PINNIPED RESPONSES DURING NAVY MISSILE LAUNCHES AT SAN NICOLAS ISLAND, CALIFORNIA

MEIKE HOLST,[1] JACK W. LAWSON[1,3], W. JOHN RICHARDSON[1], STEVEN J. SCHWARTZ[2] AND GRACE SMITH[2]

[1]*LGL Ltd., environmental research associates, 9768 Second St., Sidney, BC, V8L 3Y8, Canada*
mholst@lgl.com
[2]*Environmental Planning and Management Department, Naval Air Weapons Station China Lake, Code 870000E, Naval Air Warfare Center, Point Mugu, CA 93042–5049*
[3]*Present address: Department of Fisheries and Oceans, P.O. Box 5667, St. John's, NL, A1C 5X1, Canada*

Abstract—Pinnipeds on beaches were observed during the Navy's launches of small missiles from San Nicolas Island (SNI), California. From August 2001 to August 2003, we observed pinniped reactions to 31 missile launches from SNI. Missiles flew over or near haul-out sites occupied by California sea lions (*Zalophus californianus*), northern elephant seals (*Mirounga angustirostris*), and harbor seals (*Phoca vitulina*); some missiles produced sonic booms. The behavior of the three pinniped species during missile launches was documented by unattended video cameras set up around the periphery of SNI before each launch. Responses varied by species, distance from the launch azimuth, and other factors. Adult sea lions exhibited startle responses and increased vigilance up to two minutes after each launch. Juveniles and particularly pups reacted more vigorously by moving along the beach. Elephant seals exhibited little reaction to launches; most individuals raised their heads briefly and typically returned to their previous activity within 15 seconds. Harbor seals were the most responsive. During the majority of launches, 67 to 100% of harbor seals within 3 to 4 km of the launch trajectory entered the water and did not return for at least several hours. No evidence of injury or mortality for any pinniped species was observed during or immediately after the launches.

Keywords: California sea lion, disturbance, elephant seal, harbor seal, missile launches, response

INTRODUCTION

For over 50 years the U.S. Navy has periodically launched small missiles from San Nicolas Island (SNI). These missiles often fly over or near pinniped haul-out sites. To ensure that it was in compliance with the Marine Mammal Protection Act (MMPA), the Navy sought and obtained authorization from the National Marine Fisheries Service (NMFS) for disturbance of pinnipeds during missile launches from SNI. From August 2001 to August 2003, the Navy held two one-year Incidental Harassment Authorizations (IHA), issued by NMFS. 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 of small and moderate-sized missiles from SNI. Acoustic and mammal monitoring took place in conjunction with the missile launches during that two-year period. This was required by the IHAs, but was also designed to provide quantitative data on disturbance responses that would be of scientific value.

A total of 31 launches took place from SNI on 25 days during the two-year monitoring period (Table 1). On six dates, two missiles were launched within several minutes or hours of each other. Of the 31 launches, the majority (20) involved Vandal missiles. The launches also included one Tactical Tomahawk, one Terrier Orion missile, two Rolling Airframe Missile (RAM) launches, five Advanced Gun System (AGS) missile or test slug launches, and two GQM–163A Supersonic Sea-Skimming Target (SSST) launches. Three of the 31 launches were dual launches in quick succession, involving RAMs or Vandals. Missiles were launched from one of two launch complexes on SNI. RAM and Tomahawk missiles were launched from Building

Table 1. Details of the 31 missile launches at San Nicolas Island from August 2001 to August 2003.

