Marine Mammal and Acoustical Monitoring of Missile Launches on San Nicolas Island, August 2001 – August 2003

submitted by

Naval Air Weapons Station
China Lake, 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, August 2001 – August 2003

by

Meike Holst[a] and Charles R. Greene, Jr.[b]

[a] **LGL Ltd., environmental research associates**
22 Fisher St., POB 280, King City, Ont., L7B 1A6, Canada

and

[b] **Greeneridge Sciences Inc.**
4512 Via Huerto, Santa Barbara, CA 93110

in association with

The Environmental Company, Inc.
1525 State St., Suite 103, Santa Barbara, CA 93101

for

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ACRONYMS AND ABBREVIATIONS

The following list shows the meaning of acronyms and abbreviations used in this report.

AGS	Advanced Gun System
ASAR	Autonomous Seafloor Acoustic Recorder
ASEL	A-weighted Sound Exposure Level
ATAR	Autonomous Terrestrial Acoustic Recorder
ASL	Above Sea Level
cm	centimeter
CPA	closest point of approach
dB	decibel
DR	Ducted Rocket (pertains to SSST)
Hz	hertz
IHA	Incidental Harassment Authorization
kg	kilogram
m	meter (1 m = 1.09 yards or 3.28 feet)
km	kilometer (1 km = 3281 ft, 0.62 st.mi., or 0.54 n.mi.)
mm	millimeter
MMPA	Marine Mammal Protection Act
NAWCWD	Naval Air Warfare Center Weapons Division
NMFS	National Marine Fisheries Service, U.S. Dept of Commerce
n.mi.	nautical mile (1 n.mi. = 1.15 statute miles or 1.853 km)
rms	root mean square (a type of average)
PTS	Permanent Threshold Shift
RAM	Rolling Airframe Missile
SEL	Sound Exposure Level
SPL	Sound Pressure Level
SSST	Supersonic Sea-Skimming Target
TTS	Temporary Threshold Shift
V/μPa	volts per micropascal
μPa	micropascal
WOSA	Weighted Overlapped Segment Averaging

EXECUTIVE SUMMARY

From 26 August 2002 through 26 August 2003, Naval Air Weapons Station (NAWS) China Lake held an Incidental Harassment Authorization (IHA) 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, California (NMFS 2002). The IHA was issued pursuant to 50 Code of Federal Regulations (C.F.R.) 216, Subpart I (61 Federal Register 15884 et. seq.), and § 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 United States Code (U.S.C.) § 1371 (a) (5). The IHA for the August 2002 to August 2003 period was the second such IHA issued for this purpose; the preceding IHA had authorized the same types of non-lethal takes during the period 1 August 2001 through 31 July 2002. These IHAs allowed for the 'take by harassment' of small numbers of northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*) during routine launch operations on Navy-owned San Nicolas Island.

In both the initial and second IHA Application, a Marine Mammal Monitoring Plan was proposed to monitor any effects of launch activities on marine mammals. This report describes the results of the marine mammal and associated acoustic monitoring program during the August 2002 to August 2003 period. It includes results from 12 launches (including two dual launches) that occurred at San Nicolas Island from 23 August 2002 to 28 July 2003. Corresponding results concerning 19 launches (including one dual launch) during August 2001 through July 2002 are not discussed in detail in this report; those results were described in a previous report by Lawson et al. (2002). However, data from both years of monitoring were used for some of the data analyses. No launches occurred from 1 to 22 August 2002.

The following subsections briefly summarize the monitoring program in August 2001 – August 2003. Details are provided in subsequent chapters of this report.

Missile Launches and Monitoring Program Described

During the August 2002 to August 2003 monitoring period, 12 launches occurred from San Nicolas Island on 11 different days. The launches included one Tactical Tomahawk, a “dual launch” of two Rolling Airframe Missiles (RAM) in quick succession, six Vandals (including a dual launch; total of seven Vandals), two Advanced Gun System (AGS) missiles, and two GQM-163A Supersonic Sea-Skimming Targets (SSST). The dual RAM launch on 18 November 2002, and the dual Vandal launch on 4 April 2003, consisted of two missiles that were launched within seconds of each other, and are counted here as a single launch. On another occasion, 18 December 2002, two AGS missiles were launched sequentially, 1 hr 45 min apart; those were counted as separate launches. On eight additional launch dates, single vehicles were launched.

During the August 2001 to July 2002 monitoring period, 19 launches were conducted on 14 days. These launches involved 14 Vandals, one Terrier Orion, an Advanced Gun System (AGS) missile and two slugs, and dual launch of Rolling Airframe Missiles (RAM).

Vehicles were launched from one of two launch complexes on San Nicolas Island. The Tomahawk and dual RAMs were launched from the Building 807 Launch Complex. This site is located close to shore on the western end of San Nicolas Island, approximately 35 ft (11 m) above sea level. The other vehicles, including Vandals, AGS missiles, Terrier Orion, and GQM-163A targets, were launched from the Alpha Launch Complex. This launch site is 625 feet (190.5 m) above sea level on the west-central part of San Nicolas Island.

The vehicles launched from the Alpha Launch Complex had launch elevation angles ranging from 8 to 65º above horizontal and were directed westward. They crossed the west end of San Nicolas Island at altitudes up to 17,300 ft (5.3 km). Launches from the Building 807 Launch Complex had elevation angles of 8-10 and 90º and crossed the beach at altitudes of 50 and 1000 ft (15 and 305 m), respectively.

Acoustic Measurements During Missile Launches

Vehicle flight sounds were measured as received at various locations on the periphery of San Nicolas Island during launches conducted from August 2001 to August 2003. The Tomahawk resulted in a flat-weighted sound pressure level (SPL), measured over the 3 to 20,000 hertz (Hz) bandwidth, of 93 decibels (dB) re 20 micropascal (µPa) at a site located ~1739 ft or 530 m from the closest point of approach (CPA) of the missile. The dual RAM launches produced SPLs ranging from 90 dB ~2264 ft (690 m) from the CPA to 130 dB recorded 50 ft (15 m) from the launcher. The Terrier Orion SPLs ranged from 89 dB near the launcher to 138 dB at a nearshore site (the 138-dB value appears anomalously high given this missile's greater distance from the microphones). The AGS missiles resulted in SPLs of 95 to 109 dB at nearshore sites ~0.7-1.3 mi. (1.2-2.1 km) from the CPA. Levels were much higher (up to 156 dB) 50 ft (15 m) from the launch site.

The low-elevation (8º) Vandals produced SPLs of 137 dB near the launcher, 139 to 142 dB below the launch azimuth, 123 to 137 dB ~0.5-0.6 mi. (0.8-1.0 km) from the CPA, 95 to 135 dB 0.7-1.2 mi. (1.1-1.8 km) from the CPA, 85 to 102 dB 1.3-1.8 mi. (2.1-2.9 km) northeast of the launch site, and 92 to 121 dB ~1.9-2.5 mi. (3-4 km) east of the launcher. The high-elevation (42º) Vandals produced SPLs of 93 dB directly below the launch azimuth (2.9 km from the CPA), 92 to 97 dB ~1.4-1.7 mi. (2.3-2.8 km) from the CPA, and 96 dB 1.1 mi. (1.7 km) from the CPA. The GQM-163A targets produced SPLs of 126 dB near the launcher, 123 dB at a site ~0.6 mi. or 1 km from the CPA, 115 dB ~0.9 mi. (1.4 km) from the CPA, and 101 dB 1.8 mi. (2.9 km) to the northeast of the launcher.

Another measure of each launch sound, the SEL or Sound Exposure Level, represents the total received energy over the 3 to 20,000 Hz bandwidth at the same measurement locations as noted above. The Tomahawk produced an SEL of 105 dB re (20 ìPa)^2· s (flat-weighted). SELs ranged from 97 to 131 dB for the dual RAM flights, 93 to 138 dB for the Terrier Orion launch, and 93 to 143 dB for the AGS missiles. The low-elevation (8º) Vandals produced SELs ranging from 92 dB at nearshore locations to 136 dB near the launcher, and the high-elevation Vandal resulted in SELs ranging from 97 to 104 dB at nearby sites. The GQM-163A targets produced SELs ranging from 101 dB at a nearshore location to 126 dB at the launch site. A-weighted SPL and SEL values were generally several decibels lower.

None of the recorded sound pressures appears to be sufficiently strong to induce Temporary Threshold Shift (TTS), assuming that an ASEL of 145 dBA re (20 ìPa)^2· s from a single launch might cause TTS.

Behavior of Pinnipeds During Missile Launches

Behavior of pinnipeds around the periphery of western San Nicolas Island 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 and following the launches. Monitoring was attempted at up to three sites during each launch, with launch-to-launch variation in the locations monitored.

California sea lions

California sea lions were observed at six of the 11 launch dates in August 2002 to August 2003, with observations of one to three sites on each date (total of 10 site-date combinations). Over the course of both monitoring years, a total of 32 sites were monitored on 18 dates. Responses of California sea lions to the launches varied by individual and age group. Some sea lions exhibited startle responses and increased vigilance for a short period after each launch, whereas others hardly reacted to the launch. Other sea lions, particularly pups that were playing in groups along the margins of the haul-out beaches prior to launches, appeared to react more vigorously by moving along the beach or entering the water. For sea lions, all age classes settled back to pre-launch behavior patterns within minutes of the launch time. However, sea lions were significantly more active after the launch compared with before the launch. Responses of California sea lions to the launches were related to sound levels and CPA distances to missiles. More California sea lions moved or entered the water with decreasing CPA distances and increasing sound exposure levels (SELs).

Northern elephant seals

Elephant seals were observed at one or two sites during five of the 11 launch dates (total of seven site-date combinations). Over the course of both monitoring years, a total of 18 sites were monitored on 13 dates. The majority of elephant seals exhibited little reaction to launch sounds. Most individuals merely raised their heads briefly upon hearing the launch sounds and then quickly returned to their previous activity pattern (usually sleeping). During some launches, a small proportion of northern elephant seals on the beach repositioned or moved a small distance away from their resting site, but usually settled within minutes; one seal entered the water. The percentage of elephant seals that moved in response to the launches was marginally higher with decreasing horizontal closest point of approach (CPA) distances from the missiles.

Harbor seals

Harbor seals were observed at one or two sites during four of the 11 launch dates (total of six site-date combinations). Over the course of both monitoring years, a total of 18 sites were monitored on 11 dates. During the majority of these launches, most harbor seals left their haul-out sites, entered the water, and did not return during the duration of the video-recording period. Reactions of harbor seals to launch sounds appear to be variable. There was no evidence that the responsiveness of seals was any less for missiles whose CPA distances were large (2-3.5 km) or whose SELs were lower.

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

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 both years of monitoring, few if any pinnipeds were exposed to sound levels above 138 dB re 20 µPa SEL on a flat-weighted basis, or 130 dB SEL on an A-weighted basis, so TTS is unlikely.

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.

Approximately 770 California sea lions, 130 northern elephant seals, and 247 harbor seals on the monitored beaches are estimated to have been affected by launch sounds during the August 2002 to August 2003 period. Of the California sea lions, most were young animals such as pups or juveniles. These numbers are probably underestimates, because not all pinniped beaches around western San Nicolas Island could be monitored during any given launch, even though extrapolation of data for all potential haul-out sites was attempted. Given the lack of evidence of any serious effects on pinnipeds at the sites that were monitored, it is not likely that many (if any) of pinnipeds on San Nicolas Island were adversely impacted by the launches.

Behavior of some pinnipeds occurring near the launch azimuths during the launch operations was affected in subtle ways. 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 site until the following low tide). Previous monitoring from August 2001 to July 2002 showed that numbers of pinnipeds occupying haul-out sites after a launch were similar to pre-launch levels (Holst and Lawson 2002).

1. MISSILE LAUNCHES AND MONITORING PROGRAM DESCRIBED[1]

From 26 August 2002 through 26 August 2003, Naval Air Weapons Station (NAWS) China Lake held an Incidental Harassment Authorization (IHA) 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, California, from August 2002 – August 2003 (NMFS 2002; see Appendix A). The IHA for the August 2002 to August 2003 period was the second such IHA issued for this purpose; the preceding IHA had authorized the same types of non-lethal takes during the period 1 August 2001 through 31 July 2002 (Lawson et al. 2002). These IHAs allowed 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 launches from Navy-owned San Nicolas Island.

In both the initial and second IHA Application, a Marine Mammal Monitoring Plan was proposed to monitor any effects of launch activities on marine mammals. This report describes the results of the marine mammal and associated acoustic monitoring program during the period from August 2002 through August 2003, the second year of launch monitoring at San Nicolas Island. Twelve launches (including two dual launches) occurred at San Nicolas Island on 11 dates during that period, ranging from 23 August 2002 to 28 July 2003. Corresponding results concerning 19 launches (including one dual launch) on 14 dates during August 2001 through July 2002 are not discussed in detail in this report; those results were described in a previous report by Lawson et al. (2002). However, data from both years of monitoring were used for some of the data analyses. No launches occurred from 1 to 22 August 2002.

This report describes the vehicles and their launch processes, the associated monitoring program, and the basic monitoring results for the launches conducted by the Navy at San Nicolas Island, California.

This report includes four chapters:

1. background, introduction, and description of the Navy's missile launches in the period August 2002 through August 2003 [this chapter];
2. acoustical monitoring during the missile launches [Chapter 2];
3. visual monitoring of pinnipeds [Chapter 3];
4. estimated numbers of pinnipeds affected by the missile sounds during these launches [Chapter 4].

1.1 Background Information on Vandal

The Vandal, designated MQM-8G, is 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. 1.1). The Vandal is 25.2 feet (7.7 m) long, excluding the booster, and 28 in (71 cm) in diameter. The Vandal is an evolved version of the (former) Talos missile. There are three variants of the Vandal, the standard, ER, and EER; the EER variant, including booster, weighs 8100 lb (3,674 kg). The variants differ primarily in their operational range.

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[1] By **Meike Holst**, LGL Ltd., environmental research associates.

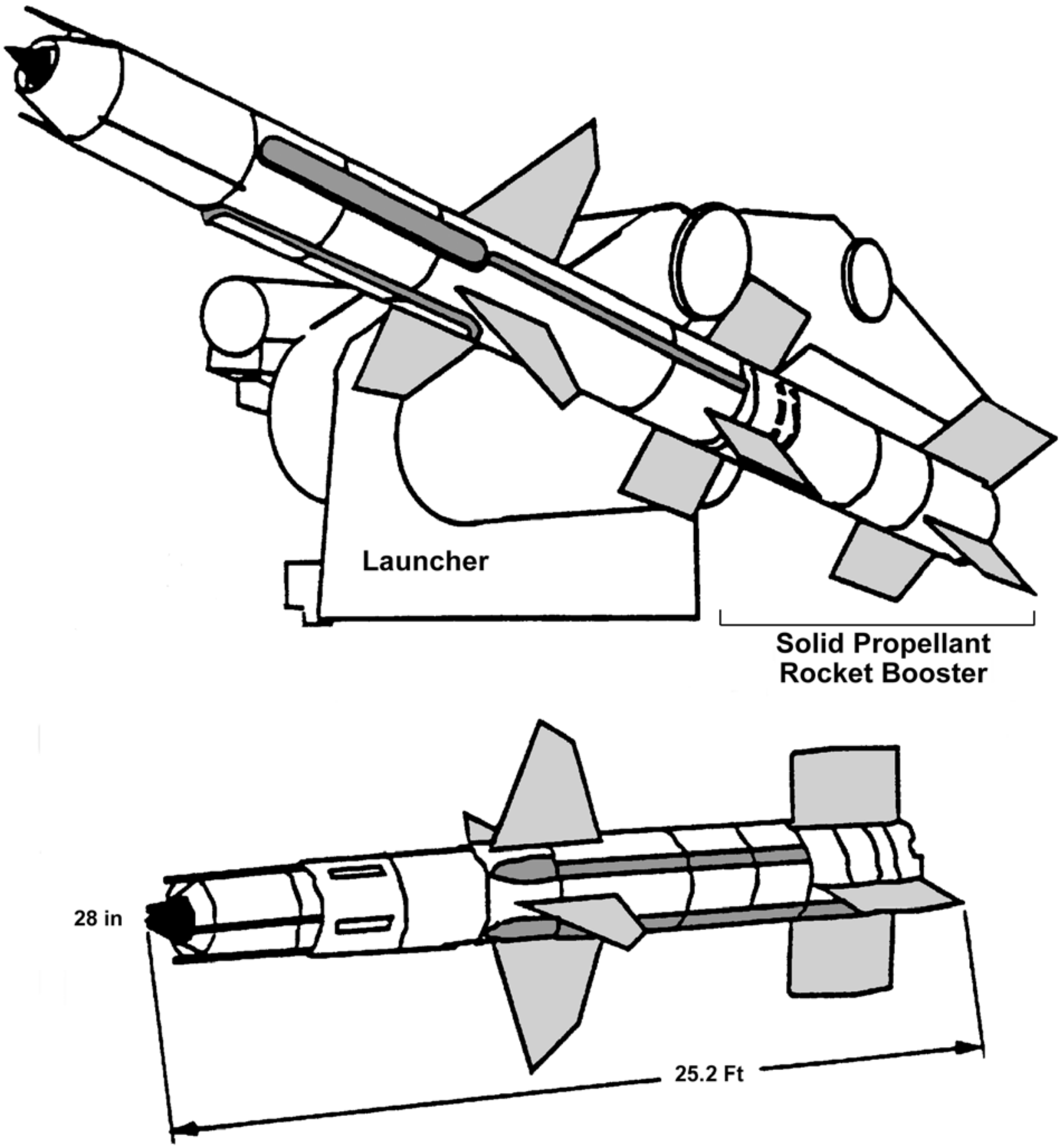

FIGURE 1.1. The Vandal is a supersonic vehicle that is accelerated to ramjet operational speed by a solid propellant rocket booster. The ER (top) and EER (bottom) Vandal variants are identical in dimensions, with the EER having greater range and weight. The Vandal is launched from a dedicated launcher system at the Alpha Launch Complex on San Nicolas Island.

Vandals have no explosive warhead. At launch, the Vandal is accelerated for several seconds by a solid propellant rocket booster, to a speed sufficient for a ramjet engine to start. After several seconds of thrust, the booster is discarded, and the missile continues along its flight path at supersonic speed under ramjet power. The expended booster rocket drops into the water west of San Nicolas Island.

Vandals are remotely-controlled, non-recoverable missiles that are launched from a land-based launch site on the western part of San Nicolas Island (Fig. 1.2). The Vandal launch site, hereafter referred to as the Alpha Launch Complex, is 625 ft (190.5 m) above sea level (ASL) on the west-central part of San Nicolas Island (Fig. 1.3).

Vandal launch trajectories can vary from near-vertical liftoff, crossing the west end of San Nicolas Island at an altitude of about 13,000 feet (3962 m), to a nearly horizontal launch profile crossing the west end of San Nicolas Island at an altitude of about 1000 feet (305 m). With a launch angle 13º, the Vandal can descend to a sea-skimming altitude several nautical miles out at sea, or it can continue offshore at higher altitude.

The Vandal can be launched singly, or in some cases, in sequential launches spaced closely in time. If launched sequentially, two Vandals are launched in succession from the same pad (Fig. 1.4).

1.2 Background Information on the GQM-163A

The GQM-163A Supersonic Sea-Skimming Target (SSST) has been designed to be an expendable, ducted rocket-powered target 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 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 GQM-163A is being developed as a replacement for the Vandal.

The SSST vehicle assembly consists of two primary subsystems: MK 12 solid propellant motor and the GQM-163A target vehicle. The GQM-163A target vehicle consists of the Ducted Rocket (DR) 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 GQM-163A target utilizes the unmodified Vandal launcher, currently installed at the Alpha Launch Complex on San Nicolas Island, with a Launcher Interface Kit (LIK). A modified AQM-37C Aerial Target Test Set (ATTS) is utilized for target checkout, mission programming, verification of the vehicle's ability to per-form the entire mission, and homing updates while the vehicle is in flight.

Following launch, booster separation, DR ignition and vehicle apogee, the GMQ-163A target dives to 16 ft (5 m) altitude while maintaining a speed of Mach 2.5. The target then 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 GQM-163A target settles down to an altitude of 13 ft (4 m) and Mach 2.3 until DR burnout.

The initial GQM-163A target launch on 24 January 2003 consisted of an unguided ballistic test vehicle.

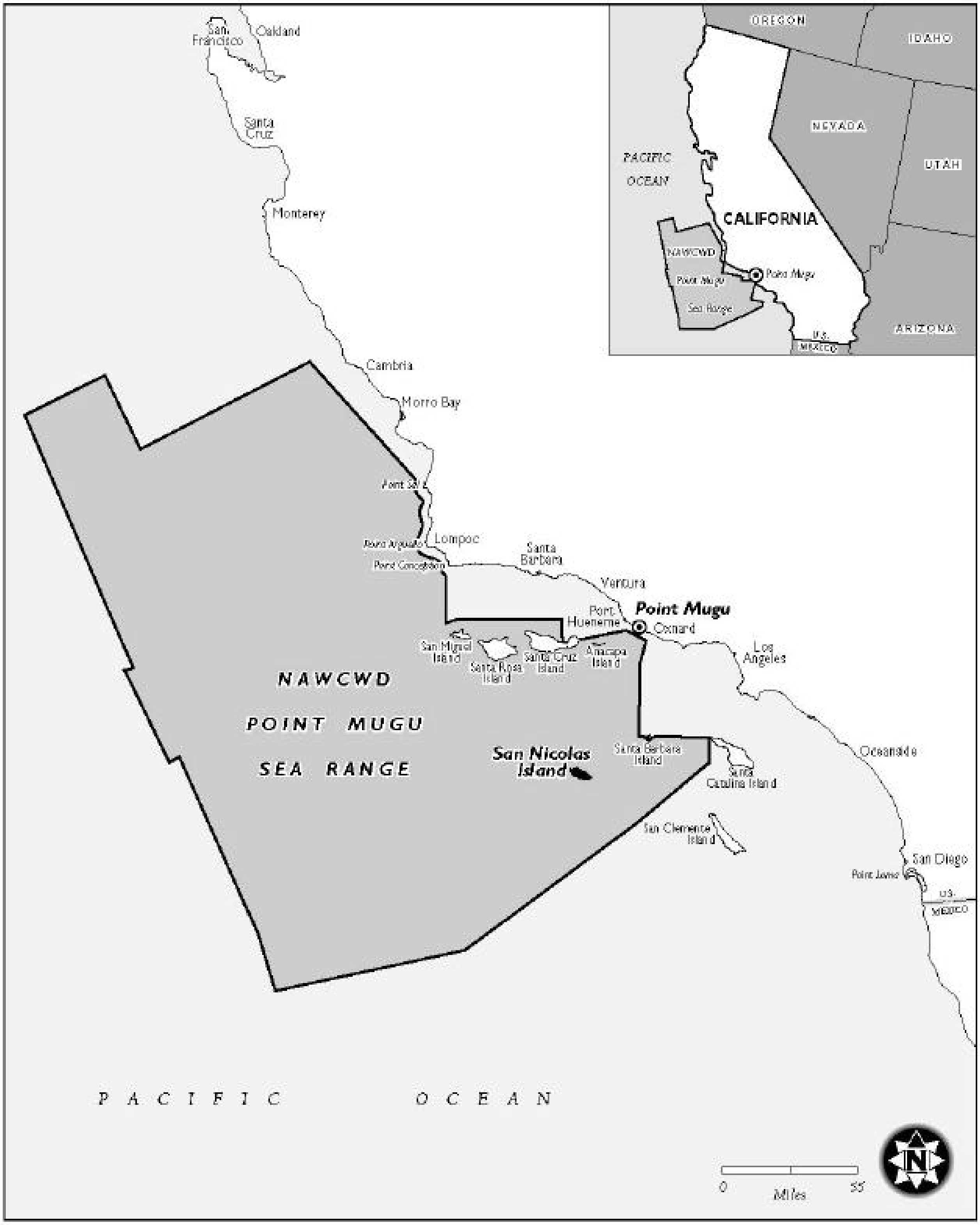

FIGURE 1.2. Regional site map of the Point Mugu Sea Range and San Nicolas Island (map by TEC).

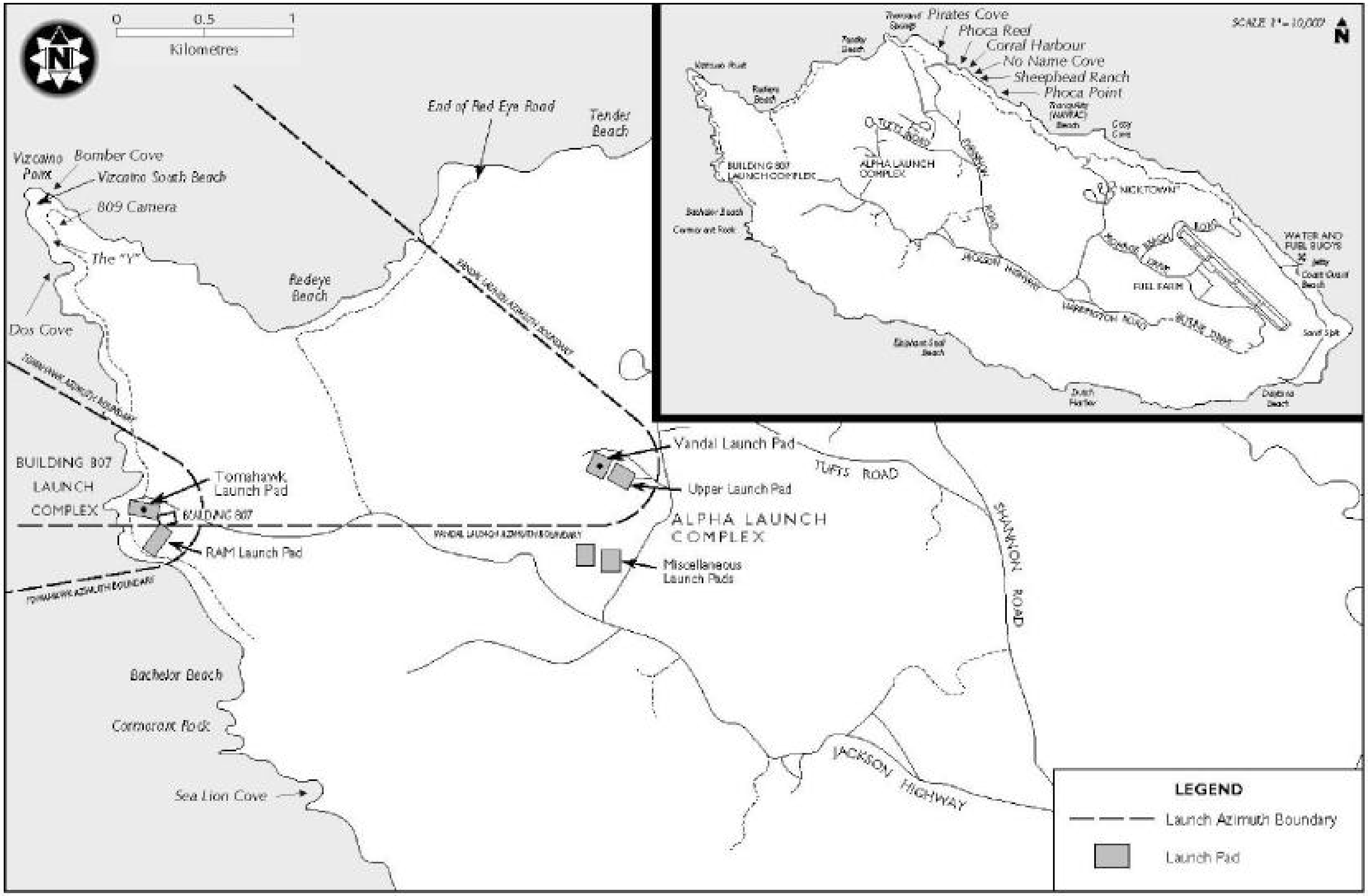

FIGURE 1.3. View of vehicle launch sites on San Nicolas Island. Shown are the Alpha Launch Complex and the Building 807 Launch Complex (at lower elevation near the shoreline). Also shown are the maximum predicted extent of the launch azimuths for vehicles leaving the two launch sites.

FIGURE 1.4. View of two Vandals mounted on the launch pad at the Alpha Complex on San Nicolas Island, California; solid rocket booster is visible at rear of closer Vandal (photograph by U.S. Navy).

FIGURE 1.5. View of the GQM-163A SSST with booster and launcher at the Alpha Launch Complex on San Nicolas Island (photograph by U.S. Navy).

1.3 Background Information on 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, consisting of 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 ft 3 in (5.6 m) in length, with a booster of 20 ft 6 in (6.3 m) long. It weighs 2900 lbs (1315 kg) without the booster or 3500 lbs (1588 kg) with the booster. Its diameter is 20.4 in (51.8 cm), and it has a wing span of 8 ft 9 in (2.7 m). At San Nicolas Island, Tomahawk missiles are launched from Building 807 Launch Complex.

FIGURE 1.6. View of the Tactical Tomahawk missile and launcher at the Building 807 Launch Complex on San Nicolas Island (photograph by U.S. Navy).

1.4 Background Information on Rolling Airframe Missile (RAM)

The Rolling Airframe Missile (RAM) is a supersonic, lightweight, quick-reaction missile (Fig. 1.7). This relatively small missile 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 with a 5-inch (12.7 cm) diameter and a length of 9.2 feet (2.8 m). Its launch weight is 162 pounds (73.5 kg), and operational versions have warheads that weigh 25 lbs (11.4 kg). At San Nicolas Island, RAMs are launched from the Building 807 Launch Complex.

1.5 Background Information on Advanced Gun System (AGS)

The Advanced Gun System (AGS) is a gun designed for a new class of Destroyer; it will be used to launch small missiles. It is to be a fully integrated gun weapon system, including a 155-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 that is usually associated with a missile. The gun gets the missile up to speed, at which point the missile's propulsion takes over. The missile itself is relatively quiet, as it does not have a booster, and it is fairly small. However, the gun blast is rather strong.

At San Nicolas Island, a howitzer (Fig. 1.8) has been used to launch test missiles, as the AGS gun is still being developed. The launcher was located at the Alpha Launch Complex, and the missiles were launched at an azimuth of 282°.

1.6 Missile Launches during the Monitoring Period

During the period from 23 August 2002 to 28 July 2003, there were a total of 12 launches from San Nicolas Island on 11 separate days (Table 1.1). One Tomahawk was launched on 23 August 2002; a dual RAM launch occurred on 18 November 2002; Vandals were launched on 10 December 2002, 14 and 16 March 2003, 4 April 2003, 26 June 2003, and 28 July 2003; two AGS vehicles were launched sequentially 1 hr 45 min apart on 18 December 2002; and GQM-163A targets were launched on 24 January and 4 June 2003. All launches occurred during daylight hours (between 08:49 and 16:28 local time). Weather during the launches was usually cool and the winds were variable (Table 1.1). Conditions ranged from clear and sunny to overcast and partly cloudy.

The Tomahawk was launched from the Building 807 Launch Complex (Fig. 1.3, 1.6); it had a launch azimuth of 305º and an elevation angle of 90º. The dual RAM launch also occurred from the Building 807 Launch Complex (Fig. 1.3, 1.7), with an azimuth of 240º and an elevation angle of 10º. Vandals were launched from the Alpha Launch Complex (Fig. 1.3, 1.4), with elevation angles ranging from 8 to 42° and azimuths varying from 270 to 285°. The two AGS vehicles were launched from the Alpha Launch Complex (Fig. 1.3, 1.8) and both had azimuths of 282° and elevation angles of 50°. The GQM-163A targets were launched at the Alpha Launch Complex at an azimuth of 270° and elevation angles ranging from 20 to 22° (Fig. 1.3, 1.5).

During the August 2001 to July 2002 monitoring period, 19 launches were conducted on 14 days (Table 1.1). These launches involved 14 Vandals, one Terrier Orion, an Advanced Gun System (AGS) missile and two slugs, and dual launch of Rolling Airframe Missiles (RAM).

FIGURE 1.7. View of the Rolling Airframe Missile (RAM) launcher at the Building 807 Launch Complex on San Nicolas Island (photograph by U.S. Navy).

FIGURE 1.8. View of the Advanced Gun Projectile System launcher at the Alpha Complex on San Nicolas Island (photograph by U.S. Navy).

TABLE 1.1. Details of the 19 launches at San Nicolas Island during August 2001 – July 2002 and 12 launches during August 2002 – August 2003. The weather data were collected at the San Nicolas Island airport, which is located at an elevation of 500 ft (152 m) ASL toward the east end of San Nicolas Island; therefore weather conditions at haul-out sites may have differed somewhat. Times are local time.

Launch Date	Launch Time	Vehicle Type	Launch Site	Launch Azimuth	Elevation Angle/Altitude Over Beach	Weather at San Nicolas Island Airport	Tide State	Video Quality	Audio Quality
15 Aug. 2001	12:56	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~100 m	Low at 12:51	Good	2 of 3 ATARs over-loaded
“	13:17	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~100 m	Low at 12:51	Good	2 of 3 ATARs over-loaded
20 Sept. 2001	08:30	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	14°C; winds 300° at 6 kt; overcast	Low at 06:03	Good	1 of 3 ATARs failed
“	17:02	Terrier Orion	Alpha Launch Complex	232.3°	64.6° / 13,000 ft	14°C; winds 300° at 6 kt; overcast	Low at 06:03	Good	OK
5 Oct. 2001	13:37	Vandal	Alpha Launch Complex	273.3°	8° / 1,300 ft	16°C; winds 290° at 9 kt; overcast with drizzle	Low at 18:09	Good	2 of 3 ATARs failed
19 Oct. 2001	09:00	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	17°C; winds 320° at 10 kt; overcast	Low at 05:15	Good	2 of 3 ATARs over-loaded
19 Dec. 2001	15:22	Vandal	Alpha Launch Complex	273°	8° / 1,300 ft	15°C; clear and sunny	Low at 19:09	Good, 2 cameras	1 of 3 ATARs failed
14 Feb. 2002	11:33	Vandal	Alpha Launch Complex	273°	8° / 1,300 ft	20°C; winds 5 kt; overcast	Low at 17:03	Good, 2 cameras	1 of 3 ATARs overloaded
22 Feb. 2002	12:13	Vandal	Alpha Launch Complex	270°	42° / 9,600 ft	27°C; winds 3 kt; sunny and warm	Low at 12:44	Good	1 of 3 ATARs failed
“	14:56	Vandal	Alpha Launch Complex	270°	42° / 9,600 ft	27°C; winds 3 kt; sunny and warm	Low at 12:44	Good	1of 3 ATARs failed
6 Mar. 2002	11:20	Vandal	Alpha Launch Complex	273.1°	8° / 1,300 ft	17°C; winds 270° at 9 kt; overcast	Low at 11:03	Good, 4 cameras	OK

TABLE 1.1. continued

1 May 2002	15:53	Vandal	Alpha Launch Complex	273°	6.5° / malfunctioned & hit land	18°C; winds 300° at 20 kt; windy but clear	Low at 07:09	Good, 2 cameras	2 of 3 ATARs failed
"	17:00	Vandal	Alpha Launch Complex	273°	42° / 9,600 ft	18°C; winds 300° at 20 kt; windy but clear	Low at 07:09	Good, 2 cameras	1 of 3 ATARs failed
8 May 2002	14:54	Vandal	Alpha Launch Complex	273°	8° / 1,300 ft	18°C; winds 270° at 10 kt; sunny and clear	Low at 13:15	Good, 4 cameras	OK
19 June 2002	15:07	AGS Test Slug	Alpha Launch Complex	305°	63° / malfunctioned & hit land	15°C; winds 290° at 15 kt; overcast	Low at 11:42	Good, 2 cameras	1 of 2 ATARs failed
21 June 2002	12:53:12/ 12:53:15	Dual RAM	Building 807 Launch Complex	240°	8° / 50 ft	16°C; winds 270° at 12 kt; overcast	Low at 13:18	Good, 2 cameras	Only 1 ATAR used; OK
26 June 2002	11:20	AGS Test Slug	Alpha Launch Complex	300°	62.5° / 500 ft	17°C; winds 290° at 16 kt; foggy and overcast	Low at 05:50	Good, 2 cameras	OK
"	12:51	AGS Missile	Alpha Launch Complex	300°	62.5° / 5,300 ft	17°C; winds 290° at 16 kt; foggy and overcast	Low at 05:50	Good, 2 cameras	OK
18 July 2002	11:54:42	Vandal	Alpha Launch Complex	273°	8° / 1,300 ft	19°C; winds 340° at 4 kt; foggy and overcast	Low at 10:04	Good, 1 camera	2 of 3 ATARs failed
23 Aug. 2002	14:09:39	Tactical Tomahawk	Building 807 Launch Complex	305°	90° / 1000 ft	15.6°C; winds 285° at 8.7-13.0 kts; overcast and partly cloudy	Low at 16:31	Good, 2 cameras	2 of 3 ATARs failed
18 Nov. 2002	11:03	Dual RAM	Building 807 Launch Complex	240°	10° / 50 ft	23.9°C; winds 125° at 1.7 kts; clear and sunny	Low at 7:52	Good, 1 of 2 cameras	1 of 3 ATARs failed
10 Dec. 2002	8:49:02	Vandal	Alpha Launch Complex	273°	8° / 1300 ft	18.3°C; winds 285° at 21.7 kts; clear	Low at 8:33	Good, 1 of 2 cameras	1 of 3 ATARs failed
18 Dec. 2002	14:30	AGS	Alpha Launch Complex	282°	50° / 4500 ft	12.8°C; winds 285° at 17.4 kts; overcast to partly cloudy	Low at 15:15	None	2 ATARs used; ok

TABLE 1.1. continued

18 Dec. 2002	16:15	AGS	Alpha Launch Complex	282°	50° / 4500 ft	12.8°C; winds 285° at 17.4 kts; overcast to partly cloudy	Low at 15:15	None	1 of 2 ATARs failed
24 Jan. 2003	14:20	GQM-163A	Alpha Launch Complex	270°	20° / 3400 ft	18.3°C; winds 293° at 8.7-13.0 kts; clear and windy	Low at 20:09	Good, 2 of 3 cameras	2 of 3 ATARs failed
14 Mar. 2003	9:13:04	Vandal	Alpha Launch Complex	273°	8° / 1300 ft	13.9°C; winds 225° at 3.5 kts; calm, overcast at shore, fog inland	Low at 13:34	Good, 2 of 2 cameras	3 ATARs ok
16 Mar. 2003	13:04:01	Vandal	Alpha Launch Complex	273°	8° / 1300 ft	15°C; winds 315° at 13.9-20.0 kts; gusty, few clouds	Low at 14:36	Good, 2 of 2 cameras	2 of 3 ATARs failed
4 Apr. 2003	15:20:01/ 15:20:06	Dual Vandal	Alpha Launch Complex	273°	8° / 1300 ft	12.8°C; winds 315° at 14.8 kts; clear	Low at 16:18	Good, 2 of 2 cameras	3 ATARs ok
4 June 2003	12:35:20	GQM-163A	Alpha Launch Complex	270°	22° / 3500 ft	17.2°C; winds 210° at 7.0 kts; haze; few clouds	Low at 7:41	Good, 3 cameras	3 ATARs ok
26 June 2003	13:27:58	Vandal	Alpha Launch Complex	285°	42° / 17,277 ft	23°C; winds 230° at 7.0 kts; clear but some haze; fog	Low at 13:37	Good, 3 cameras	1 of 3 ATARs failed
28 July 2003	16:27:50	Vandal	Alpha Launch Complex	270°	8° / 1280 ft	20°C; winds 300° at 11kts; few clouds	Low at 15:16	Good, 3 cameras	2 of 3 ATARs failed

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. 1.3; Appendix B).

