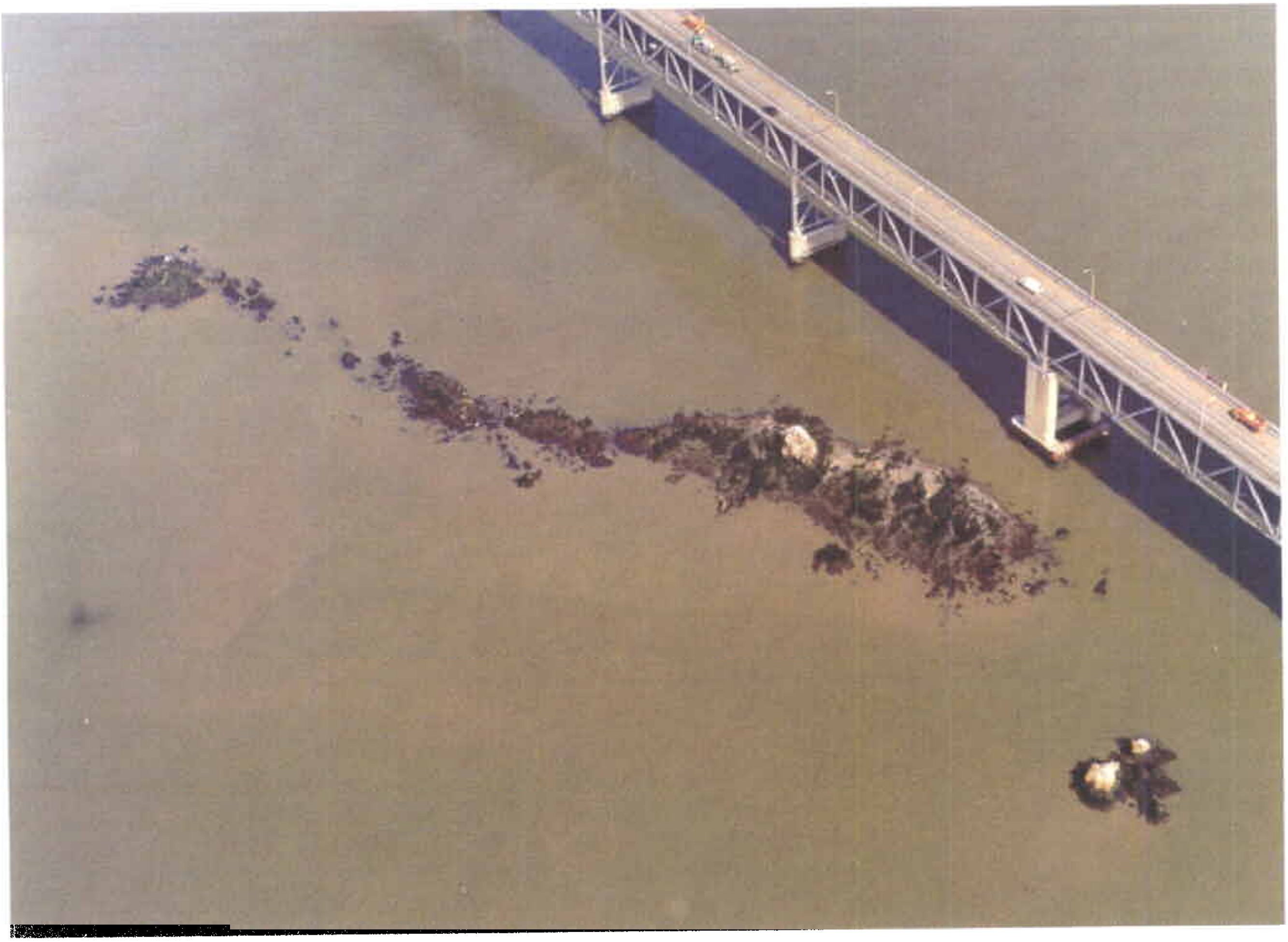
# Monitoring the Potential Impact of the Seismic Retrofit Construction Activities at the Richmond San Rafael Bridge on Harbor Seals (*Phoca vitulina*): May 1998-February 2002




**Deborah E Green**
**Project Manager**

**Emma Grigg**
**Field Coordinator**

**Sarah Allen and Hal Markowitz**
**Principal Investigators**


**Draft Interim Report**
**IHA 9/19/01-9/18/02**
**February 2002**

The following report is submitted in accordance with the requirements of an Incidental Harassment Authorization (IHA) issued by the National Marine Fisheries Service to the California Department of Transportation (Caltrans) for the time period September 19, 2001 through September 18, 2002. This IHA is under the authority of Section 101 (a) (5) (D) of the Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*), and refers to monitoring of harbor seals during the seismic retrofit construction of the Richmond-San Rafael Bridge, San Francisco Bay, CA. Caltrans provides all funding associated with this project.

# TABLE OF CONTENTS

# List of Tables

# LIST OF FIGURES

## INTRODUCTION

Harbor seals (*Phoca vitulina*) haul out on rocky shores, mud flats or beaches for a number of reasons. Haul out sites serve as breeding and resting areas (Allen 1991, Sydeman and Allen 1999), and hauling out may aid in thermoregulation (Feltz and Fay 1966). By hauling out in groups, seals are able to maximize the likelihood of detecting disturbances (Terhune 1985). There is also some speculation that seals haul out to avoid marine predators (Watts 1993). In addition, haul out sites provide researchers with the means to assess the status of a given population and the maximum number of harbor seals present on a haul out provides a means for estimating the local population size.