Launch date (mm/dd/yy)	Launch time (local)	Vehicle type	Number of sites monitored for each species		
			Harbor seals	California sea lions	Northern elephant seals
08/15/01	12:56	Vandal	1	2	0
"	13:17	Vandal	1	2	0
09/20//01	08:30	Vandal	1	2	0
"	17:02	Terrier Orion	1	2	2
10/05/01	13:37	Vandal	2	2	0
10/19/01	09:00	Vandal	0	2	1
12/19/01	15:22	Vandal	0	1	0
02/14/02	11:33	Vandal	0	0	2
02/22/02	12:13	Vandal	0	0	1
"	14:56	Vandal	0	0	1
03/06/02	11:20	Vandal	3	1	0
05/01/02	15:53	Vandal	1	1	0
"	17:00	Vandal	1	1	0
05/08/02	14:54	Vandal	3	2	2
06/19/02	15:07	AGS Test Slug	0	1	1
06/21/02	12:53	Dual RAM	0	2	1
06/26/02	11:20	AGS Test Slug	1	2	0
"	12:51	AGS Missile	1	2	0
07/18/02	11:54	Vandal	0	1	0
08/23/02	14:09	Tactical Tomahawk	0	1	1
11/18/02	11:03	Dual RAM	0	1	1
12/10/02	08:49	Vandal	0	0	1
12/18/02	14:30	AGS	0	0	0
"	16:15	AGS	0	0	0
01/24/03	14:20	GQM–163A	0	1	2
03/14/03	09:13	Vandal	1	0	0
03/16/03	13:04	Vandal	2	0	0
04/04/03	15:20	Dual Vandal	2	0	0
06/04/03	12:35	GQM–163A	1	1	0
06/26/03	13:28	Vandal	0	3	0
07/28/03	16:28	Vandal	0	3	1

807 Launch Complex on the west coast of SNI (Fig. 1). This site was located close to shore on the western end of SNI, 11 m above sea level. All other missiles were launched from the Alpha Launch Complex, located 190 m above sea level on the west-central part of SNI (Fig. 1). The Vandal, GQM–163A, and Terrier Orion are medium-sized missiles, whereas RAM and AGS missiles are small. All launches occurred during daylight hours. Conditions ranged from clear and sunny to overcast and partly cloudy, with variable winds. On three occasions, missiles (including AGS test slugs and Vandals) malfunctioned and hit land or water nearshore.

Behavioral responses of pinnipeds on beaches around the periphery of western SNI were documented by unattended video cameras set up before each launch. The video data were supplemented by direct visual observations of the hauled out pinniped groups several hours prior to and occasionally following the launches. Related studies have been conducted in the past, but no directly comparable data on responses to launches of small and moderate-sized missiles like those launched at SNI have been published. Stewart (1981) and Stewart et al. (1994) noted the behavioral responses of northern elephant seals and California sea lions on SNI to loud impulse noises of other types. Bowles and Stewart (1980) examined the response of harbor seals on San Miguel Island, California, to low-altitude jet overflights.