1.7 Acoustical Monitoring of the Missile Launches

Audio recordings were obtained to document launch sounds at several distances from the launch trajectory of the vehicles. In addition, these recordings provided measures of 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 missiles;
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 detect (or not) the launch sounds; and
3. determining whether the sound levels from missile 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), it is evident that the sound levels that might cause notable disturbance for each of the pinniped species are variable and context-dependent. Lawson et al. (1998) estimated the minimum received level (on an A-weighted "Sound Exposure Level" or ASEL basis) that might elicit substantial disturbance as 100 dBA re 20 ìPa. That 100-dBA figure pertained to exposure to prolonged sounds, which were taken to last at least several seconds. It is arguable whether 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 much less than 1 to ~5 seconds (Greene and Malme 2002; see also Chapter 2). In any event, the assumption that reactions might occur at distances up to those where received levels diminished to 100 dBA re 20 ìPa on an SEL basis was one factor in selecting acoustic (and video) monitoring sites during Year 1. Sites at distances up to ~4 km (2.5 mi.) from the launcher and/or launch trajectory were monitored in Year 1.

After reviewing video recordings of launches at San Nicolas Island during 2001-2002 (also see Holst and Lawson 2002), the 100-dBA level still seemed reasonable as a minimum received level (SEL) that might elicit disturbance for 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. The majority of elephant seals usually exhibited little or no reaction to launch sounds. The received levels of sounds from the larger missiles, as measured during Year 1, indicated that levels at or above 90 dBA SEL could be expected out to distances of about 4 km from the launch trajectory (see Fig. 2.39 *in* Greene and Malme 2002). This determined where acoustic (and video) monitoring was done during Year 2. Sites at distances up to ~4 km (2.5 mi.) from the launcher and/or launch trajectory were monitored in Year 2.

1.8 Visual Monitoring of Pinnipeds During Missile Launches

The Navy conducted continued video and visual monitoring of marine mammals during the missile launches from San Nicolas Island in the August 2002 to August 2003 period, supplemented by simultaneous autonomous audio recording of launch sounds (see Chapter 2). The data were collected and analyzed in a manner comparable to that applied during the preceding August 2001 through July 2002 period. The video and visual monitoring provided data on samples of the pinnipeds hauled out on western San Nicolas Island during launches. The accumulation of such data across numerous launches will provide the data required to characterize the extent and nature of disturbance effects. In particular, it will provide the information needed to document the nature, frequency, occurrence, and duration of any changes in pinniped behavior resulting from the missile launches, including the occurrence of stampedes from haul-out sites if they occur.

The video records are to be used to document pinniped responses to the launches. The objectives include the following:

1. identify and document any change in behavior or movements that occurred at the time of the launch;
2. compare pre- and post-launch behavioral data on launch day to quantify the interval required for pinniped numbers and behavior to return to normal[2] if there was a change as a result of launch activities;
3. 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[3] for missile sounds under different launch conditions;
4. ascertain periods or launch conditions when pinnipeds are most and least responsive to launch activities, and
5. document numbers of pinnipeds affected by missile launch sounds and, although unlikely, any mortality or injury.

For the present August 2002 to August 2003 period, the number of launches with paired acoustic and pinniped data from the same site is limited. Also, several different types of vehicles were launched (Table 1.1). Therefore, data from the present monitoring period were pooled with those from previous monitoring in August 2001 to July 2002 (Lawson et al. 2002), in order to meet objectives (3) and (4). However, given the variability in sound propagation and in pinniped behavioral reactions, data from a relatively large number of otherwise comparable launches are required to determine the dose-response relationship (objective 3, above) and conditions when pinnipeds were most or least responsive to launch sounds (objective 4). Additional data will 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.

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

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

1.9 Incidental Harassment Authorization

The monitoring programs for the Navy’s missile launches in 2001-2003 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 Temporary Threshold Shift (TTS) might have occurred as a result of a launch, or if biologically significant behavioral patterns of pinnipeds are disrupted. NMFS (2000) defines 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.” 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 are not considered a 'take' under the MMPA definition of harassment”.

An IHA to authorize possible harassment takes of pinnipeds hauled out at San Nicolas Island during missile launches was issued to the Navy on 1 August 2001; that IHA dealt with the period from 1 August 2001 to 31 July 2002 (NMFS 2001). A second IHA was issued to the Navy on 26 August 2002; the second IHA concerned the period 26 August 2002 through 26 August 2003 (NMFS 2002). Acoustic and visual monitoring has been conducted during launches from San Nicolas Island from August 2001 to August 2003. Lawson et al. (2002) described the results from the first year. The present report describes the results from the second year, with some integration of results across the two years.

1.10 Summary

From August 2002 through August 2003, Naval Air Warfare Center Weapons Division (NAWCWD) conducted a total of 12 launches from San Nicolas Island, on 11 different days. Vehicles were launched from the Building 807 Launch Complex near the beach on the west-central part of San Nicolas Island (two launches on two days) and from the Alpha Launch Complex farther inland on San Nicolas Island (ten launches on nine days).

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 were consistent with those during 19 previous launches in the August 2001 through July 2002 period (see Lawson et al. 2002). Monitoring procedures and results of the acoustic and visual monitoring during August 2002 to August 2003 are described in Chapters 2 and 3. Those chapters also summarize some key results from August 2001 through July 2002, and use the combined August 2001 through August 2003 data to characterize the launch sounds and pinniped responses.

2. ACOUSTICAL MEASUREMENTS OF MISSILE LAUNCHES, AUGUST 2001 – AUGUST 2003[1]

2.1 Introduction

A total of 34 vehicles were launched from San Nicolas Island during the period from 15 August 2001 through 28 July 2003. Of these, 19 launches were during the August 2001 through July 2002 period, and 12 launches were during August 2002 through August 2003. Three launches were dual launches in quick succession, including dual RAM launches on 21 June 2002 and 18 November 2002, and a dual Vandal launch on 4 April 2003. On six days (15 August 2001, 20 September 201, 22 February 2002, 1 May 2002, 26 June 2002, and 18 December 2002), two missiles were launched sequentially, varying from 21 min. up to 8.5 hr apart. Table 2.1 lists the launch dates, times, and types of vehicles. Maps of the launch azimuths and monitoring locations for each launch date can be found in Appendix B.

The acoustic measurement program during the August 2002 – July 2003 period was consistent in approach and methodology with that used during the preceding year (Greene and Malme 2002). The sounds of each vehicle, as well as background sounds, were recorded at up to three sites on the island during each vehicle flight. Autonomous Terrestrial Acoustic Recorders (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. Of the 93 possible recordings over the two years (31 launches × three recording sites per launch), 78 recordings were attempted and 64 recordings were obtained and analyzed (Table 2.1). During 21 launches, one or two ATARs did not operate successfully.

2.2 Field Methods

Acoustical recordings were usually attempted at three locations during each vehicle flight. ATARs were usually positioned so that, given the planned launch azimuth, at least one ATAR was near the launch azimuth (or the launch site itself). Others were positioned at locations to the side of the azimuth where it was of interest to monitor sounds (Appendix B). These 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 will be combined with the pinniped behavioral data to determine if there is a "dose-response" relationship between received sound levels and pinniped behavioral reactions. Chapter 3 contains an interim analysis of that type. However, additional data from ongoing and planned future monitoring are required to fully meet that objective.

The Navy's acoustical contractor, Greeneridge Sciences Inc. (Santa Barbara, CA), provided three autonomous audio recorders (described below). During most launches, at least two of these were located as close as practical to three pinniped haul-out sites at various distances from the launch site. These three ATAR sites typically included locations (1) as close as possible to the vehicle's planned flight path, (2) where the received sound levels were estimated to reach a sound exposure level (SEL) ~100 dBA re 20 $\mu Pa^2 \cdot s$, as shown in Greene and Malme (2002), and (3) midway between sites 1 and 2. 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 ATARs were designed to record two sensor channels continuously and unattended for up to 48 hours. It was necessary to use autonomous recorders because safety considerations required all personnel to leave the monitoring sites

[1] By **Charles R. Greene**, **Jr**., Greeneridge Sciences Inc.

TABLE 2.1. Vehicle launches recorded at San Nicolas Island from August 2001 to August 2003.

Date	Local Time	Vehicle	Elevation Angle	Acoustic Recording Sites	Acoustic Data
Year 1					
15 Aug. 01	12:55	Vandal	8°	3	1 OK*
"	13:16	Vandal	8°	3	1 OK*
20 Sept. 01	08:29	Vandal	8°	3	2 OK
"	17:00	Terrier Orion	64.6°	3	3 OK
5 Oct. 01	13:36	Vandal	8°	3	1 OK
19 Oct. 01	08:59	Vandal	8°	3	1 OK*
19 Dec. 01	15:20	Vandal	8°	3	2 OK
14 Feb. 02	11:33:00	Vandal	8°	3	2 OK*
22 Feb. 02	12:13:04	Vandal	42°	3	2 OK
"	14:56:22	Vandal	42°	3	2 OK
6 Mar. 02	11:20:38	Vandal	8°	3	3 OK
1 May 02	15:53:20	Vandal	6.5°	3	1 OK
"	17:00:23	Vandal	42°	3	2 OK
8 May 02	14:54:02	Vandal	8°	3	3 OK
19 June 02	15:07:00	AGS Test Slug	63°	2	1 OK
21 June 02	12:53:12 & 12:53:15	Dual RAM	8°	1	1 OK
26 June 02	11:20:00	AGS Test Slug	62.5°	3	3 OK
"	12:51:00	AGS Missile	62.5°	3	3 OK
18 July 02	11:54:42	Vandal	8°	3	1 OK
Year 2					
23 Aug. 02	14:09:39	Tomahawk	90°	3	1 OK
18 Nov. 02	11:03	Dual RAM	10°	3	2 OK
10 Dec. 02	08:49:02	Vandal	8°	3	2 OK
18 Dec. 02	14:30	AGS	50°	2	2 OK
"	16:15	AGS	50°	2	1 OK
24 Jan. 03	14:20	GQM-163A	20°	3	1 OK
14 Mar. 03	9:13:04	Vandal	8°	3	3 OK
16 Mar. 03	13:04:01	Vandal	8°	3	1 OK
4 Apr. 03	15:20:01 & 15:20:06	Dual Vandal	8°	3	3 OK
4 June 03	12:35:20	GQM-163A	22°	3	3 OK
26 June 03	13:27:58	Vandal	42°	3	2 OK
28 July 03	16:27:50	Vandal	8°	3	1 OK

* Other ATARs overloaded

one hour prior to the planned launch. The extended recording capabilities of the ATAR units, as compared with DAT audio recording units used previously (e.g., Greene 1999), were important in accommodating any launch delays and periods between launches on the same day.

When acoustic data from sufficient flights are available, measured sound levels at various microphone locations can be used to characterize sound exposure vs. distance downrange and laterally from the launch azimuth. Initial analyses of this type are included in this chapter. Weather is expected to have important effects on the received sounds and needs to be considered in later analyses, along with results from additional flights. Other factors to be considered will include vehicle type, launch azimuth, and launch characteristics (e.g., low- vs. high-angle launch).

The ATARs are much like the Autonomous Seafloor Acoustic Recorders (ASARs) employed during several recent projects involving monitoring of underwater industrial sounds in the Beaufort Sea (e.g., Burgess et al. 1999). The ASARs and ATARs, designed and assembled by Greeneridge Sciences, can record sounds for extended periods (dependent on sampling rate) without intervention. Thus, an ATAR can still make recordings of flight sounds even if prolonged launch delays occur. The ATARs can record a bandwidth of 3 to 20,000 Hz at a 44.1 kHz sample rate on two channels. The ATAR is designed to record both high-level and normal background sounds. The principal components of an ATAR are two calibrated 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.

PCB 106B50 quartz microphones (PCB Piezotronics Inc., Depew, NY) were used to convert sound pressure to voltage at all sites. 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 re 20 µPa. To record ambient sounds concurrently, more sensitive microphones (the TMS 130P10; –157 dB re 1 V/µPa) were used to provide additional dynamic range. Each ATAR includes two microphones, one of each type. Each microphone signal is sampled at 44.1 kHz and digitized to a 16-bit two-byte integer.

Each microphone required a PCB model 480E09 signal conditioner. These low-noise, unity-gain amplifiers apply the microphone polarizing voltage. The signal conditioners had gain selections of 1, 10 and 100 (corresponding, respectively, to 0, 20 and 40 dB). These signal conditioners were mounted in waterproof Pelican cases with the remaining equipment, excluding the battery.

Prior to the launch of each vehicle, Navy personnel typically deployed three ATAR units at three sites, usually with video cameras operating at some or all ATAR sites as well (see Appendix B). Most sites were selected on the basis of distance from the anticipated flight trajectory and the presence of pinnipeds on shore. However, in some situations ATARs were deployed at locations without pinnipeds and without a video camera in order to document sounds under specific circumstances, e.g., near the launcher (Table 2.2).

The locations of the ATARs varied from launch to launch, although the Navy distributed the ATARs such that recordings were made at a variety of different distances and locations relative to the flight trajectories of the various vehicles (Table 2.2; Appendix B).

At each of the monitoring sites, the microphones were placed in hemispherical windscreens and positioned so they were 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 inches thick and 22 inches 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

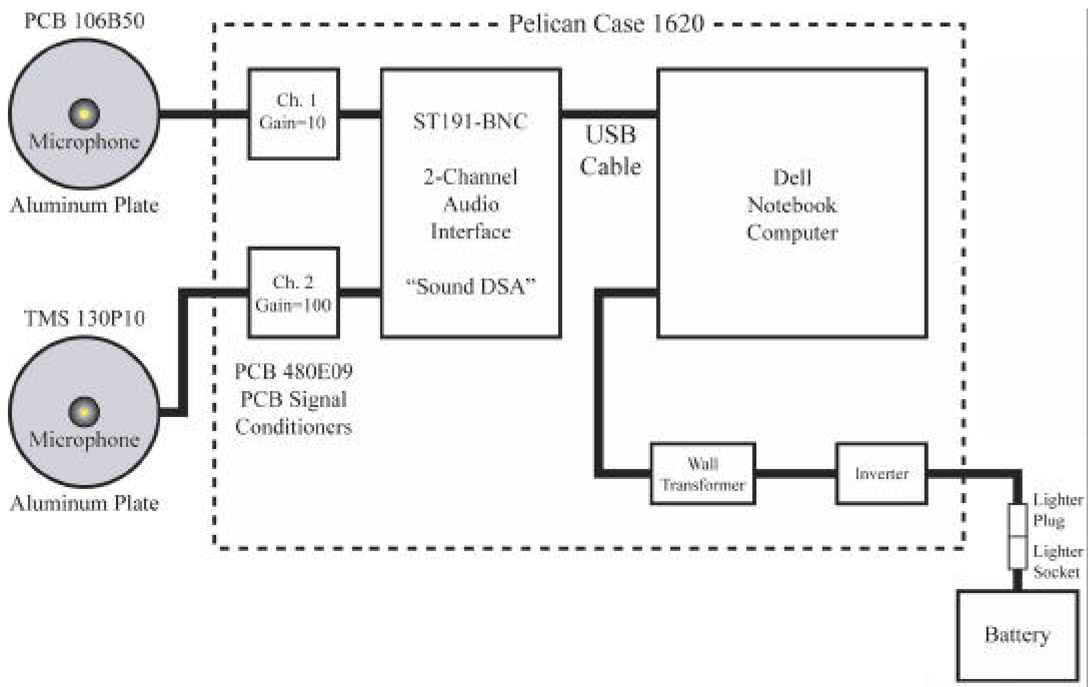

FIGURE 2.1. Block diagram of an Autonomous Terrestrial Acoustic Recorder (ATAR).

ground assures that the microphones sense the combined direct and reflected sound, just as an animal would near the ground (Greene 1999).

Setting optimum recording levels presented a challenge, given that these had to be set in advance of the launch, with no opportunity to make adjustments based on initial results at that location. Setting recording levels too high would result in clipping the desired 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.

Signals were also recorded on a second data channel with a higher sensitivity. This provided data suitable for measuring ambient sound levels before and after the flights.

The ATARs have not recorded successfully during about one of four deployments, an undesirably high rate. The recording program aborted prematurely, 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 does 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 launches in June and July 2003 (Table 2.2).

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

Launch Date	Vehicle	ATAR Locations
Year 1		
15 Aug. 01	Vandal	End of Redeye Road; 809 Camera[o]; Dos Coves[o]
20 Sep. 01	Terrier	Alpha Launch Complex; Building 807; Cormorant Rock Blind
20 Sep. 01	Vandal	809 Camera; Tender Beach; Dos Coves*
5 Oct. 01	Vandal	Phoca Reef; 809 Camera*; Vizcaino Point*;
19 Oct. 01	Vandal	NAVFAC Beach; 809 Camera[o]; Bachelor Beach South[o]
19 Dec. 01	Vandal	809 Camera; Building 807; Dos Coves*
14 Feb. 02	Vandal	809 Camera; Bachelor Beach North; Alpha Launch Complex[o]
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 Test Slug	Redeye II; Alpha Launch Complex*
21 June 02	RAM	Building 807 Launch Complex
26 June 02	AGS Test Slug & 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	50 ft from Launcher, Near 809 Camera[‡]
24 Jan. 03	GQM-163A	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	GQM-163A	Sheephead Ranch, 809 Camera, 100 ft from Launcher
26 June 03	Vandal	The "Y", 809 Camera, Bomber Cove*
28 July 03	Vandal	809 Camera, Bachelor Beach North*, Dos Coves*

[o] ATAR overloaded
* ATAR malfunctioned or 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.

Recently, 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. This suggests 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 new grounding will be tested on a launch in the near future.

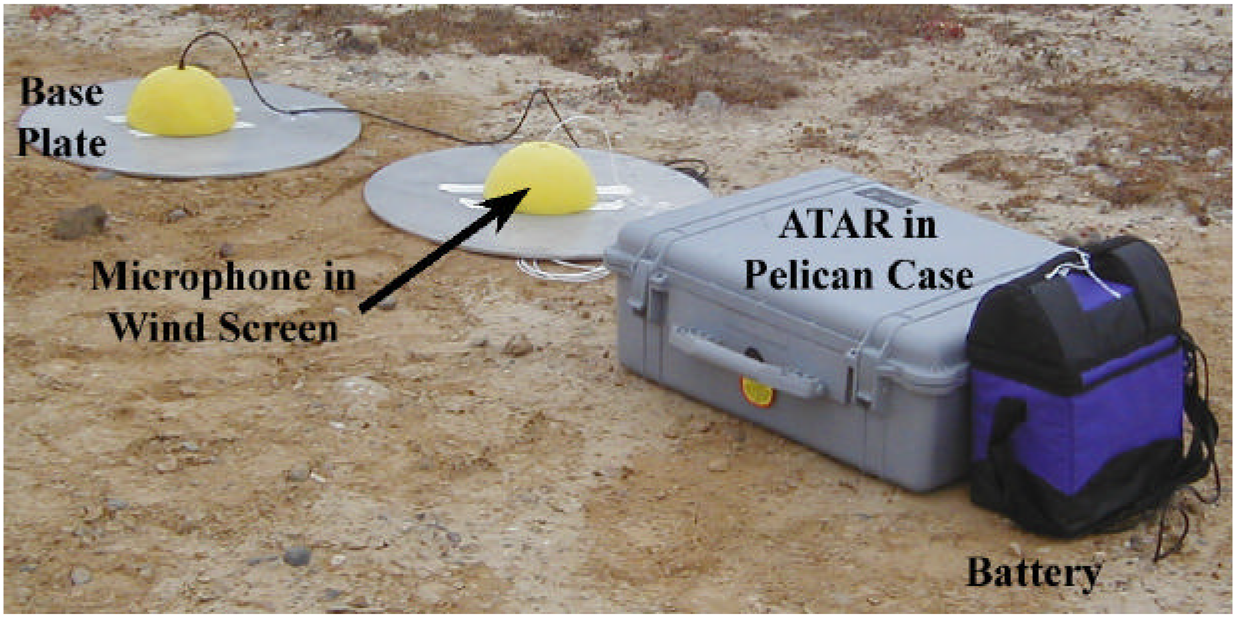

FIGURE 2.2. Typical field installation of an Autonomous Terrestrial Acoustic Recorder (ATAR) at the west end of San Nicolas island, California (photograph by J. Lawson, LGL).

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 sound pressure level (SPL), root mean square (RMS) SPL, and sound exposure level (SEL). 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.

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:

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

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** (sound exposure level) was determined from $10 \cdot \log$ (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 (root-mean-square) value of the signal, less background noise, over the duration. **SPL** (sound pressure level) was determined from $20 \cdot \log$ (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 $20 \cdot \log$ (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 (missile signal plus background noise). This time series was segmented according to duration (determined from the broadband time series analysis) as follows:

- for duration > 1 second, use 32,768-sample blocks of total length 0.74 s with Blackman-Harris minimum three-term window, overlapped by 50%. This results in frequency cells spaced by 1.35 Hz and an effective cell width (resolution) of 2.3 Hz.
- for 0.0929 < duration < 1 second, 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 second, use the samples spanning the signal duration and apply a uniform window. This results in cell spacing in hertz 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 seconds of data selected from before the missile signal, were segmented into 44,100-sample blocks overlapped by 50% and weighted by the Blackman-Harris minimum 3-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 A-Weighting

Time-series results for the full 3 to 20,000 Hz bandwidth were calculated both for A- and flat-weighted data. With A-weighting, the signal's spectrum is multiplied by the standard A-weighting spectrum (Kinsler et al. 1982, p. 280; Richardson et al. 1995, p. 99). This multiplication slightly amplifies signal energy at frequencies between 1 and 5 kHz and attenuates signal energy at frequencies outside this band. This process is designed to mimic the weighting applied by the human ear and is a standard method of presenting data on airborne sounds. Flat weighting, on the other hand, leaves the signal spectrum unchanged. The relative sensitivity of pinnipeds listening in air to different frequencies is generally similar to that of humans (Richardson et al. 1995), so A-weighting may also be relevant to pinnipeds. However, measurement data from each launch are presented by one-third octave band (see Appendix C), so other weighting methods, e.g., C-weighting or species-specific weighting functions, could be applied to these data.

Only flat weighting was used for frequency-domain analyses. The concept of A-weighting is not useful when reporting results for specific frequencies or narrow frequency bands.

2.3.4 Closest Point of Approach Distance by the Missile

To relate missile sounds to the proximity of the missile trajectory, the 3-D distance from the recording site to the closest point of approach (CPA) of the missile was calculated for each launch date and sound monitoring site. The relationship between CPA distance and the measured parameters of the missile sound was then examined in a preliminary way using scatter plots and Spearman Rank Order Correlations.

2.4 Results

Measurements of the missile flight sounds are reported based both on "flat-weighting" and on "A-weighting". The background sound levels are also reported based on each of these weighting methods.

2.4.1 Missile Flight Sounds

Four parameters are reported for the missile flight sounds: peak pressure level, sound pressure level (SPL), sound exposure level (SEL), and duration. These parameters are explained in Section 2.3. Table 2.3 presents the results for acoustic monitoring during August 2002 to August 2003 (Year 2) based on flat- and A-weighting. Table 2.4 shows the results for the August 2001 through July 2002 monitoring period (Year 1), from Greene and Malme (2002). It was to be expected that A-weighted levels would almost always be less than flat-weighted levels because the sonic boom noise is strong at frequencies below 1000 Hz, which are de-emphasized with A-weighting. The flight sound durations are sometimes long because of rocket noise reverberation.

During the August 2002 to August 2003 monitoring period (Year 2), sounds from various missiles were recorded at a variety of 3-D CPA distances:

- The Tomahawk launch resulted in a flat-weighted SPL of 93 decibels (dB) re 20 micropascal (µPa) at Dos Coves, located ~1739 ft or 530 m from the CPA, and a flat-weighted SEL of 105 dB re (20 ì Pa)^2· s (Fig. B-1A).
- The dual RAM launch produced SPLs ranging from 90 dB at Bachelor Beach North, located ~2264 ft (690 m) from the CPA, to 130 dB recorded 50 ft (15 m) from the launcher (Fig. B-1B). SELs ranged from 97 to 129 dB.

- The AGS missiles resulted in an SPL of 109 dB at 809 Camera, located ~0.7 mi. (1.2 km) from the CPA (Fig. B-1D). Levels were much higher 50 ft (15 m) from the launch site (155 to 156 dB), but the launcher was far from any beach (Fig. B-1D). SELs ranged from 119 to 143 dB.
- The GQM-163A SSST targets produced SPLs of 126 dB near the launcher, 123 dB at a nearshore site ~0.6 mi. (1 km) from the CPA, 115 dB 0.9 mi. (1.4 km) from the CPA, and 101 dB 1.8 mi. (2.9 km) to the northeast of the launcher (see Fig. B-1I,E).
- Vandal launches on several dates produced a wide variety of measurements, depending in part on CPA distance (Table 2.3; see also Fig. 2.3, later).

The Vandal launch on 10 December 2002 produced SPLs of 140 dB below the launch azimuth and 123 dB at Bachelor Beach North, located 0.7 mi. (1.2 km) from the CPA (Fig. B-1C). On 14 March 2003, the Vandal launch resulted in SPLs of 88 and 90 dB at two sites located 1.5-1.8 mi. (2.4-2.9 km) northeast of the launch azimuth, and a higher SPL of 137 dB was produced near the launcher (Fig. B-1F). The Vandal that was launched on 16 March 2003 resulted in an SPL of 98 dB at a site 1.6 mi. (2.6 km) northeast of the launch azimuth (Fig. B-1G). On 4 April 2004, the dual Vandals resulted in SPLs ranging from 92 to 106 dB at three locations ~1.9-2.5 mi. (3-4 km) east of the launch azimuth (Fig. B-1H). The Vandal launched on 28 July 2003 produced an SPL of 137 dB ~0.6 mi. (1 km) from the CPA (Fig. B-1K). The high-elevation (42º) Vandal launched on 26 June 2003 produced SPLs of 93 dB at distances of 1.7-1.8 mi. (2.8-2.9 km) from the CPA.

The low-elevation (8º) Vandals produced SELs ranging from 95 dB at nearshore locations to 136 dB near the launcher. The high-elevation (42º) Vandal produced SELs ranging from 101 to 103 dB at nearby locations. The GQM-163A targets produced SELs ranging from 101 dB at a nearshore location to 126 dB at the launch site.

Sonic booms were evident on four occasions in Year 2:

- Vandal on 10 December as received at Dos Coves (1378 ft or 420 m from CPA), and at Bachelor Beach North (0.7 mi. or 1.2 km from the CPA),
- GQM-163A on 24 January as received at Redeye I (0.6 mi. or 1 km from the CPA),
- GQM-163A on 4 June 2003, as received at 809 Camera (0.9 mi. or 1.4 km from the CPA), and
- Vandal on 28 July 2003 at 809 Camera, located 0.6 mi. or 1 km north of the launch azimuth.

Two graphs are presented in Appendix C for each flight recording for August 2002 through August 2003 [graphs of August 2001 through July 2002 data are shown in Greene and Malme (2002)]. For each launch, both graphs are based on flat-weighted data; no graphs are presented for A-weighted waveforms. One graph presents the pressure signature (pressure vs. time waveform). The second presents the sound exposure levels by one-third octave band for each of three signals: (1) the missile sounds; (2) the background instrumentation noise from the low-sensitivity channel (the same sensor used to measure the missile sounds but using data recorded before the missile sounds); and (3) the background noise levels from the high sensitivity channel—i.e., the ambient sound pressure levels. Because the ambient sounds are continuous, expressing them as sound exposure levels is unconventional. However, for purposes of comparison with the transient missile sounds, one can consider the sound pressure levels for ambient noise to be the sound exposure levels in a one-second period.

TABLE 2.3. Pulse parameters for flat- and A-weighted sound from vehicle flights at San Nicolas Island during August 2002 to August 2003 (Year 2). The peak levels and sound pressure levels are in dB relative to 20 µPa, the sound exposure levels (energy levels) are in dB relative to (20 µPa)^2· s, and the durations (Dur.) are in seconds. The 3-D closest point of approach (CPA) distance of the missile from the monitoring site is given in m. Broadband (10-20,000 Hz) flat- and A-weighted sound levels for each site as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds are also given (dB re 20 µPa). See Appendix B for maps of monitoring locations.

				CPA	Flat-weighted sound				A-weighted sound				Ambient sound	
Date	Time	Vehicle	Site	(m)	Peak	SPL	SEL	Dur.	Peak	SPL	SEL	Dur.	Flat-wt	A-wt
23 Aug. 02	14:09:39	Tomahawk ‡	Dos Coves	539	111	93	105	16.3	112	91	102	10.83	72	58
18 Nov. 02	11:03	RAM	75 ft from Launcher **	4	146	124	129	3.26	147	122	128	3.23	68	61
"	11:03	RAM	75 ft from Launcher *	4	146	130	126	0.38	147	130	125	0.31	65	50
"	11:03	RAM	Bachelor Beach North **	693	112	90	97	5.15	103	84	92	5.75	71	54
"	11:03	RAM	Bachelor Beach North *	693	112	90	94	2.60	103	84	89	3.05	N/A	N/A
10 Dec. 02	08:49:02	Vandal	Dos Coves †	421	150	140	128	0.061	147	131	118	0.046	91	60
"	08:49:02	Vandal	Bachelor Beach North †	1206	136	123	117	0.27	133	108	102	0.25	86	60
18 Dec. 02	14:30	AGS	50 ft from Launcher	12	166	155	141	0.050	161	143	130	0.058	82	72
"	14:30	AGS	809 Camera	1196	130	109	119	9.04	108	78	88	8.12	71	44
"	16:15	AGS	50 ft from Launcher	12	165	156	143	0.050	159	143	131	0.066	71	70
24 Jan. 03	14:20	GQM-163A	Redeye I †	1034	134	123	118	0.27	126	104	98	0.26	74	55
14 Mar. 03	9:13:04	Vandal	Pirates Cove	2388	112	88	98	10.7	77	58	66	6.64	51	35
"	9:13:04	Vandal	Sheephead Ranch	2909	112	90	98	6.00	74	51	60	8.49	52	42
"	9:13:04	Vandal	100 ft from Launcher	27	156	137	136	0.80	141	119	118	0.82	61	28
16 Mar. 03	13:04:01	Vandal	Corral Harbor	2590	115	98	100	1.61	84	64	71	4.74	61	41
4 Apr. 03	15:20:01	Vandal	NAVFAC Beach	3911	108	92	95	2.09	80	58	59	1.21	62	41
"	15:20:01	Vandal	No Name Cove	3506	116	104	101	0.52	85	62	67	3.63	47	35
"	15:20:01	Vandal	Phoca Point	3273	115	106	101	0.34	82	58	63	3.59	69	36
4 Apr. 03	15:20:06	Vandal	NAVFAC Beach	3911	107	95	95	0.99	77	55	51	0.38	74	49
"	15:20:06	Vandal	No Name Cove	3506	115	98	101	1.99	87	63	68	3.71	68	34
"	15:20:06	Vandal	Phoca Point	3273	115	98	101	2.04	82	60	66	3.83	69	36
4 June 03	12:35:20	GQM-163A	809 Camera	1397	136	115	116	1.40	135	99	99	0.90	69	41
"	12:35:20	GQM-163A	Sheephead Ranch †	2906	116	101	102	1.19	112	90	87	0.49	59	42
"	12:35:20	GQM-163A	100 ft from Launcher	72	142	126	128	1.51	124	113	115	1.47	60	32
26 June 03	13:27:58	Vandal	The "Y"	2948	112	93	101	7.23	96	80	89	7.35	62	51
"	13:27:58	Vandal	809 Camera	2757	113	97	103	3.64	96	83	90	5.22	70	42
28 July 03	16:27:50	Vandal	809 Camera †	1045	143	137	122	0.032	139	121	106	0.036	78	43

‡Chase planes preceded and followed the missile. †Sonic boom evident. *One missile (only the signature from the second missile was analyzed). **Two missiles (signatures from both missiles were analyzed together). N/A = data not available.

TABLE 2.4. Pulse parameters for flat- and A-weighted sound from vehicle flights at San Nicolas Island during August 2001 to July 2002 (Year 1). The peak levels and sound pressure levels are in dB relative to 20 µPa, the sound exposure levels (energy levels) are in dB relative to (20 µPa)^2· s, and the durations (Dur.) are in seconds. The 3-D closest point of approach (CPA) distance of the missile from the monitoring site is given in m. Broadband (10-20,000 Hz) flat- and A-weighted sound levels for each site as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds are also given (dB re 20 µPa).

				CPA	Flat-weighted sound				A-weighted sound				Ambient sound	
Date	Time	Vehicle	Site	(m)	Peak	SPL	SEL	Dur.	Peak	SPL	SEL	Dur.	Flat-wt	A-wt
15 Aug. 01	12:55	Vandal	End of Redeye Road	1763	109	95	100	3.28	102	84	90	3.57	60	44
"	12:55	Vandal	Dos Coves		Overloaded				Overloaded				52	35
"	12:55	Vandal	809 Camera		Overloaded				Overloaded				62	40
15 Aug. 01	13:16	Vandal	End of Redeye Road	1763	112	96	100	2.61	103	85	89	2.38	61	43
"	13:16	Vandal	Dos Coves		Overloaded				Overloaded				53	36
"	13:16	Vandal	809 Camera		Overloaded				Overloaded				74	48
20 Sept. 01	08:29	Vandal	Tender Beach	2256	116	102	107	3.66	108	89	95	4.07	65	55
"	08:29	Vandal	809 Camera †	1046	140	133	119	0.044	130	100	101	1.32	55	41
20 Sept. 01	17:00	Terrier	Building 807	2686	153	138	138	0.93	145	131	130	0.80	59	42
"	17:00	Terrier	100 ft from Launcher	23	103	89	93	2.85	94	77	82	3.01	69	55
"	17:00	Terrier	Cormorant Rock Blind	2433	104	91	96	2.82	93	78	83	3.37	59	38
5 Oct. 01	13:36	Vandal	Phoca Reef	2424	109	90	94	2.92	No signal after A-weighting				48	43
19 Oct. 01	08:59	Vandal	Bachelor Beach South		Overloaded				Overloaded				51	41
"	08:59	Vandal	809 Camera		Overloaded				Overloaded				48	39
"	08:59	Vandal	NAVFAC Beach	3911	133	121	120	0.82	No signal after A-weighting				32	21
19 Dec. 01	15:20	Vandal	Building 807 †	823	144	136	123	0.052	134	107	106	0.82	69	51
"	15:20	Vandal	809 Camera †	897	142	134	121	0.050	133	106	103	0.52	69	48
14 Feb. 02	11:33:00	Vandal	150 ft from Launcher		Overloaded				Overloaded				34	29
"	11:33:00	Vandal	809 Camera †	897	134	123	116	0.19	116	105	91	0.036	63	55
"	11:33:00	Vandal	Bachelor Beach North †	1206	144	135	123	0.065	138	118	107	0.077	59	45
22 Feb. 02	12:13:04	Vandal	809 Camera	2372	110	93	97	2.48	98	80	85	2.80	55	36
"	12:13:04	Vandal	Redeye Beach	1718	111	96	101	3.30	104	87	92	2.71	53	45
22 Feb. 02	14:56:22	Vandal	809 Camera	2372	109	92	99	4.56	102	82	88	3.55	54	44
"	14:56:22	Vandal	Redeye Beach	1718	111	96	102	3.74	103	87	92	3.04	52	44
6 Mar. 02	11:20:38	Vandal	Dos Coves †	399	149	142	129	0.053	142	119	113	0.23	71	46
"	11:20:38	Vandal	Sheephead Ranch	2909	109	98	95	0.57	No signal after A-weighting				45	29
"	11:20:38	Vandal	809 Camera †	897	143	133	121	0.059	137	119	106	0.052	65	46
1 May 02	15:53:20	Vandal	Bachelor Beach South	N/A	110	102	102	0.97	No signal after A-weighting				80	68
1 May 02	17:00:23	Vandal	Bachelor Beach South	2318	115	95	104	6.93	112	86	92	4.00	69	46
"	17:00:23	Vandal	809 Camera	2312	112	96	103	5.39	105	85	90	3.15	76	49

TABLE 2.4. (continued)

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	SPL	SEL	Dur.	A-weighted sound Peak	SPL	SEL	Dur.	Ambient sound Flat-wt	A-wt
8 May 02	14:54:02	Vandal	Vizcaino Point †	1121	144	131	122	0.121	136	117	104	0.052	66	40
"	14:54:02	Vandal	Sea Lion Cove	2139	104	85	92	5.80	96	73	80	4.59	55	33
"	14:54:02	Vandal	Pirates Cove	2388	111	96	96	1.04	84	60	67	4.85	57	33
19 June 02	15:07:00	AGS Test Slug	Redeye II	N/A	111	95	97	1.43	86	68	72	2.50	67	55
21 June 02	12:53:12	RAM	50 ft from Launcher	2361	147	126	131	3.19	146	124	130	3.19	68	52
26 June 02	11:20:00	AGS Test Slug	50 ft from Launcher	N/A	158	150	137	0.051	153	137	125	0.059	59	37
"	11:20:00	AGS Test Slug	Redeye Beach	N/A	110	100	96	0.407	80	57	62	2.86	59	48
"	11:20:00	AGS Test Slug	809 Camera	N/A	109	97	96	0.808	88	59	64	2.92	61	47
26 June 02	12:51:00	AGS Missile	50 ft from Launcher	22	157	148	136	0.056	148	133	122	0.072	57	29
"	12:51:00	AGS Missile	Redeye Beach	1536	108	102	93	0.120	80	57	64	4.85	62	49
"	12:51:00	AGS Missile	809 Camera	2115	107	98	94	0.411	91	72	64	0.15	59	45
18 July 02	11:54:42	Vandal	Dos Coves †	399	149	139	128	0.069	140	122	110	0.065	54	42

Note: Some ATARs overloaded. N/A means data are unavailable (missiles malfunctioned, so CPA could not be calculated). †Sonic boom evident.

2.4.2 Pulse Parameters in Relation to 3-D CPA Distance

Scatter plots of broadband pulse parameters relative to 3-D CPA distance to Vandals and other missiles are shown in Figure 2.3 and Figures 2.4–2.5, respectively. As expected, levels generally decreased with increasing CPA distance. The anomalously high points for the Terrier Orion at 2.7 km (Fig. 2.4) may have resulted from a higher amplifier gain than was allowed for in the analysis.

Vandal Launch Sounds.—Sound parameters associated with Vandal launches were examined in relation to CPA distance and other factors. The Vandal was the one type of missile for which we obtained data during numerous launches over the August 2001 through August 2003 period. Peak pressure level, sound pressure level, and sound exposure level were all strongly and inversely related to CPA distance, as shown in Figure 2.3 and Table 2.5. As expected, flat-weighted levels were generally several decibels stronger than A-weighted levels at corresponding CPA distances, with increasing divergence between the two at the longer CPA distances (Fig. 2.3). 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.

The Vandal missiles were launched from a location in the interior of western San Nicolas Island, about 1.2 mi. (2 km) from the closest shoreline, and were at least 1280 ft (390 m) above sea level when they crossed the beach at the western end of the island. Thus, the measurements made at the closest distance (e.g., launcher; see Fig. 2.3) are higher than those that would have been received by any pinnipeds on the beaches.

The relationship of Vandal sound to CPA distance was stronger for the A-weighted parameters than for flat-weighted parameters, probably because A-weighting de-emphasizes low frequencies where wind effects can dominate, and wind would not be related to the CPA distance. For a given type of weighting, the Spearman rank correlations with CPA distance were similar regardless of the specific measure—in the range -0.66 to -0.73 for flat-weighted data, vs. -0.90 to -0.92 for A-weighted data (Table 2.5). Because pulse parameters showed no signal after A-weighting on three occasions, there were 35 useable measurements for flat-weighted Vandal sounds, and 32 cases for A-weighted Vandal sounds. 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 missile flight path). All *P*-values were < 0.001.