Haul out locations are characterized by ease of access to the water, proximity of food resources, and minimal disturbance levels. Timing of haul out site use relative to tide varies by location; some sites are used exclusively at low tides, others at mid or high tides, while some show haul out patterns independent of the tide level. Other factors, such as time of day and season, may also affect haul out patterns.

There is considerable evidence that human activities adversely affect behavioral patterns of harbor seals. Primary sources of disturbance for harbor seals in San Francisco Bay (SFB), California includes boats, kayaks, jet skis, aircraft, foot traffic and dogs in the vicinity of the haul out. Distance between the seals and the disturbance source appears to play a role in the seals' response. Disturbance sources within 100 meters of the seals typically provoke a stronger negative response (Allen *et al.* 1984).

Seals are known to react to both visual and acoustic disturbance sources (Richardson *et al.* 1995). Watercraft, particularly those with erratic behavior, are a common source of disturbance to seals. However, boats with quiet engines that maintain a steady, slow speed and have little visible movement onboard elicit less reaction from harbor seals (Hoover 1988, Kopec and Harvey 1995).

In cases of long-term exposure to disturbance, seal responses vary by site. In some areas, seals habituate to disturbances near the haul-out site (Bonner 1982, Johnson *et al.* 1989), while in other areas increased levels of disturbance have contributed to the abandonment of a haul-out site (Bartholemew 1949, Paulbitski 1975, Allen 1991). If the frequency and magnitude of disturbances are sufficient, seals may permanently abandon a site. One SFB example of site abandonment due to human disturbance occurred at Strawberry Spit (Paulbitski 1975, Allen 1991). Increased development pressures and human foot traffic beginning in the late 1970's caused a precipitous drop in the number of seals that used this haul out. Seals eventually abandoned this site in the late 1980's (Allen 1991) and no reestablishment has occurred to date.

In addition, disturbances which cause seals to flush into the water often result in the separation of mothers and pups (Johnson 1977), and may be a significant source of mortality for seal pups in disturbed areas (Bartholomew 1949, Clifton 1971, Johnson 1977, Calambokidis *et al.* 1978).

When analyzing the impact of disturbance on harbor seals at a given site, a number of factors which may influence the degree of response must be taken into account, including season (i.e. the presence of pups or changes in prey availability), site topography, and the number of seals present on the haul-out site. For example, based on reports of increased vigilance, mothers with pups may be more sensitive to disturbance (Stein 1989). In addition, an increase in the number of seals on a haul-out site fosters an increased ability to detect disturbance, while decreasing the time spent scanning by each individual seal (da Silva and Terhune 1988). Protecting haul out locations is an important measure for protecting populations.

A large-scale seismic retrofit of the Richmond-San Rafael Bridge, located in northern SFB, began in February 2001. A primary SFB harbor seal haul out site, Castro Rocks, is located next to the southeastern section of the bridge. Monitoring is being conducted at Castro Rocks in order to assess any effects that this construction may have on harbor seal haul out behavior and productivity.

Disturbances due to construction at the Richmond-San Rafael Bridge may affect where seals forage in and around the Richmond-San Rafael Bridge, as well as the number of harbor seals using other haul out sites within the Bay. Regular monitoring is also being conducted at two alternate haul out sites in the Bay, Yerba Buena Island (YBI) and Mowry Slough (MS). Castro Rocks, YBI and MS are the three largest harbor seal haul out sites in SFB.

The objectives of this study are as follows:

1) to study the effects of the seismic retrofit construction of the Richmond-San Rafael Bridge on harbor seal behavior in SFB;

2) to recommend procedural changes which may reduce the incidental disturbance of the seals without significantly hindering construction;

3) to provide information concerning the productivity and distribution of harbor seals in San Francisco Bay

4) to provide information on the SFB harbor seal population which will be useful in determining threshold values for disturbances, and may assist in the design of future construction projects situated near harbor seal haul out sites.

## STUDY AREA

### CASTRO ROCKS

Castro Rocks is located in northern San Francisco Bay, near the southeastern edge of the Richmond-San Rafael Bridge. It is situated approximately 600 m northwest from the

Chevron Long Pier where tankers offload oil. Castro Rocks is composed of a chain of six rock clusters which stretch approximately 250 m in a southwesterly direction from the Richmond-San Rafael Bridge. The rocks span the distance of three bridge piers, beginning approximately 17 m from the bridge (pier 55) and ending approximately 75 m from the bridge (pier 52) (Figure 1).

Castro Rocks is the largest harbor seal haul out site in the north Bay and is the second largest pupping site in the Bay (Kopec and Harvey 1995). Seals haul out year-round on Castro Rocks during medium to low tides; few alternative low tide sites are available within San Francisco Bay.

The seals at Castro Rocks have habituated to a degree to some sources of human disturbance such as large tanker traffic and the noise from car traffic on the bridge, but often flush into the water when small boats maneuver close by or when people work on the bridge (Kopec and Harvey 1995).

YERBA BUENA ISLAND

YBI is located at the midpoint of the San Francisco Oakland Bay Bridge in central San Francisco Bay, and seals haul out on the southern shoreline of the island. The haul out site at YBI is a cobble intertidal beach backed by a steep 15-25 m high cliff. Several rocky outcroppings extend into the Bay from the haul out site and a shallow shelf extends a short distance from the shore before dropping off to depth (Kopec and Harvey 1995).