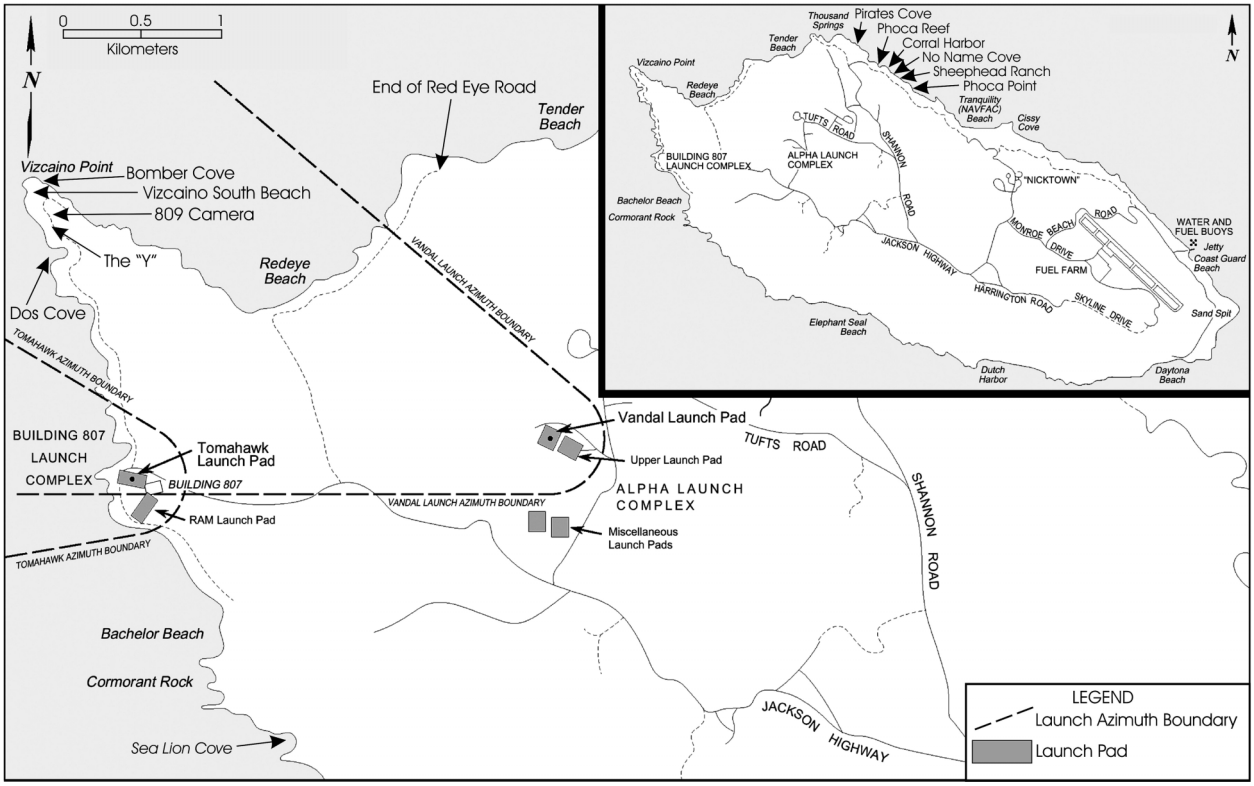

Figure 1. View of vehicle launch sites on San Nicolas Island. Shown are the Alpha Launch Complex and the Building 807 Launch Complex (at lower elevation near the shoreline). Beaches where pinnipeds were monitored are labeled, and the maximum extent of possible launch azimuths for vehicles leaving the two launch sites is indicated.

The video monitoring effort, spread across numerous launches, was intended to provide the information needed to document the nature, frequency, and duration of any changes in pinniped behavior resulting from the missile launches, including the occurrence of stampedes or injuries (if any) at haul-out sites. Consequently, the specific objectives of the monitoring program were (1) to identify and document changes in behavior or movements that occurred during the launch, (2) to compare pinniped responses with distance from the missile launch azimuth, and (3) to compare the responses of the three pinniped species.

METHODS

Video Monitoring

The pinniped monitoring program was based primarily on remote video recordings made before, during, and after each missile launch. Remote cameras were essential during launches because safety rules prevented personnel from being present in many areas of interest. Use of three video systems allowed observations of up to three pinniped species during the same launch, and/or observations of a given species at up to three locations, depending on how many species were hauled out within the field of view of each camera (Table 1).

For each launch, we attempted to obtain video recordings from three locations at different distances from the flight path of the missile. Two or three portable cameras were set up temporarily near haul-out sites, and we often used a permanent camera ("809 Camera") installed near Vizcaino Point (Fig. 1). Placement of the portable cameras was such that disturbance to the pinnipeds during installation and retrieval was minimal. Each camera was set to record a haul-out aggregation for four hours, the maximum permitted by the videotape capacity of the mobile cameras. During most launches, one camera was located near the planned launch azimuth or near the launcher itself when the launcher was near the beach; the other two monitoring sites were located up to four km from the launch azimuth. Monitoring locations

varied from launch to launch, depending on seasonal abundance of pinnipeds and logistics of equipment deployment.

Visual Observations

Navy personnel from the Environmental Project Office, Point Mugu, made direct visual observations of the pinniped groups prior to deployment of the cameras and (sometimes) during camera retrieval. Observations included local weather conditions; the species, ages, and locations of any pinnipeds hauled-out; and the type of launch activity.