The various measures of the Vandal launch sounds were strongly and positively related with one another (Table 2.6). The relationships are strongest within each weighting type.

TABLE 2.5. Dependence of sound from Vandal missiles on 3-D CPA distance. Spearman rank correlations are shown for flat- and A-weighted broadband pulse parameters vs. 3-D CPA distance. The data are graphed in Figure 2.3. $n = 35$ for flat-weighted sound; $n = 32$ values for A-weighted sound. $P < 0.001$ for all entries.

	Flat-Weighted			A-Weighted		
	Peak	SPL	SEL	Peak	SPL	SEL
Correlation	-0.66	-0.68	-0.73	-0.92	-0.92	-0.90

TABLE 2.6. Relationships among different measures of Vandal launch sounds. Spearman rank correlations are shown for flat- and A-weighted broadband pulse parameters. n = 35 for flat-weighted sound and n = 32 for A-weighted sound. P < 0.001 for all entries. The table is symmetric, as required.

	Flat-Weighted			A-Weighted		
	Peak	SPL	SEL	Peak	SPL	SEL
Peak-Flat		0.91	0.94	0.80	0.80	0.80
SPL-Flat	0.91		0.90	0.83	0.83	0.83
SEL-Flat	0.94	0.90		0.91	0.91	0.93
Peak-A	0.80	0.83	0.91		0.99	0.98
SPL-A	0.80	0.83	0.91	0.99		0.98
SEL-A	0.80	0.83	0.93	0.98	0.98	

Sounds from Other Missiles.—Figures 2.4 and 2.5 summarize the measurements of sounds from missiles other than Vandals in relation to 3-D CPA distance. Because there were few launches of any one type of missile other than the Vandal, no detailed analysis of levels vs. distance or other factors is practical as yet. In general, it can be seen that sound levels from some of these missile types were comparable to those from Vandals (*cf*. Fig. 2.3). The AGS, GQM-163A, and Terrier Orion missiles were launched from the interior of the island, so no pinnipeds were exposed to sounds as strong as those measured near the launcher during those launches. The Tomahawk and RAM missiles were launched from the Building 807 launch complex near a beach (Fig. 1.3), so for those missiles, it is possible that some pinnipeds could be close to the launcher.

2.4.3 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 2.3 for the August 2002 to August 2003 period and in Table 2.4 for the August 2001 to July 2002 monitoring period. The averaging time was 4.0 seconds.

The effect of A-weighting compared to flat weighting is manifest. These are very quiet background sounds, comparable to sound levels expected in quiet residential areas. Furthermore, 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 quoted in Tables 2.3 and 2.4 for the 10-20,000 Hz band.

2.5 Discussion

Sounds from a launch of the Tomahawk missile had not been recorded previously at San Nicolas Island. During test flights, the Tomahawk cruise missile is normally followed by two to four chase planes, and that was the case for the launch on 23 August 2002. Sound signatures were analyzed for the chase plane overflights and found to be very similar to the missile sounds. In fact, although they appeared in sequence, it was not possible to distinguish between the missile and the chase plane

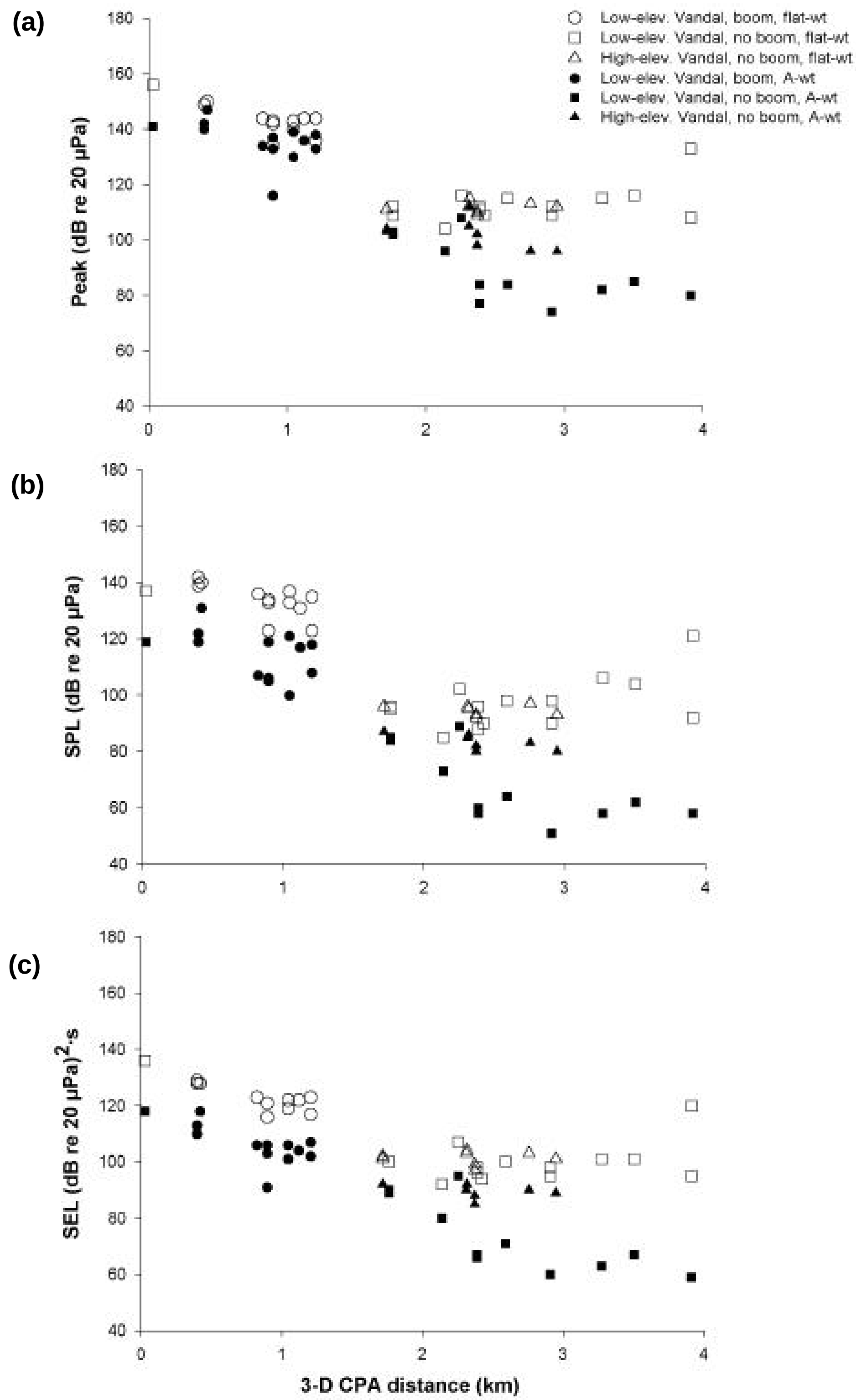

FIGURE 2.3. Sounds from launches of Vandal missiles relative to the 3-D CPA distance: **(a)** Peak sound, **(b)** SPL, and **(c)** SEL. Both flat-weighted (open symbols) and A-weighted (closed symbols) measurements are shown. Low-elevation Vandal launches with sonic booms are indicated by circles, those at low-elevation without booms are indicated by squares, and those at high-elevation angles are shown by triangles.

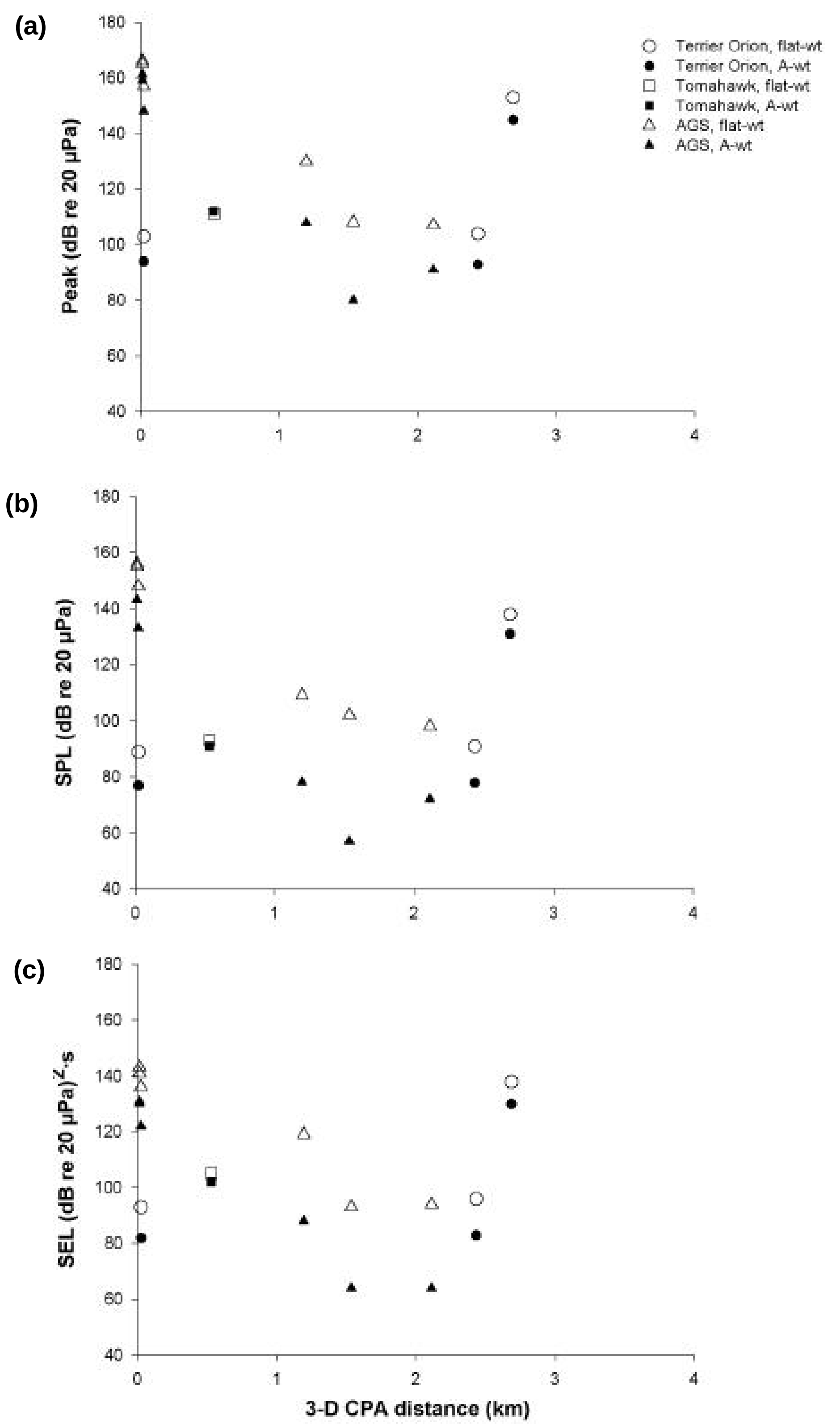

FIGURE 2.4. Sounds from Terrier Orion (circles), Tomahawk (squares), and AGS (triangles) launches relative to the 3-D CPA distance: **(a)** Peak sound, **(b)** SPL, and **(c)** SEL. Both flat-weighted (open symbols) and A-weighted (closed symbols) measurements are shown.

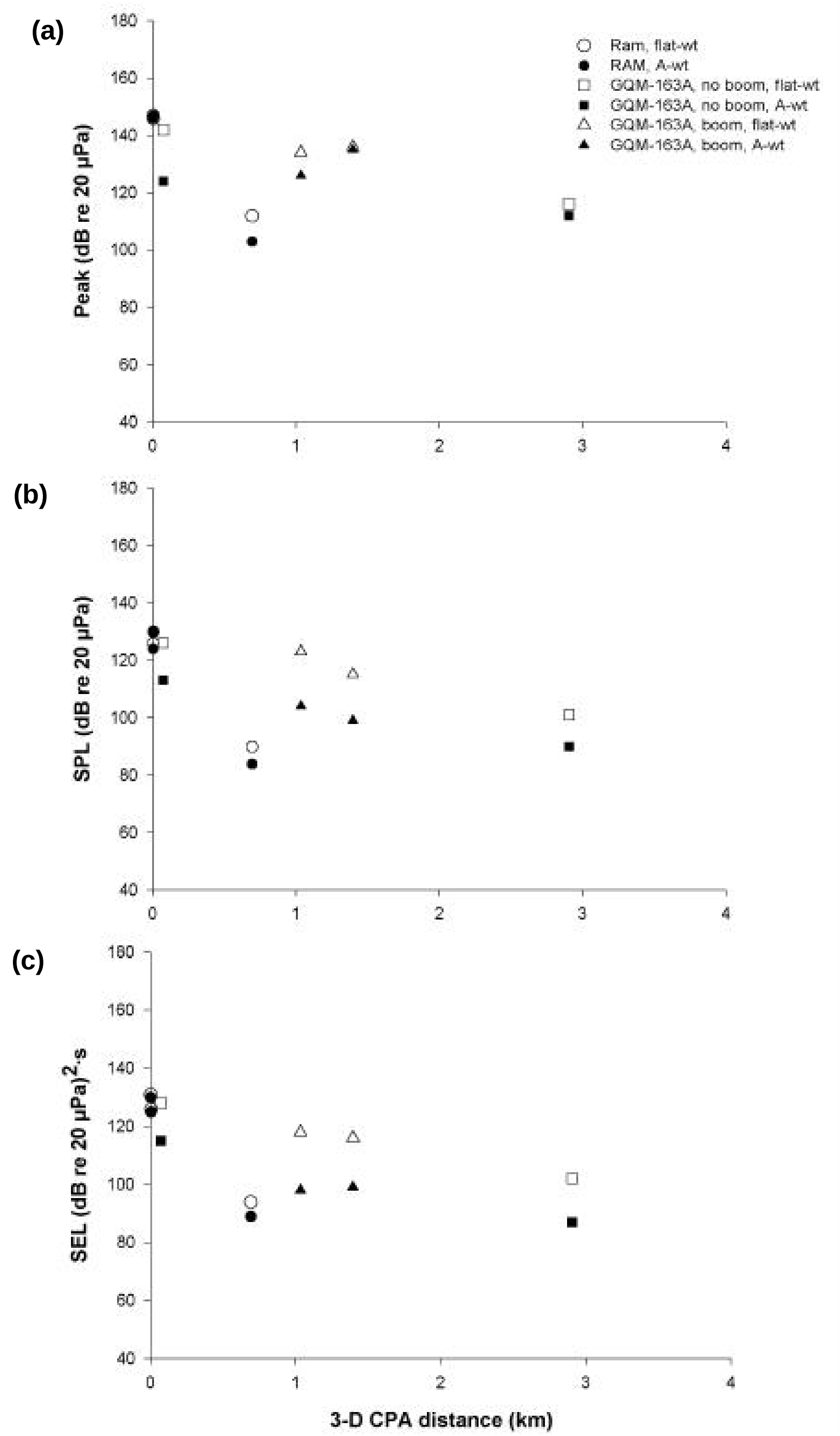

FIGURE 2.5. Sounds from RAM (circles) and GQM-163A launches relative to the 3-D CPA distance. **(a)** Peak sound, **(b)** SPL, and **(c)** SEL. Both flat-weighted (open symbols) and A-weighted (closed symbols) measurements are shown. Triangles and squares represent GQM-163A sounds with and without sonic booms, respectively.

signatures. Of the missile flight and aircraft sounds received at the Dos Coves recording site, the first signature detected, which was around the launch time, was assumed to represent the missile launch.

The GQM-163A is a supersonic sea-skimming target designed to replace the Vandal target missiles. The flight on 24 January 2003 was the first of 11 planned tests, and the missile was unguided and in fact malfunctioned. The sound levels recorded at Redeye I, located ~0.6 mi. (1 km) from the CPA were 134 dB$_{peak}$ re 20 µPa and 123 dB$_{rms}$ re 20 µPa. Another GQM-163A target was launched on 4 June 2003. This launch was monitored 100 ft from the launcher, where the sound levels were recorded as 142 dB$_{peak}$ re 20 µPa and 126 dB$_{rms}$ re 20 µPa, ~0.9 mi. (1.4 km) from the CPA, where the launch produced sound levels of 136 dB$_{peak}$ re 20 µPa and 115 dB$_{rms}$ re 20 µPa), and 1.8 mi. (2.9 km) northeast of the launch azimuth, where the recorded sound levels were 116 dB$_{peak}$ re 20 µPa and 101 dB$_{rms}$ re 20 µPa). Received sound levels from the GQM-163A targets were similar to or less than some sound levels recorded at similar distances from Vandal flightpaths during the 2001-2003 monitoring period (also see Greene and Malme 2002).

Of the recorded sound pressures, none exceeded 145 dBA re (20 ìPa)^2· s SEL. That is the level above which Lawson et al. (1998) assumed that a pinniped might experience TTS upon exposure to a single launch. Few if any pinnipeds were exposed to sound levels above 128 dB re (20 ìPa)^2· s SEL on a flat-weighted basis or 118 dBA SEL. Thus, none of the recorded sound pressures appears to have been sufficiently strong to have induced TTS if the TTS onset occurs at about the level assumed by Lawson et al. (1998). Chapter 4 discusses this topic further.

The monitoring work during the August 2002 through August 2003 period provided additional data on flight sounds from several types of missiles and targets. However, the frequent failures (24%) of the autonomous recording equipment limited the number of data collected. The data from the launches in this period were combined with those from previous launches (August 2001 through July 2002) to provide the basis for a more comprehensive assessment of the flight sounds as a function of vehicle type, receiver location, and other factors. The results showed strong relationships with CPA distance, especially for the A-weighted parameters of peak level, sound pressure level, and sound exposure level.

2.6 Summary

Fourteen vehicles of a variety of types were launched from San Nicolas Island from 23 August 2002 to 28 July 2003. The sound levels received from Vandal, RAM and AGS vehicles were comparable to those recorded previously (Greene and Malme 2002). A new type of target missile, the GQM-163A SSST, was recorded for the first time. It has been designed to replace the Vandal target. Based on limited data from the GQM-163A, its sound levels were similar to or less than those recorded at similar distances from flight paths of Vandal targets. Sound levels ~2300 ft (600 m) from the Tomahawk launcher were found to be on the same order as the associated chase plane sounds.

During the monitoring period, several ATARs stopped recording before the missile was launched. The problem appears to be caused by a software failure, due to a driver in the recording program interacting with the operating system. The driver software has been updated and the operating systems have been upgraded from Windows 2000 (Professional) to Windows XP (Professional). It is suspected that electromagnetic interference from radars and/or telemetry on San Nicolas Island may be causing computer failures. Shielding and grounding will be employed to attempt to defeat the interference effects.

3. BEHAVIOR OF PINNIPEDS DURING MISSILE LAUNCHES[1]

3.1 Introduction

A total of 12 launches occurred from the west end of San Nicolas Island, California, during August 2002 through August 2003, on 11 separate dates. Two of the 12 launches were dual launches of two vehicles within seconds of one another, so a total of 14 vehicles were launched. Specific information about each of the launches is given in Chapter 1. Chapter 2 documents the sounds measured at various sites on western San Nicolas Island during each launch. Corresponding information concerning 19 launches (including one dual launch) during August 2001 through July 2002 were described in Lawson et al. (2002). The acoustic information from the earlier 19 launches as well as the more recent 12 launches is summarized in Chapter 2. This chapter documents the behavioral reactions of pinnipeds exposed to the launch sounds, concentrating on the 12 recent launches but also considering data from the previous 19 launches.

Three species of pinnipeds are common on the beaches of San Nicolas Island: the California sea lion *Zalophus californianus*, the harbor seal *Phoca vitulina*, and the northern elephant seal *Mirounga angustirostris*. No other species were recorded during the present monitoring work. There were relatively few pinnipeds ashore during launches in August – November 2002. That period does not coincide with the pupping season for any of the three pinniped species. The flight paths of the missiles during that period were in proximity to haul-out sites occupied by non-breeding California sea lions and northern elephant seals. In December 2002 – January 2003, missiles flew over haul-out sites occupied by breeding/pupping northern elephant seals and non-breeding California sea lions. Non-breeding harbor seals were likely also hauled out near several of the vehicle flight paths. However, harbor seals were not monitored during launches at San Nicolas Island from August 2002 to January 2003.

The only launches during August through November were the Tomahawk and dual RAM launches from the Building 807 Launch Complex, which is situated about 1.2 mi. (2 km) from any harbor seal haul-out site, with intervening topography. In addition, RAM launches are presumably fairly quiet. No video recordings of harbor seals were obtained during launches in December 2002 and January 2003 due to the emphasis then being placed on elephant seals, which breed at that time of year.

Harbor seals were monitored during March and April 2003, when missiles flew high over haul-out sites occupied by breeding/pupping harbor seals. Although no other pinnipeds were monitored during this period, breeding/pupping northern elephant seals were likely also hauled out near the vehicle flight paths in March; molting elephant seals may have been hauled out in April. As well, non-breeding California sea lions were likely also hauled out near several of the vehicle flight paths during February to April 2003.

From May to July 2003, missiles flew high over haul-out sites occupied by molting harbor and elephant seals, as well as breeding/pupping California sea lions.

No evidence of injury or mortality was observed on the day of any launch. However, on three occasions, 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.

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[1] By **Meike Holst,** LGL Ltd., environmental research associates. Thanks also to John W. Lawson who planned the work and established the format for earlier related reports.

In most cases, sea lion and elephant seal behavior returned to pre-launch states within minutes following the launches. In fact, most northern elephant seals demonstrated little or no reaction to the missile 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. Data from monitoring during August 2001 to July 2002 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).

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 missile 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, depending on how many species were hauled out within the presumed area of influence. However, in practice, only northern elephant seals and California sea lions were monitored from August 2002 to January 2003 and in July 2003, and only harbor seals were monitored in March and April 2003.

For the combined pinniped and acoustic monitoring, the Navy usually attempts to obtain video and audio records from three locations at different distances from the flight path of the missile during each launch from San Nicolas Island. Video data are generally obtained via two or three portable cameras that can be set up temporarily at any site, plus a permanent ("fixed") camera that has been installed near Building 809. However, the latter fixed camera was not operational during the launches from July 2002 through April 2003. 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 B shows the monitoring locations relative to the launch azimuths. The monitoring locations varied from launch to launch. During the present monitoring period, video monitoring was planned to occur at two or three locations during each 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 sound propagation and in pinniped behavioral reactions, this analysis will require data from a relatively large number of otherwise comparable launches. The few launches (of diverse types) in the August 2002 – August 2003 period could not, in themselves, provide sufficient data for such an analysis. Also, paired video and audio data were obtained from less than three sites during most launches in the August 2002 – August 2003 period, and the species present at the various monitoring sites varied from launch to launch. Thus, for each species, the total number of observations of responses to launches was considerably less than three times the number of launches, especially when only the cases with simultaneous acoustic data are considered (Table 3.1).

To investigate the dose-response relationships, acoustic and pinniped response data from the present monitoring period will be used along with corresponding data from previous monitoring during August 2001 – July 2002 (Holst and Lawson 2002) and from future monitoring. As an initial step toward that analysis, in this Chapter we summarize the pinniped response information available to date (August 2001 through August 2003) relative to distance from the launch trajectory.

TABLE 3.1. Video data collected for California Sea Lions, northern elephant seals, and harbor seals during vehicle launches at San Nicolas Island, August 2001 – August 2003. Data collected on 23 August 2002 and subsequently were collected under the most recent IHA Application. Multiple launches are indicated by (x2) and dual launches are indicated by (d).

	Launch Date																								
	2001					**2002**													**2003**						
Video Recording Location	**08/ 15 (x2)**	**09/ 20 (x2)**	**10/ 05**	**10/ 19**	**12/ 19**	**02/ 14**	**02/ 22 (x2)**	**03/ 06**	**05/ 01**	**05/ 08**	**06/ 19**	**06/ 21 (d)**	**06/ 26 (x2)**	**07/ 18**	**08/ 23**	**11/ 18 (d)**	**12/ 10**	**12/ 18 (x2)**	**01/ 24**	**03/ 14**	**03/ 16**	**04/ 04 (d)**	**06/ 04**	**06/ 26**	**07/ 28**
California Sea Lion																									
Dos Coves North	x	x												x											
Dos Coves South	x	x										x			x	x			x						x
809 Camera	x	x	x	x	x			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	x					x			x	x	x								x
Bachelor Beach South		x		x															x						
Dos Coves South																x			x						
Pirates Cove									x	x															
Redeye Beach						x																			
Redeye I											x														
Sea Lion Cove										x															
Harbor Seal																									
809 Camera	x	x	x					x																	
Phoca Reef			x																						
Redeye Beach								x		x			x												
Sea Lion Cove										x															
Corral Harbor																					x				
Pirates Cove								x	x	x										x	x				
Phoca Point																						x			
No Name Cove																						x			
Sheephead Ranch																							x		

Note: Some video data were lost or could not be analyzed due to technical problems - these data are not included in the table. On 20 Sep. 2001, sea lions were observed at 809 Camera, but the video quality was inadequate to provide quantitative data. On 19 Dec. 2001, segments of the video for elephant seals at Bachelor Beach were lost. On several occasions (19 Dec. 2001, 22 Feb. 2002, 1 May 2002, and 14 March 2003), cameras were set up at harbor seal haul-out sites, but no seals were seen during the launch. Detailed data could not be extracted from the video recording of elephant seals at Bachelor Beach North on 18 Nov. 2002 due to poor video quality. Two launches occurred on 18 Dec. 2002, but all cameras failed. Two separate harbor seal sites were monitored at the same beach (Sheephead Ranch) on 4 June 2003.

3.2.1 Fixed Camera

A permanent, fixed camera was installed in an elevated position at Building 809 at the west end of San Nicolas Island (see Appendix B). This camera, designated "809 Camera", was situated on a metal tower overlooking Vizcaino Point (Fig. 3.1). The camera was remotely zoomed, tilted, and panned by an observer stationed in a remote blockhouse (Building 127). Digital video data from this camera were sent back to the blockhouse where they were viewed on a large video monitor and recorded on large- format digital videotape. 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 launches from July 2002 to April 2003.

3.2.2 Mobile Cameras

During the day of each launch, Navy personnel placed up to two portable Sony Hi-8 digital video cameras on tripods that overlooked haul-out sites (Appendix B). Placement of the camera 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. Missile 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 missile passed, but were 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 other portable video 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 did not include a built-in microphone. During the day of each launch, Navy personnel placed up to two wagoncams at locations overlooking haul-out sites (Appendix B). 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 personnel from the Environmental Project Office, China Lake, 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 exact time (to the second) was shown superimposed on the video. For most launches during which sea lions and elephant seals were monitored, the observers returned to the monitoring sites for follow-up monitoring several hours after the launch to note the status of pinnipeds at the haul-out site (e.g., were there similar numbers of pinnipeds? Was there obvious evidence of recent injury or mortality?). Most video recordings of harbor seals showed that haul-out sites were usually occupied by only a few seals or void of seals for minutes or even hours following launches.

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, which unlike other portable video cameras, can transmit its signal back to a centralized location where it is recorded. (Photograph by U.S. Navy)

3.3 Video and Data Analysis

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

Subsequent to the launch, experienced biologists 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.

Quantitative observations of pinnipeds were made based on two 1-min samples of each video recording from the day of each launch. Data were recorded for the 1-min interval immediately preceding the launch and for a 1-min duration starting 10 min after the launch (i.e., from 10-11 min after the launch). A focal subgroup 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.

The variables transcribed from the videotapes include:

1. composition of the focal subgroup of pinnipeds (numbers by sex and age class),
2. description and timing of disruptive event (missile 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.

In addition, the following variables concerning the circumstances of the observations were also recorded from the videotape or from direct observations at the site:

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

To relate pinniped behavior (e.g., percent of focal group that moved or entered the water) to the proximity of the missile launch, two measures of proximity were calculated for each launch date and pinniped monitoring site. These included:

1. 3-D distance from the recording site to the closest point of approach (CPA) of the missile, and
2. horizontal distance from the recording site to the CPA.

3.4 Descriptions of Pinniped Behavior During Specific Launches

The following subsections provide overall descriptions of pinniped responses during each launch in the present monitoring period, descriptions of any notable reactions, and quantitative descriptions of pinniped behavior and distribution prior to and following the launches. See Holst and Lawson [2002] for corresponding descriptions concerning pinniped responses to launches in the August 2001 – July 2002 period.

Video recordings of pinniped behavior during launches in the August 2002 – July 2003 period were collected for California sea lions on six dates, for northern elephant seals on five dates, and for harbor seals on four dates (Table 3.1). During that period, sea lions were monitored at five different sites (total of 10 site-date combinations), elephant seals were observed at three different sites (seven site-date combinations), and harbor seals were monitored at five sites (six site-date combinations). Over the course of both monitoring years (August 2001 to August 2003), sea lions were monitored at a total of 32 sites on 18 dates, northern elephant seals were observed at 18 monitoring sites on 13 dates, and harbor seals were monitored at a total of 18 sites on 11 dates (Table 3.1). The video recordings generally provided data on the responses of a sample of the total pinnipeds present on a given beach. The total number of pinnipeds hauled out at several sites could not be determined due to intervening topography, reduced horizontal visibility, or limitations of video resolution.

3.4.1 Tomahawk Launch, 23 August 2002

A Tactical Tomahawk was launched from the Building 807 Launch Complex, with a launch azimuth of 305º and an initial elevation angle of 90º. California sea lions were videotaped at Dos Coves South, ~1970 ft (600 m) from the CPA, and elephant seals were observed at Bachelor Beach North, ~2460 ft (750 m) from the CPA (Table 3.1; Fig. B-1A). Launch sounds were recorded at Dos Coves (Table 2.2 in Chapter 2; Fig. B-1A).

In addition to the Tomahawk missile launch, F-14 chase planes were to escort the missile during flight. On the launch day, the cloud cover was very low, so the planes had to fly very low to be under the clouds to see the launcher. The planes made numerous (~10) low-level passes during each of several planned launch times, including the final attempt, when the missile was launched.

California Sea Lions.—Prior to the launch, California sea lions at Dos Coves South were repeatedly disturbed by chase planes. About 50 individuals were monitored on the video, although more animals were likely present, but could not be observed within the field of view of the camera. During these disturbance events, the sea lions displayed vigorous and prolonged movements on the beach. On most of these occasions, all animals of all ages reacted by either moving on the beach, entering the water, or exiting the water and coming up onto the beach. Pups reacted more vigorously to these disturbances than did adults. Prior to the launch, some pups and juveniles were playing in the shallow water near the beach, while other pups were moving around on the beach. In addition, it appeared that some sea lions in the shallow water would sometimes rush ashore during heavy surf conditions.

During the launch, all animals on the beach reacted by moving vigorously up the beach, one pup entered the water, while yet another pup came out of the water and moved rapidly up the beach in response to the launch. Within several minutes after the launch, most sea lions had settled again. A small number of pups remained active for several minutes after the launch, and a few were playing in the shallow waters near the shoreline; this type of activity had been occurring prior to the launches (Table 3.2).

Northern Elephant Seals.—Groups of juvenile northern elephant seals were videotaped at Bachelor Beach North. Upon launch, the Tomahawk missile departed to the northwest and away from this monitoring site. Seals showed no overt reaction to the missile launch or to the chase planes prior to the launch (Table 3.3). Seals were neither observed looking up nor moving in response to any possible disturbance. Seal behavior was thus similar prior to, during, and after the launch, and consisted of resting. The launch sound was documented nearby at Bachelor Beach South (Table 2.2).

Follow-up Monitoring.—During follow-up monitoring several hours after the launch, the distribution, numbers, and behavior patterns of California sea lions and northern elephant seals were similar to those during the pre-launch period. No injury or mortality attributable to the launch was observed.

3.4.2 Dual RAM Launch, 18 November 2002

A dual RAM launch occurred from the Building 807 Launch Complex, with an azimuth of 240º and an elevation angle of 10º. The two RAM vehicles were launched within seconds of each other. With regard to effects on pinniped behavior, these two launches could not be distinguished and were not analyzed separately. Video recordings of California sea lions and northern elephant seals were made at Dos Coves South, ~1970 ft (600 m) from the CPA. Another recording of elephant seals was attempted at Bachelor Beach North, 2460 ft (750 m) from the CPA (Table 3.1; Fig. B-1B). Launch sound was audible on the audio track of the video recording at Dos Coves South. Launch sounds were recorded at Bachelor Beach North and 75 ft from the launcher (Table 2.2 in Chapter 2; Fig. B-1B).

California Sea Lions.—At Dos Coves South, sea lion pups responded more vigorously than adults to the launch. During the launch, the majority of sea lion pups moved vigorously along the beach. Some adult females looked up or got up in response to the launch, but hardly moved otherwise. In total, approximately 57% of 70 observed sea lions hauled out at Dos Coves reacted vigorously to the launch. Within two minutes after the launch, adult sea lions settled back to their resting positions, although they were more vigilant. However, several pups remained active for some time after the launch, but they had also been observed moving along the beach prior to the launch (Table 3.2).

Northern Elephant Seals.—During the recording of elephant seals at Bachelor Beach North, video interference occurred during the launch. Thus no accurate observations were possible. However, there did appear to be some seal reaction in response to the launch; some animals may have looked up or moved a short distance. However, the degree of this reaction could not be determined from the limited video. Prior to and after the launch, seals were resting on the beach (Table 3.3). The launch sound was also documented at this site (Table 2.2).

At Dos Coves South, most elephant seals reacted to the launch by looking up, but only a few animals (29%) moved a small distance along the beach. The seals settled quickly after the launch. Elephant seals were seen resting prior to and after the launch (Table 3.3).

TABLE 3.2. Details of vehicle launches, sound exposure levels (SEL), and ***California sea lion*** reactions at San Nicolas Island during August 2002 – August 2003; corresponding information for August 2001 – July 2002 is reported in Lawson et al. (2002) and Table D.1 in Appendix D. There were no recordings of sea lions from February to May 2003. A dual RAM launch occurred on 18 November 2002. The Tomahawk and RAM vehicles were launched from the Building 807 Launch Complex, whereas the GQM-163A targets were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded quantitatively at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 µPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
23 Aug. 2002	14:10	Tomahawk	305°	90° / 1000 ft	Dos Coves South[n]	594	105/102	All 50 animals moved around vigorously on the beach; one pup entered the water; one pup came out of the water. Animals settled within minutes after launch.
18 Nov. 2002	11:03	RAM	240°	10° / 50 ft	Dos Coves South[n]	580	Launch sound audible on audio track of video recording	Most sea lion pups moved vigorously along beach; some adults looked or got up, but did not move any further; 57% of 70 animals reacted vigorously. Animals settled within minutes after the launch.
24 Jan. 2003	14:20	GQM-163A	270°	20° / 3400 ft	Dos Coves South[c]	993	N/A	About 30 s after the launch, 40 sea lions were seen moving vigorously down the beach and possibly entered the water; most animals seen were pups
4 June 2003	12:35:20	GQM-163A	270°	22° / 3500 ft	809 Camera[n]	1429	116/99	Most sea lions (60% of 15) got up and moved 1-10 m; one adult female entered the water. Remained vigilant for ~1.5 min after the launch.

TABLE 3.2. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
26 June 2003	13:27:58	Vandal	285°	42° / 17,300 ft	809 Camera[n]	2807	103/90	Most of the 10 sea lions looked up from their resting positions, but did not move. Settled back to their resting positions within seconds after launch.
					The "Y"[c]	2824	101/89	Majority of 20 sea lions looked up, but did not move. Settled back within seconds after launch.
					Bomber Cove[n]	3054	Launch sound audible on audio track of video recording	Most adult sea lions (92% of 100) looked up and some sat up, but did not move. One male and one female sea lion moved ~2 m. Six pups ran through the water. Animals settled several minutes after launch.
28 July 2003	16:27:50	Vandal	270°	8° / 1280 ft	Dos Coves South[c]	388	Launch sound audible on audio track of video recording	All 100 sea lions scattered; about 50% of the adults (~25) moved 2-3 m; the other 50% moved >10 m. All pups ran around on the beach, and several pups (~12 of 50) entered the water. After launch, adults remained vigilant and pups were still moving on beach.
					809 Camera[n]	1081	122/106	All 35 sea lions startled and got up. Several animals (26%) moved 3-8 m, but none entered water. Several animals were more vigilant up to 10 min after launch.
					Bachelor Beach North[s]	1082	N/A	Several of the 7 animals looked up or got up, but none moved. Sea lions settled within 30 sec after launch.

Note: N/A means that sound exposure levels are not available for that location, and there is no audio track on the video recording for that site.
[n] monitoring site located north of the launch azimuth.
[c] monitoring site located near the launch azimuth.
[s] monitoring site located south of the launch azimuth.

TABLE 3.3. Details of vehicle launches, sound exposure levels (SEL), and ***northern elephant seal*** reactions at San Nicolas Island during August 2002 – August 2003; corresponding information for August 2001 – July 2002 is reported in Lawson et al. (2002) and Table D.2 in Appendix D. There were no recordings of elephant seals from February to June 2003. A dual RAM launch occurred on 18 November 2002. The Tomahawk and RAM vehicles were launched from Building 807 Launch Complex, whereas the Vandal and GQM-163A targets were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded quantitatively at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 µPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
23 Aug. 2002	14:10	Tomahawk	305°	90° / 1000 ft	Bachelor Beach North[s]	746	N/A	All 10 seals did not respond to launch.
18 Nov. 2002	11:03	RAM	240°	10° / 50 ft	Bachelor Beach North[s]	683	97/92*	Some of the 60 seals likely reacted by looking up, but poor video quality.
					Dos Coves South[n]	580	Launch sound audible on audio track of video recording	All 10 seals looked up; 29% of animals moved a small distance along beach. Seals settled within seconds after launch.
10 Dec. 2002	8:49	Vandal	273°	8° / 1300 ft	Bachelor Beach North[s]	1206	117/102	Majority of 40 seals looked up and several animals (38%; mainly pups) moved; one seal entered water. Seals settled within a minute after launch.
24 Jan. 2003	14:20	GQM-163A	270°	20° / 3400 ft	Bachelor Beach South[s]	1677	Launch sound audible on audio track of video recording	All 100 seals looked up and several (5%) moved. Seals settled quickly.
					Dos Coves South[c]	993	N/A	All 7 seals looked up and 3 of 7 moved a short distance; seals settled quickly.
28 July 2003	16:27:50	Vandal	270°	8° / 1280 ft	Bachelor Beach North[s]	1082	N/A	Majority of 7 seals looked up and some did not respond to launch at all.

Note: N/A means that sound exposure levels are not available for that location, and there is no audio track on the video recording for that site.
[n] monitoring site was located north of the launch azimuth.
[s] monitoring site was located south of the launch azimuth.
[c] monitoring site was located near the launch azimuth.
*SEL taken nearby Bachelor Beach South, located < 0.5 km south of Bachelor Beach North.

***Follow-up Monitoring*.**—During follow-up monitoring, the distribution, numbers, and behavior patterns of California sea lions and northern elephant seals were similar to those during the pre-launch period. California sea lions were seen nursing pups. No injury or mortality attributable to the launch was observed.

3.4.3 Vandal Launch, 10 December 2002

A Vandal target was launched from the Alpha Launch Complex, with an azimuth of 273º and an 8º elevation angle. The Vandal passed over Dos Coves South at an altitude of about 1300 ft. A video recording of California sea lions and northern elephant seals was attempted there, but no data could be extracted from this video, because the lens on this remote camera had become obscured by moisture by launch time. Elephant seals were recorded at Bachelor Beach North, 0.7 mi. (1.2 km) from the CPA (Table 3.1; Fig. B-1C). The launch sound was audible on the audio track of the video recording. Another video recording was attempted at another site at Bachelor Beach, but that camera's signal did not transmit properly. Launch sounds were recorded at Bachelor Beach North and at Dos Coves, and a sonic boom was evident at both of those locations (Tables 2.2, 2.3 in Chapter 2; Fig. B-1C).

