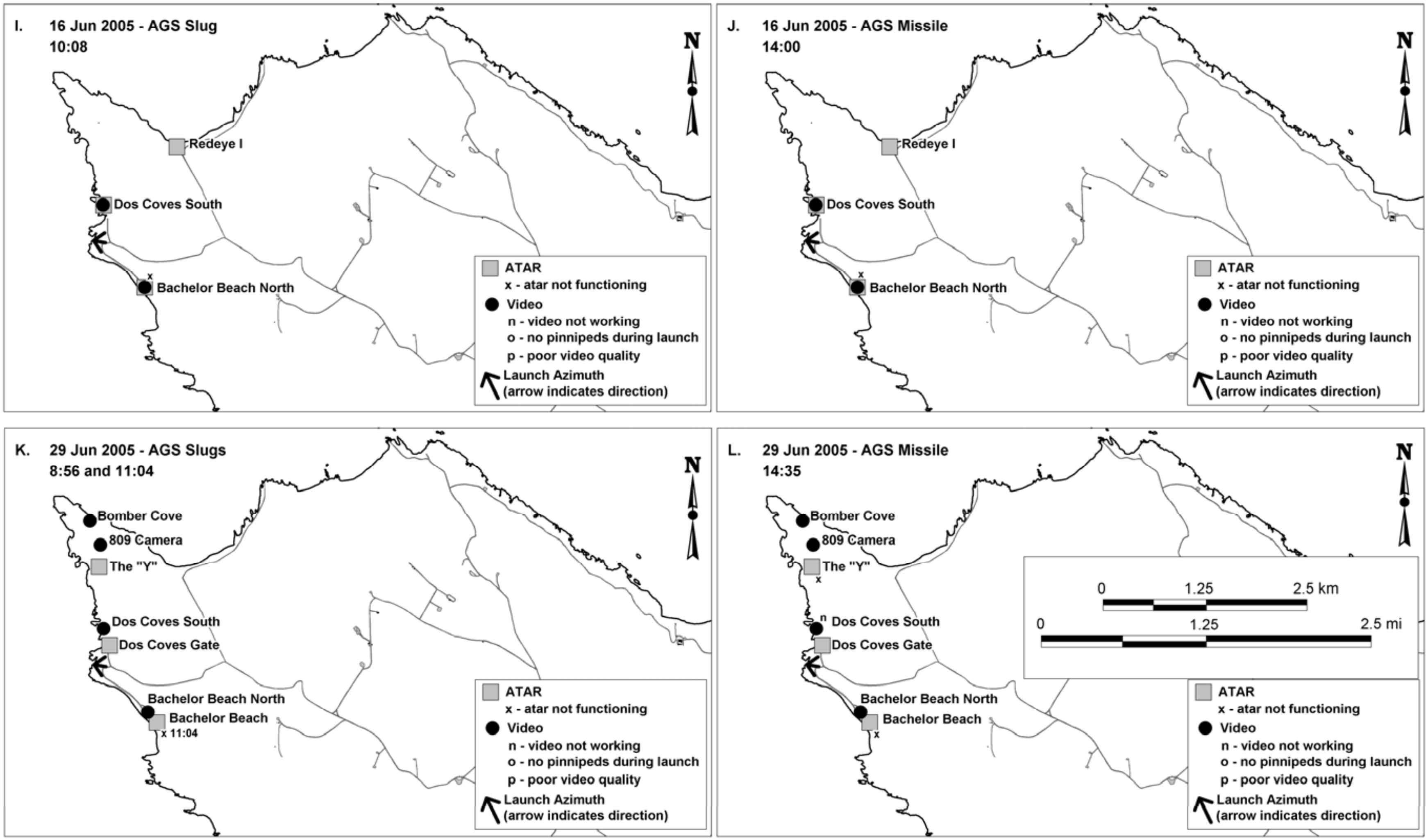

FIGURE A-4 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 4.