Harbor seals haul out on YBI year-round. Previous researchers have reported that YBI is the only major SFB haul out site not used extensively for pupping (Kopec and Harvey 1995). Maximum harbor seal numbers at YBI are found during the winter months (defined here as mid-November through mid-March), when Pacific herring (*Clupea pallasi*) spawn in SFB (Spencer 1997, Kopec and Harvey 1995).

MOWRY SLOUGH

Located on the Don Edwards San Francisco Bay National Wildlife Refuge near Newark, California, Mowry Slough (MS) is the largest harbor seal rookery in SFB. Both sloughs, Newark and Mowry, are surrounded by tidal marsh vegetation and are bordered by smooth mudflats. During the pupping season (defined here as mid-March through May), MS is utilized during low tides, and at other times of the year from mid to high tides (Alcorn and Fancher 1980).

CORTE MADERA

The Corte Madera harbor seal haul out site is located in Marin county between Corte Madera Creek and San Clemente Creek. This site is typically used by less than thirty seals during pupping and molting season. Seals haul out on the marsh bank at mid to high tides.

## METHODS

We began monitoring harbor seal populations at three haul out locations in SFB in May 1998, during the last month of the pupping season for seals in the Bay. Baseline data were collected until the start of the retrofit construction, which began in February 2001. Construction activities occurred in the area of the haul out site during January and February 2001 and from August 2001 – February 14, 2002 (during the "work period"). This report summarizes the data collected thus far (May 1998 – February 2002).

### FIELD DATA COLLECTION

A combination of data collection techniques were used, including direct observations and surveys by trained field biologists and documentation of disturbances to harbor seals. Counts were taken at Castro Rocks based on six subsites, A through F, which represent the six rock clusters at this site (Figure 1). Surveys at Castro Rocks and YBI were centered around the low tide when possible. Counts at MS were also taken based on six subsites, five of which are located along or at the mouth of MS itself. The sixth subsite, Newark, is located at the mouth of neighboring Newark Slough. Surveys at MS were taken on a falling tide, with one survey taken at each of the six subsites. Difficulties in accessing MS limited the duration and number of surveys conducted at this site.

During surveys, biologists recorded information concerning 1) demographic data, 2) environmental data, and 3) behavioral data. Demographic data included 1) total count of all seals present on the haul out site taken once every 30 minutes for Castro Rocks and YBI, and once per research day at each of six subsites at MS, 2) number of red pelaged seals, and 3) number of each age class and sex, when possible. In addition, biologists recorded pupping season chronology and pup numbers during each pupping season: the number of pups seen with a female and those seen alone. The total number of pups present on a haul out site was not included in the total count. Because of logistical issues of data collection at MS, the six subsites at this location (Newark, Mowry Slough South, North Salt Pile, South Salt Pile, Mud Flat, and Mowry Slough North) were combined in order to examine average and maximum harbor seal counts. Due to the distance between subsites and the time necessary to move between them, each subsite at MS was normally surveyed at a slightly different time and tide height. However, all six subsites were normally surveyed within a 2-hour time period. Each MS subsite was examined independently for trends in seasonal and tidal haul out use. Corte Madera was sporadically surveyed during each pupping season by using a trail located in the Corte Madera Ecological Reserve, and more recently by using a spotting scope at the entrance to San Quentin Prison. The prison is located directly across from the Corte Madera haul out site (approximately 800 m) and therefore allows biologists to survey the site.

Field biologists collected environmental data including temperature, cloud cover, wind speed and direction, low tide time/level and the presence or absence of rainfall.

Behavioral data included seal response to disturbances, both human and non-human in origin. The same variables that have been used in past studies to measure the response of seals to disturbance were utilized in this study. Responses included seals looking toward the direction of a disturbance source (head alert), seals moving suddenly towards the water (approach water), and seals entering the water (flushing) (Sullivan 1979, Allen 1991). In addition, if a potential disturbance source was noted, but no response was seen from the seals, a behavior of "no response" was recorded. If animals flushed into the water due to a disturbance, additional information was recorded concerning the number of animals that flushed into the water, elapsed time before seals rehauled and the location where seals rehauled. Other data collected were the source of disturbance, the distance of the source to the harbor seals, and the number of seals that remained on the haul out. In May 2000 we began utilizing a method of triangulation, using a rangefinder and compass, to calculate the distance from a disturbance source to the seals. Prior to using the method of triangulation in order to calculate the distance from a disturbance source to the seals, distances were estimated using a rangefinder and a list of reference distances.

Logistical issues exist in accessing these study sites. The ability of researchers to survey seals from the viewing platform on the lower deck of the Richmond-San Rafael Bridge at Pier 55, overlooking the haul out site, is dependent upon weather conditions. For safety reasons, researchers are not permitted on the viewing platform during periods of high wind or storms. In addition, when construction took place within the immediate area of the haul out site (August 2001 – February 14, 2002), we frequently gathered data from either the upper deck of the Richmond-San Rafael Bridge or from the base of Pier 55 when the normal platform at Pier 55 was unavailable. The YBI observation site is located at a private residence on U.S. Coast Guard (USCG) land and requires an access permit from the USCG. Surveys are only conducted during daylight hours during the weekdays at YBI. Since 1999, the USCG has placed several restrictions on data collection at YBI. Starting in September 1999, surveys were limited to weekdays at YBI. Access to MS is limited by weather. Researchers are not permitted to drive on the levees that provide access to the observation points in wet weather, or on the days immediately following wet weather. Access to MS is also dependent on yearly access permits from the Cargill Salt Company and the Don Edwards San Francisco Bay National Wildlife Refuge.