***Northern Elephant Seals*.**—At Bachelor Beach North, ~40 elephant seals were observed during the launch. Elephant seals pups responded to the launch more than did adult females. During the launch, almost all animals looked up, several animals moved in response to the launch, and one animal entered the water (Table 3.3). The majority of the seals that moved in response to the launch were pups; most of these animals moved a distance of several meters (up to about 10 m or 33 ft) along the beach, although some only moved several feet. Seals settled within a minute after the launch and returned to their resting positions. Prior to the launch, seals were also seen resting. The launch sound was documented at the same site (Table 2.2).

***Follow-up Monitoring*.**—During follow-up monitoring, the distribution, numbers, and behavior patterns of northern elephant seals were similar to those during the pre-launch period at Bachelor Beach. At Dos Coves, elephant seals and California sea lions were also hauled-out after the launch. No injury or mortality attributable to the launch was observed.

3.4.4 Double AGS Launches, 18 December 2002

Two AGS missiles were launched sequentially from the Alpha Launch Complex, 1 hr 45 min apart. Both launches had an azimuth of 282º and an elevation angle of 50º. The missiles passed north of Dos Coves at an altitude of ~4500 ft; California sea lions typically are hauled out at that location (Table 3.1; Fig. B-1D). However, no video recordings were obtained for these launches, due to equipment malfunction. Launch sounds were recorded 50 ft (15 m) from the launcher during both launches and also at a site close to 809 Camera during the first launch at 14:30 (Table 2.2 in Chapter 2; Fig. B-1D).

3.4.5 GQM-163A Launch, 24 January 2003

A GQM-163A Supersonic Sea-Skimming Target was launched from the Alpha Launch Complex at an azimuth of 270º and an elevation angle of 20º. The missile passed over Dos Coves South at an altitude of ~3400 ft. Video recordings of elephant seals were obtained at Dos Coves South, 0.6 mi. or 1 km from the CPA and at Bachelor Beach South, ~1.1 mi. (1.7 km) from the CPA. At both sites, elephant seals were hauled out and video data were obtained (Table 3.1; Fig. B-1E). Launch sounds were audible on the audio track of the video recording at Bachelor Beach. Another recording of elephant seals was attempted at Redeye I Beach, but the video lens was obscured by moisture and no observations could be made. Although no California sea lions were in the video camera's field of view at Dos Coves South during the launch, sea lions were seen hauled-out at the location several hours prior to the launch, and a group moved into view immediately after the launch. Launch sounds were recorded at Redeye I, and a sonic boom was evident at this location (Tables 2.2, 2.3 in Chapter 2; Fig. B-1E).

California Sea Lions.—Immediately after the launch, sea lions at Dos Coves South responded vigorously by moving down the beach and entering the water. About 40 animals that were out of sight prior to the launch moved rapidly into the field of view ~10 sec after the overflight. Within 2 minutes after the overflight, adult sea lions had assumed resting positions on the beach, but remained vigilant. A few pups remained active for several minutes after the launch, but they had been observed moving along the beach several hours prior to the launch (Table 3.2).

Northern Elephant Seals.—Adult female elephant seals and pups were observed at Bachelor Beach South (100 seals) and at Dos Coves (7 seals) during the launch. During the launch, all seals looked up and several moved a short distance of less than 5 ft (Table 3.3). Approximately 30 seconds after the launch, seals had returned to their resting positions.

Follow-up Monitoring.—During follow-up monitoring, the distribution, numbers, and behavior patterns of California sea lions and northern elephant seals were similar to those during the pre-launch period. No injury or mortality attributable to the launch was observed.

3.4.6 Vandal Launch, 14 March 2003

A Vandal was launched from the Alpha Launch Complex, with an azimuth of 273º and an 8º elevation angle. A video recording of harbor seals was obtained at Sheephead Ranch, located ~1.8 mi. (2.9 km) northeast (away) from the launcher (Table 3.1; Fig. B-1F). Launch sounds were audible on the audio track of the video recording. Another video recording of harbor seals was attempted at Pirates Cove, but no seals were hauled out at the time of the launch. Sounds were monitored at Pirates Cove, Sheephead Ranch, and near the launcher (Table 2.2; Fig. B-1F).

Harbor Seals.—Most of the harbor seals (four out of five) hauled out at Sheephead Ranch entered the water in response to the Vandal launch, but some of them did so slowly (Table 3.4). One pup that was hauled out looked up, but did not move in response to the launch. No harbor seals returned to the haul out site for the duration of the recording period, which continued for ~1 hr after the launch.

3.4.7 Vandal Launch, 16 March 2003

A single Vandal was launched from the Alpha Launch Complex, with an azimuth of 273º and an 8º elevation angle. Video recordings were made of harbor seals at Corral Harbor (located 1.6 mi. ~2.6 km northeast of the launcher) and Pirates Cove, located 1.5 mi. (~2.4 km) northeast of the launcher (Table 3.1; Fig. B-1G). Launch sounds were audible on the audio tracks of both video recordings. Sounds were monitored at Corral Harbor; two other sound recordings at Sheephead Ranch and the launcher were attempted but failed (Table 2.2; Fig. B-1G).

Harbor Seals.—All eight of the harbor seals hauled out on the sand at Corral Harbor entered the water in response to the Vandal launch, although some did so slowly (Table 3.4). No seals were left on the beach 10 min after the launch. Seals started to haul out again at the site 30 min after the launch. At Pirates Cove, the majority of the 45 seals entered the water in response to the launch; some seals entered the water during or immediately after the launch, whereas other seals took their time (up to 1 min or so).

TABLE 3.4. Details of vehicle launches, sound exposure levels (SEL), and ***harbor seal*** reactions at San Nicolas Island during August 2002 – August 2003; corresponding information for August 2001 – July 2002 is reported in Lawson et al. (2002) and in Table D.3 in Appendix D. There were no recordings of harbor seals from August 2002 to February 2003. A dual Vandal launch occurred on 4 April 2003. The Vandals were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded quantitatively at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 µPa)$^2 \cdot$ s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
14 Mar. 2003	9:13	Vandal	273°	8° / 1300 ft[e]	Sheephead Ranch[e]	2923	98/60	Most seals (4 of 5) entered water; one pup looked but did not move.
16 Mar. 2003	13:04	Vandal	273°	8° / 1300 ft[e]	Corral Harbor[e]	2589	100/71	All (8 of 8) seals entered water; some more slowly than others.
					Pirates Cove[e]	2389	N/A	Majority of 45 seals entered water; 20% did not but moved at least several feet on beach. A pup was knocked over by an adult seal, but did not appear hurt.
4 Apr. 2003	15:20	Dual Vandal	273°	8° / 1300 ft[e]	Phoca Point[e]	3274	101/63-66	Majority of 35 seals entered water; 11% of seals did not enter the water, but moved at least several feet on the beach. Two pups were knocked over by adult seals, but did not appear hurt.
					No Name Cove[e]	3514	101/67-68	Majority of 30 seals entered water, 10% did not and moved only short distances on beach.
4 June 2003	12:35:20	GQM-163A	270°	22° / 3500 ft	Sheephead Ranch[e]	2923	102/87	Six of 7 seals looked up in response to the launch, but did not move. One seal moved 0.5 m.

Note: N/A means that sound exposure levels are not available for that location, and/or there is no audio track on the video recording for that site.
[e] monitoring site located northeast (away) from the launch azimuth; “altitude over beach” pertains to the beach on the west end of San Nicolas Island where the launch azimuth went offshore—far from these pinniped monitoring sites.

About 20% of the seals that were hauled out at Pirates Cove did not enter the water in response to the launch, but moved <10 ft along the beach (Table 3.4). One adult seal traveled over a seal pup on its way down to the water. The pup was momentarily startled, but then continued to move toward the water; the pup did not appear to be hurt. Seals started hauling out on the beach again 4 min after the launch.

3.4.8 Dual Vandal Launch, 4 April 2003

Dual Vandal targets were launched within 5 sec of each other from the Alpha Launch Complex, with an azimuth of 273º and an 8º elevation angle. With regard to effects on pinniped behavior, these two launches could not be distinguished and were not analyzed separately. Video recordings of harbor seals were obtained at Phoca Point (located 2.1 mi. and 3.3 km northeast of the launcher) and an unnamed cove (No Name Cove), located 2.2 mi. (3.5 km), northeast (away) from the launcher (Table 3.1; Fig. B-1H). Launch sounds were audible on the audio tracks of both video recordings. Sounds were monitored at NAVFAC Beach, No Name Cove, and Phoca Point (Table 2.2; Fig. B-1H).

Harbor Seals.—Most of the 35 harbor seals hauled out on the sand at Phoca Point entered the water in response to the Vandal launch (Table 3.4). About 11% of the seals did not enter the water, but moved at least several feet along the beach in response to the launch. Two adult seals each traveled over seal pups on their way down to the water. The two pups were momentarily startled, but then continued to move toward the water; the pups did not appear to be hurt. At No Name Cove, the majority of 30 seals also entered the water (Table 3.4). Those that did not do so (10%) moved only a short distance on the beach and were more vigilant compared with prior to the launch. Seals started to haul out again at Phoca Point about 15 min after the launch; at No Name Cove, no seals hauled out on the beach during the remaining 20 min of video recording after the launch.

3.4.9 GQM-163A Launch, 4 June 2003

A GQM-163A Supersonic Sea-Skimming Target was launched from the Alpha Launch Complex at an azimuth of 270º and an elevation angle of 22º. The missile passed over the west side of San Nicolas Island at an altitude of ~3500 ft. California sea lions were observed at 809 Camera, ~0.9 mi. (1.4 km) from the CPA, and harbor seals were video-taped at Sheephead Ranch, located ~1.8 mi. (2.9 km) northeast of the launcher (Table 3.1; Fig. B-1I). Launch sounds were recorded at Sheephead Ranch and at 809 Camera (Tables 2.2, 2.3 in Chapter 2; Fig. B-1I).

California Sea Lions.—During the launch, most sea lions monitored near 809 Camera responded by getting up and moving a short distance (1-3 m) across the beach. Several animals (3 out of 15) moved more than 7 m, and one adult female entered the water. Sea lions remained vigilant for ~1.5 min after the overflight, but assumed resting positions on the beach (Table 3.2).

Harbor Seals.—Most of the harbor seals (six out of seven) hauled out at Sheephead Ranch looked up in response to the launch, but they did not move (Table 3.4). One seal moved a short distance of 0.5 m. The harbor seals remained hauled-out on the rocky outcrop during the remainder of the video recording period (~1 hr), but were more vigilant for ~1 min after the launch.

3.4.10 Vandal Launch, 26 June 2003

A single Vandal was launched from the Alpha Launch Complex, with an azimuth of 285º and a 42º elevation angle; it crossed the west end of San Nicolas Island at an altitude of 17,300 ft (5274 m). Video recordings of California sea lions were obtained at three sites: near 809 Camera and the "Y", both located ~1.7 mi. or 2.8 km from the CPA, and at Bomber Cove, situated ~1.9 mi. or 3 km from the CPA

(Table 3.1; Fig. B-1J). Launch sounds were audible on the audio tracks of video recordings at Bomber Cove and The "Y". Sounds were monitored at all three of these sites (Table 2.2; Fig. B-1J).

***California Sea Lions*.—**Near 809 Camera and The "Y", sea lions hardly reacted to the launch. Most looked up from their resting positions, but did not move (Table 3.2). They settled back to their resting positions within seconds after the launch. At Bomber Cove, before the launch, several pups were wandering around in the water, but adults were resting. Pups responded more vigorously than adults to the launch. Adult sea lions hardly reacted to the launch; most animals looked up and some sat up but did not move (Table 3.2). One male sea lion that was sitting in shallow water moved slightly farther into the water, but did not leave the area. However, several pups (6) ran through the water along the beach in response to the launch. Several minutes after the launch, the sea lions had returned to their pre-launch behaviors.

3.4.11 Vandal Launch, 28 July 2003

A single Vandal was launched from the Alpha Launch Complex, with an azimuth of 270º and an 8º elevation angle. Video recordings were obtained of California sea lions at three sites: near 809 Camera, located ~0.6 mi. or 1 km from the CPA; at Dos Coves South, located directly below the flight path; and at Bachelor Beach North, situated ~0.7 mi. or 1.1 km from the CPA (Table 3.1; Fig. B-1K). Launch sounds were audible on the audio tracks of the video recording at Dos Coves South. Sounds were monitored at 809 Camera (Table 2.2; Fig. B-1K).

***California Sea Lions*.—**Before the launch, several California sea lion pups were moving about the beach at Dos Coves South and playing, whereas adults were resting. In response to the launch, all sea lions on the beach scattered, but some adult females did not move very far (Table 3.2). About half of the adults (~25 females) moved 2-3 m, whereas the other 25 females moved >10 m. All pups reacted vigorously to the launch by running around on the beach, and several pups (~12 out of 50) entered the water. Adult female sea lions were more vigilant for at least 3 min after the launch. Many pups continued to move around on the beach after the launch; more pups were moving around on the beach after the launch compared with prior to the launch.

Near 809 Camera, all sea lions were startled during the launch, and got up. Several animals (~10 out of 35) moved 3-8 m, but none entered the water. No pups were observed during this recording. Most of the sea lions settled back to their pre-launch behavior (mostly resting) within seconds after the launch. However, several animals were more vigilant up to 10 min after the launch.

At Bachelor Beach North, sea lions hardly reacted in response to the launch. Several animals looked up or got up, but none moved. The sea lions settled within 30 sec after the launch.

***Northern Elephant Seals*.—**Juvenile elephant seals were observed at Bachelor Beach South (7 seals) during the launch. During the launch, most seals looked up, but some did not respond to the launch at all (Table 3.3). Within seconds after the launch, seals had returned to their resting positions.

3.5 Quantitative Comparisons of Pinniped Behavior and Distribution Prior to and Following Launches

The "units of observation" for the quantitative studies 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 chosen for the focal subgroups before and after the 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 noise (e.g., young California sea lions and harbor seals). In the case of northern elephant seals, the focal animals were often the same individuals that were observed prior to the launch, and hence not as likely to be statistically independent.

The data for the August 2002 – August 2003 period were pooled with those from August 2001 – July 2002 (see Holst and Lawson 2002), in order to increase the statistical power of the analyses.

Means and standard deviations are presented for inter-individual spacing, total distance moved, and number of position changes before and after launches, separately by species (Table 3.5). For all tests, data from pinnipeds monitored during all missile launches, on all dates, and at all locations were included, notwithstanding the differences in types of missiles, sound exposure, etc.

Body Position Changes

An analysis comparing the number of body position changes of the three species showed that there were significant differences among the species both before launches (Kruskal-Wallis, $H = 13.42$, df = 2, $P < 0.01$) and after launches ($H = 22.29$, $P < 0.001$). Before launches, California sea lions were generally more mobile than both harbor and elephant seals (Table 3.5). After launches, California sea lions were significantly more mobile than harbor and elephant seals (Dunn's multiple comparison, $P < 0.05$).

Significantly more body position changes were made by focal California sea lions in the 1-min periods following missile launches than in the minute preceding the launches (Mann-Whitney U = 69,913, $P < 0.001$; Table 3.5). Most of the difference for the sea lions can be attributed to the vigorous responses by young animals. Harbor seals also made more body position changes after the launch as compared to before the launch (U = 13,488.5, $P = 0.003$, Table 3.5). Northern elephant seals did not become significantly more active (as indicated by frequency of body position changes) in response to launches ($P = 0.6$). However, since harbor seals often left the haul-out site after a launch, the number of animals observed post launch was less than that before launch.

Total distances moved

This measure of behavior differed among the three species both before and after the launches (Kruskal-Wallis $H = 14.02$ and 28.38, respectively; both $P < 0.001$). Before launches, California sea lions generally moved greater distances compared to harbor and elephant seals (Table 3.5). After launches, California sea lions were significantly more mobile than both harbor and elephant seals (Dunn's multiple comparisons, $P < 0.05$).

The total distances moved by focal California sea lions in the 1-min sample periods following missile launches were significantly greater than in the minute preceding the launches (Mann-Whitney U = 70,423, $P < 0.001$; Table 3.5). As for the body position changes, most of the difference for the sea lions can be attributed to the vigorous responses by young animals. Similarly, harbor seals moved greater distances after the launch as compared to before the launch (U = 13,489; $P = 0.003$; Table 3.5). There was no pre- vs. post-launch difference for northern elephant seals ($P = 0.7$). However, harbor seals often left the haul-out site after a launch, so the number of animals observed post launch were less than half the number of animals observed before launch.

TABLE 3.5. Description of pinniped behavior and distribution prior to and after launches, August 2002 – August 2003. *n* = number of animals; SD = standard deviation; *P* = significance level.

	Before Launch			After Launch			
Behavior Analyzed	*n*	Mean	SD	*n*	Mean	SD	*P*[a]
Number of Position Changes							
California Sea Lions	378	0.29	0.79	311	0.59	1.02	***
Northern Elephant Seals	158	0.20	0.49	141	0.29	0.72	Ns
Harbor Seals	229	0.10	0.46	107	0.25	0.67	**
Total Distance Moved (m)							
California Sea Lions	378	0.36	1.41	311	1.05	2.94	***
Northern Elephant Seals	158	0.12	0.45	141	0.19	0.75	Ns
Harbor Seals	229	0.05	0.27	107	0.11	0.34	**
Distance to neighbor (m)							
California Sea Lions	378	0.63	1.44	311	0.57	1.05	Ns
Northern Elephant Seals	158	0.30	0.63	141	0.28	0.68	Ns
Harbor Seals	229	0.87	1.30	106	1.68	3.08	**

[a] Statistical significance column shows results of Mann-Whitney *U* tests comparing results before vs. after launch. *P*-values are approximate, because individual animals probably were not all statistically independent of one another; *** means $P \leq 0.001$, ** means $0.001 < P \leq 0.01$, and Ns means not significant, $P > 0.1$.

Distances Between Focal Animals

These values, shown in Table 3.5, differed significantly among the three species both before launches and after launches ($H = 78.26$ and $H = 95.80$, respectively, $P < 0.001$). Before and after launches, distances between harbor seals were significantly greater than those between the other two species (Dunn's multiple comparisons, $P < 0.001$). In addition, after launches, distances between focal sea lions were significantly greater than those between elephant seals (Dunn's multiple comparison, $P < 0.05$).

Focal harbor seals were significantly farther apart after than before launches (U =14,496, P = 0.003). For elephant seals and California sea lions, distances between individuals did not change significantly from before launch to after launch ($P = 0.3$ and $P = 0.2$, respectively).

3.7 Pinniped Behavior Relative to CPA Distance of Missile

For these analyses, data from August 2001 to August 2003 were combined. Monitoring data collected on days when missiles malfunctioned were not included in the analyses. Graphs showing responses vs. CPA distance are based on the 3-D CPA distance, which is expected to be most closely related to received sound level. However, graphs plotting responses vs. horizontal CPA distance showed very similar results. Spearman rank correlation coefficients (r_s) between pinniped responses and 3-D CPA distance are given. In quoting the statistical significance of those correlations, one-sided P values are given, since the direction of the effect was predictable (i.e., pinnipeds were expected to be more responsive closer to the missile flight path). Emphasis is given to the behavior of pinnipeds during Vandal launches, as that was the one type of launch for which there was a substantial sample size.

California Sea Lions

Considering all types of missiles together, the percentage of sea lions that moved decreased with increasing 3-D CPA and horizontal CPA distance from the missiles and with increasing horizontal CPA distance (Table 3.6, Fig. 3.3a). When only Vandals were considered, the percentage of sea lions that moved increased with decreasing 3-D CPA and horizontal CPA distance (Table 3.6). The percent of sea lions that entered the water was generally low or zero (Fig. 3.3a). Considering all missile launches, there was a significant relationship between the percentage of sea lions entering the water and CPA distance or horizontal CPA distance (Table 3.6, Fig. 3.3a). Likewise, when only the Vandal launches were considered, the percentage of sea lions that entered the water decreased with a increasing 3-D CPA and horizontal CPA distance (Table 3.6).

Sea lions generally entered the water only in response to launches of the larger missiles (e.g., mainly Vandals), and then only for some of those passing within 1-1.4 km (Fig. 3.3a). High-elevation launches generally elicited responses from fewer sea lions as compared with low-elevation launches, presumably because missiles launched from the Alpha Complex at high elevation angles passed over or near the haul-out locations at high altitudes (Table 3.2, Table C-1).

Northern elephant seals

The percentage of elephant seals that moved was generally low, even rather close to the launch azimuth (Fig. 3.3b). During only 1 of 16 occasions launches was there evidence of an elephant seal entering the water, and that involved only a single individual. The behavior of elephant seals was marginally related to proximity to the launch azimuth. When all missile launches were considered, the percentage of elephant seals that moved increased only marginally with decreasing 3-D CPA distance, but somewhat more consistently with decreasing horizontal CPA distance (Table 3.6). When only Vandals were considered, the percentage of elephant seals that moved increased marginally with decreasing 3-D CPA and horizontal distance (Table 3.6).

Harbor seals

Moderate to high proportions of the harbor seals at monitoring sites moved during 21 missile launches for which we have data—even in the case of missiles whose 3-D CPA distance was 2.0-3.5 km away. Likewise, harbor seals commonly entered the water during launches with 3-D CPA 2.0-3.5 km as well as during launches when the missile came closer to the seals (Fig. 3.3c). No significant relationships were found between the responses of harbor seals and CPA distance. That is, there was no evidence that the effect was any less for the missiles whose 3-D CPA distances were large (e.g., 2.0-3.5

km) than for those at closer distances. When all missile types were considered, the percentage of harbor seals that moved did not change with the 3-D CPA or horizontal CPA distance (Table 3.6, Fig. 3.3c). Also, the number of animals that entered the water was not correlated with the 3-D CPA or horizontal distance (Table 3.6).

3.8 Pinniped Behavior Relative to Missile Sounds

This section provides a comparison of pinniped reactions to sound exposure levels (SEL) for launches conducted from August 2001 to August 2003. All SELs used in this section are expressed in dB re 20 ì $Pa^{2}\cdot$ s.

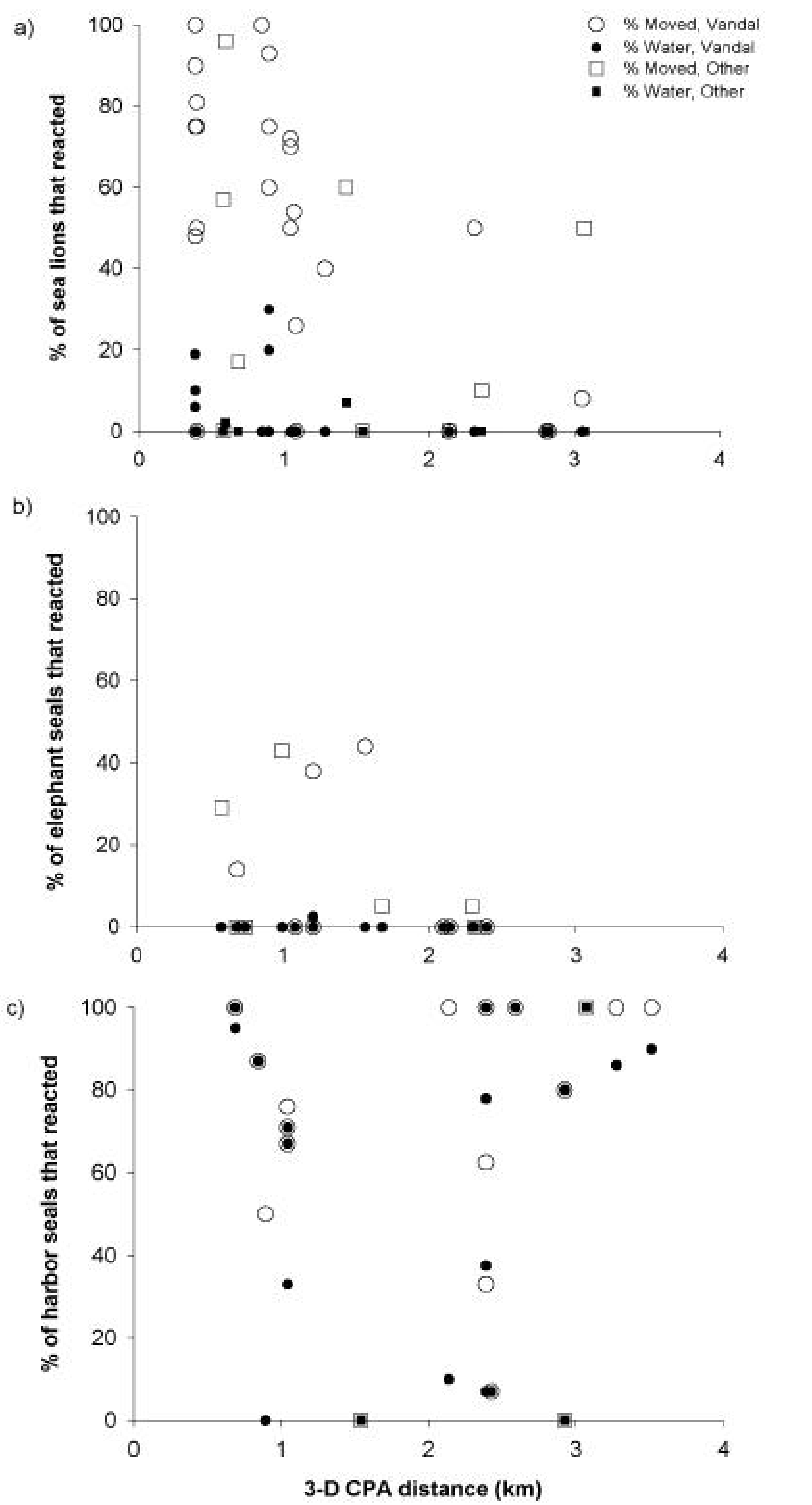

Figure 3.3. Percent of (a) sea lions, (b) elephant seals, and (c) harbor seals that moved (open symbols) or entered the water (solid symbols) in relation to the 3-D CPA distance of missiles launched at SNI. Data from launches of Vandals vs. all other missiles are distinguished by circles and triangles, respectively.

TABLE 3.6. Spearman correlation coefficients (r_s) for pinniped responses relative to closest point of approach (CPA) from the missiles and sound exposure levels (SEL) for launches conducted during August 2001 – August 2003. *n* = number of animals; SD = standard deviation; *P* = significance level (one-sided).

Species			All missiles			Vandals only		
			r_s	*n*	*P*	r_s	*n*	*P*
Sea lion	3-D CPA	% moved	-0.53	33	0.0005	-0.63	24	0.0005
		% water	-0.33	33	.03	-0.42	24	.02
	Horizontal CPA	% moved	-0.51	33	0.002	-0.63	24	<0.0001
		% water	-0.33	33	.03	-0.42	24	.02
	SEL A-wt.	% moved	0.80	15	<0.001	0.69	9	0.02
		% water	0.46	15	0.04	0.35	9	0.2
	SEL flat-wt.	% moved	0.78	15	<0.001	0.69	9	0.02
		% water	0.45	15	0.05	0.33	9	0.2
Elephant seal	3-D CPA	% moved	-0.33	16	0.1	-0.46	9	0.1
		% water		N.A.			N.A.	
	Horizontal CPA	% moved	-0.42	16	0.05	-0.46	9	0.1
		% water		N.A.			N.A.	
Harbor seal	3-D CPA	% moved	0.02	21	0.5	0.09	17	0.4
		% water	0.02	21	0.5	0.09	17	0.4
	Horizontal CPA	% moved	0.004	21	0.5	0.03	17	0.5
		% water	-0.01	21	0.5	0.03	17	0.5
	SEL A-wt.	% moved	-0.10	12	0.4	-0.26	8	0.3
		% water	-0.26	12	0.2	-0.47	8	0.1
	SEL flat-wt.	% moved	0.01	13	0.5	0.08	9	0.4
		% water	-0.02	13	0.5	0.12	9	0.4

Note: N.A. means data could not be analyzed.

California sea lions

Sea lions and sound levels were monitored at the same location on 15 occasions. Strong responses were usually elicited by low-elevation (8º) Vandals at haul-out sites located ~0.6 mi. (1 km) from the CPA. Most sea lions reacted strongly by moving around on the beach, and during several of the launches, some sea lions entered the water. SELs for these launches ranged from 119 to 128 dB or 101 to 110 dBA.

A GQM-163A launch from the Alpha Launch Complex and a Tomahawk launched from the Building 807 Launch Complex also elicited strong responses from sea lions. During the GQM-163A launch on 4 June 2003, 60% of sea lions that were hauled out near Camera 809, ~0.9 mi. (1.4 km) from the CPA, moved short distances along the beach, and one adult female sea lion entered the water. The GQM-163A produced an SEL of 116 dB (99 dBA). On 23 August 2002, the Tomahawk launch was monitored at Dos Coves South, situated ~1970 ft (600 m) from the CPA. The vehicle crossed the beach at an altitude of 1000 ft (305 m) and produced an SEL of 105 dB (102 dBA). During this launch, all sea lions moved around the beach vigorously, and one pup entered the water, and another left the water and came up on the beach.

Sea lions monitored during a high-elevation (42°) Vandal launches on 26 June 2002 hardly reacted to the vehicles that crossed the west end of San Nicolas Island at altitudes of up to 17,300 ft (5273 m). During these launches, sea lions were monitored at sites 1.7-1.9 mi. (2.8-3.0 km) from the CPA (these sites were located directly below the high-altitude trajectory). Most sea lions looked up, only a few animals moved short distances, but none entered the water. The Vandals produced SELs ranging from 101 to 103 dB (89 to 90 dBA).

Two AGS launches on the 26 June 2002 were monitored via 809 Camera as well as at Redeye Beach, ~0.9-1.3 mi. (1.5-2.1 km) from the CPA. The launches produced SELs ranging from 94 to 96 dB (62 to 64 dBA). Sea lions at both of these sites hardly reacted to the launch sounds at all, although some individuals looked up and several moved slightly.

During two years of monitoring from August 2001 to August 2003, paired sound measurements and video data on sea lions were available for a total of 15 site-date combinations. When all launches were considered, the percentage of sea lions that moved or entered the water tended to increase with increasing SEL (Table 3.6, Figs. 3.4 and 3.5a). When only Vandal launches were considered, the sample size was small (n = 9). Nonetheless, there was a significant relationship between the percentage of sea lions that moved and SEL (Table 3.6). There was a positive but non-significant relationship between the percentage of animals that entered the water and SEL (Table 3.6).

Northern Elephant Seals

Elephant seals and sound levels were monitored at the same location on four occasions. Four low-elevation Vandals elicited minimal responses from elephant seals when these were monitored at locations ranging from 0.7-1.5 mi. (1.2-2.4 km) from the flightline. The highest SEL of 123 dB (107 dBA) was produced during a low-elevation Vandal launch monitored at Bachelor Beach North on 14 February 2002. This site was located 0.7 mi. (1.2 km) from the CPA. Seals exhibited very little reaction to the launch.

Responses to another low-elevation Vandal launch were monitored on 8 May 2002 at Pirates Cove and Sea Lion Cove. Pirates Cove was located 1.5 mi. (2.4 km) northeast of the launch pad, and Sea Lion Cove was situated 1.3 mi. (2.1 km) from the CPA. These launches produced SELs of 92 and 96 dB (67 and 80 dBA, respectively). Again, elephant seals hardly responded to the launch sounds or other stimuli. On 10 December 2002, a SEL of 117 dB was produced by a Vandal launch monitored at Bachelor Beach North. This site was located 0.7 mi. (1.2 km) from the flightline. Most seals exhibited little reaction to the launch; the majority looked up, several (38%) moved short distances, and 1 of 40 seals entered the water.

For the period August 2001 to August 2003, paired sound measurements and video data on elephant seals were available on four occasions (Figs. 3.4 and 3.5b). With a sample size of only four, it is not possible to assess in a meaningful way the relationship between SEL and the percentage of elephant seals that moved or entered the water.

Harbor Seals

Harbor seals and sounds were monitored at the same location on 13 occasions. Strong responses occurred during two low-elevation Vandal launches monitored at 809 Camera (0.6 mi. or 1 km from

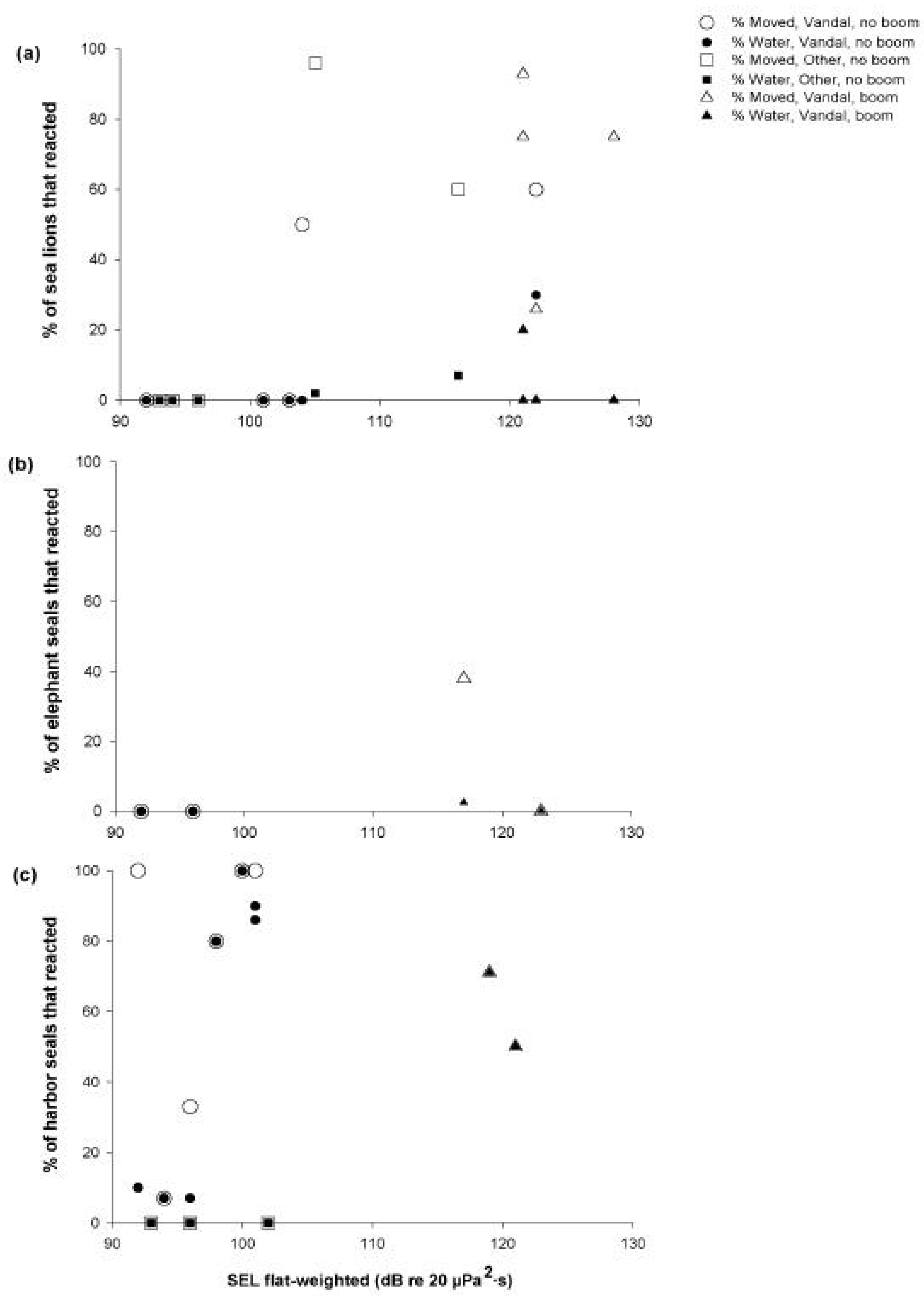

Figure 3.4. Percent of (a) sea lions, (b) elephant seals, and (c) harbor seals that moved (open symbols) or entered the water (solid symbols) in relation to sound exposure level (SEL flat-weighted) of missiles launched at SNI. Vandal launches without booms are indicated by circles, other missile launches without booms are indicated by triangles, and Vandal launches with booms are shown by triangles.

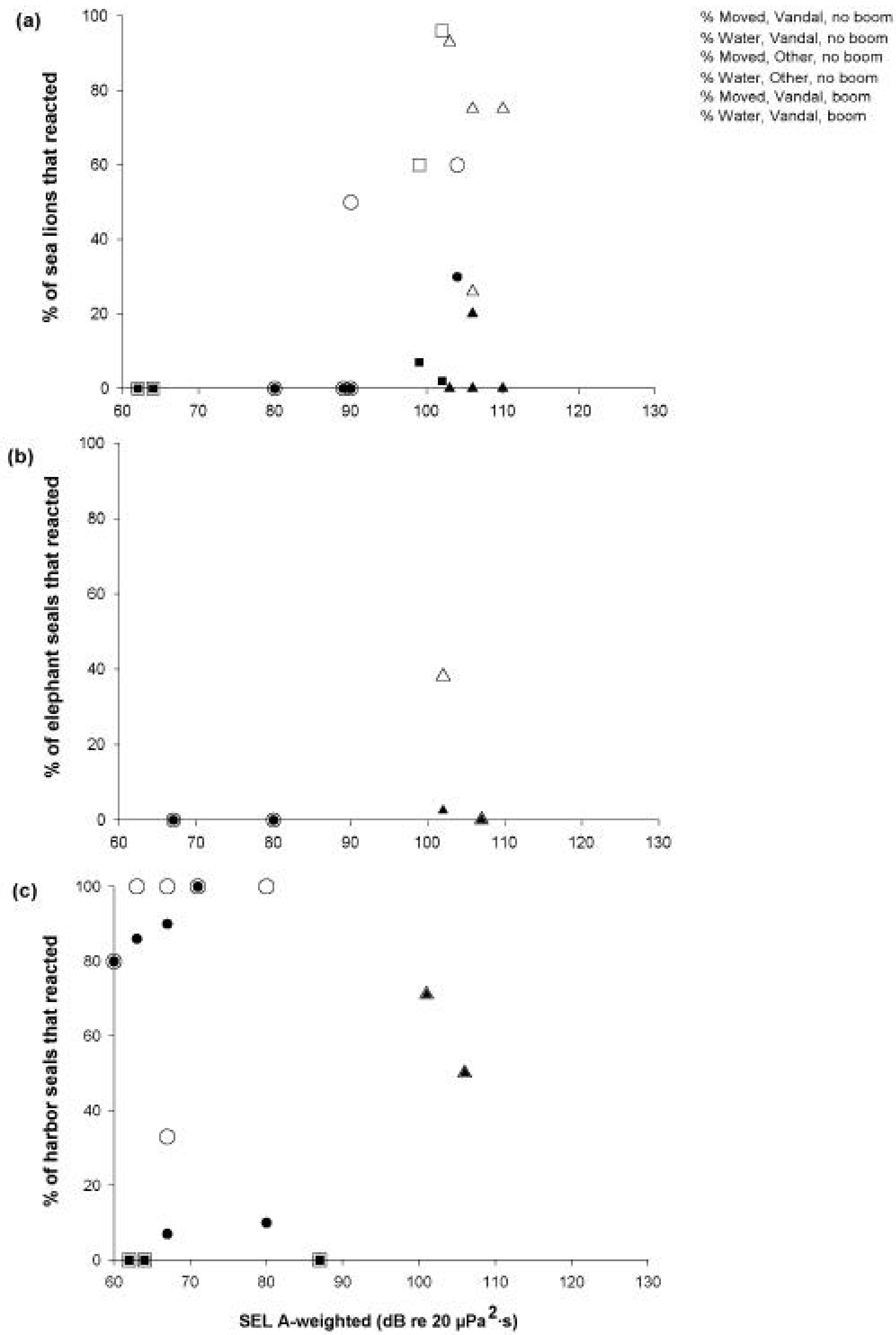

Figure 3.5. Percent of (a) sea lions, (b) elephant seals, and (c) harbor seals that moved (open symbols) or entered the water (solid symbols) in relation to sound exposure level (SEL A-weighted) of missiles launched at SNI. Vandal launches without booms are indicated by circles, other missile launches without booms are indicated by triangles, and Vandal launches with booms are shown by triangles.

the flightline) on 20 September 2001 and Sea Lion Cove (1.3 mi. or 2.1 km from flightline) on 8 May 2002. The Vandal monitored at 809 Camera produced an SEL of 119 dB (101 dBA), and the other Vandal monitored at Sea Lion Cove produced an SEL of 92 dB (80 dBA). At 809 Camera, most seals (75%) that were hauled entered the water. At Sea Lion Cove, at least 90% of seals entered the water. Another low-elevation Vandal launch, on 6 March 2002, did not elicit strong responses from seals near 809 Camera, even though the azimuth and elevation angle were similar to the other two Vandal launches and the SEL was higher (121 dB or 106 dBA). On that occasion, no seals entered the water, but some animals moved. It is uncertain why this group did not exhibit the same strong reaction as seals did on 20 September and 8 May. It is possible that clear observations of these animals were inhibited by poor video quality.