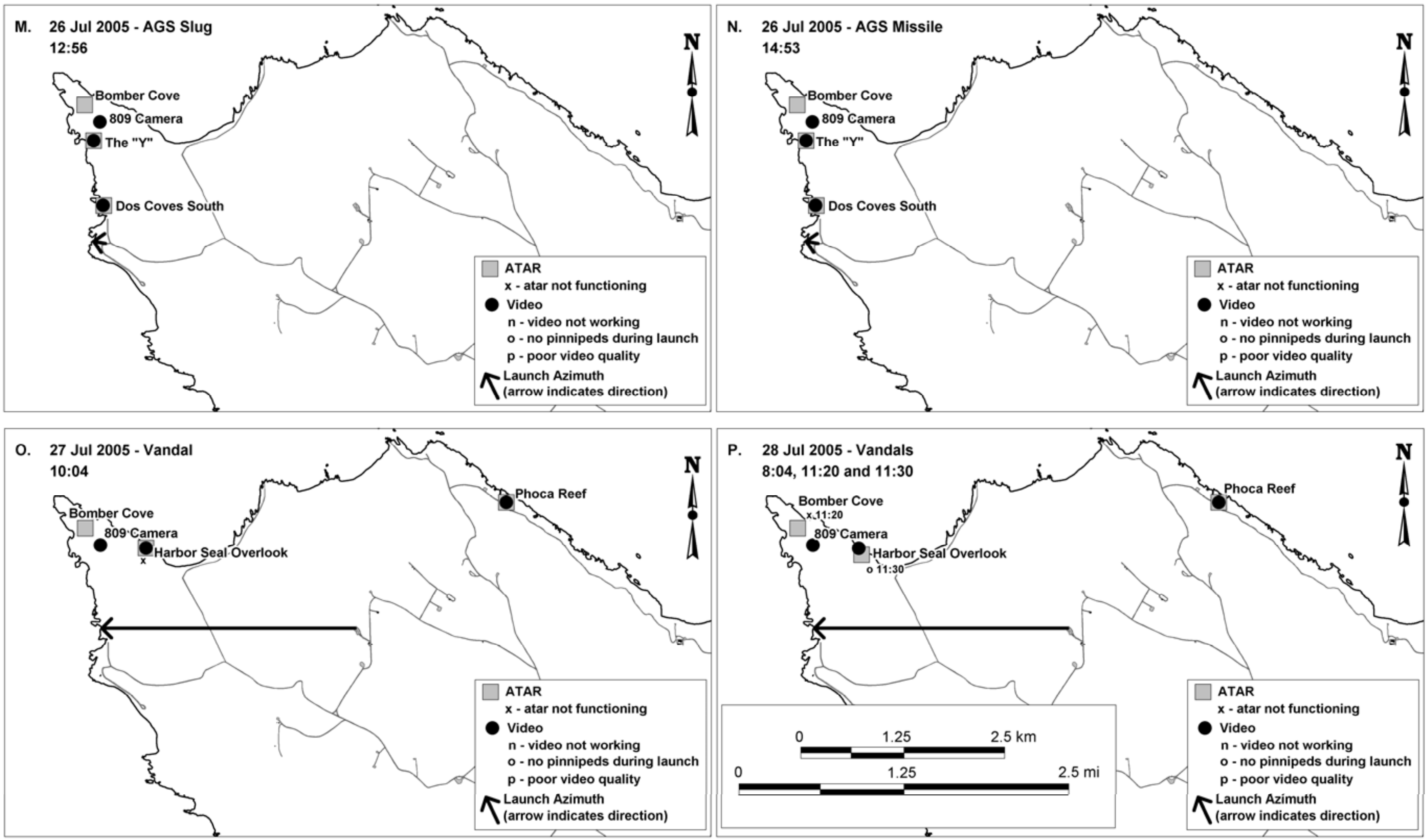

FIGURE A-4 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 4.