The frequency of research sessions at each location was determined in conjunction with the construction activities scheduled to take place in the vicinity of the haul out site (Table 1). Harbor seal pupping and molting seasons were taken into account in determining when construction occurs in the vicinity of Castro Rocks. A "work period", the time of year during which work on the area of the bridge closest to Castro Rocks is permitted, has been designated from August through mid-February. From mid-February through July (during pupping and molting seasons), work is not allowed to take place on the sections of the bridge closest to the harbor seal haul out site, between Pier 52 and Pier 57 (work "closure period"). A boat exclusion zone (BEZ) was set up in February 2001, which extends 91 m from the northern, southern, eastern and western most tips of the Castro Rocks haul out site. Construction boats are not permitted within the BEZ during the work closure period.

AIR ACOUSTIC DATA LOGGER

A Larson-Davis Model 820 Air Acoustics Data Logger was set up on subsite A of Castro Rocks in November 2000. The logger records the decibel level (A-weighted) of sounds surrounding the haul out site. The $L_{eq}$, the level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period, is recorded every 30-minutes, 24 hours a day.

RADIO- AND SATELLITE-LINKED TELEMETRY

On January 7-9, 2001, we initiated a pilot study to determine the feasibility of capturing seals at Castro Rocks for radio- and satellite-linked telemetry work. We captured eight harbor seals at Castro Rocks for tagging (NMFS Research Permit # 373-1575 issued to Sarah Allen). Individuals experienced in tagging harbor seals were recruited to carry out the seal captures (Steve Jeffries, Washington Department of Fish & Game, and Dr. Jim Harvey, Moss Landing Marine Laboratory). In addition, a marine mammal veterinarian was present during the captures and tagging to monitor animal well-being (Dr. Frances Gulland, DVM, The Marine Mammal Center, Sausalito, CA). Due to the rocky substrate surrounding Castro Rocks, a "tangle net" method was utilized for seal capture. Nets which were approximately 20-40 m in length and approximately 5 m in depth were set to the south of Castro Rocks, and seals were passively caught as they became tangled in the net. Once captured, seals were weighed, sexed, and blood and tissue samples were taken. Three seals were fitted with head mount VHF (very high frequency) radiotags (Advanced Telemetry Systems), and one seal was fitted with a dorsally-mounted satellite-linked ST-18 Platform Terminal Transmitter (PTT) from Telonics (Table 9). Tags were attached to the seals' pelage using Loctite 422 adhesive (radiotags) or 5-minute marine epoxy (PTTs). The PTTs were first glued to a small (approximately 15 cm x 22 cm) square of mesh to increase the surface area for tag attachment; this mesh was then glued to the seal's pelage. A similar procedure was used for the radiotags, only instead of mesh a thin piece of rubber was used (~2 mm), and the tags were additionally cable-tied to the rubber before attachment on the seal. All seals captured were also flipper-tagged on both rear flippers to allow for later identification in the field.

From July 15 through 19, 2001, 13 additional seals were captured and tagged at Castro Rocks. Of those seals captured, five were tagged with satellite PTTs and two with VHF radiotags (Table 9). One radiotag (seal 320) was mounted on the top of the head, as with the January seals; one radiotag (seal 611) was mounted dorsally, just behind the head. All satellite tags were mounted dorsally, as in the January capture. Seals were captured using similar methodologies to the January capture, and data were collected on weight, sex, etc. as with the January seals. On one occasion, two seal handlers were able to quietly approach one seal from behind and net the animal on Castro Rocks (subsite A). Further attempts to use this 'sneak approach' were unsuccessful, however.

On January 24, 2002, six more seals were captured and tagged at Castro Rocks, using methods as described for earlier captures. Five radiotags were deployed at this time, and one PTT (Table 9). As we had lost 3 tags from the July 2001 capture prematurely due to attachment failure, the January 2002 PTT was fitted with a mesh harness, completely enclosing the tag and securely attached to the attachment mesh, before being epoxied to the seal's pelage.

DATA ANALYSIS

Certain assumptions were made in summarizing the data collected to date. In discussing patterns of haul out site use by the seals, an even distribution of age and sex classes is assumed. In addition, we assumed that data were collected consistently by all field researchers and any bias was minimized by pairing observers in the field.

Trends in harbor seal counts at each of the three haul out locations were examined at each 30 minute survey in relation to both the tidal height and time of day. In examining counts by time of day, only those counts taken during surveys when the tidal height was ≤2 ft (~0.61 m) were used, since this is the tidal height when we tend to see the greatest number of seals on the haul out sites. Data are shown for the entire study period, as well as by season. Seasons have been defined to coincide with those used by D. Kopec (pers. comm. 1999), in order to allow for comparisons between the present data and data collected by Kopec at each of the three research sites from April 1995 to November 1997. The four seasons are identified by Kopec as; pupping (March 15$^{th}$ – May 31$^{st}$), molting (June 1$^{st}$ – August 15$^{th}$), fall (August 16$^{th}$ – November 15$^{th}$) and winter (November 16$^{th}$ – March 14$^{th}$) (Kopec and Harvey 1995). In analyzing average seal haul out numbers, a daily average count was calculated (using only those surveys with a survey tide height of ≤ 2 ft) which was then used for yearly and seasonal analyses.

Trends in harbor seal counts during the "work period" were examined and compared to average and maximum harbor seal counts during past years. In addition, any effect which construction may have on individual subsite use at Castro Rocks was examined. Due to variations in the location and type of construction activity taking place near the haul out site, average counts were compared monthly.