Video and Data Analysis

Digital video data were copied to DVD–ROMs and reviewed using a high-resolution color monitor via an S-video output. The player had a high-resolution freeze-frame capability. When portable cameras were used, launch sounds were sometimes recorded on an audio track, thus confirming specific timing of the launch or flyover. The variables transcribed from the videotapes included (1) composition of each haul-out aggregation, i.e., species, sex and age class, (2) description and timing of the missile launch, and (3) number and proportion of pinnipeds that moved or entered the water during and immediately after the launch. The total number of animals present at the monitored beaches was determined by observations prior to placement of the camera at the haul-out site. The proportion of the monitored animals that moved or entered the water in apparent response to the launch was determined by noting the total number of animals that reacted in relation to the total number under observation.

The following variables concerning the circumstances of the observations were also recorded from videotape or from direct observations at the site: (1) location, (2) local time, (3) substratum type on which pinnipeds were resting, (4) substratum slope estimated from video records, (5) weather, including estimated wind strength and direction, and presence of precipitation, (6) horizontal visibility, and (7) tidal state. To relate pinniped behavior (e.g., percent of animals that moved or entered the water) to distance from the missile launch, two measures of proximity were calculated for each launch date and pinniped monitoring site. These were the 3-dimensional (3-D) distance from the recording site to the closest point of approach (CPA) of the missile, and the horizontal distance from the recording site to the CPA.

Spearman Rank Order Correlations were used to determine relationships between the behavior of pinnipeds and proximity to the missile. One-sided *P* values are given, since the direction of the effect was predictable (i.e., pinnipeds closer to the missile flight path were expected to be more responsive). Most analyses included data from all missile launches on all dates during the two years of monitoring. For some analyses, only Vandal launches were considered. Vandals were the most common (and largest) missiles launched. Data collected on days when missiles malfunctioned were not included in the analyses.

RESULTS

Video recordings of pinniped behavior during launches were collected on 18 dates and at nine different sites for California sea lions (n = 37 observation sites), on 13 days and seven different sites for northern elephant seals (n = 17), and 11 days and nine different sites for harbor seals (n = 22). The video recordings provided data on the responses of a sample of the total pinnipeds present on a given beach.

California Sea Lion

Responses of California sea lions to the launches varied by individual. Some sea lions exhibited startle responses and increased vigilance for a short period (<2 min) after each launch, whereas others hardly reacted to the launch (Table 2). At half of the observation sites, 50 to 100% of sea lions moved around vigorously on the beach in response to the launch, moving distances of several meters. At the other sites, fewer sea lions (0 to 48%) moved around vigorously. Pups that were playing in groups along the margins of the haul-out beaches prior to launches reacted more vigorously than adults. Those pups moved along the beach or entered the water. Other pups in the water rushed onto shore. All sea lions settled back to pre-launch behavior patterns within two minutes of the launch time.

The percentage of sea lions that moved decreased with increasing 3-D CPA distance from

Table 2. California sea lion reactions to missile launches at San Nicolas Island from August 2001 to August 2003.

Missile type	Number of sites monitored	Launch azimuth	Elevation angle	Altitude over beach (m)	3-D CPA distance (km)	Percent that moved [a]	Percent that entered water [a]
Larger							
Vandal	12	270–273.3°	8°	390–396	0.4–1.0	71 (0–100)	7 (0–30)
Vandal	7	270–273.3°	8°	390–396	>1.0–1.3	46 (0–72)	0
Vandal	1	273°	8°	396	2.1	0	0
Vandal	3	285°	42°	5266	2.8–3.1	3 (0–8)	0
Vandal	1	273°	42°	2926	2.3	50	0
Vandal	1	273°	6.5°	hit land	N.A.[b]	0	0
GQM–163A	1	270°	22°	1067	1.4	60	7
Terrier Orion	2	232.3°	64.6°	3962	2.4–3.1	30 (10–50)	0
Tomahawk	1	305°	90°	305	0.6	96	2
Small							
RAM	3	240°	8–10°	15	0.6–0.7	25 (0–57)	0
AGS missile	2	300°	62.5°	1615	1.5–2.1	0	0
AGS test slug	2	300°	62.5°	152	N.A.	0	0
AGS test slug	1	305°	63°	hit land	N.A.	10	0