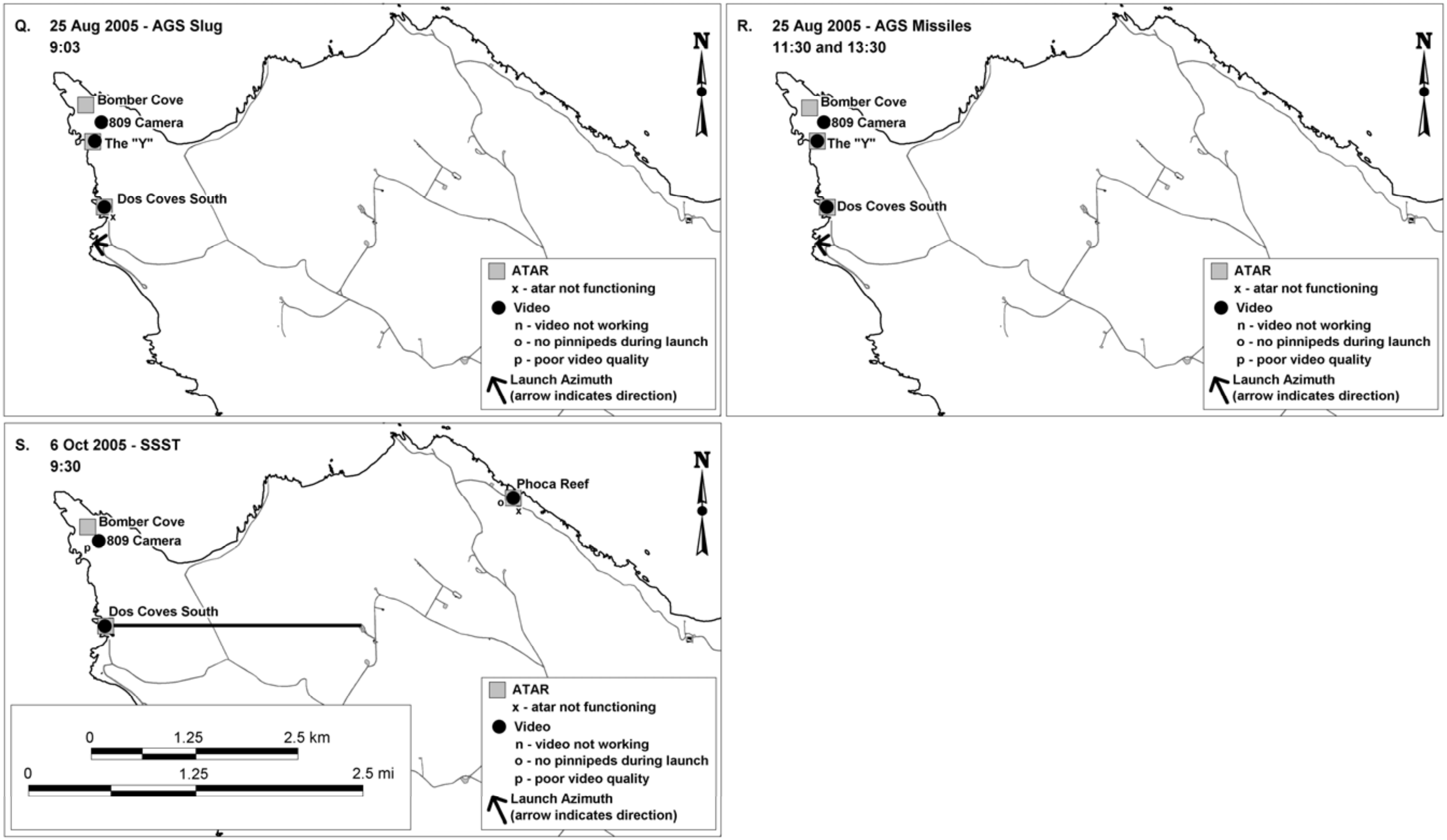

FIGURE A-4 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 4.