Analyses of harbor seal counts at each haul out site were done using t-tests and analysis of variance tests (ANOVA). A t-test compares two sample means to determine if the parameters they are estimating differ from each other, represented by a statistic t. An ANOVA is used to compare sample means in determining if they differ significantly (represented by the statistic F), and in contrast to the t-test, an ANOVA is not limited to comparing only two means. Therefore, a t-test can be used to compare, for example, average seal counts between two seasons, whereas an ANOVA can be used to compare average seal counts across the four seasons. In presenting statistical results, degrees of freedom (df) and probability (p) are calculated. Degrees of freedom provides a representation of the sample size used for the statistic (with a larger number meaning that more samples were used). The p value represents the probability that the results are due to chance alone, with typically a probability of less than 5%, or 0.05 used as a standard for accepting that there is a difference between the two or more groups.

The proportion of red pelaged harbor seals present at Castro Rocks and YBI was calculated using the maximum harbor seal count per day with its corresponding number of red coats. The proportion of red coats at MS was calculated using the single count that was collected at each research survey (only one per day). Since the greatest number of red coats are typically present just before molting season (June-mid August), the proportion of red coats present at each site was calculated using red pelage numbers recorded during pupping season (mid March – May). In order to avoid any bias due to a low number of seals hauled out, only surveys that had a minimum of 5 seals present on the haul out site were used in the red coat analysis.

Comparisons were made between the data collected during this study (1998-2001) and data collected by D. Kopec during the previous three years (1995-1997). Seasonal maximum harbor seal counts taken at each of our research locations were compared to maximum counts collected at the same sites by Kopec.

Patterns in disturbances at the three study sites were also examined. Predominant disturbance sources at each location were identified and the frequency of disturbances per hour of field time was analyzed. T-tests were used to compare differences in the frequency of disturbances per hour of field time at Castro Rocks and YBI, as well as differences in the distance from seals to disturbance sources at each site. ANOVA's were used to examine the number of disturbances per hour of field time across years at each site. In addition, trends in disturbances during preconstruction core sampling (conducted close to the haul out site from January 24, 2001 – February 15, 2001) and the "work period" (August 1, 2001 – February 14, 2002) were analyzed and compared to the same time periods in past years.

Trends in air acoustic dBA levels throughout the course of the day were examined and differences in daytime and nighttime dBA levels were analyzed using a t-test. In addition, monthly air acoustic levels were compared between years when available, and sound levels were compared between the 2000/2001 "work period" (prior to construction activity) and the 2001/2002 "work period" (construction activity was taking place).

Sighting location for radio-tagged seals was obtained using a biangulation method during land-based tracking and with a handheld GPS (Global Positioning System) receiver (after visual confirmation) during boat-based tracking. Location data, distance and depth calculations for radio-tagged seals were provided by Barry Nickel, a graduate student at San Francisco State University working on the project in conjunction with his Master's thesis.

Location readings for seals tagged with satellite-linked PTT's were provided by Service Argos, Inc. Satellite location readings were filtered to remove unlikely or impossible readings (for example, points that fell inland or represented an unrealistic travel speed between two successive locations for an individual seal, and isolated points – i.e. not corroborated by other spatially correlated points for the same seal – that fell outside the study area). For this report, the study area was defined by Point Reyes Head to the north, the Farallon Islands to the west, Pillar Point (San Mateo County) to the south, and Suisun Bay (in the SFB delta) to the east. Location accuracy ratings assigned to each point location by Argos were also used in evaluating suspect locations. According to Argos, estimated accuracy of locations ranges from <150 m to >1000 m. Although we believe that mean accuracy of seal point locations is considerably improved through the filtering process, caution should be used when drawing conclusions about fine-scale habitat use patterns based on satellite-linked telemetry. Marine mammals are considered to be good study animals for satellite-linked telemetry as time at the surface to breathe allows sufficient time for a location reading to be established by the satellites.

In analyzing data for all tagged seals, depth information was obtained for each animal location using the ArcView GIS (Geographical Information System) version 3.2 Spatial Analyst Extension. Note that seal "depth" does not refer to the depth to which the seal was known to dive, but the water depth over which the seal was sighted/located. Bathymetry data for SFB and for the coast was obtained from a California Department of Fish and Game 200 m bathymetry grid, compiled by the Teale Data Center from 75 mosaicked original DEM's (Digital Elevation Model). Spatial data analysis and mapping were done in ArcView GIS version 3.2 (ESRI 1998).

## RESULTS AND DISCUSSION

Over 10,000 hours of data were collected at the three study sites from May 1998 – February 2002. Coverage was greatest at Castro Rocks, with more than 2/3 of the field hours spent at this site (Table 2).

### HARBOR SEAL SURVEYS

In examining the overall study period (May 1998 – February 2002), the average harbor seal count at both Castro Rocks and YBI were greatest at tide heights ≤ 2 ft (Figure 2). However, harbor seals appear to utilize Castro Rocks and YBI at tide heights up to 4 ft and 7 ft, respectively. The majority of the Castro Rocks haul out site is submerged at tide heights above 4 ft, and is therefore unavailable as seal haul out. Since Castro Rocks and YBI are predominantly used at tide heights ≤ 2 ft, only those surveys taken under these tidal conditions were considered in examining use of each haul out site by time of day and season.

#### Castro Rocks

During the daytime, the average number of seals using Castro Rocks was slightly greater at higher tides during the pupping and molting seasons (Figure 3). During the pupping season, females nursing pups tend to stay on the haul out for longer periods of time, and therefore during higher tides. Similarly, during the nighttime, seals remained on CR at higher tides during the molting season. During the molting season, seals haul out for longer periods to facilitate the molting process (Feltz & Fay 1966). Seals remaining hauled out at higher tides during both the daytime and nighttime during the molting season may be associated with facilitating the molting process.