[a] Means are given for percent of animals that reacted during missile launches at several different locations and dates (ranges in parentheses).
[b] CPA distance could not be calculated.

the missile (r_s = -0.53, $P_{\text{one-sided}}$ = 0.0005, n = 33; Fig. 2a) and with increasing horizontal CPA distance (r_s = -0.51, P = 0.002, n = 33). Sea lions entered the water on seven of 37 occasions, but the proportion of animals that entered the water was low (≤30%). 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 (both r_s = -0.33, P = 0.03, n = 33; Fig. 2a).

Sea lions entered the water only in response to launches of the larger missiles (mainly Vandals), and then only for some of those passing within 1 to 1.4 km (Table 2; Fig. 2a). High-elevation launches generally elicited responses from fewer sea lions than did 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.

Northern Elephant Seal

The majority of elephant seals exhibited little reaction to launch sounds (Table 3). At half of the observation sites, all elephant seals merely raised their heads briefly upon hearing the launch sounds and then quickly returned to their previous activity pattern (e.g., sleeping). At the remaining sites, especially during launches of the larger missiles, up to 44% of northern elephant seals on the beach repositioned or moved a small distance (1–3 m) away from their resting site, but settled within 30 seconds. Only on one of 17 occasions did an elephant seal enter the water in response to the launch (Table 3), and in that case, only one of 40 seals under observation 1.2 km from the Vandal launch trajectory entered the water. A sonic boom was evident on that occasion. Elephant seals were not very responsive to launches, irrespective of missile type, elevation angle, or location. The behavior of elephant seals was marginally related to the launch variables. The percentage of elephant seals that moved increased with decreasing horizontal CPA distance (r_s = -0.42, P = 0.05, n = 16), but increased only marginally with decreasing CPA distance (r_s = -0.33, P = 0.1, n = 16; Fig. 2b).

Harbor Seal

At 12 of 22 observation sites, most harbor seals (67 to 100%) left their haul-out sites and entered the water (Table 4). At the remaining sites, up to 38% of seals entered the water. Harbor seals that left their haul-out site generally did not return during the duration of the video-recording period. Harbor seals were more responsive to launches of larger missiles than to smaller missiles (Table 4).