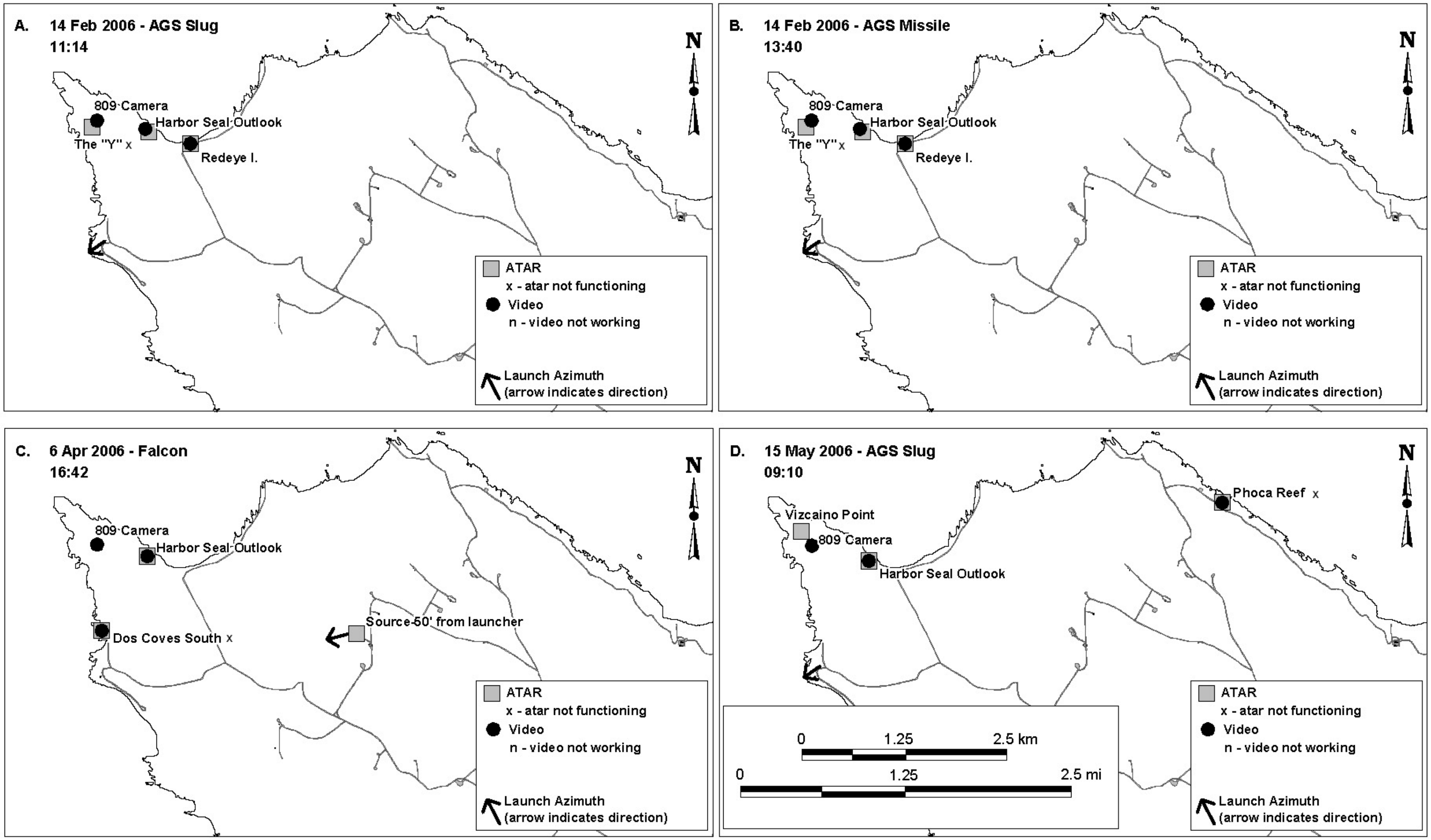

FIGURE A-5. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 5.

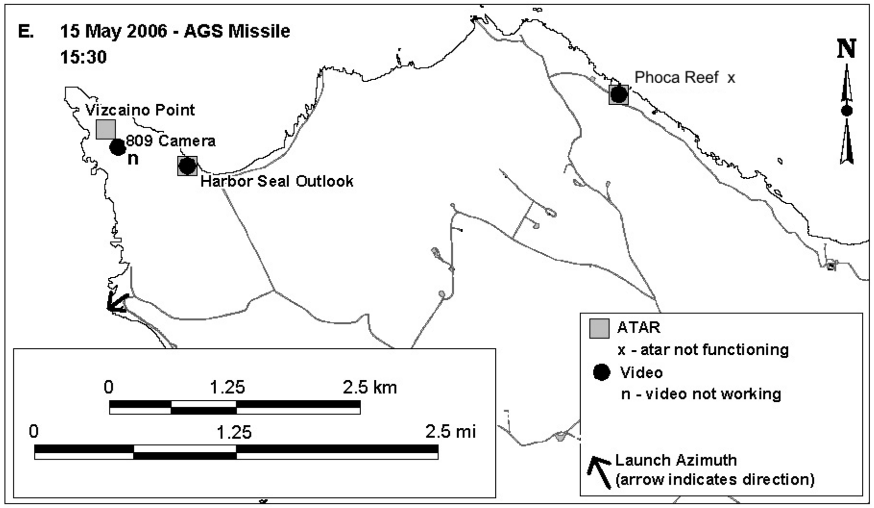

FIGURE A-5 (continued). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 5.