When examining the overall study period, the average number of harbor seals at Castro Rocks was slightly lower during the mid morning hours and increased in the afternoon and nighttime, particularly between 2000 hr and 0600 hr. (Figure 4). A similar trend was seen during the fall season, with seal numbers lowest during the midday (Figure 5). Seal numbers during the molting season remained fairly stable throughout the course of the day, while numbers during the winter season were lowest from early morning until noon.

During the pupping season, haul out numbers were greatest in the mid to late afternoon, with numbers dropping off during the nighttime. The higher daytime seal counts recorded during the pupping season may be related to the fact that the nighttime tide heights were significantly higher than daytime tide heights during this season ($t = 11.23$, $p < 0.0001$, $df = 102$). These same trends were seen in the August 2001 Interim Report submitted to National Marine Fisheries Service (Green *et al.* 2001).

In comparing average seasonal haul out numbers, counts at Castro Rocks (day) remained fairly consistent throughout the entire study period (Figure 6), while nighttime counts increased during the molting and fall seasons. Similarly, maximum seasonal counts at Castro Rocks during the day were relatively stable throughout all seasons, while nighttime maximum counts were greatest during the fall season (Table 3).

In comparing average haul out numbers during years where a full year of data was available (1999 - 2001), there was a significant difference in the average number of seals hauled out at Castro Rocks during the daytime when the tide height was $\leq 2$ ft ($F=3.14$, $p<0.05$, $df=591$). Average counts in both 2000 (mean=78.6 $\pm$2.49 SE) and 2001 (mean=77.9 $\pm$ 2.77 SE) were higher than in 1999 (mean=70.6 $\pm$ 2.36 SE) at Castro Rocks during the day. Although these averages are statistically significantly different, they may not be biologically different. Overall, there was a 12% increase in numbers during the day from 1999 to 2000. There was no significant difference in the average number of seals hauled out on Castro Rocks during the night in 1999 (mean=86.2 $\pm$ 6.04 SE), 2000 (mean=99.6 $\pm$ 5.44 SE), and 2001 (mean=94.3 $\pm$ 5.67 SE).

In addition, when comparing seasonal counts between years (1999 – 2001), the daily average number of seals hauled out at Castro Rocks was significantly different at Castro Rocks Day during each season across years. There was a trend toward increasing numbers during pupping, molting and fall seasons across years (Pupping: $F=5.06$, $p<0.01$, $df=143$; Molting: $F=7.69$, $p<0.001$, $df=123$; Fall: 3.53, $p<0.05$, $df=136$). During the winter, average seal numbers during 2000 were lower than during 1999 and 2001 ($F=5.50$, $p<0.01$, $df=185$) (Figure 7).

Although there was a trend toward increasing numbers at Castro Rocks at night, there was no significant difference in the daily average number of seals hauled out during the nighttime within each season (Figure 7).

Use of the six subsites at Castro Rocks during the day fluctuated depending on the season. There was a significant difference in the average number of seals hauled out on each subsite between the four seasons when the tide height was ≤2 ft (Subsite A: $F=97.57$, $p<0.0001$, df=733; Subsite B: $F=29.26$, $p<0.0001$, df=728; Subsite C: $F=38.63$, $p<0.0001$, df=729.; Subsite D: $F=5.92$, $p<0.001$, df=614; Subsite E: $F=4.87$, $p<0.005$, df=578 and Subsite F: $F=23.26$, $p<0.0001$, df=724). Seals hauled out on subsite A, the largest subsite, in greater numbers during the pupping and molting seasons, whereas subsites B and C were used more during the fall and winter seasons. In addition, seals hauled out on subsites D and E, the smallest subsites, in greater numbers during the molting and winter seasons (though very few seals) and subsite F was used more during the molting and fall seasons (Figure 8).

As was found during the daytime, the average number of seals hauled out on each subsite across seasons during the nighttime was significantly different for all subsites (Subsite A: $F=46.96$, $p<0.0001$, df=325; Subsite B: $F=21.60$, $p<0.0001$, df=321; Subsite C: $F=25.40$, $p<0.0001$, df=322; Subsite D: $F=11.48$, $p<0.001$, df=254; Subsite E: $F=6.34$, $p<0.001$, df=244; and Subsite F: $F=18.85$, $p<0.0001$, df=316). Subsite A was used in greatest numbers during molting and fall, whereas the number of seals hauling on subsites B, C and F were greater during the fall and winter. Both subsites D and E had the greatest seal numbers during the winter season (though very few seals).

Castro Rocks - Work Period (August $1^{st}$ – February $14^{th}$)

The average number of seals hauled out on subsites A and C during the fall 2001 (when construction activity was taking place within the area of the haul out site) was significantly different than the average number of seals hauled out on CR in 1998-2000 (prior to the work period) ($F=3.80$, $p<0.05$, df=176 and $F=3.90$, $p<0.05$, df=176, respectively). Fewer seals were using subsite A, located closest to the bridge, and more seals were hauling out on subsite C, located farther from the bridge. In addition, during fall 2000 and 2001, the average number of seals hauled out on subsite D ($F=3.61$, $p<0.05$, df=127) and subsite F ($F=17.54$, $p<0.0001$, df=176) was greater than the number of seals hauled out during the fall 1998 and 1999. The number of seals hauled out on subsite B and E was not significantly different across years within the fall season.