Seals responses to low-elevation Vandals at sites on the northeast coast of San Nicolas Island, ~1.6-2.2 mi. (2.5-3.5 km) away from the Vandal launcher, were generally strong. Most seals moved into the water in response to the launch and the animals that did not enter the water moved at least a short distance on shore. All of these Vandal launches had the same launch azimuth (273°) and elevation angle (8°). The SEL values for the launch sounds, as recorded at the locations where the seals were observed, ranged from 96 to 101 dB (60 to 71 dBA).

A low-elevation Vandal launch on 5 October 2001 monitored at Phoca Reef (located ~1.5 mi. or 2.4 km to the northeast of the launch pad), produced a smaller SEL value of 94 dB and elicited a reduced response from harbor seals. Not many seals responded to this launch at either location; <10% entered the water.

Two AGS launches on 26 June 2002 were monitored at Redeye Beach, located ~0.9 mi. (1.5 km) from the CPA. These launches were at high elevation (62.5°) and produced SELs of 93 and 96 dB (62 to 64 dBA). They elicited minimal responses from harbor seals.

Sounds and seals were also monitored during the GQM-163A target launch on 4 June 2003. This vehicle had a similar launch azimuth (270°) to the Vandals, but its elevation angle was higher (22°). The vehicle produced a SEL of 102 dB (87 dBA) at Sheephead Ranch (1.8 mi. or 2.9 km from the launch pad), where harbor seals were observed. Seals hardly reacted to this launch and the associated low SEL; most animals looked up, but only one seal moved a short distance.

Considering all launches in the period August 2001 to August 2003, paired data were available on 13 occasions. When all launches were considered, no significant relationships were found between the percentages of harbor seals that moved or entered the water and SEL (Table 3.6). When only Vandals were considered, the sample size was low but the percentages of harbor seals that moved or entered the water were unrelated to SEL (Table 3.6, Figs. 3.4 and 3.5c).

3.9 Summary

Pinniped behavioral responses to launch sounds during the August 2002 – August 2003 period were usually brief and not severe. These responses were similar to those for the 2001–2002 monitoring period (Holst and Lawson 2002). 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. Even sound levels as high as 123 dB (107 dBA) 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, but settled within 1 minute. The percentage of elephant seals that moved in response to the launches was marginally higher with decreasing horizontal CPA distance from the missile.

Responses of California sea lions to the missile launches varied by individual and age group. 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. All age classes often settled back to pre-launch behavior patterns within minutes of the launch time. However, sea lions were significantly more active after the launch compared with before the launch. Responses of California sea lions to the launches was related to sound levels and CPA distances to missiles. More California sea lions moved or entered the water with decreasing CPA distances and increasing SELs. Sea lions appeared to react strongly to launch sounds from low-elevation Vandals, GQM-163A targets, and a Tomahawk launch.

During the majority of launches, most harbor seals left their haul-out sites to enter the water and did not return during the duration of the video-recording period (which sometimes extended up to several hours 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 that stayed hauled out were more active after the launch compared with before the launch, and they were situated farther apart from each other.

Reactions of harbor seals to launch sounds appear to be variable. There was no evidence that the responsiveness of seals was any less for missiles whose CPA distances were large (2-3.5 km) or whose SELs were lower. Harbor seals reacted to SELs as low as 60 dBA (or 92 dB). Therefore, it appears that the minimum received level (SEL) that might elicit disturbance for harbor seals is much lower than the anticipated 90-dBA level. The level that might elicit disturbance for harbor seals will be examined during future launches, by monitoring haul-out sites >4 km from the launcher.

No evidence of injury or mortality was observed during or immediately succeeding the launches. However, several 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.

4. ESTIMATED NUMBERS OF PINNIPEDS AFFECTED BY MISSILE LAUNCHES, AUG. 2002–AUG. 2003[1]

4.1 Pinniped Behavioral Reactions to Noise and Disturbance

Some of the pinnipeds on the beaches at San Nicolas Island show disturbance reactions to missile 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 considered likely. The correlation analyses in Chapter 3 provide the first direct evidence for such relationships at San Nicolas Island, at least for California sea lions and (weakly) for elephant seals.

For pinnipeds hauled out on land, behavioral changes may 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, but pinnipeds often show considerable tolerance of noise and other forms of human-induced disturbance (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, in the case of harbor seals, several harbor seal pups were knocked over by adult seals as both pups and adults moved toward the water in response to the launch. This type of behavior could potentially result in occasional injury or even deaths of pups.

Since no injuries or deaths were observed during the monitored launches, disturbance rather than injury or mortality is the primary concern in this project. Given that the pinniped reactions to the launches were brief or negligible, the minimum numbers of pinnipeds on the monitored beaches that might have been affected by the launch sounds were estimated. The Navy, consistent with NMFS (2002), assumes 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 significantly affected.

In this report 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 (e.g., by stampedes),
2. pinnipeds exposed to launch sounds equal to or greater than 145 dBA re 20 μPa SEL for harbor

[1] By **Meike Holst**, LGL Ltd., environmental research associates.

seals and California sea lions, or 165 dBA re 20 μPa SEL for northern elephant seals (see next subsection for rationale), 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.

The numbers of such affected pinnipeds were calculated for the periods during and immediately following the 12 launches (including one dual RAM launch and one dual Vandal launch) on 11 days in August 2002 through August 2003. 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 an hour of 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 permanent hearing impairment (PTS) is presumed to be higher, by a variable and generally unknown amount, 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, the difference may be smaller (Kryter 1985).

Although the effects of missile-like sounds on in-air hearing sensitivity of pinnipeds have not been measured, it is unlikely that launch sounds as received on any pinniped beach on San Nicolas Island were sufficient to cause TTS:

- Results from acoustic monitoring of Vandal launches in 1997 (Burgess and Greene 1998) and 1999 (Greene 1999) showed that pinnipeds on the beaches near the launch sites were exposed to maximum received levels of about 131 dB SEL re 20 $\mu Pa^2 \cdot s$, flat-weighted (Table 1 in Greene 1999). A-weighted values were lower.
- During the August 2001 – July 2002 monitoring period, the maximum SEL values measured for Vandal launches near haul-out locations were 129 dB flat-weighted and 113 dBA re 20 $\mu Pa^2 \cdot s$ (Greene and Malme 2002; see also Chapter 2).
- During the August 2002 – August 2003 monitoring period, the maximum SEL value measured near a pinniped haul-out site was 128 flat-weighted and 118 dBA re 20 $\mu Pa^2 \cdot s$ (Chapter 2).

In 2001–2003, SEL values from 130 to 143 dB (flat) and up to 131 dBA were occasionally measured (Table 2.3, Fig. 2.4), but these values were recorded close to the launcher and not near pinnipeds on the beaches.

Thus, the received SEL values on the beaches with pinnipeds were below (usually by a wide margin) the acoustic criteria proposed by Lawson et al. (1998). Those were 145 dBA SEL for harbor seals and California sea lions, and 165 dBA SEL for northern elephant seals (re 20 $\mu Pa^2 \cdot s$). Some pinnipeds were no doubt exposed to higher levels than those documented by recorders placed at nearshore locations (Chapter 2), as pinnipeds sometimes occurred closer to the launcher or launch azimuth than the location of the closest functional sound recording system. However, based on all the data collected in the August 2001 – August 2003 period, it is unlikely that pinnipeds were exposed to sounds exceeding the criteria listed above.

The rationale for the speculative criteria proposed by Lawson et al. was given in § 4.7.1.4 of Lawson et al. (1998), and was based on assumed TTS thresholds. More recently, J. Francine quoted in NMFS (2001, p. 41837) has mentioned evidence of mild TTS in captive California sea lions exposed to a 0.3-sec transient with level 135 dB SEL re 20 μPa^2· s (see also Bowles et al. 1999). The measured SEL values near the pinniped beaches during missile launches during August 2002 – August 2003 were below this 135-dB level. However, mild TTS may occur in harbor seals exposed to received levels lower than 135 dB SEL (A. Bowles, pers. comm. to W.J. Richardson, LGL, 2003).

However, PTS would not be expected unless the received levels were considerably higher than the TTS threshold, as noted above. This issue was discussed at the NMFS-organized "Acoustic Criteria" workshop (see also Gisiner [ed.] 1999). The consensus then was that received levels would have to be at least 10 dB above the TTS threshold, and probably considerably higher than that, before there would be concern about the possibility of permanent hearing impairment as a result of relatively short-term exposure. At the time of writing (Dec. 2003), an expert panel is evaluating (for NMFS) the likely relationship between sound levels associated with onset of PTS vs. TTS in marine mammals. Their conclusions are not yet available. However, for pinnipeds in air exposed to non-impulse sound, the PTS threshold probably is well above an SEL value of 130 dB re 20 ìPa^2· s. For impulse sounds, the PTS threshold may be lower.

Overall, the results to date indicate that there is little potential for appreciable TTS or especially PTS in pinnipeds hauled out near the vehicle azimuths during the launch operations. This conclusion is necessarily speculative given the lack of directly relevant TTS data for pinnipeds in air exposed to strong sounds for brief periods. In the event that levels are 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 San Nicolas Island, 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 no 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 launches when sonic booms occur at beach locations. These cases should be re-considered when specific noise exposure criteria become available for possible PTS in pinnipeds in air that are exposed to impulse sounds. Recommended criteria are expected to become available within the next year.

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 2002 – August 2003, as in August 2001 – July 2002, appeared to cause no more than limited, short-term, and localized disturbance. With the exception of most harbor seals, the majority of pinnipeds remained in the haul-out areas (see Chapter 3). There was no evidence that pinniped reactions to launches resulted in any pup mortality.

Levels of missile sounds recorded near pinniped haul-out locations around western San Nicolas Island during launch operations in the present monitoring period were up to 128 dB re 20 μPa^2· s on a flat-weighted SEL basis, and up to 118 dBA on an A-weighted SEL basis. These values represent substantial levels of transient noise, and probably underestimated the maximum values occurring at certain unmonitored nearshore locations. However, they are below the levels expected to be necessary to cause permanent hearing impairment, and for pinnipeds at most locations, it is unlikely that temporary threshold shift would occur either.

4.4 Estimated Numbers of Pinnipeds Affected by Launches

The approach to estimating the numbers of pinnipeds affected by launch sounds during August 2002 through August 2003 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 calculated only for the periods during and immediately following the 12 launches on 11 days. 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 within 1 hour after the launch but others did not return during post-monitoring periods of up to 2 hours.

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 section 4.1) were then extrapolated to the estimated total number of individuals hauled out in this area (Table 4.1). 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. Thus, despite this extrapolation, the estimates of the numbers of pinnipeds affected by launch sounds are likely underestimates. While these numbers may be underestimates, it is not likely that any of the pinnipeds present on western San Nicolas Island were adversely impacted by such reactions, given the results from the beaches that were monitored. (One task that will be attempted during the ongoing launch monitoring in late 2003 and 2004 will be to develop a more effective extrapolation process, with the objective of providing more complete estimates of the total numbers of pinnipeds affected.)

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 the 2001 – 2002 monitoring period (Lawson 2002). That is, the number of affected animals for the corresponding season and vehicle type was used, if possible, from Lawson (2002; Table 4.1). For example, for sea lions, the estimate for the 10 December 2002 Vandal launch corresponds to the number of affected animals for the Vandal launch on 19 December 2001.

Navy personnel did not sight any northern fur seals or Guadalupe fur seals on San Nicolas Island from August 2002 through July 2003 or in August 2001 through July 2002, and none were evident in the video segments that were analyzed.

There appeared to be no increase in aggressive interactions as a result of the reactions to the launches. There was no evidence of injury or mortality during any of the launches. However, several 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.

Observations from the 2001-2002 monitoring period showed that all of the haul-out sites continued to be occupied in subsequent days following the launches (Holst and Lawson 2002).

4.5 Summary

This chapter provides estimates of the numbers of pinnipeds affected by the Navy's missile launches on San Nicolas Island, California, August 2002 – August 2003, based mainly on information provided in previous chapters of this report.

TABLE 4.1. Minimum estimated numbers of California sea lions, northern elephant seals, and harbor seals affected by launch sounds from the Navy's missile launch program on San Nicolas Island, August 2002 – August 2003. Some individual pinnipeds were probably affected on more than one launch day, so total numbers of different individuals affected could have been less than the totals shown here.

Date	Missile Type	California Sea Lions	Northern Elephant Seals	Harbor Seals
23 August 2002	Tomahawk	100	0	**10**
18 November 2002	RAM	80	8	**0**
10 December 2002	Vandal	**95**	15	**20**
18 December 2002	AGS	**10**	**0**	**15**
24 January 2003	GQM-163A	80	31	**25**
14 March 2003	Vandal	**90**	**15**	4
16 March 2003	Vandal	**90**	**15**	53
4 April 2003	Vandal	**90**	**15**	62
4 June 2003	GQM-163A	50	**31**	0
26 June 2003	Vandal	10	**0**	**0**
28 July 2003	Vandal	75	0	**58**
	Total	770	130	247

Note: Numbers in bold are estimates derived from data previously collected during the August 2001 - July 2002 monitoring program (Lawson 2002), as well as the current monitoring period, for launch dates when monitoring of certain pinniped species did not occur.

No evidence of pinniped injuries or fatalities related to launch noises was evident, nor was it expected. Few if any pinnipeds were exposed to levels above 128 dB SEL re 20 $\mu Pa^2 \cdot s$ or above 118 dBA SEL. TTS is unlikely to have occurred, and if it did occur in some pinnipeds, it would have been mild and would have disappeared quickly. PTS is highly unlikely to have occurred.

Approximately 770 California sea lions, 130 northern elephant seals, and 247 harbor seals are estimated to have been affected by launch sounds during the August 2002 – August 2003 period. These figures are very approximate, because they (a) include extrapolations for pinnipeds on beaches that were not monitored on any given launch day, and (b) very likely count some of the same individuals more than once, but also (c) 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 left the water at a vigorous pace, or exhibited prolonged movement or behavioral changes relative to their behavior immediately prior to the launch. Of the California sea lions, most were young animals such as pups or juveniles. It is not likely that any of these pinnipeds on San Nicolas Island were adversely impacted by such behavioral reactions.

The results suggest that any effects of these launch operations were minor, short-term, and localized, with no consequences for the pinniped populations. Any localized displacement of pinnipeds was of short duration (although some harbor seals may have left their haul-out site until the following low tide), and numbers occupying haul-out sites shortly after a launch, or the next day, were similar to pre-launch levels.

There was no evidence of injury or mortality during any of the launches, and the haul-out sites continued to be occupied in subsequent days. However, several 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.

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At LGL, Ted Elliott assisted with mapping of launches and audio/video recording sites, and Valerie Moulton provided valuable advice on video analysis approaches. Dr. Jack Lawson was principally responsible for the project design and initial project reports. He has continued to provide various types of input since leaving LGL in 2002. Dr. W. John Richardson of LGL helped with project design and administration, and reviewed the draft report. Anne Wright helped with report production.

Elizabeth Becker at TEC, prime contractor for this work, assisted with management and logistical matters.

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APPENDIX A: IHA

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

The Department of the Navy, Naval Air Warfare Center Weapons Division, Point Mugu, 1 Administration Circle, China Lake, California 93555 is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass a small number of marine mammals incidental to target missile launch operations from the western end of San Nicolas Island, California, contingent upon the following conditions:

1. This Authorization is valid only from the date of this Authorization until August 20, 2003.

2. This Authorization is valid only for activities associated with 15 Vandal missile launch operations and 5 smaller target missile launch operations from the western end of San Nicolas Island, California.

3. General Conditions:

(a). The taking, by incidental harassment only, is limited to the species listed under condition 3(b) below. The taking by serious injury or death of these species, the taking by harassment, injury or death of any other species of marine mammal, or the taking by harassment of a species listed under condition 3(b) greater than authorized under condition 3(c) is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b). The species authorized for incidental harassment takings are: northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and northern fur seals (*Callorhinus ursinus*).

(c). Limited to harassment, as defined in the Marine Mammal Protection Act, the following numbers of individual animals are authorized for incidental taking during the calendar year during which this authorization is in effect: less than 2,390 northern elephant seals, less than 457 harbor seals, between 9,614 and 10,086 California sea lions, and 3 northern fur seals.

(d). Without an amendment to this Authorization, authorization for taking by harassment is limited to the following missile types:

(1). Vandal missiles (standard, ER, and ERR variants);
(2). BQM-34 missile;
(3). BQM-74 missile;

(4). Exocet missile;
(5). Tomahawk missile; and
(6). Rolling Airframe Missile (RAM).

(e). The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 48 hours of the taking to Christina Fahy at the Southwest Regional Office, National Marine Fisheries Service (NOAA Fisheries) at (562) 980-4023.

4. Cooperation: The holder of this Authorization is required to cooperate with NOAA Fisheries and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify Christina Fahy, Southwest Regional Office, NOAA Fisheries, at least 48 hours prior to launches (unless constrained by the date of issuance of this Authorization).

5. Mitigation Requirements:

(a). The holder of this Authorization must prohibit personnel from entering pinniped haul-out sites below the missile's predicted flight path for 2 hours prior to planned missile launches.

(b). The holder of this Authorization must avoid launch activities during harbor seal pupping season (February to April), when operationally practicable.

(c). The holder of this Authorization must limit launch activities during other pinniped pupping seasons, when operationally practicable.

(d). The holder of this Authorization must not launch Vandal target missiles from the Alpha Complex at low elevation (less than 1,000 feet) on launch azimuths that pass close to pinniped haul-out site(s).

(e). The holder of this Authorization must avoid, where practicable, launching multiple target missiles in quick succession over haul-out sites, especially when young pups are present.

(f). The holder of this Authorization must limit launch activities during nighttime hours when operationally practicable.

(g). Aircraft and helicopter flight paths must maintain a minimum altitude of 1,000 feet from pinniped haul-outs.

(h). If injurious or lethal take is discovered during monitoring, the holder of this Authorization must contact Christina Fahy at the Southwest Regional Office, NOAA Fisheries at (562) 980-4023 within 48 hours and, in cooperation with NOAA Fisheries, launch procedure, mitigation measures, and monitoring methods must be reviewed and appropriate changes made prior to the next launch.

6. Monitoring Requirements:

(a). General.

(1). The holder of this Authorization must designate biologically-trained, on-site individual(s), approved in advance by NOAA Fisheries, to record the effects of the launch activities and the resulting noise on pinnipeds.

(2). The NOAA Fisheries must be informed immediately of any changes or deletions to any portions of the proposed monitoring plan submitted, in accordance with condition 7(a) of this Authorization.

(b). Visual Land-Based Monitoring.

(1). Prior to each missile launch, an observer(s) will place 3 autonomous digital video cameras overlooking chosen haul-out sites located varying distances from the missile launch site. Each video camera will be set to record a focal subgroup within the larger haul-out aggregation for a maximum of 4 hours or as permitted by the videotape capacity.

(2). Systematic visual observations, by those individuals described in condition 6(a)(1) above, on pinniped presence and activity will be conducted and recorded in a field logbook a minimum of 2 hours prior to the estimated launch time and for no less than 1 hour immediately following the launch of Vandal and similar types of target missiles.

(3). Systematic visual observations, by those individuals described in condition 6(a)(1) above, on pinniped presence and activity will be conducted and recorded in a field logbook a minimum of 2 hours prior to launch, during launch, and for no less than 1 hour after the launch of the BQM-34, BQM-74, Exocet, Tomahawk, RAM target and similar types of missiles.

(4). Documentation, both via autonomous video camera and human observer, will consist of: (a) numbers and sexes of each age class in focal subgroups; (b) description and timing of launch activities or other disruptive event(s); (c) movements of pinnipeds, including number and proportion moving, direction and distance moved, and pace of movement; (d) description of reactions; (e) minimum distances between interacting and reacting pinnipeds; (f) study location; (g) local time; (h) substratum type; (i) substratum slope; (j) weather condition; (k) horizontal visibility; and (l) tide state.

(c). Acoustic Monitoring.

(1). During all target missile launches, calibrated recordings of the levels and characteristics of the received launch sounds will be obtained from 3 different locations of varying distances from the target missile's flight path. Insofar as possible, these acoustic recording locations will correspond with the haul-out sites where video and human observer monitoring is done.

(2). Acoustic recordings will be supplemented by the use of radar and telemetry systems to obtain the trajectory of target missiles in three dimensions.

(3). Acoustic equipment used to record launch sounds will be suitable for collecting a wide range of parameters, including the magnitude, characteristics, and duration of each target missile.

7. Reporting:

(a). For each target missile launch, the lead contractor or lead observer for the holder of this Authorization must provide a status report by telephone to Christina Fahy, or her designee, at the Southwest Regional Office, NOAA Fisheries (562-980-4023), providing reporting items found under condition 7(b), unless other arrangements for monitoring are agreed in writing.

(b). An initial report must be submitted to the Office of Protected Resources, and the Southwest Regional Office after the first 90 days of the authorization period. This report must contain the following information:

(1). Timing and nature of launch operations;

(2). Summary of pinniped behavioral observations;

(3). Estimate of the amount and nature of all takes by harassment or in other ways.

(c). A draft final technical report will be submitted to the Office of Protected Resources and Southwest Regional Office, NOAA Fisheries, 120 days prior to the expiration of this Authorization providing full documentation of the methods, results, and interpretation of all monitoring tasks for launches to date plus preliminary information for launches planned during the next 1-2 months.

(d). A revised final technical report, including all monitoring results during the entire period of the Authorization will be due 90 days after the end of the Authorization's expiration.

(e). Both the 90-day and final reports will be subject to review and comment by NOAA Fisheries. Any recommendations made by NOAA Fisheries must be addressed in the final comprehensive report prior to acceptance by NOAA Fisheries.

8. Activities related to the monitoring described in this Authorization and as described in the holders application, do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

9. A copy of this Authorization must be in the possession of the personnel operating under the authority of this Incidental Harassment Authorization.

AUG 26

Donald R. Knowles, Director
Office of Protected Resources
National Marine Fisheries Service

Date

APPENDIX B: MAPS OF LAUNCH AZIMUTHS AND MONITORING SITES FOR AUGUST 2002–AUGUST 2003

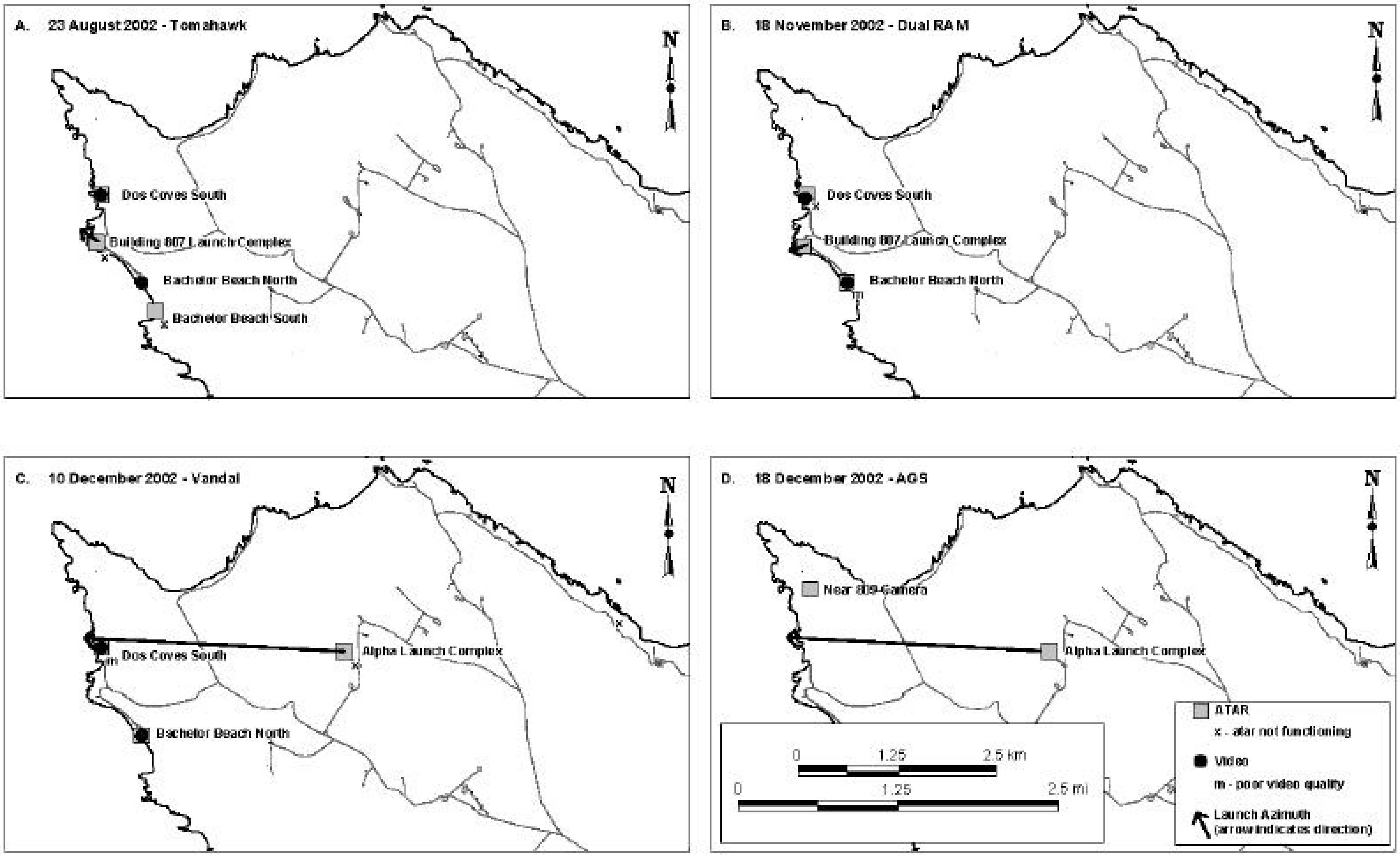


FIGURE B-1. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 23 August 2002 to 28 July 2003.

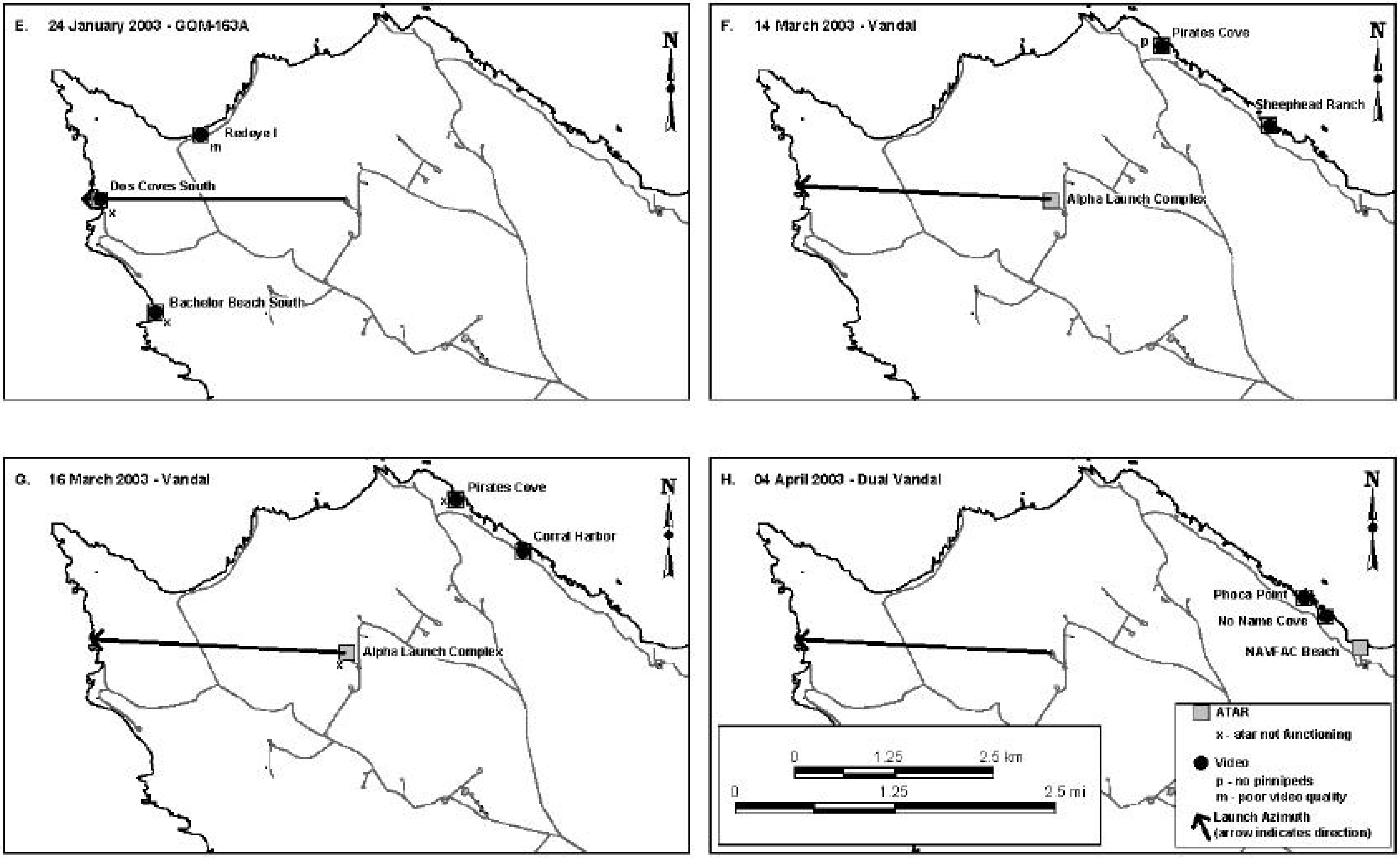


FIGURE B-1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 23 August 2002 to 28 July 2003.

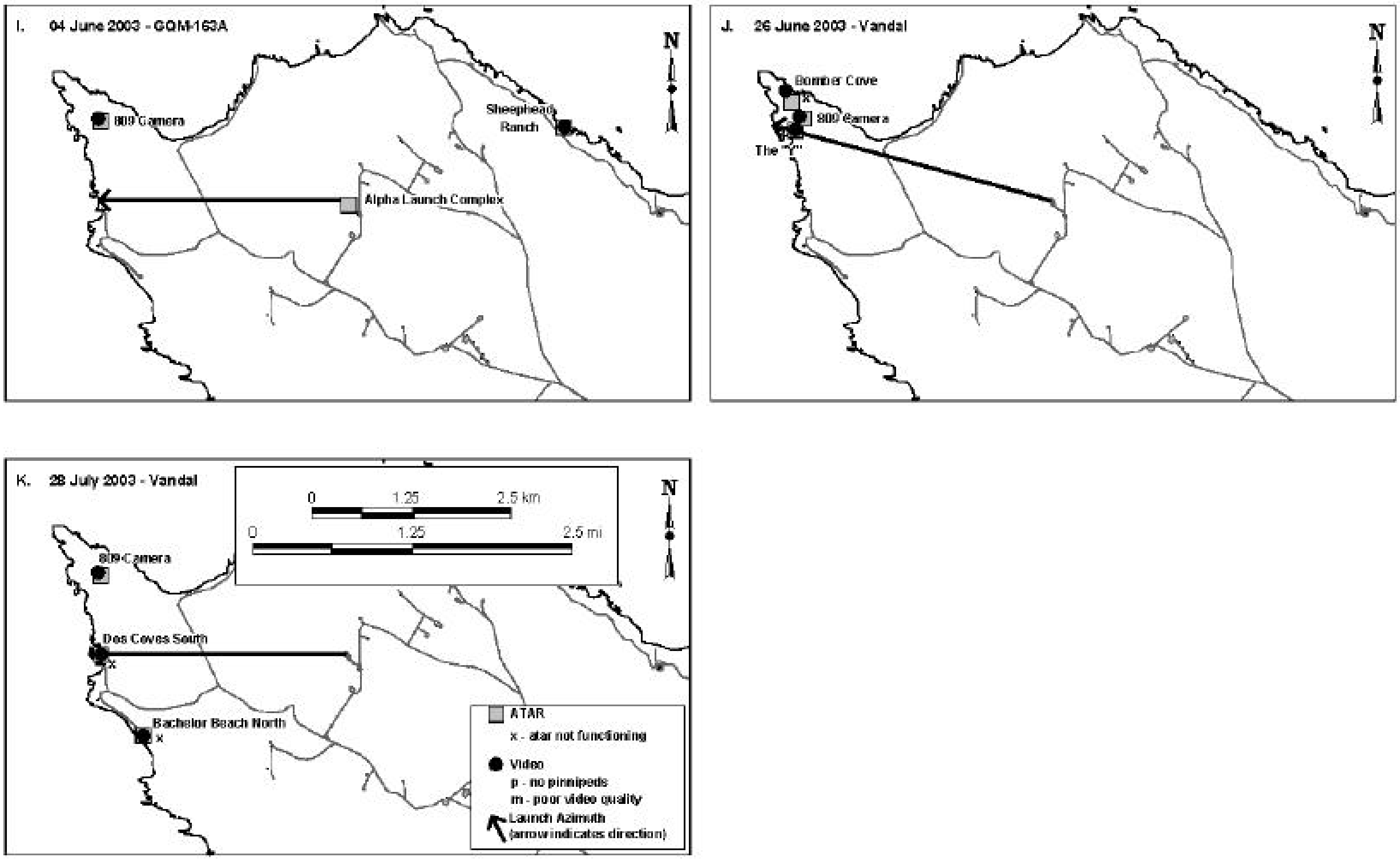


FIGURE B-1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 23 August 2002 to 28 July 2003.