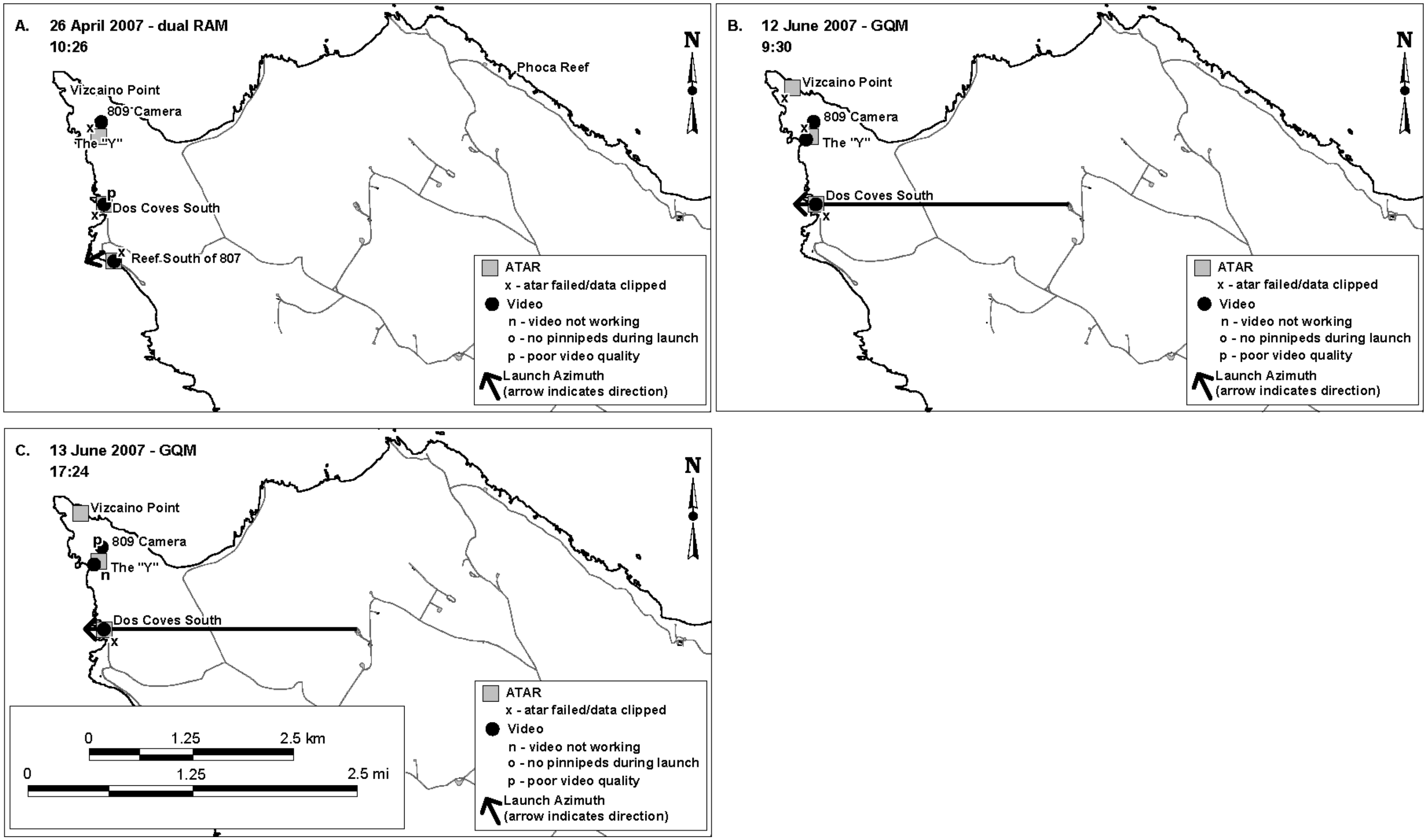

FIGURE A-6. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at SNI in Year 6. GQM = Coyote launch.

APPENDIX B: PREVIOUS RELATED REPORTS AND PAPERS ON CD-ROM

- Annual Report, Aug. 2001–July 2002 launches: LGL Rep. TA2630-3, Oct. 2002
- Annual Report, Aug. 2002–Apr. 2003 launches: LGL Rep. TA2665-2, Jul. 2003
- Comprehensive Report, Aug. 2001–Aug. 2003 launches: LGL Rep. TA2665-3, Jan. 2004
- Published Paper on Aug. 2001–Aug. 2003 launches: M. Holst, J.W. Lawson, W.J. Richardson, S.J. Schwartz and G. Smith (2005), *Pinniped responses during Navy missile launches at San Nicolas Island, California.* p. 477–484 *In:* D.K. Garcelon & C.A. Schwemm (eds.), Proc. 6th Calif. Isl. Sympos., Ventura, CA, Dec. 2003. Nat. Park Serv. Tech. Publ. CHIS-05-01. Inst. Wildl. Stud., Arcata, CA.
- Annual Report, Oct. 2003–July 2004 launches: LGL Rep. TA2665-4, Dec. 2004
- Comprehensive Report, Aug. 2001–May 2005 launches: LGL Rep. TA2665-5, Jun. 2005
- Annual Report, Oct. 2004–Oct. 2005 launches: LGL Rep. TA2665-6, Apr. 2006
- Annual Report, Feb.–Sep. 2006 launches: LGL Rep. TA2665-7, Oct. 2006
- Annual Report, Feb.–Nov. 2007 launches: LGL Rep. TA2665-8, Dec. 2007