Due to variations in the location and type of construction activity taking place during the "work period" within the BEZ, further analyses were conducted comparing monthly average seal numbers on Castro Rocks. In comparing haul out numbers during each month of the work period to past years, the daily average number of seals hauling out on Castro Rocks was not significantly different across years within each month. Although overall seal numbers each month were not significantly different across years, there were differences in subsite use by seals at Castro Rocks during both the daytime and nighttime.

During the daytime in October 2001, there were significantly fewer seals hauling out on subsite A compared to October 1999 ($t=2.54$, df=23, $p<0.05$) and October 2000 ($t=2.81$, df=19, $p<0.05$). There was a significant difference in the number of seals hauling out on subsite A during January ($F=4.39$, $df=71$, $p<0.01$) and February ($F=5.05$, $df=43$, $p<0.01$), with fewer seals using this subsite in 2001 and 2002 compared to 1999-2000. This may be related to increased construction-related disturbances in the area of Pier 54/55 during this time. In January/February 2001, preconstruction core sampling was conducted in the area of the haul out site.

There were no significant differences in the number of seals hauling out on subsites B and C throughout the work period. However, there were trends towards fewer seals using these two subsites during both December 2001 and January 2002 during the construction work period. The trend in January was also seen during the preconstruction core sampling in 2001. Additionally, there was a significant difference in the number of seals hauling out on subsite D during January ($F=6.83$, $df=65$, $p<0.0001$), with more seals hauling out on D during construction in 2002. There was a significant difference in the number of seals hauling out on subsite E during both January ($F=12.15$, $df=62$, $p<0.0001$) and February ($F=4.27$, $df=32$, $p<0.05$), with seals hauling out in greater numbers on subsite E during the 2002 construction work period.

Haul out numbers on subsite F were significantly different across years for the month of November ($F=4.49$, $df=57$, $p<0.01$), with more seals hauling out on subsite F in 2001 during construction. Additionally, haul out numbers on subsite F were significantly different across years in January ($F=3.14$, $df=69$, $p<0.05$) and February ($F=6.63$, $df=43$, $p<0.01$), with more seals hauling out on subsite F in 2002 during construction.

During nighttime surveys, the average number of seals hauled out on subsite F each month was significantly different across years for each month except December and January; with more seals on subsite F during each month of the work period. For the other subsites, the number of seals hauling out each month across all years did not display the same consistent trends as subsite F. Seal numbers on subsite A were significantly different during November ($F=5.62$, $df=38$, $p<0.005$), with fewer seals using subsite A during the construction work period in 2001. In addition, there was a trend towards increasing seal numbers on subsite C during August-October 2001 (though not significant).

Yerba Buena Island

Seals used YBI year-round and at higher tides during the winter season (Figure 3). Herring spawn during the winter within the vicinity of the YBI haul out site (Spratt 1981). Given that harbor seals are opportunistic feeders (Allen *et al.* 1984), it seems likely that the seals would take advantage of this nearby and seasonally abundant food source (Spencer 1997). During the winter, we routinely document harbor seals with herring roe on their faces when they are hauled out at YBI.

At YBI, there was a large drop in the average harbor seal count beginning at 0900 until 1300, followed by an increase in numbers through the late afternoon (Figure 4). The same drop in numbers in the morning was seen in all four seasons at YBI (Figure 5). This decline in numbers of seals on the haul out site may be due to high daytime disturbance levels at YBI (see disturbances section of results). The greatest average number of seals at YBI was seen in the molting and winter seasons (Figure 6).

In comparing daily average counts in 1999, 2000 and 2001, there was no difference in the number of seals hauled out at YBI when the tide height was ≤2 ft. In contrast to CR, in comparing average seasonal counts between years, there was no significant difference in daily average counts at YBI (Figure 7).

Short-term access to YBI during the nighttime allowed us to collect preliminary data concerning nighttime haul out patterns of seals at this site. Three nighttime surveys were conducted at YBI in July and August 2001. The maximum number of seals hauled out during each survey was 26 (survey tide height = 1 ft), 161 (survey tide height = -0.6), and 248 (survey tide height = 1.3). The average number of seals hauled out at YBI during the nighttime was 137.3 ± 24.1 SE.

<u>Mowry Slough</u>
Over the past 4 years, haul out numbers at MS were greatest during pupping and molting seasons, with a large drop in haul out numbers during the fall and winter (Figure 6).

The maximum number of harbor seals seen at each MS subsite occurred during pupping or molting seasons (Table 4). Newark (NW), South Salt Pile (SSP), Mowry Slough North (MSN) and Mud Flats (MF) were used regularly throughout the year. Mowry Slough South (MSS) was primarily used during pupping and molting season and North Salt Pile (NSP) was only used during the pupping season (except for winter 2000 and 2001). The maximum count at each MS subsite is probably a more reliable indicator of when seals are utilizing each subsite (i.e. during which season and under what tidal range each subsite is used) than the average count, due to variability in the tide height when surveys were taken.

The lower counts reported at MS during the late fall and early winter months may be related to the onset of duck hunting season (mid-October to mid-January) at the Don Edwards San Francisco Bay National Wildlife Refuge. Duck hunters have been seen on several occasions in the area of the SSP and in boats around NW. Furthermore, harbor seal numbers at the SSP in the fall 1998 may have been influenced by work conducted by a private landowner to build up a portion of the levees located nearby. Levee construction began in early October 1998 and extended through mid-November 1998.