APPENDIX C: ACOUSTIC DATA FROM INDIVIDUAL LAUNCHES FOR AUGUST 2002–AUGUST 2003

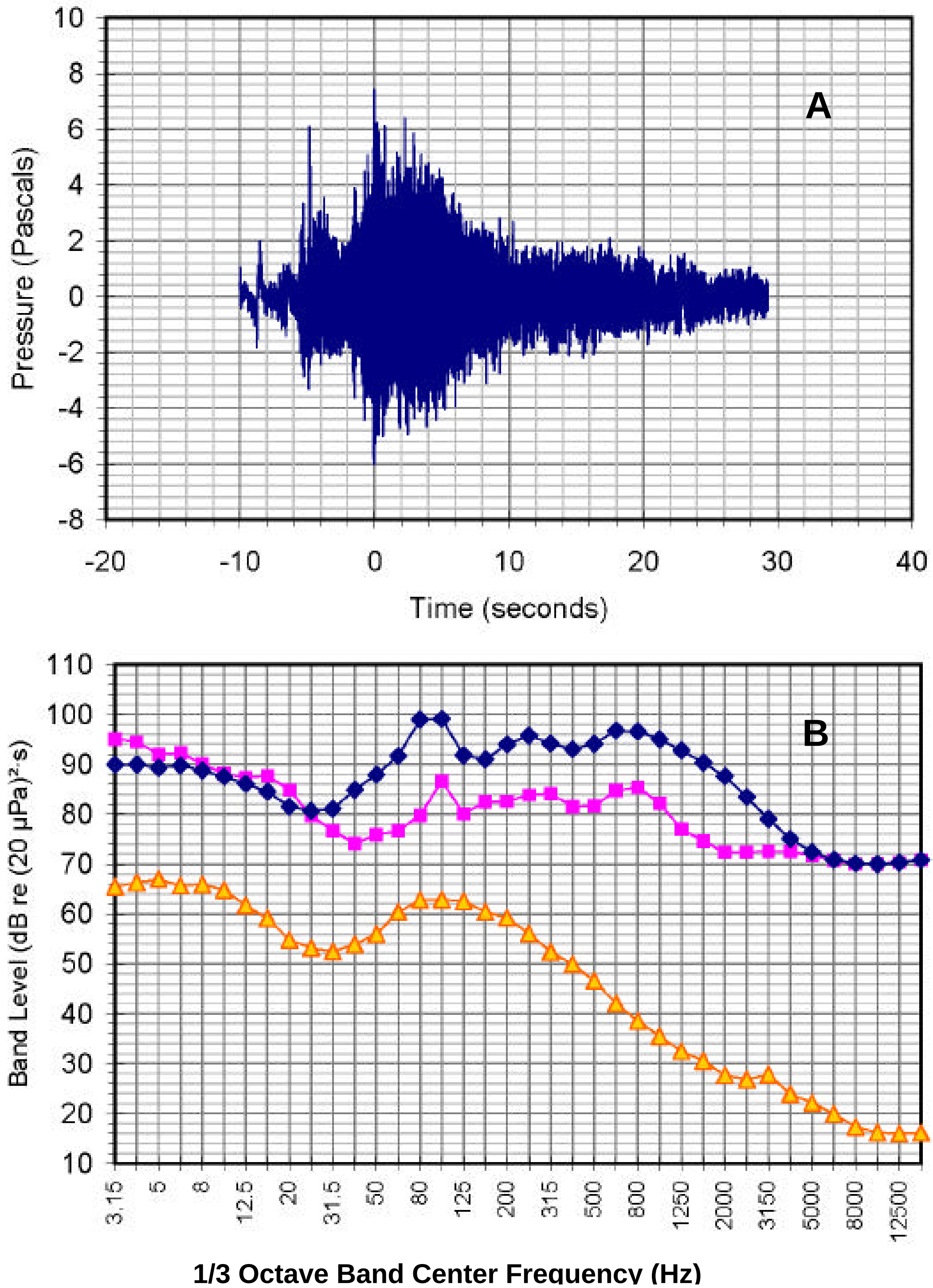


FIGURE C-1. (A) Pressure waveform and (B) one-third octave band levels for a Tomahawk flight at 14:09:39 on 23 August 2002 recorded at "Dos Coves". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

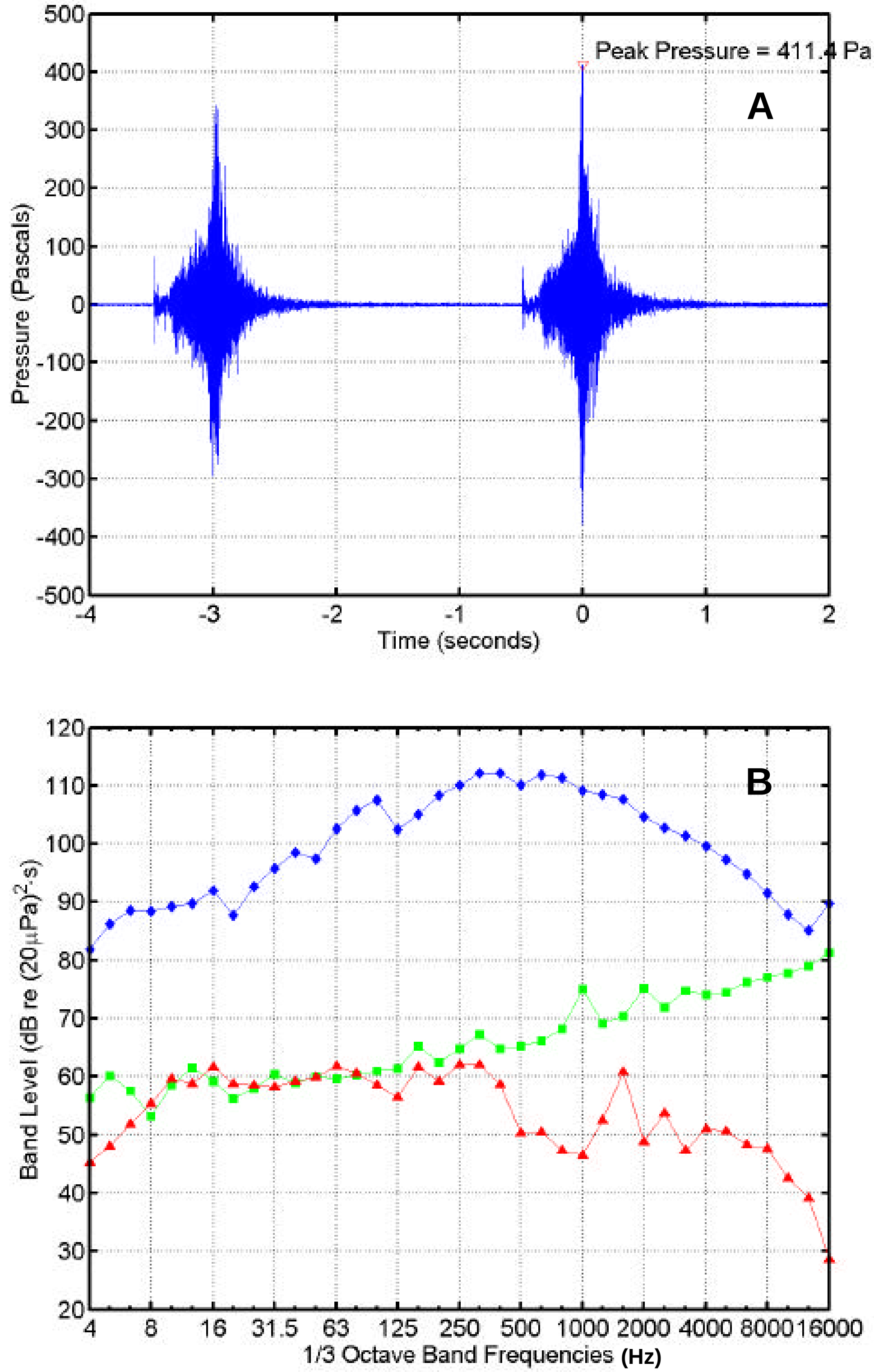


Figure C-2. (A) Pressure waveform and (B) one-third octave band levels for a flight of two RAMs at 11:03 on 18 November 2002 recorded 75 ft from the Launcher. In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

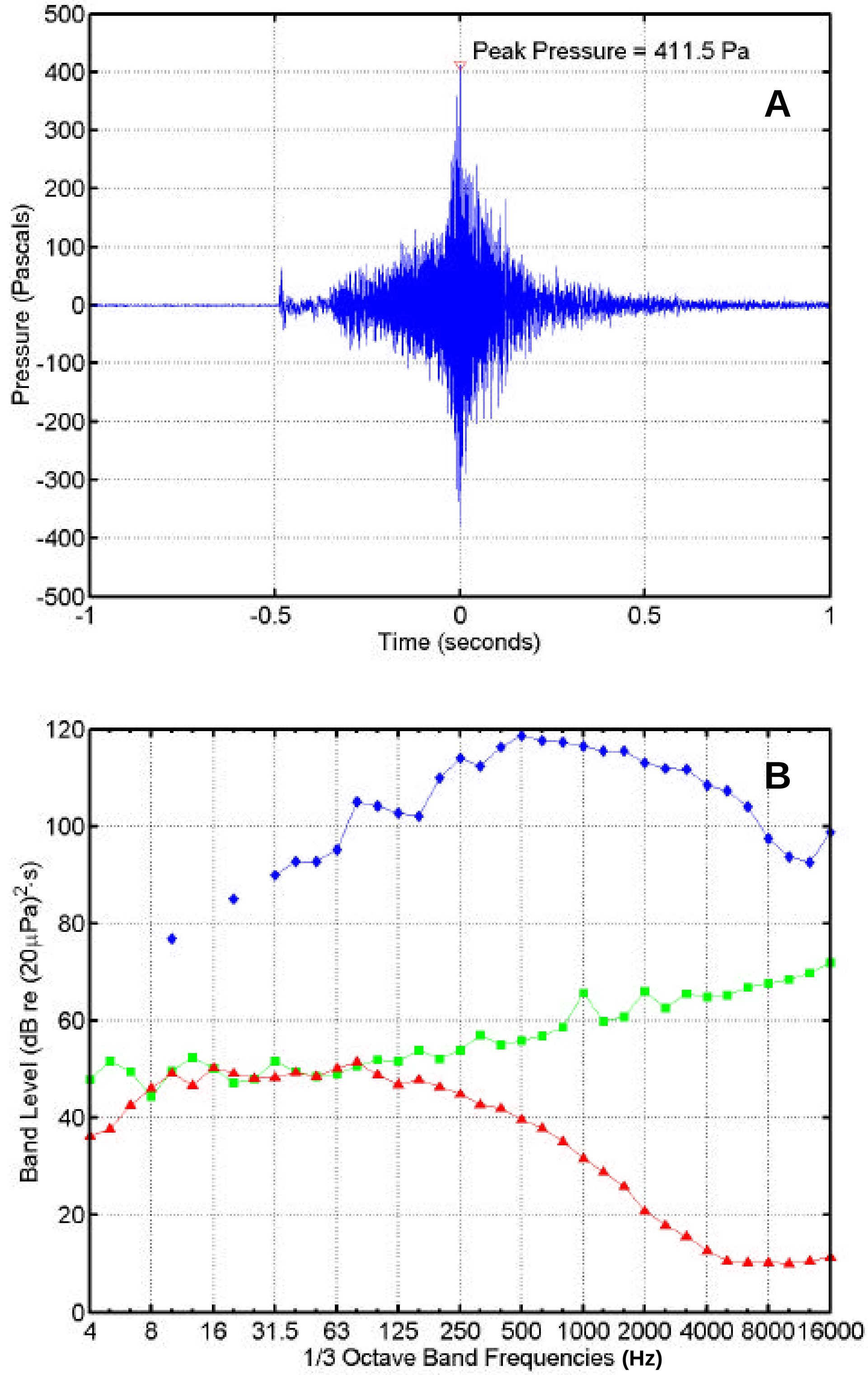


FIGURE C-3. (A) Pressure waveform and (B) one-third octave band levels for the second of the two RAMs in Figure 2.2. In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

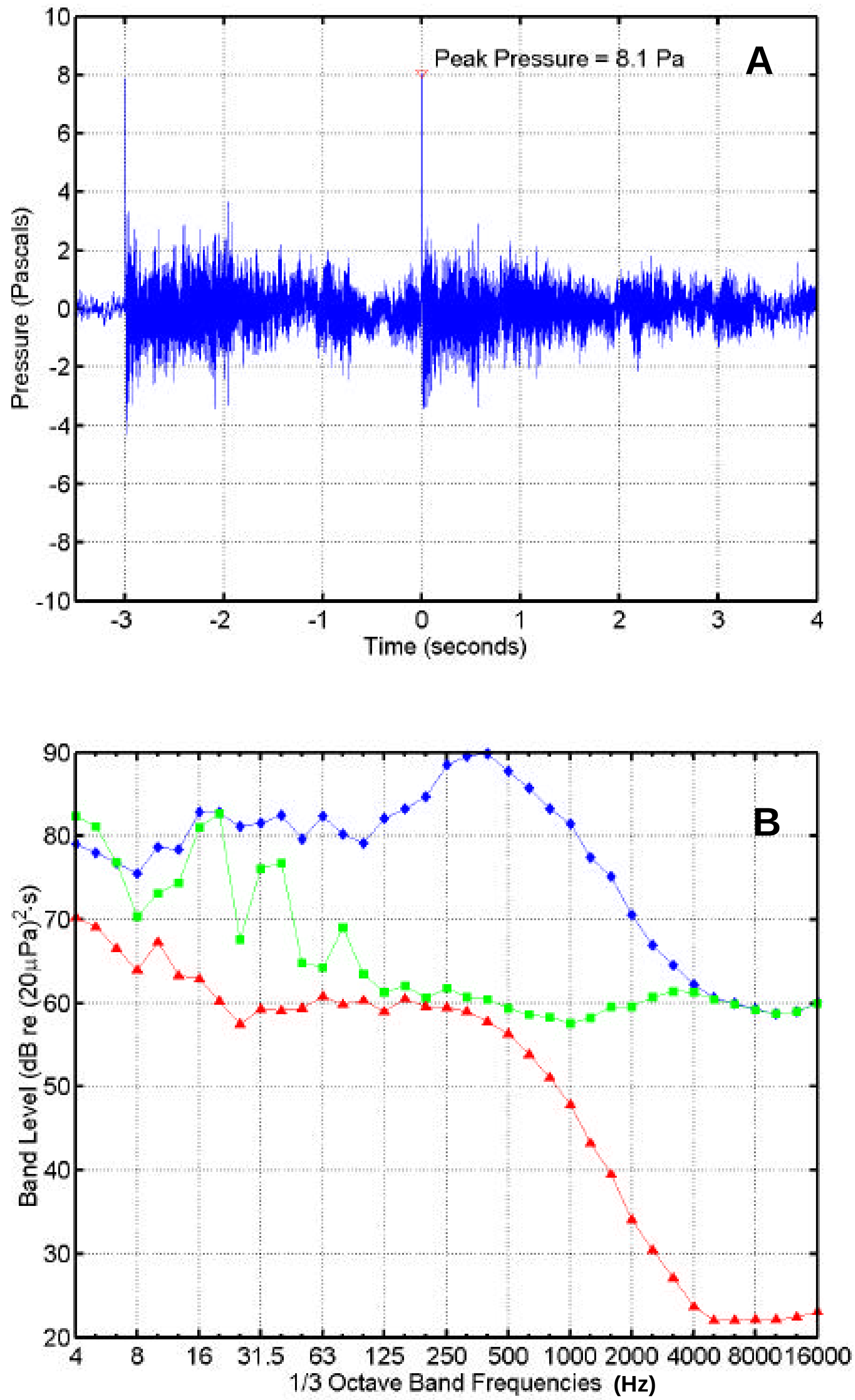


FIGURE C-4. (A) Pressure waveform and (B) one-third octave band levels for a flight of two RAMs at 11:03 on 18 November 2002 recorded at "Bachelor Beach North". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

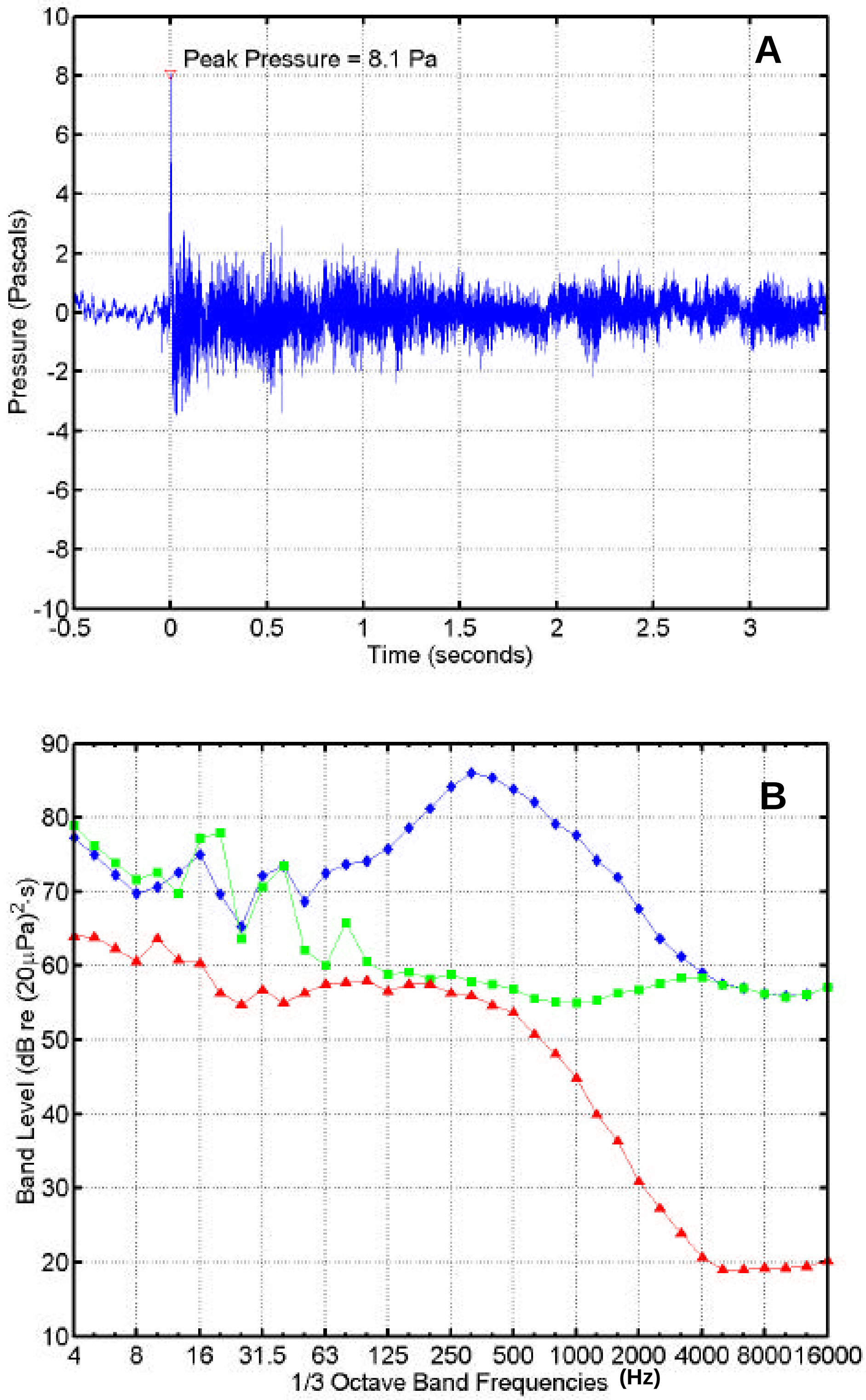


FIGURE C-5. (A) Pressure waveform and (B) one-third octave band levels for the second of the two RAMs in Figure 2.4. In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

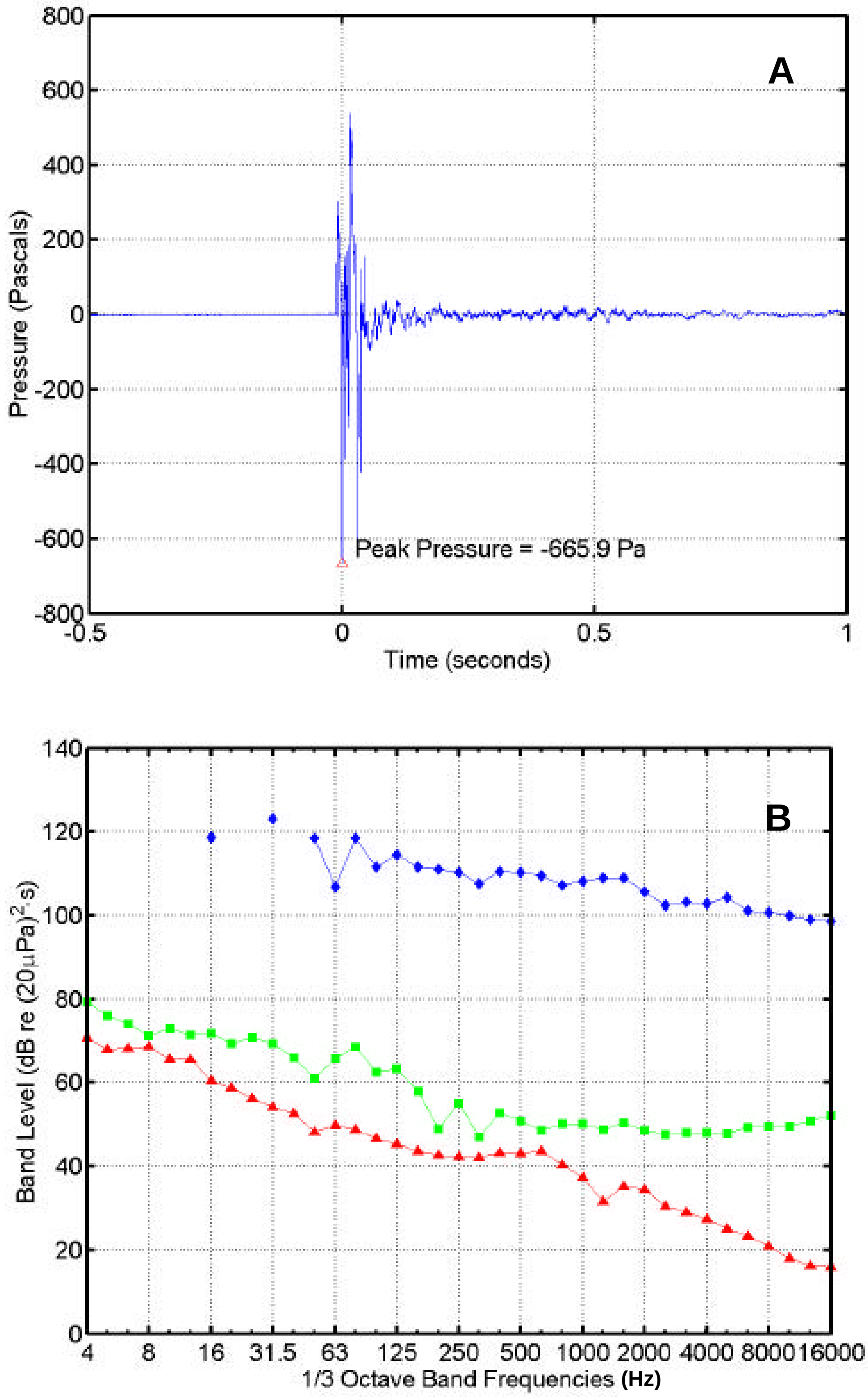


FIGURE C-6. (A) Pressure waveform and (B) one-third octave band levels for a Vandal missile at 08:49:02 on 10 December 2002 recorded at "Dos Coves". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

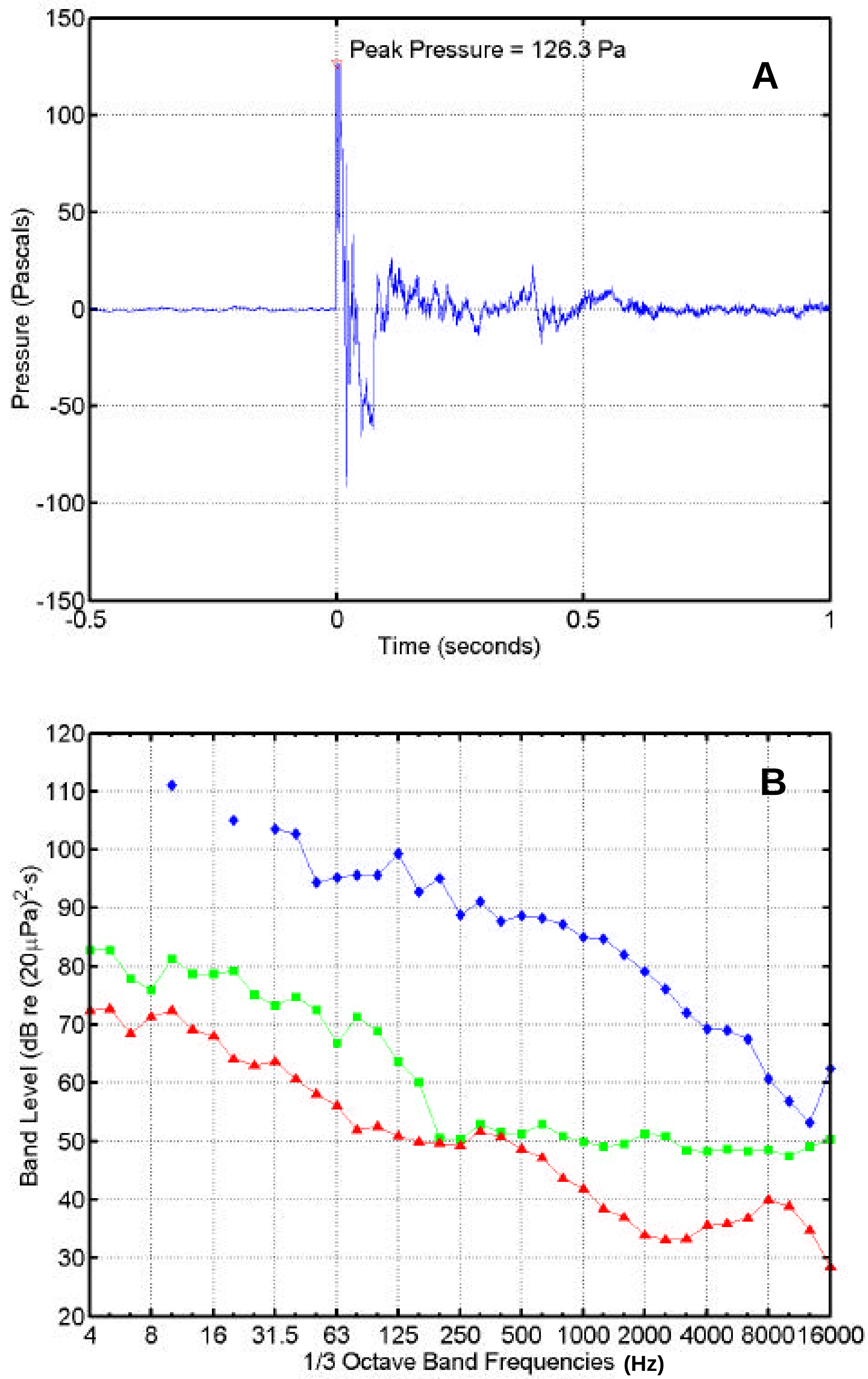


FIGURE C-7. (A) Pressure waveform and (B) one-third octave band levels for a Vandal missile at 08:49:02 on 10 December 2002 recorded at "Bachelor Beach North". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

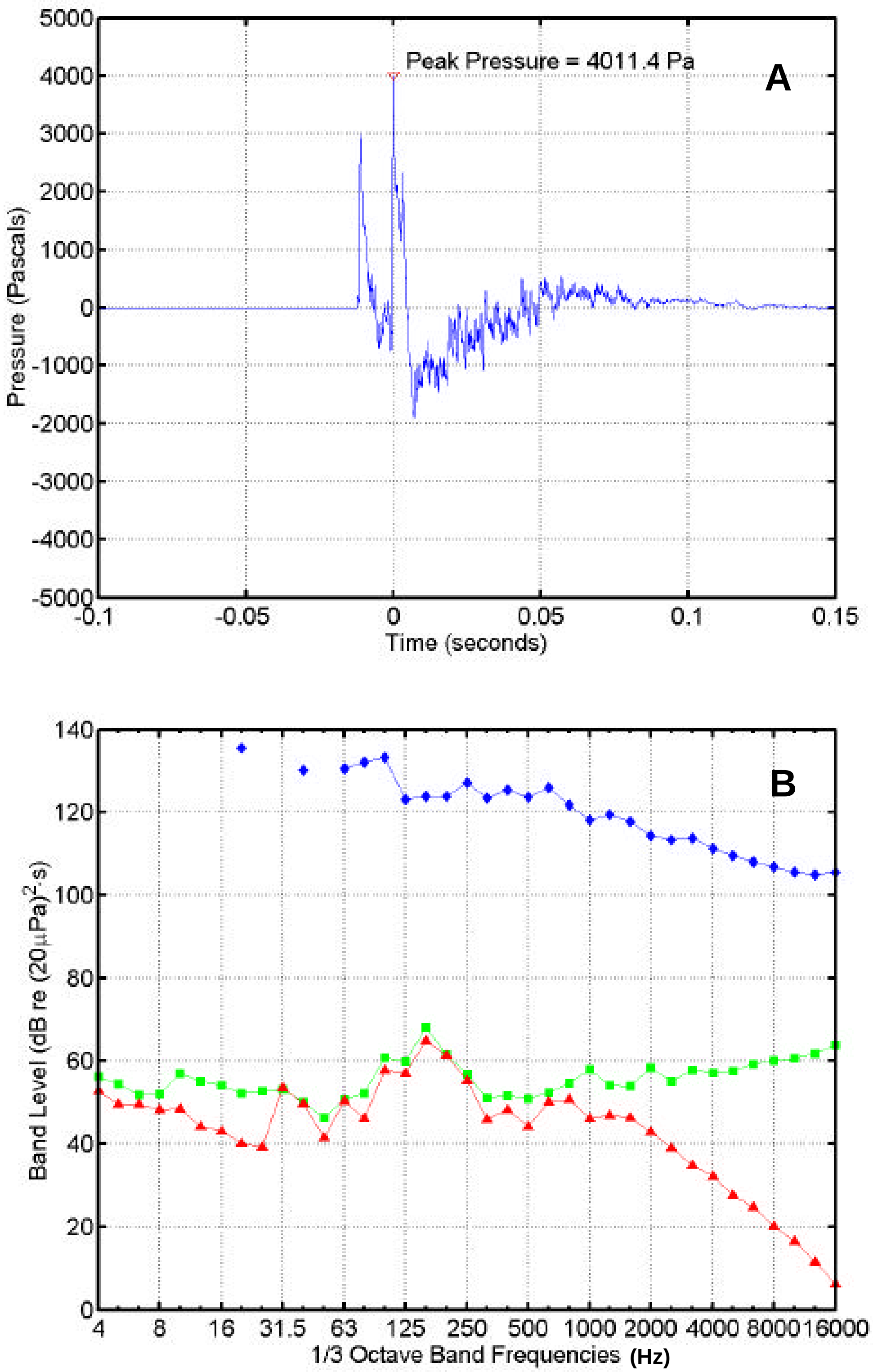
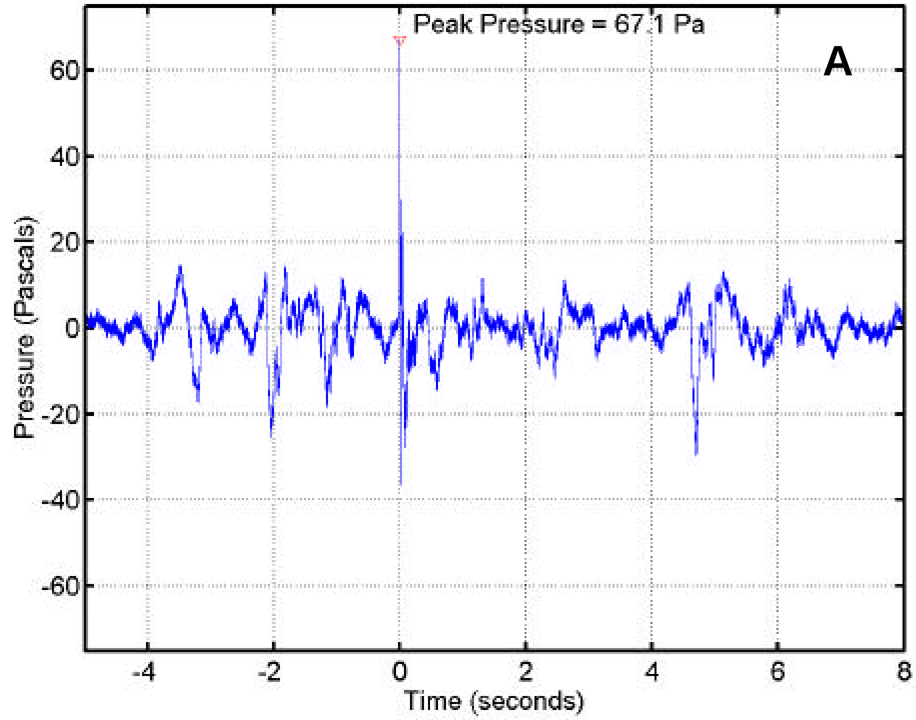


FIGURE C-8. (A) Pressure waveform and (B) one-third octave band levels for an AGS event at 14:30 on 18 December 2002 recorded 50 ft from the Launcher. In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.



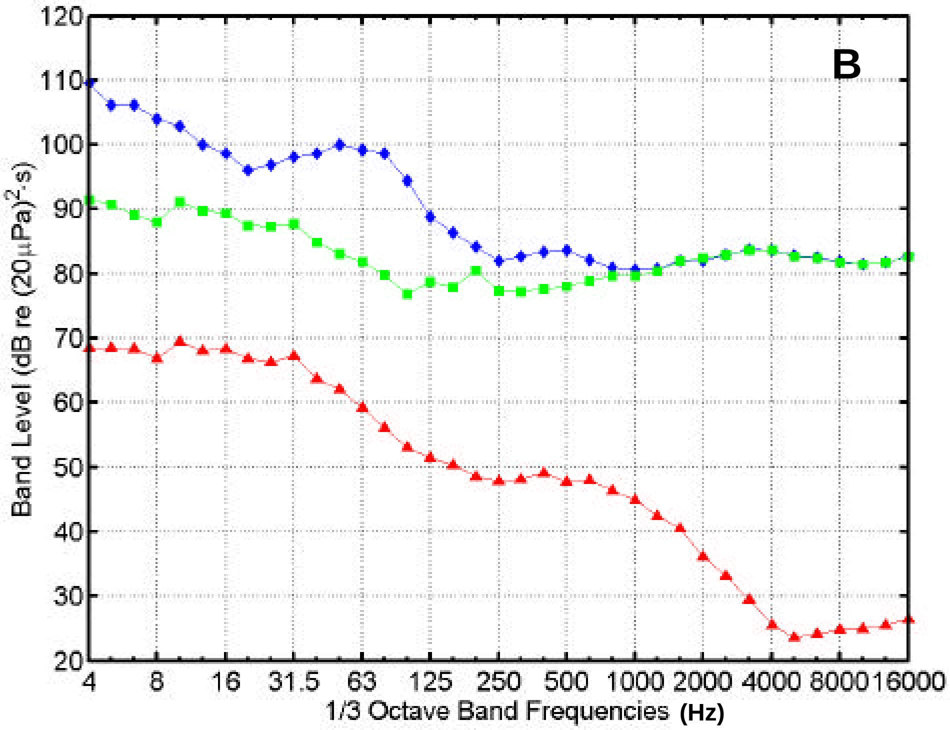


FIGURE C-9. (A) Pressure waveform and (B) one-third octave band levels for an AGS event at 14:30 on 18 December 2002 recorded at "Near 809 Camera". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

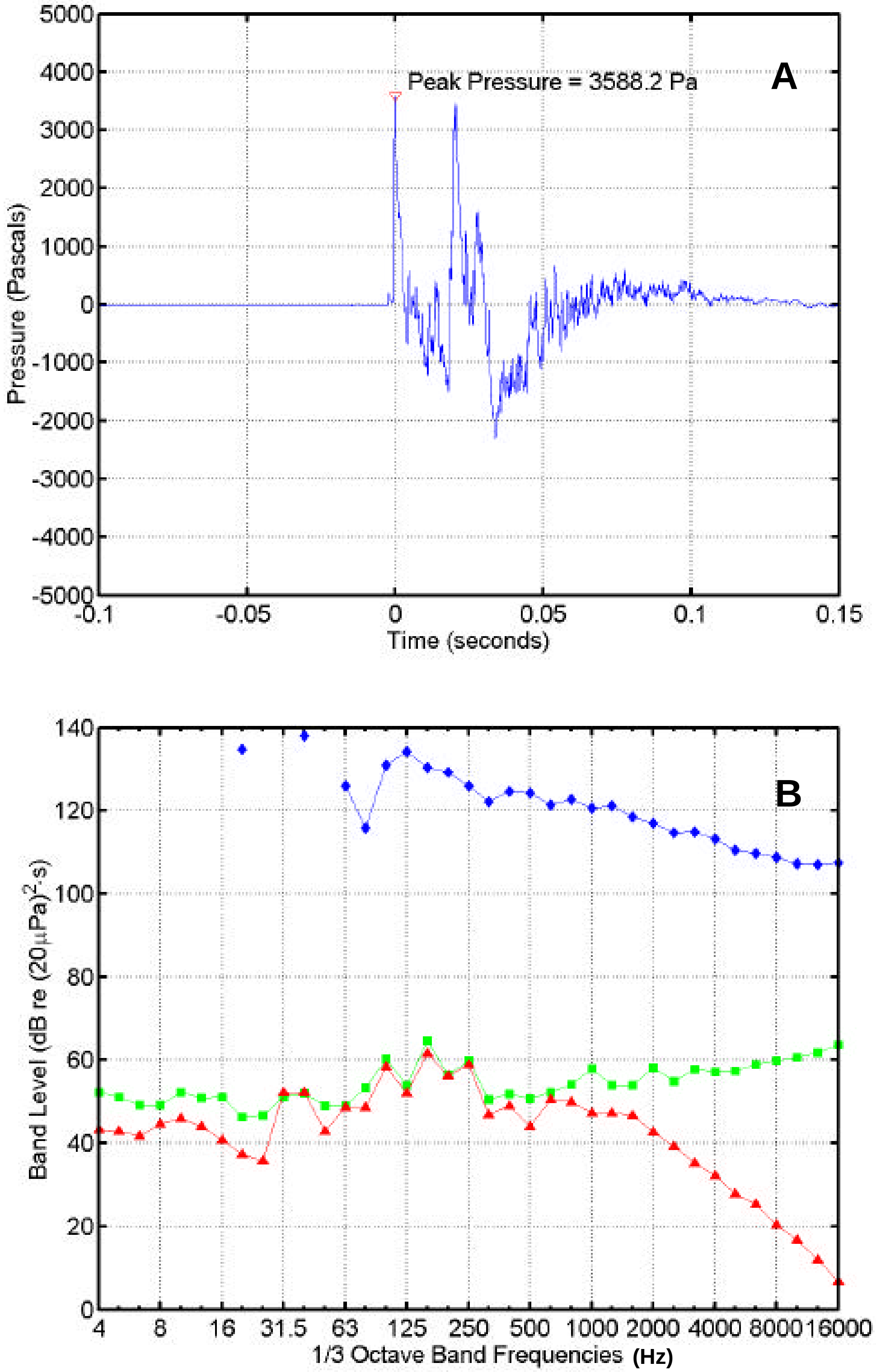


FIGURE C-10. (A) Pressure waveform and (B) one-third octave band levels for an AGS event at 16:15 on 18 December 2002 recorded 50 ft from the Launcher. In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

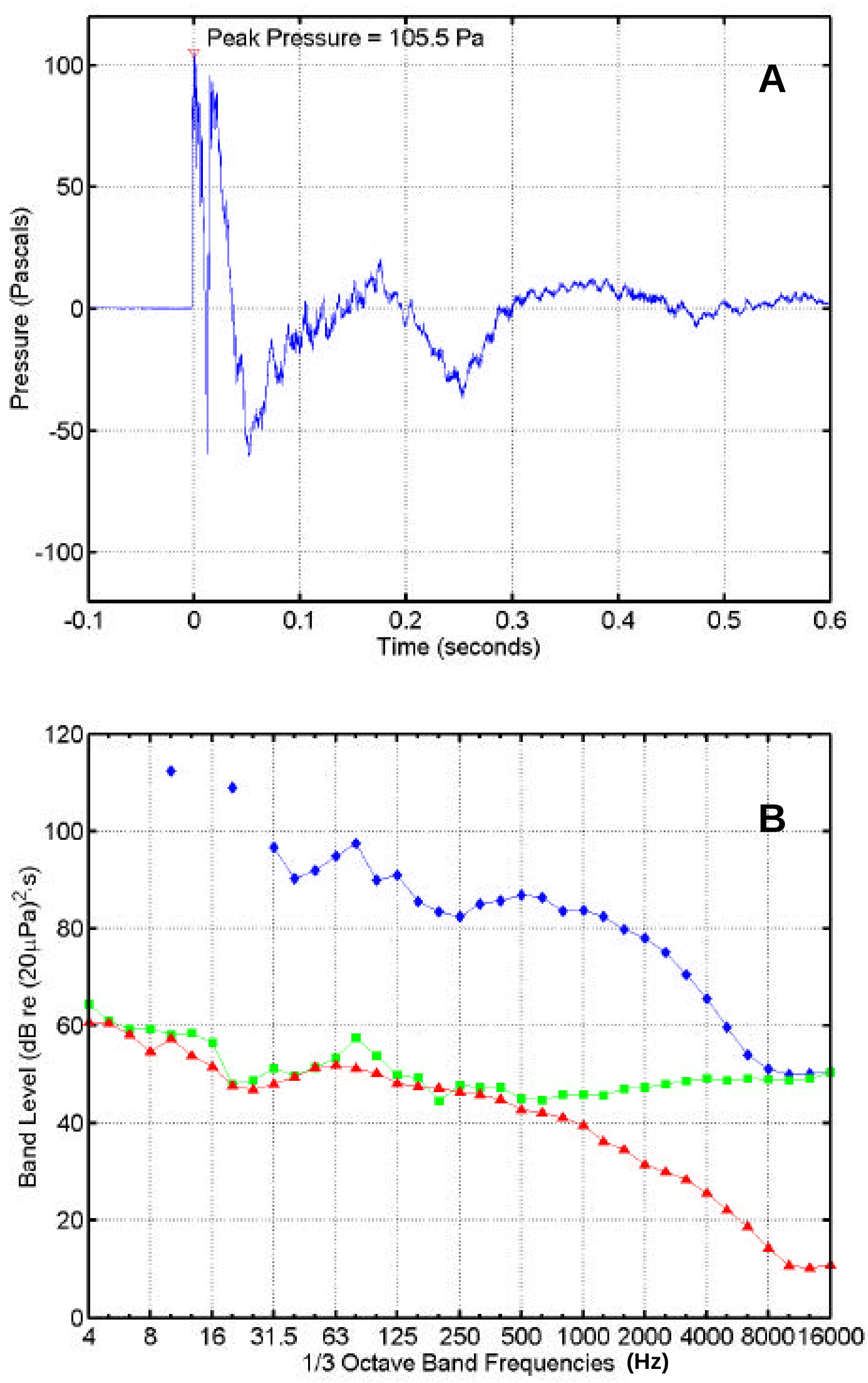


FIGURE C-11. (A) Pressure waveform and (B) one-third octave band levels for a GQM-163A SSST at 14:20 on 24 January 2003 at "Redeye I". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

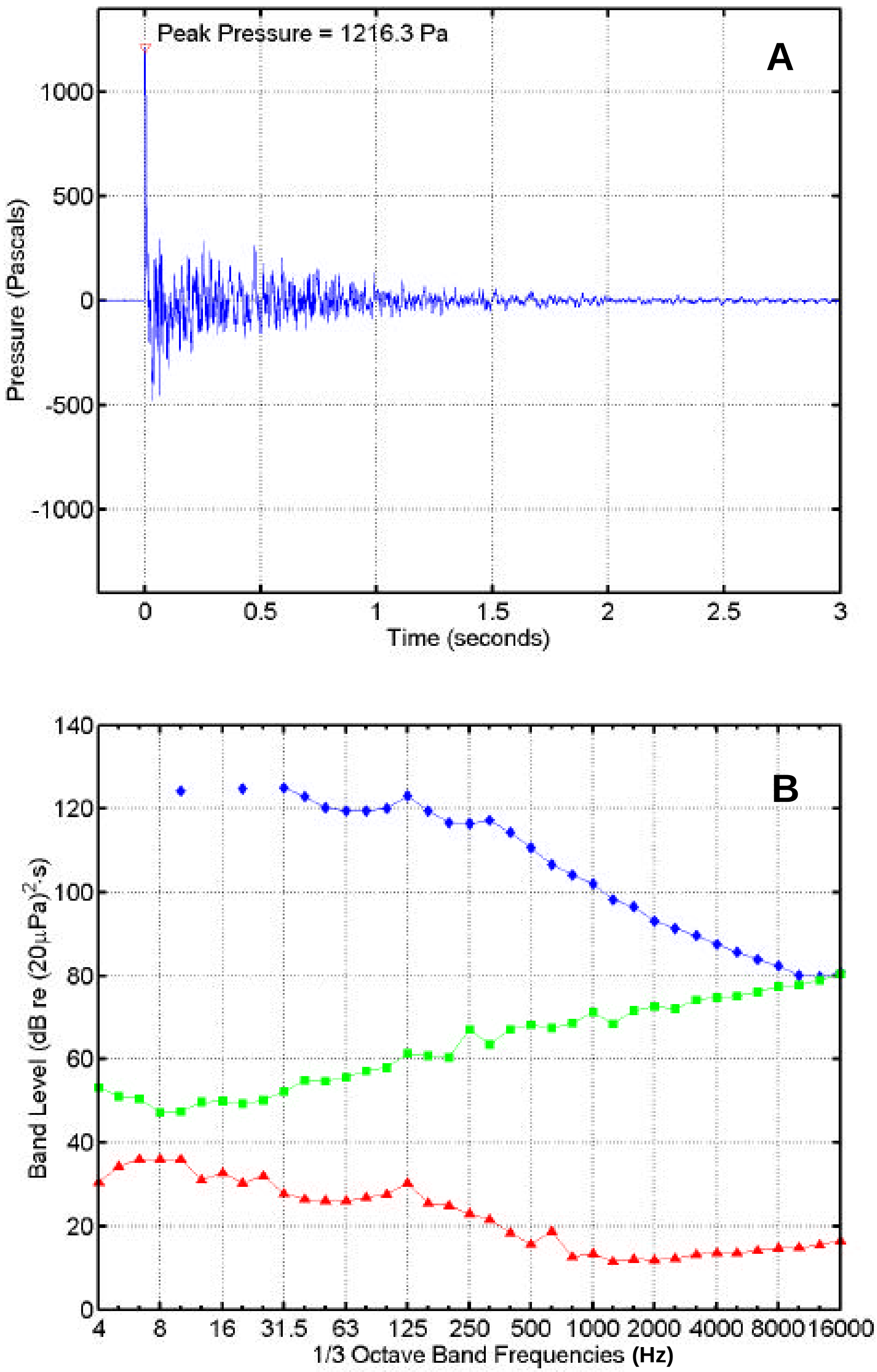
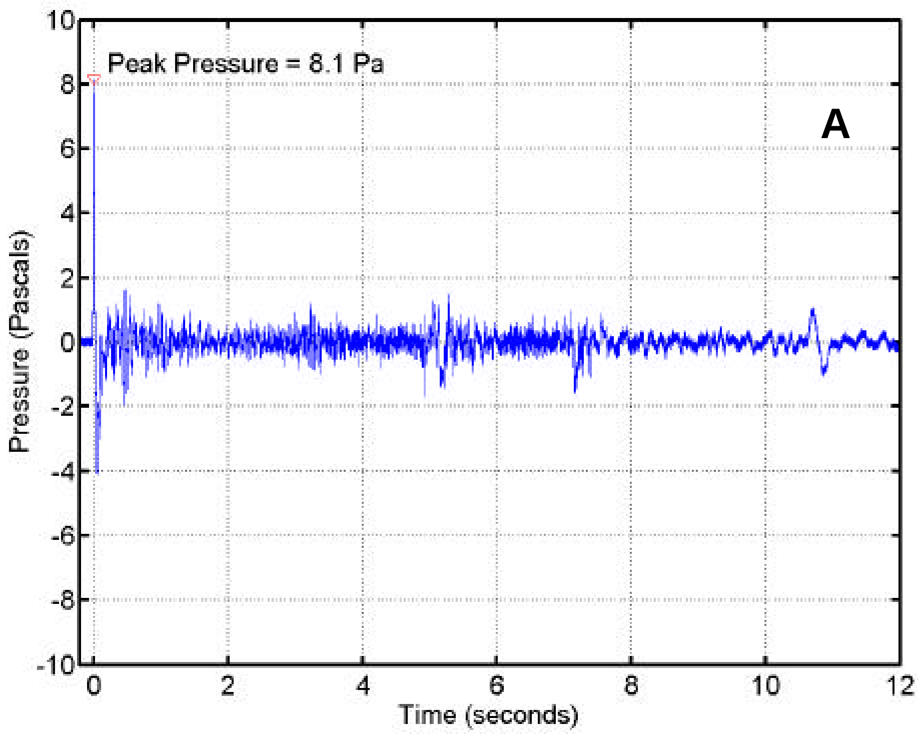


FIGURE C-12. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 9:13 on 14 March 2003 at the "Launcher". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.