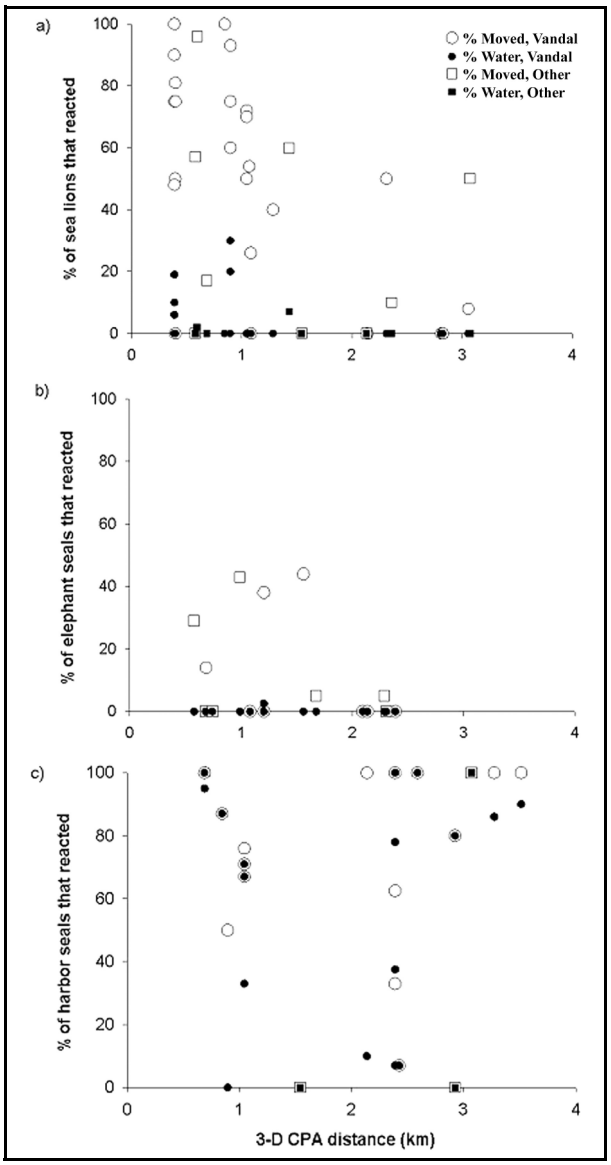

Figure 2. Percent of (a) sea lions, (b) elephant seals, and (c) harbor seals that moved (open symbols) or entered the water (solid symbols) in relation to the 3–D CPA distance of missiles launched at SNI. Reactions to Vandal launches vs. all other missiles are distinguished by circles and squares, respectively.

No significant relationships were found between the behavior of harbor seals on 21 occasions and variables related to the missile launches. There was no evidence that the effect was any less for the missiles whose CPA distances were large (e.g., 2 to 3.5 km) than for those at closer distances. The number of animals that entered the water was not correlated with the CPA distance (r_s = 0.02, P = 0.5; Fig. 2c) or the horizontal CPA distance (r_s = -0.01, P = 0.5). Similarly, the percentage of harbor seals that moved did not change with the CPA distance (r_s = 0.02, P = 0.5; Fig. 2c) or horizontal CPA distance (r_s = 0.004, P = 0.5).

No evidence of injury or mortality to harbor seals (or other species) was evident during or immediately succeeding the launches. However, during two launches, one or two harbor seal pups within the field of view were knocked over by adult seals as the pups and adults moved toward the water in response to the launch. These seal pups were momentarily startled, but did not appear to be injured and continued to move toward the water.

DISCUSSION

Overall, northern elephant seals exhibited little reaction to the launches, California sea lions showed stronger but variable responses, and harbor seals were the most responsive. The harbor seal was the one species that frequently moved into the water during launches. Likewise, Stewart (1981) and Stewart et al. (1994) noted that elephant seals rarely if ever show more than a momentary alert reaction, even when exposed to noise levels or types that caused nearby harbor seals and California sea lions to flee. Bowles and Stewart (1980) reported that harbor seals on San Miguel Island reacted to low-altitude jet overflights with alert postures and often with rapid movement across the haul-out sites. In those instances, the harbor seals flushed into the water in response to some sonic booms and to a few overflights by light aircraft (Bowles and Stewart 1980). We obtained similar results for harbor seals reacting to small-to-moderate missiles. Bowles and Stewart (1980) also noted that harbor seals sometimes did not return to land until the next day, although they more commonly returned the same day.

No evidence of injury or mortality was noted during or immediately succeeding the launches within our two year study period. Similarly, Stewart (1982) found that sonic booms and tests with a carbide cannon simulating sonic booms at San Miguel and San Nicolas islands provided no evidence of pinniped injury or mortality.

The responses of pinnipeds may be affected by several factors besides the proximity of the animals to the missile flight path. For example, variation in the received sound levels from the missiles likely

Table 3. Northern elephant seal reactions to missile launches at San Nicolas Island from August 2001 to August 2003.

Missile type	Number of sites monitored	Launch azimuth	Elevation angle	Altitude over beach (m)	3-D CPA distance (km)	Percent that moved [a]	Percent that entered water [a]
Larger							
Vandal	1	273°	8°	396	0.7	14	0
Vandal	4	273–273.3°	8°	396	1.1–1.6	21 (0–44)	1 (0–3)
Vandal	2	273°	8°	396	2.1–2.4	0	0
Vandal	2	270°	42°	2926	2.1	0	0
GQM–163A	2	270°	20°	1036	1.0–1.7	24 (5–43)	0
Terrier Orion	2	232.3°	64.6°	3962	2.2–2.3	3 (0–5)	0
Tomahawk	1	305°	90°	305	0.7	0	0
Small							
RAM	2	240°	8–10°	15	0.6–0.7	15 (0–29)	0
AGS test slug	1	305°	63°	hit land	N.A.	0	0