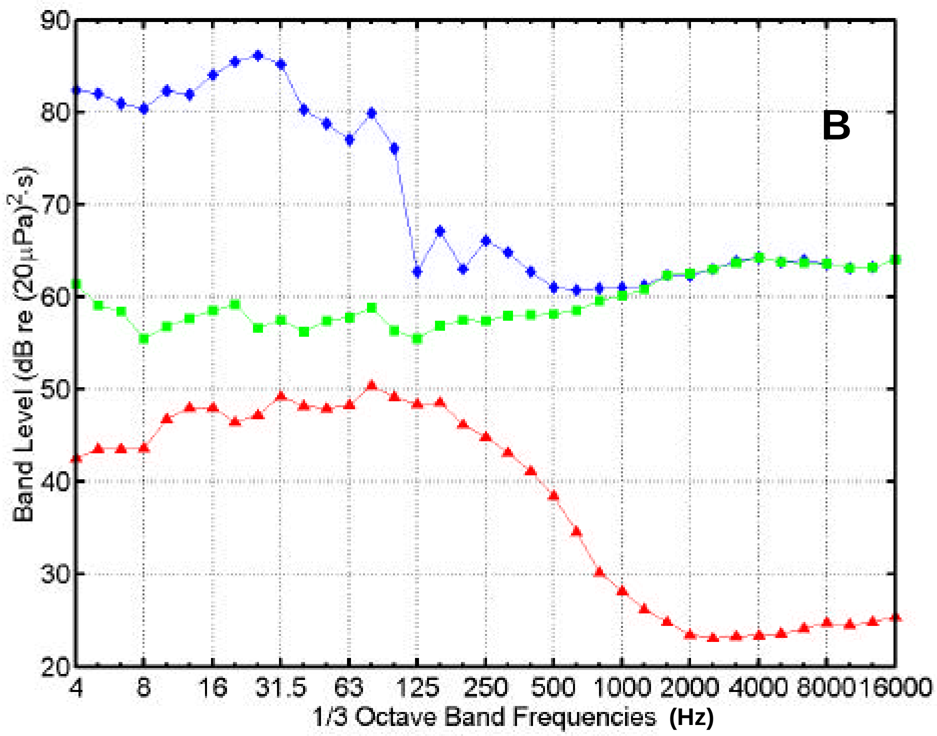


FIGURE C-13. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 9:13 on 14 March 2003 at "Pirates Cove". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

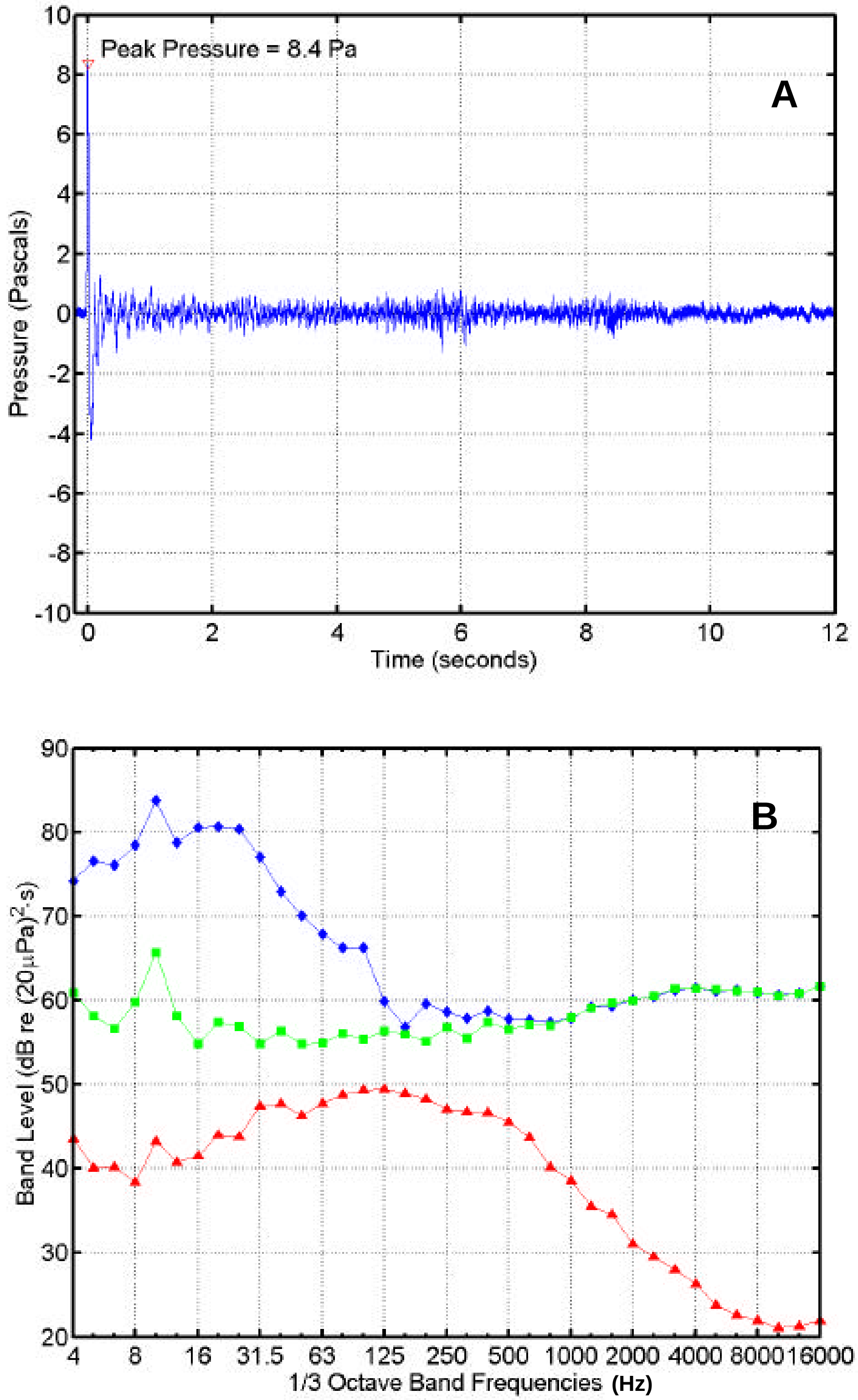
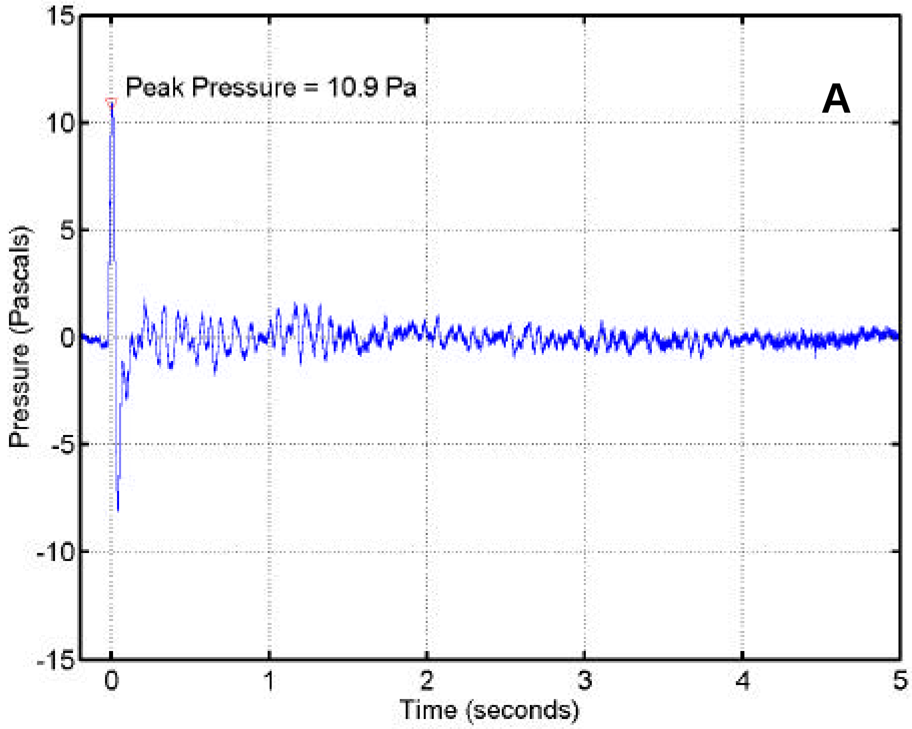


FIGURE C-14. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 9:13 on 14 March 2003 at "Sheephead Ranch". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.



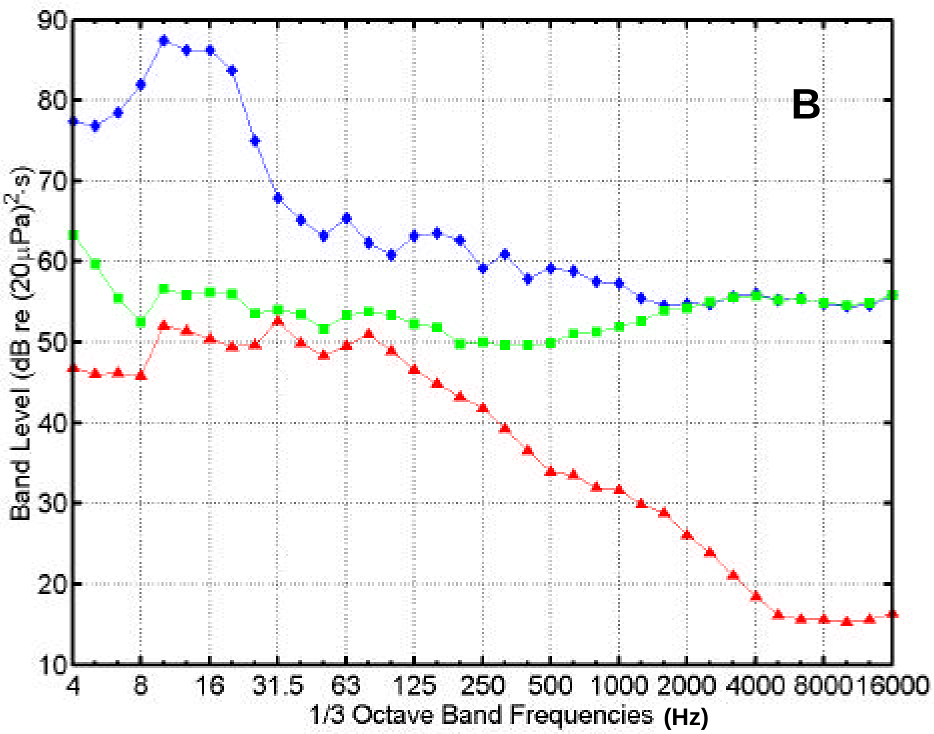


FIGURE C-15. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 13:04 on 16 March 2003 at "Corral Harbor". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

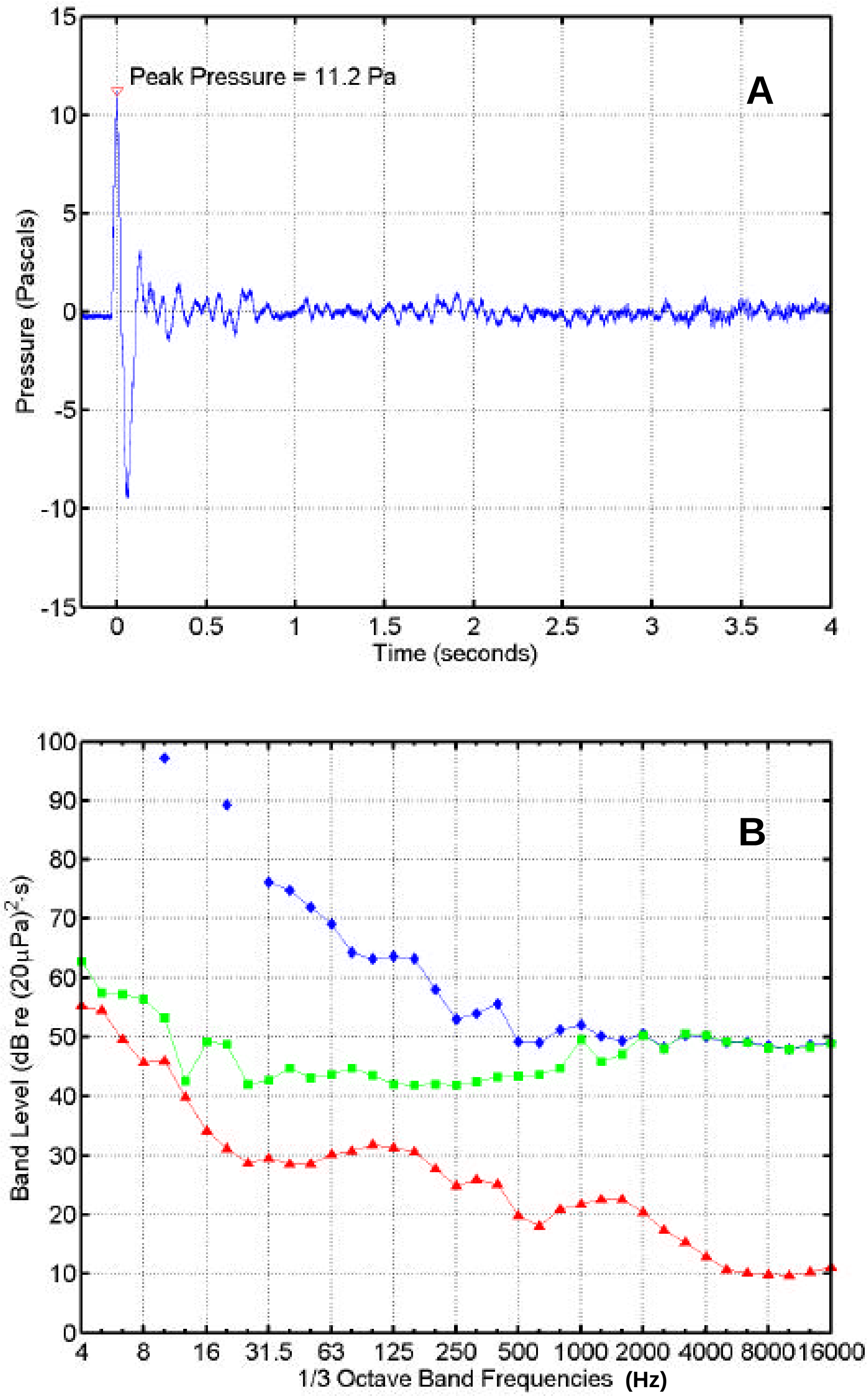


FIGURE C-16. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 15:20:01 on 4 April 2003 at "Phoca Point". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

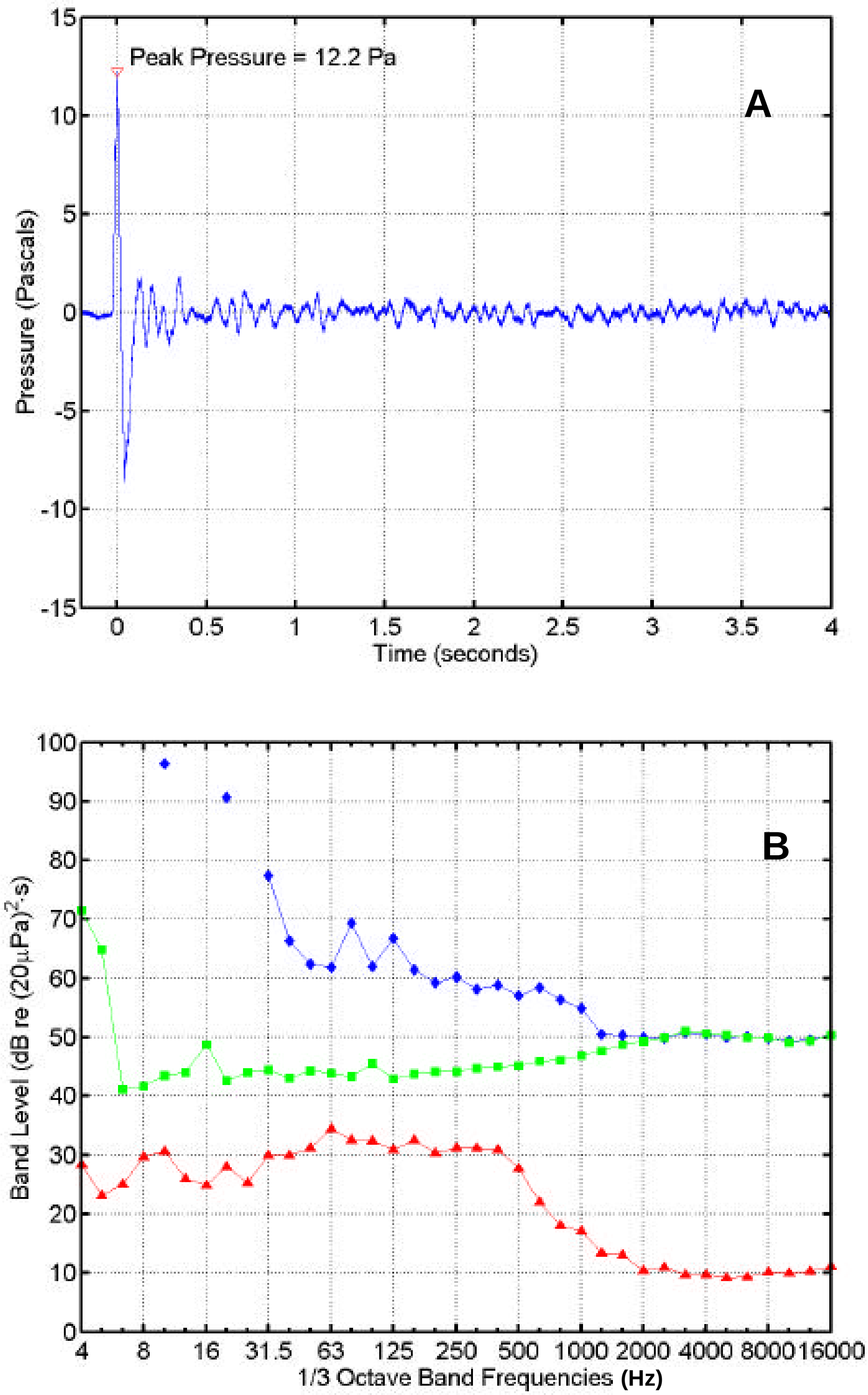


FIGURE C-17. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 15:20:01 on 4 April 2003 at "No Name Cove". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

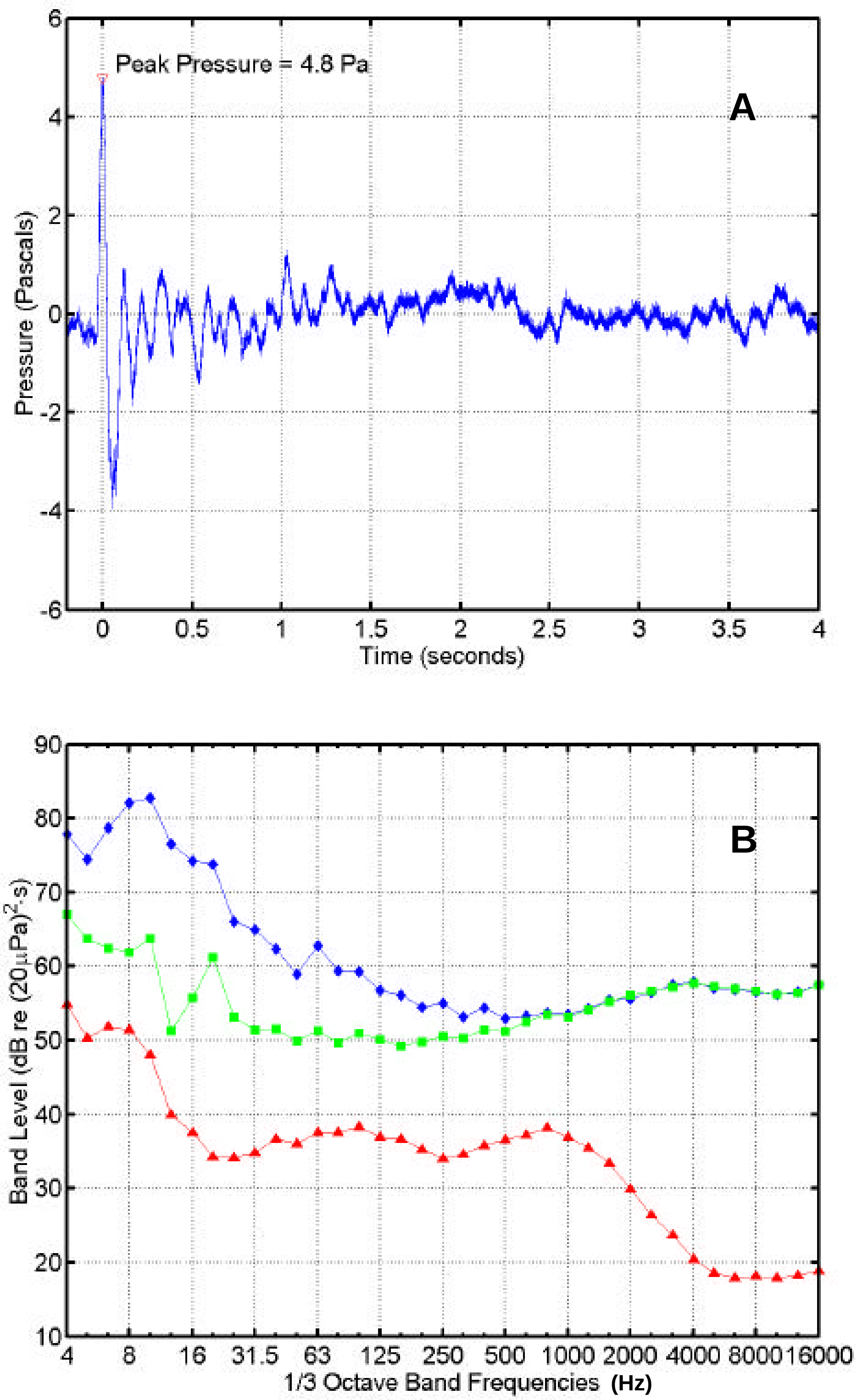


FIGURE C-18. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 15:20:01 on 4 April 2003 at "NAVFAC Beach". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

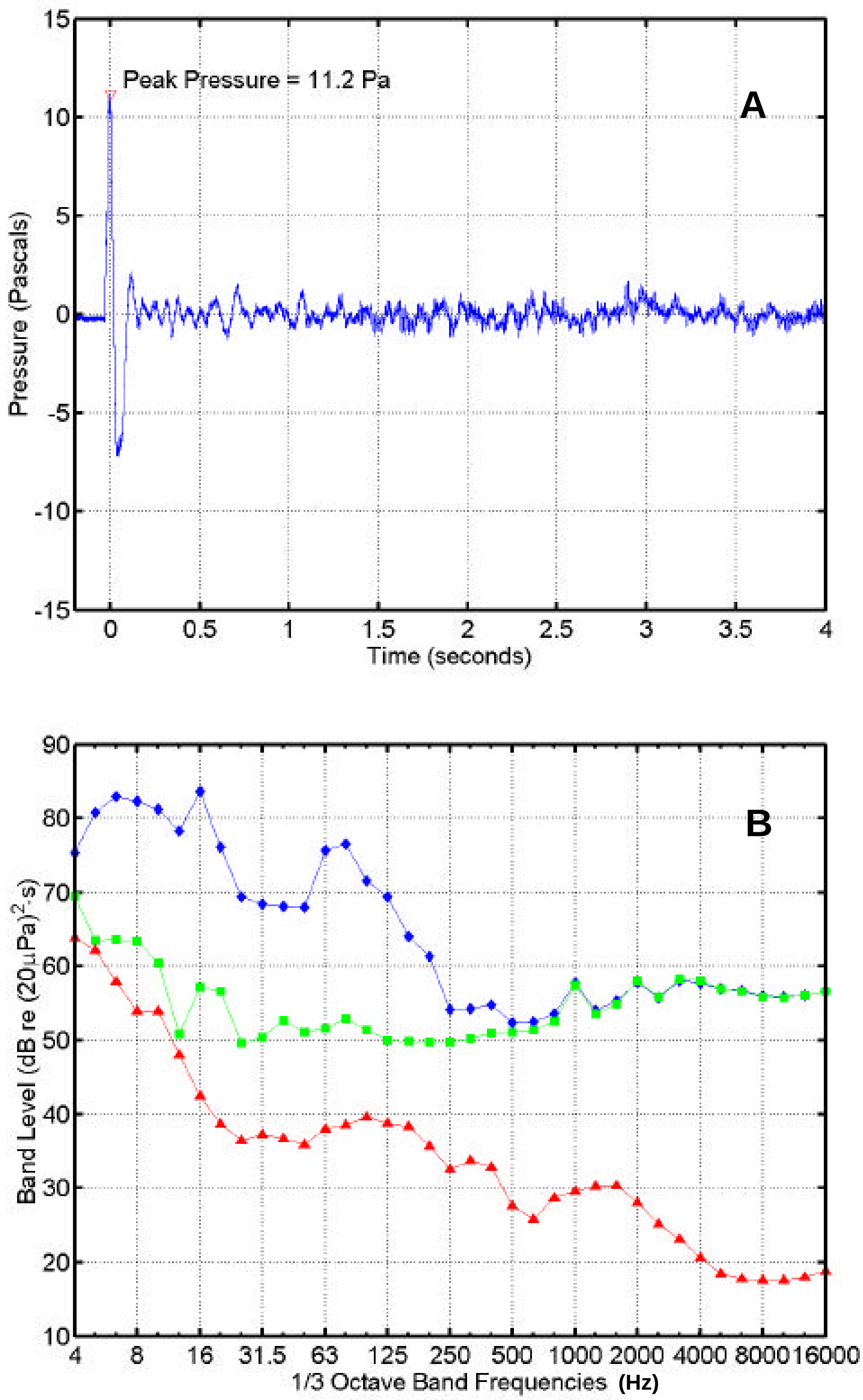


FIGURE C-19. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 15:20:06 on 4 April 2003 at "Phoca Point". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

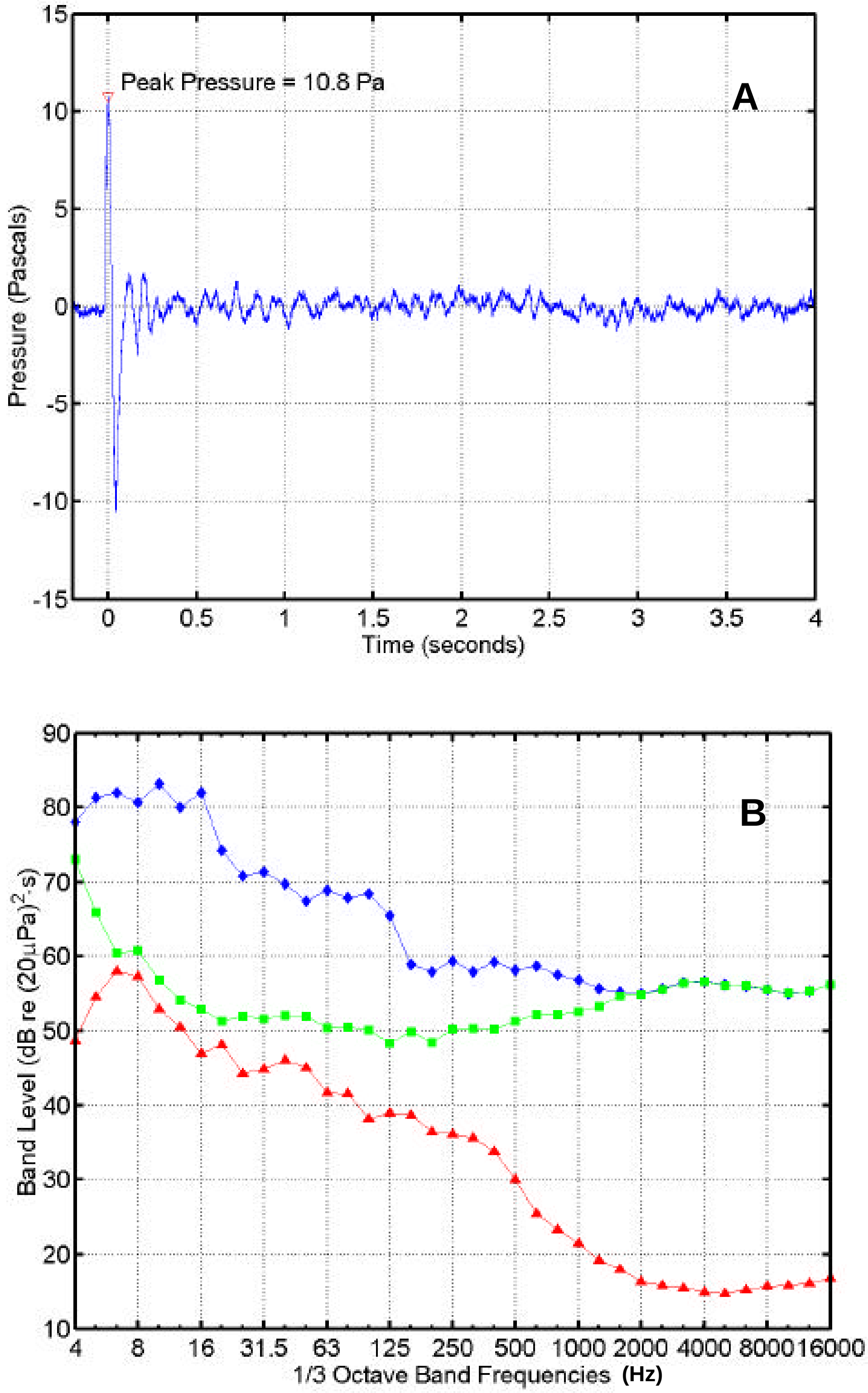
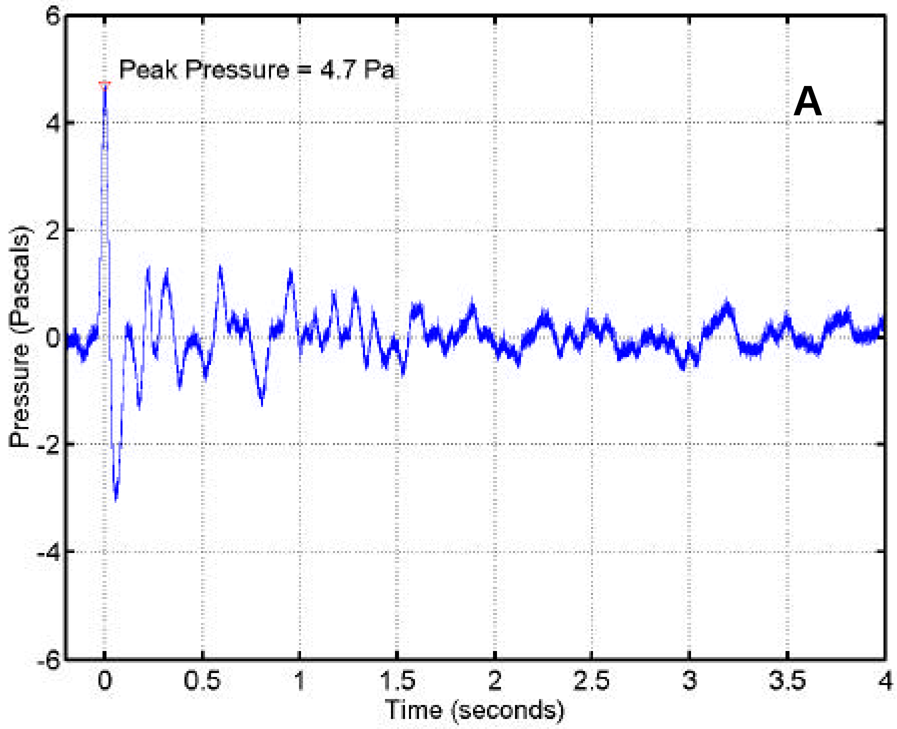


FIGURE C-20. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 15:20:06 on 4 April 2003 at "No Name Beach". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.



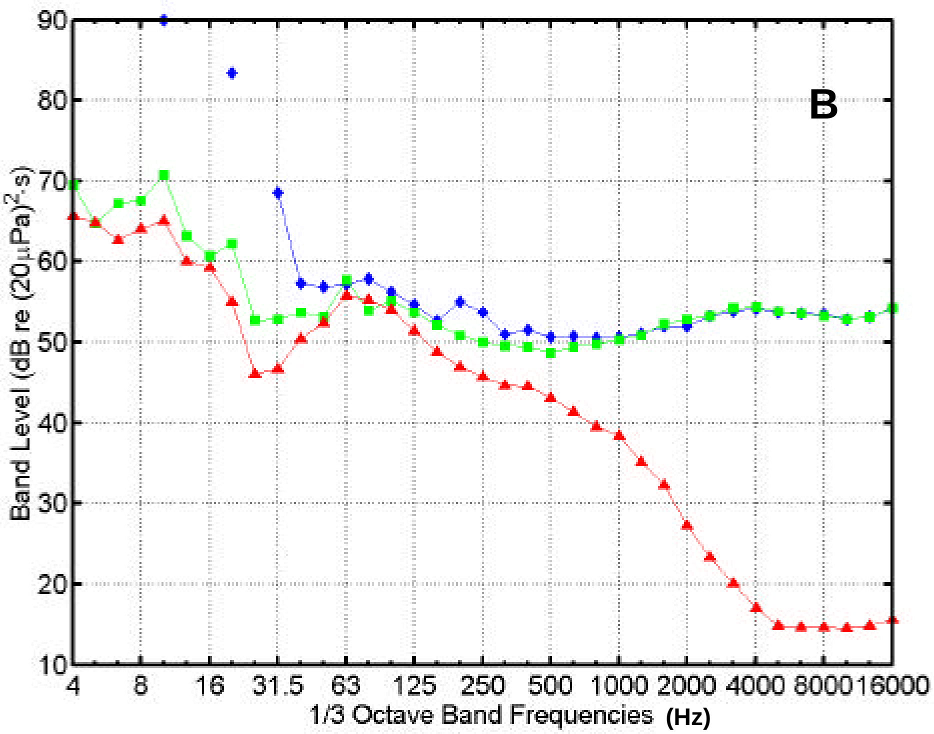


FIGURE C-21. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 15:20:06 on 4 April 2003 at "NAVFAC Beach". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

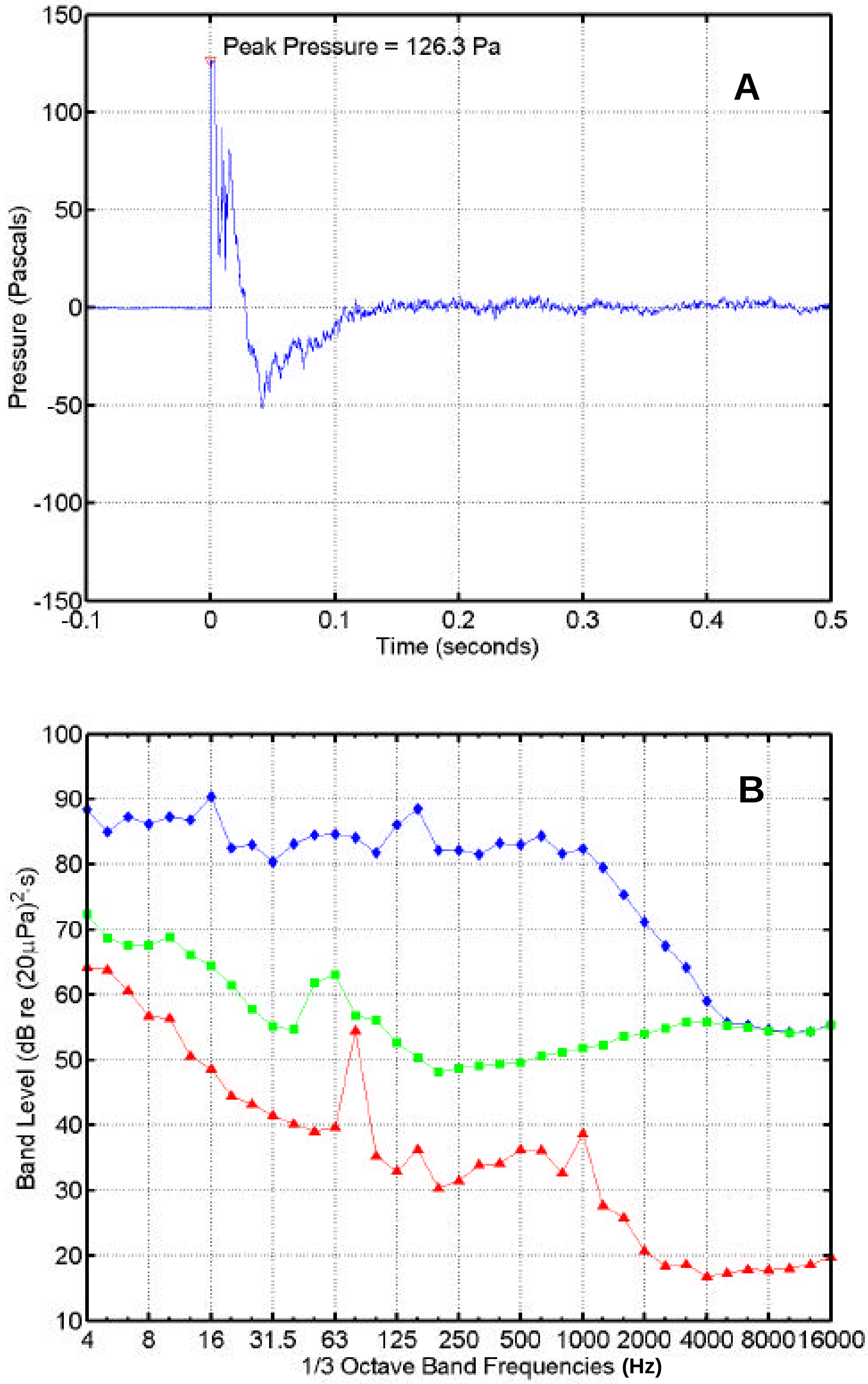


FIGURE C-22. (A) Pressure waveform and (B) one-third octave band levels for the GQM-163A at 12:35:20 on 4 June 2003 at "809 Camera". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

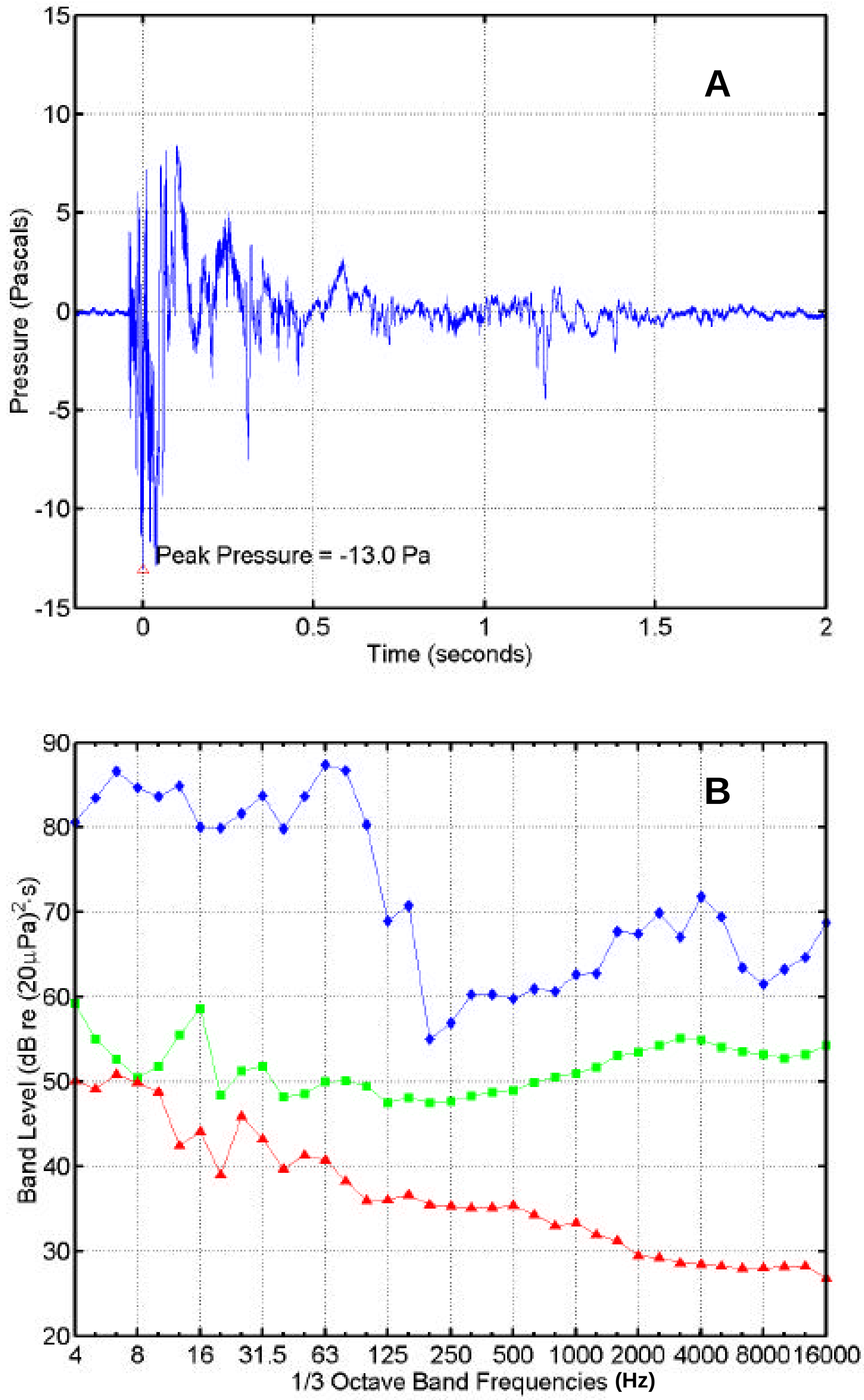
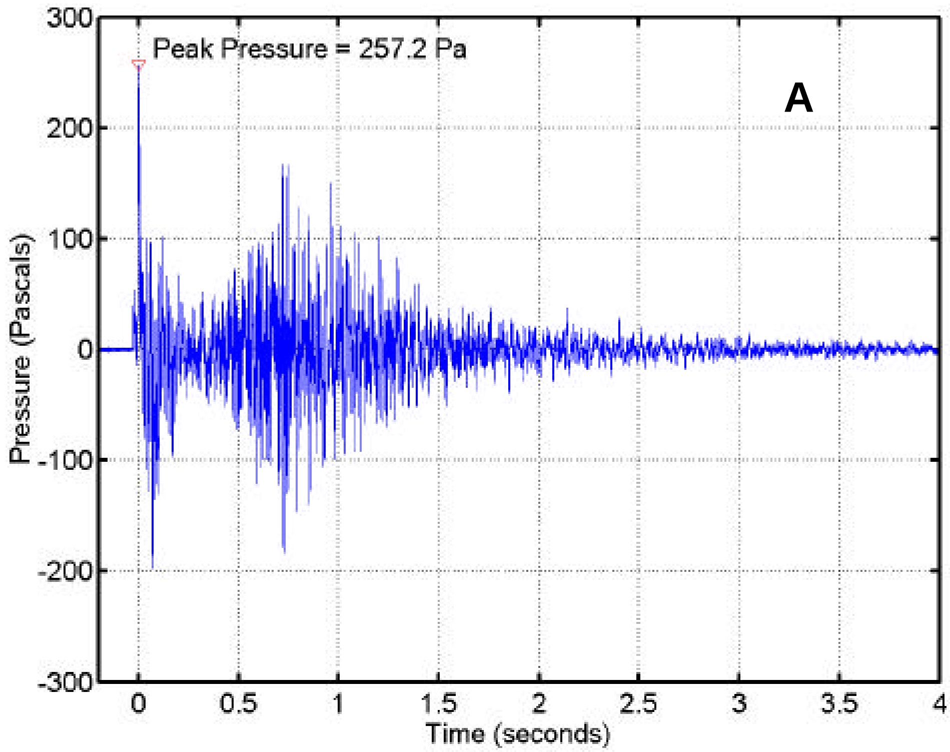


FIGURE C-23. (A) Pressure waveform and (B) one-third octave band levels for the GQM-163A at 12:35:20 on 4 June 2003 at "Sheephead Ranch". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.



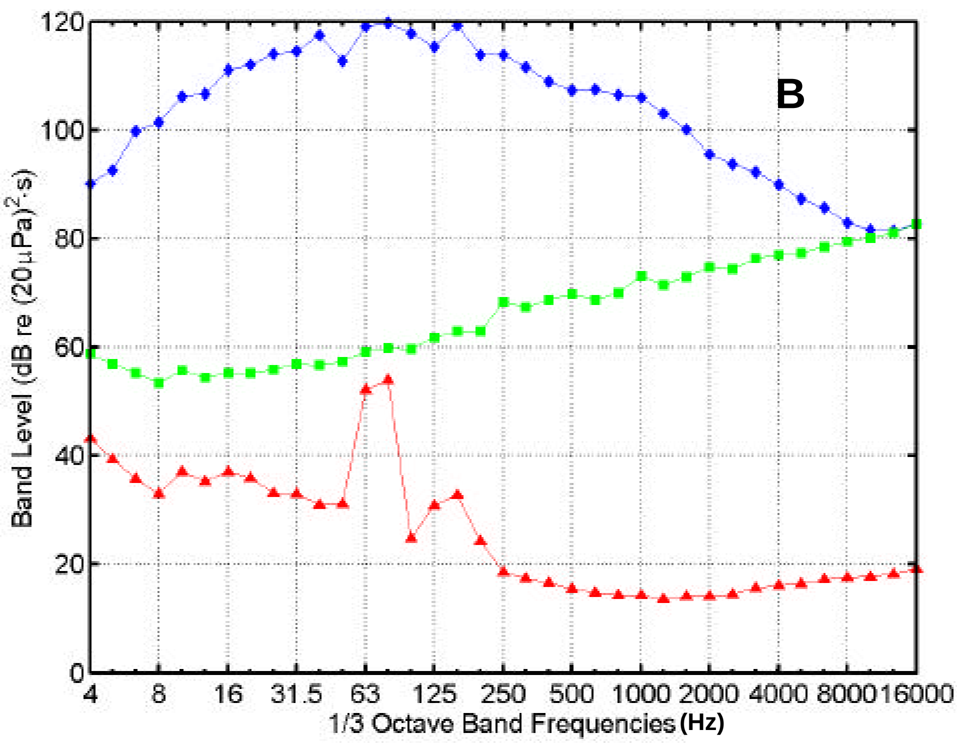


FIGURE C-24. (A) Pressure waveform and (B) one-third octave band levels for the GQM-163A at 12:35:20 on 4 June 2003 100 ft from "Launcher". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

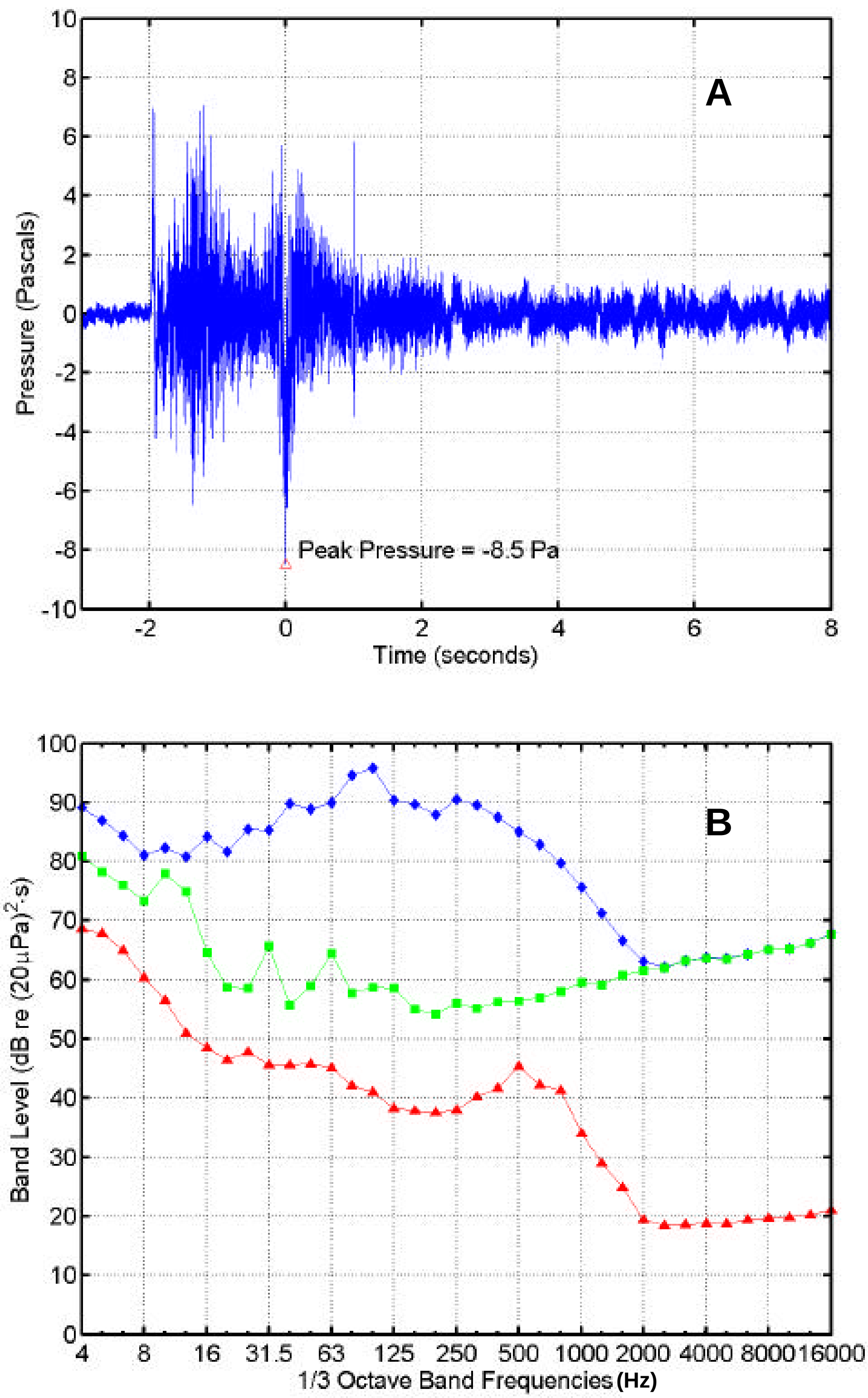


FIGURE C-25. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 13:27:58 on 26 June 2003 100 at "809 Camera". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

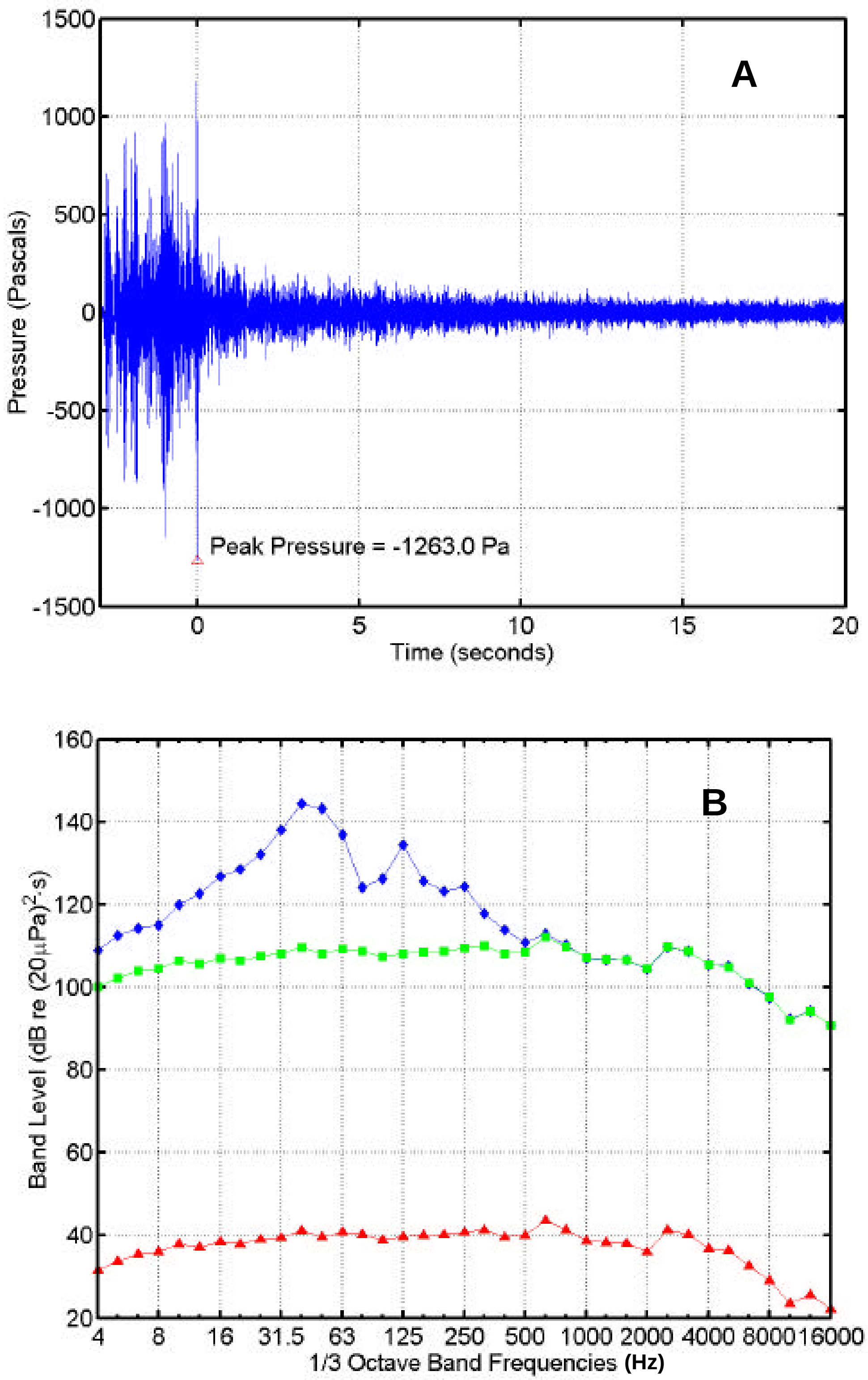


FIGURE C-26. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 13:27:58 on 26 June 2003 100 at "Bomber Cove". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

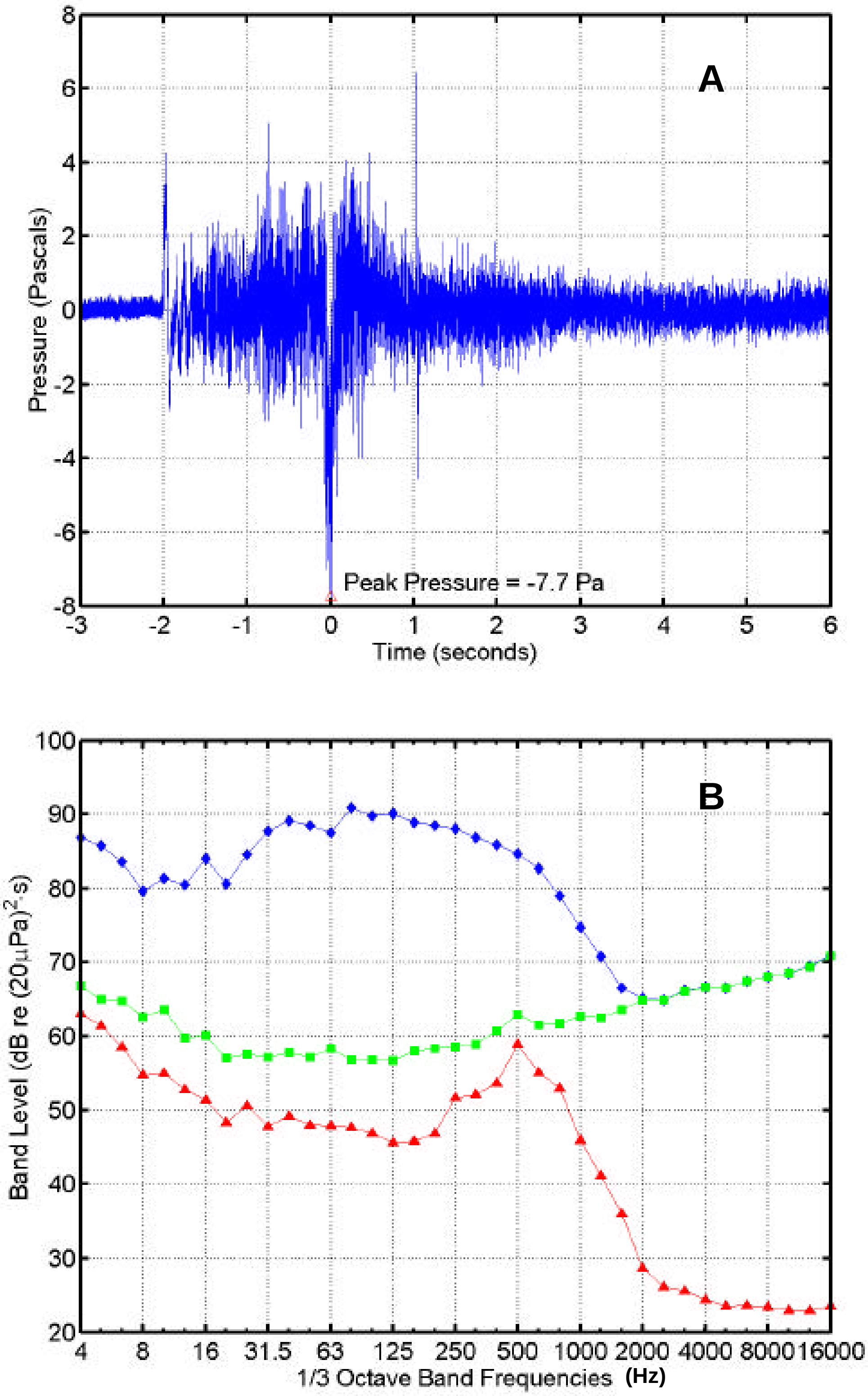
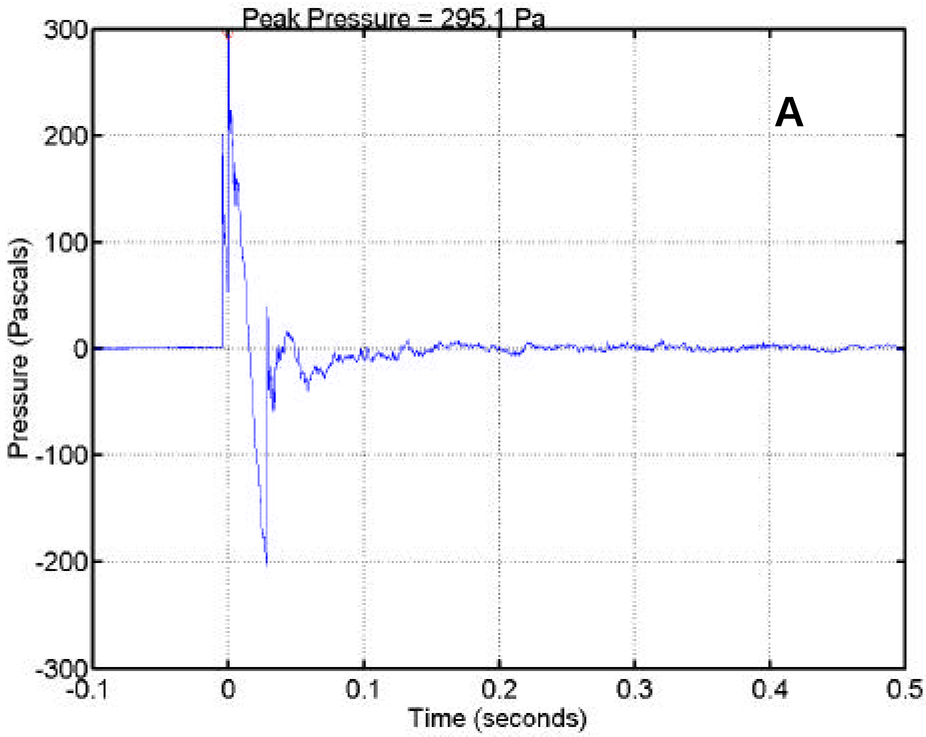


FIGURE C-27. (A) Pressure wb bb aveform and (B) one-third octave band levels for the Vandal at 13:27:58 on 26 June 2003 100 at "The Y". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.



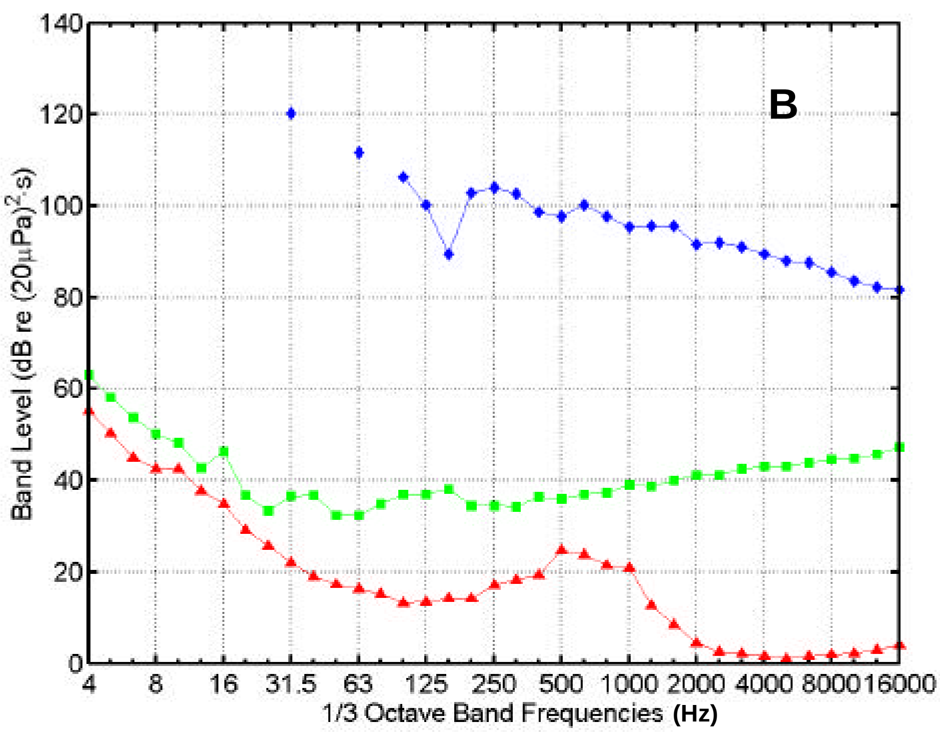


FIGURE C-28. (A) Pressure waveform and (B) one-third octave band levels for the Vandal at 16:27:50 on 28 July 2003 100 at "809 Camera". In (B), = missile sound energy; = instrumentation noise energy; Δ = ambient noise power.

APPENDIX D: DETAILS OF VEHICLE LAUNCHES, SOUND EXPOSURE LEVELS, AND PINNIPED REACTIONS AT SAN NICOLAS ISLAND DURING AUGUST 2001 TO JULY 2002

TABLE D.1. Details of missile launches, sound exposure levels (SEL), and ***California sea lion*** reactions at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 15 August 2001, 20 September 2001, 1 May 2002, and 26 June 2002. A dual RAM launch occurred on 21 June 2002. All missiles were launched from the Alpha Launch Complex, except for the dual RAM, which was launched from Building 807 Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction
15 Aug. 01	12:56	Vandal	270°	8° / 1,280 ft	809 Camera[n]	N/A	Most adults lifted their heads and were more vigilant; only a few animals entered the water. Pups in water rushed on shore. Animals settled within 5 min after launch.
					Dos Coves North and South[d]	N/A	Most adults lifted their heads, but did not move; only a few animals entered the water. Adults settled within minutes; pups stayed active longer.
"	13:17	Vandal	270°	8° / 1,280 ft	809 Camera[n]	N/A	Sea lions appeared to show less reaction to second launch. Less than 5% of the adults and juveniles flushed into water.
					Dos Coves North and South[d]	N/A	Most adults lifted their heads, but did not move. Pups were more active prior to this launch compared to the first launch.
20 Sep. 01	08:30	Vandal	270°	8° / 1,280 ft	Dos Coves North and South[d]	N/A	Adults looked up, some moved, but did not leave area; settled within minutes. Pups reacted vigorously by running around.
					809 Camera[n]	119/101	Sea lion pups in water swam about vigorously.*
"	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	Sea Lion Cove[s]	96/83[#]	Little reaction by pups and adults in response to launch; animals settled within minutes.
					809 Camera[n]	N/A	Sea lion pups in water swam vigorously and came ashore.*

TABLE D.1. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)$^2 \cdot$ s] flat-weighted/A-weighted	Behavioral Reaction
5 Oct. 01	13:37	Vandal	273.3°	8° / 1,300 ft	809 Camera[n]	N/A	Pups on shore moved around, but did not enter water. Some pups that were in water came ashore. Animals settled within a few minutes and resumed previous activities.
					Vizcaino Pt.[n]	N/A	Sea lions looked and got up, but did not enter water; a few individuals left the area. Pups scattered more than adults.
19 Oct. 01	09:00	Vandal	270°	8° / 1,280 ft	809 Camera[n]	N/A	Some pups reacted to the launch by moving up on the beach. Several pups came out of the water and came ashore.
					Vizcaino Pt.[n]	N/A	Most sea lions were startled and scattered, but only some animals (10 %) left the area; they were mostly pups. Within 5 min animals resumed pre-launch activities.
19 Dec. 01	15:22	Vandal	273°	8° / 1,300 ft	809 Camera[n]	121/103	Most animals (60%) left the location were they had rested but did not enter the water. Within 5 minutes all animals had settled back to their pre-launch activities.
6 Mar. 02	11:20	Vandal	273.1°	8° / 1,300 ft	809 Camera[n]	121/106	Most animals looked up and some moved. . Only 16% of animals entered water; they were mostly juveniles. Within 5 min after launch animals had settled.
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	809 Camera[n]	N/A	Sea lions showed no distinct reaction to the first launch.
"	17:00	Vandal	273°	42° / 9,600 ft	809 Camera[n]	103/90	Most of the sea lions looked up, and several moved in response to the launch sound (mostly younger animals).

TABLE D.1. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)$^2\cdot$ s] flat-weighted/A-weighted	Behavioral Reaction
8 May 02	14:54	Vandal	273°	8° / 1,300 ft	809 Camera[n]	122/104^	All sea lions looked up, some got up and moved around, and 33% entered the water.
					Sea Lion Cove[s]	N/A	Most sea lions looked up, but did not move.
19 June 02	15:07	AGS Test Slug	305°	63° / hit land	809 Camera[d]	N/A	Most sea lions sat up and some moved, but none entered the water.
21 June 02	12:53:12/ 12:53:15	RAM	240°	8° / 50 ft	Bachelor Beach North[s]	N/A	During the launch, most sea lions looked up and some moved slightly, but none entered the water.
					Dos Coves South[n]	N/A	Sea lions looked up during the launches, but did not move; they settled within minutes after the launch.
26 June 02	11:20	AGS Test Slug	300°	62.5° / 500 ft	Redeye Beach[s]	96/62	The sea lions did not show much reaction; some looked up and several moved slightly.
"	12:51	AGS Missile	300°	62.5° / 5,300 ft	809 Camera[s]	94/64	The sea lions did not show much reaction; some looked up and several moved slightly.
18 July 02	11:54:42	Vandal	273°	8° / 1,300 ft	Dos Coves North[d]	128/110	During the launch, all of the sea lions looked up, and 50% left the area immediately. All but one sea lion left the immediate area within several minutes after the launch.

Note: N/A means that sound exposure levels are not available for that location.
[n] monitoring site located north of the launch azimuth.
[s] monitoring site located south of the launch azimuth.
[d] monitoring site located directly near launch azimuth.
[#] SEL taken at nearby Cormorant Rock Blind; situated < 0.5 km northwest of Sea Lion Cove.
* incidental sightings of sea lions at harbor seal haul-out sites.
^ SEL taken nearby at Vizcaino Pt.; located < 0.5 km from 809 Camera.

TABLE D.2. Details of missile launches, sound exposure levels (SEL), and ***northern elephant seal*** reactions at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 20 September 2001, 22 February 2002, and 1 May 2002. All missiles were launched from the Alpha Launch Complex, except for the dual RAM, which was launched from Building 807 Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)$^2\cdot$ s] flat-weighted/A-weighted	Behavioral Reaction
20 Sep. 01	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	Bachelor Beach North[n]	N/A	All seals glanced up, and some shuffled positions slightly, but did not move out of the area. Seals settled within 30 sec after launch.
					Bachelor Beach South[n]	96/83*	Exhibited very little overt reaction. Most seals looked up, but did not move.
19 Oct. 01	09:00	Vandal	270°	8° / 1,280 ft	Bachelor Beach South[s]	N/A	Most animals looked up briefly and then settled back. 20% of juveniles moved but did not enter water.
14 Feb. 02	11:33	Vandal	273°	8° / 1,300 ft	Bachelor Beach North[s]	123/107	Elephant seals showed little reaction to launch. Most seals looked up briefly, but no seals moved.
					Redeye Beach[n]	N/A	All seals looked up and several moved, but not into the water. Seals settled within 30 sec. after launch.
22 Feb. 02	12:13	Vandal	270°	42° / 7,150 ft	Bachelor Beach North[s]	N/A	Most seals glanced up, but hardly any seals moved or shifted position. All animals settled within seconds.
"	14:56	Vandal	270°	42° / 7,150 ft	"	N/A	Most elephant seals hardly reacted to second launch. Some animals looked up, but settled within seconds after launch.
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	Pirates Cove[e]	N/A	The seals got up and moved, but likely in response to the startled harbor seals, not the launch sound. Several minutes after the launch, the seals walked up the beach.
"	17:00	Vandal	273°	42° / 9,600 ft	Pirates Cove[e]	N/A	No elephant seals were seen.

TABLE D.2. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction
8 May 02	14:54	Vandal	273°	8° / 1,300 ft	Pirates Cove[e]	96/67	The seals looked up when the missile was launched, but settled within seconds after the launch.
					Sea Lion Cove[s]	92/80	The seals looked up when the missile was launched, but settled within seconds after the launch.
					Redeye Beach[n]	N/A	The seals moved to the water several seconds after the launch.[#]
19 June 02	15:07	AGS Test Slug	305°	63° / hit land	Redeye I[n]	97/72^	Some seals looked up, but settled within seconds after the launch.
21 June 02	12:53:12/ 12:53:15	RAM	240°	8° / 50 ft	Bachelor Beach North[s]	N/A	All seals looked up during the launch, but none moved. They settled within seconds.

Note: N/A means that sound exposure levels are not available for that location.

[n] monitoring site was located north of the launch azimuth.

[s] monitoring site was located south of launch azimuth.

[e] monitoring site was located northeast of launch azimuth.

[*]SEL taken at nearby Cormorant Rock Blind; located < 0.5 km south of Bachelor Beach South.

[^] SEL taken at nearby Redeye II; situated < 0.5 km from Redeye.

[#] Incidental sightings of elephant seals at harbor seal haul-out site.

TABLE D.3. Details of missile launches, sound exposure levels (SEL), and ***harbor seal*** reactions at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 15 August 2001, 20 September 2001, 1 May 2002, and 26 June 2002. All of these missiles were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 µPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction
15 Aug. 01	12:56	Vandal	270°	8° / 1,280 ft	809 Camera[n]	N/A	Most seals (66%) fled into the water; seals that had remained on beach settled within 5 min after the launch.
"	13:17	Vandal	270°	8° / 1,280 ft	"	N/A	Less reaction to second launch; only 40% fled into water.
20 Sep. 01	08:30	Vandal	270°	8° / 1,280 ft	809 Camera[n]	119/101	Most seals (75%) entered the water; the remaining seals settled a few minutes after the launch.
"	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	"	N/A	All seals entered water.
5 Oct. 01	13:37	Vandal	273.3°	8° / 1,300 ft	809 Camera[n]	N/A	Most seals (70%) entered water in response to launch; 10 min after launch, no seals were left on beach.
					Phoca Reef[e]	94/*	Less than 10% of seals entered water; most looked up but did not move in response to launch.
6 Mar. 02	11:20	Vandal	273.1°	8° / 1,300 ft	809 Camera[n]	121/106	Seals looked up or moved in response to launch but did not enter water; settled within minutes.
					Pirates Cove[e]	N/A	All seals entered water; seals started to return to beach 16 min after launch.
					Redeye Beach[n]	N/A	Most seals (98%) entered the water in response to launch, but some individuals took as long as 6 min to do so. Seals started to return to beach 13 min after launch.

TABLE D.3. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 µPa)^2· s] flat-weighted/A-weighted	Behavioral Reaction
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	Pirates Cove[e]	N/A	Most of the seals were startled and looked up, but did not enter the water. Very few moved (14%) in reaction to the launch sound; those that did were pups.
"	17:00	Vandal	273°	42° / 9,600 ft	Pirates Cove[e]	N/A	Seals appeared to react more to the second launch; some seals scattered, and 38% fled into the water. The majority of seals that entered the water were pups.
8 May 02	14:54	Vandal	273°	8° / 1,300 ft	Pirates Cove[e]	96/67	All seals looked up and some moved slightly; 7% entered the water
					Redeye Beach[n]	N/A	All seals rushed into the water; they started hauling out again 13 min after the launch.
					Sea Lion Cove[s]	92/80	Most of the seals (90%) entered the water and did not return to the beach.
26 June 02	11:20	AGS Test Slug	300°	62.5° / 500 ft	Redeye Beach[n]	96/62	Seals looked up, but did not move.
"	12:51	AGS Missile	300°	62.5° / 5,300 ft	Redeye Beach[n]	93/ 64	Seals looked up, but did not move.

Note: N/A means that sound exposure levels are not available for that location.

[n] monitoring site was located north of the launch azimuth.

[e] monitoring site was located north east of launch azimuth.

[s] monitoring site was located south of the launch azimuth.

*A-weighted SEL not available.