[a] Means are given for percent of animals that reacted during missile launches at several different locations and dates (ranges in parentheses).

affects pinniped behavior. Acoustic measurements were obtained simultaneously with some of our behavioral data, but paired acoustic and behavioral data are still limited. In addition, variation in missile types, altitudes, CPA distances, wind direction, and other weather factors are expected to affect received sound level and perhaps pinniped response. Other factors such as season, tide state, and time of day are also expected to play a part in determining pinniped behavior and responsiveness (e.g., Bowles and Stewart 1980). Because of the variety of potentially important factors, and the variety of missile types involved in the launches during the two-year study period, additional data are needed to separate the influences of these factors on pinniped responses. Collection of paired behavioral and acoustic data is ongoing during additional launches. These data, when available, should allow analysis of the relationship between pinniped responses and launch sounds, with allowance for covarying factors.

Despite occasional missile launches for many years, pinniped numbers on SNI have been increasing gradually over the years or remained stable. The California population of harbor seals increased from the mid-1960s to the late 1990s, although the rate of increase may have slowed since 1990 (Hanan 1996). On SNI, the harbor seal

Table 4. Harbor seal reactions to missile launches at San Nicolas Island from August 2001 to August 2003.

Missile type	Number of sites monitored	Launch azimuth	Elevation angle	Altitude over beach (m)	3-D CPA distance (km)	Percent that moved [a]	Percent that entered water [a]
Larger							
Vandal	4	273–273.3°	8°	396	0.7–0.9	84 (50–100)	71 (0–100)
Vandal	3	270°	8°	390	1.0	71 (67–76)	57 (33–71)
Vandal	7	273–273.3°	8°	396	2.1–2.9	74 (7–100)	55 (7–100)
Vandal	2	273°	8°	396	3.3–3.5	100	88 (86–90)
Vandal	1	273°	6.5°	hit land	N.A.[b]	14	0
Vandal	1	273°	42°	2926	2.4	63	38
GQM–163A	1	270°	22°	1067	2.9	0	0
Terrier Orion	1	232.3°	64.6°	3962	3.1	100	100
Small							
AGS missile	1	300°	62.5°	1615	1.5	0	0
AGS test slug	1	300°	62.5°	152	N.A.	0	0

[a] Means are given for percent of animals that reacted during missile launches at several different locations and dates (ranges in parentheses).

[b] CPA distance could not be calculated.

population was relatively stable from mid-1980 to mid-1990 (Hanan 1996). The abundance of elephant seals in the Channel Islands has increased since the mid-1960s (Barlow et al. 1993), and they are expanding into areas that were previously occupied solely by harbor seals (e.g., Mortenson and Follis 1997). The California sea lion is by far the most common pinniped on SNI. The U.S. stock has increased from the early 1900s to the present. Since 1983 the annual rate of increase has been 6.2%, and the population on SNI increased even faster, at 21.4% per year up to 1994 (NMFS 2000).

Overall, the number of individual animals that were disturbed during the missile launches was small in relation to regional population sizes. Also, pinniped populations at SNI are growing or stable despite Navy launch activities at SNI for decades. Together, these considerations indicate that the ongoing missile launch program at SNI has no more than minor impacts on these pinniped species. Missile launches are expected to continue. Future monitoring will give particular attention to the harbor seal, the most responsive species.

ACKNOWLEDGMENTS

This study was funded by Naval Air Warfare Center Weapons Division, Point Mugu, California, and was conducted under the provisions of IHAs issued by NMFS. We thank A. Stone, G. Smith, S. Harvill, T. Parisi, and many others at Point Mugu and on San Nicolas Island for their support, assistance, and very positive approach to the monitoring effort. T. Elliott and V. Moulton of LGL Ltd. provided valuable advice on analysis approaches. E. Becker, then at TEC, Santa Barbara, assisted with management and logistical matters. Charles Greene of Greeneridge Sciences Inc. analyzed the acoustical data.

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