<u>Corte Madera</u>
Not more than 15 harbor seals (May 1999) and two pups (April 1999) were documented at Corte Madera since 1999 (A. Bohorquez, pers. comm.). In both 2000 and 2001, a maximum of 8 harbor seals and 1 pup was seen at Corte Madera during the pupping season. Due to its location, the Corte Madera site can not accommodate many seals (Allen et. al 2002).

PUP COUNTS

The first pups born each pupping season at Castro Rocks were seen in mid to late March (3/17/99, 3/24/00, 3/24/01). However, a pup was seen earlier in both 1999 and 2000, but did not survive. The pup seen in 1999 was born on 2/24/99, but the mother did not interact with the pup and we believe that the pup did not survive. In 2001, a pup was seen on 2/28/01 with its mother. However, by 3/2/01, the pup had died and the mother was carrying the dead body with her.

The first pups at YBI were seen later in the season compared to Castro Rocks in both 1999 (4/17/99) and 2001 (4/9/01), but at approximately the same time in 2000 (3/22/00). The first pups of the season at MS were seen at approximately the same time as at Castro Rocks (3/31/99, 3/22/00 and 3/27/01).

The maximum number of pups hauled out at Castro Rocks during the day increased over the last three years; 9 in 1998 (this count was influenced by the fact that data was only collected during May and this was an El Niño year), 21 in 1999, 27 in 2000 and 35 in 2001 (these numbers only represent the maximum number of pups hauled out at once). According to A. Bohorquez, a graduate student at San Francisco State University who is studying mother/pup pairs at Castro Rocks for her Master's thesis, estimated total pup numbers were 35 in 1999, 40 in 2000, and 40 in 2001. This information was based on tracking individual mother/pup pairs by coat patterns and may represent a more accurate estimate of the total number of pups born at Castro Rocks each pupping season (A. Bohorquez, pers. comm., Table 5). Maximum pup numbers have also increased over the last three years at MS, from 78 in 1999, 90 in 2000, and 102 in 2001. Although not considered a pupping site, up to 9 pups have been seen at once on the YBI haul out site (during the 2001 pupping season). Although no births have been witnessed at YBI, mother/pup pairs have repeatedly been seen at this site. In addition, afterbirth and several dead pups have been seen at this YBI.

A maximum of 2 pups was documented at Corte Madera during the 1999 pupping season, and only one was seen in 2000 and 2001.

Of the total number of pups documented within SFB during the 2000 (126) and 2001 (146) pupping seasons, the number of pups at Castro Rocks represents ~ 22-24% of the pups in SFB. The number of pups documented at MS represent ~ 70-72% of the pups in SFB during these two years.

We typically see pups on all haul out sites until early to mid-June. Lone pups are seen on the haul out site in greater numbers later in the pupping season, probably as females wean pups.

PROPORTION OF RED COATS

Using the maximum daily count (with its corresponding red coat count), the average proportion of red pelage seals present at Castro Rocks across all pupping seasons was 31.4%. The average proportion of red pelage seals at YBI during pupping season was less than at Castro Rocks (19.5%), but the proportion of red coats at MS (33.2%) was similar to the proportion of red pelaged animals at Castro Rocks. However, since seals are often covered with mud at MS and the observer to seal distance is much greater at MS than at Castro Rocks and YBI (~200-300 m compared to ~30-150 m), identifying red coats is more difficult. Therefore, this may be a conservative calculation of the proportion of red coats present at MS. As noted earlier, in order to avoid a bias due to a low number of seals present on each haul out site, only surveys with at least 5 seals present on each haul out site were used to analyze the proportion of red coat seals at Castro Rocks and MS.

COMPARISONS TO PAST DATA

Comparisons between data collected by D. Kopec (1995-1997) and this study (1998-2001) were difficult because we have not received a final report from D. Kopec. Therefore, we had to rely on summary data provided by Kopec for making comparisons (Table 6). In addition, the limited number of surveys conducted by Kopec at all sites and the lack of information concerning yearly seasonal counts at YBI and Newark Slough made comparisons difficult.

Castro Rocks

The maximum seal counts taken during pupping at Castro Rocks (day) were highest during 1997 (max = 187). In the last 4 pupping seasons, the Richmond Bridge Harbor Seal Survey has not recorded more than 172 seals on the haul out site during pupping season (Table 6). The smaller number of seals counted in 1998 may be largely due to the fact that 1998 was an El Niño year and conditions associated with El Niño are believed to have an adverse effect on seal populations. Similar declines were seen at Point Reyes, California (Delong *et al.* 1999, Sydeman and Allen 1999, Allen *et al.* 2002). The present study has recorded a greater maximum number of seals hauled out at Castro Rocks during molting, fall and winter compared to Kopec's reports from 1995-1997, with the overall maximum count recorded in 2001 for all three seasons.

Yerba Buena Island

Although yearly seasonal maximum counts were not available at YBI from 1995-1997, the number of seals using the haul out site during the pupping and molting season were comparable across all years (Table 6). Fall season numbers have declined in comparison to the 236 recorded in 1995 (D. Kopec, pers. comm. 1999), but have remained stable at ~140 seals over the last several years. The maximum count for all years was recorded during the winter of 1998 (296 seals).

Mowry and Newark Sloughs

Due to differences in data analysis methodology between D. Kopec and the present study, Newark Slough was considered separately from the five subsites at MS for the purposes of this comparison. Yearly maximum counts at MS occur in pupping and molting season (Table 6). The extremely low maximum count recorded at MS in 1998 during pupping was likely due to the fact that: 1) only two surveys were conducted in 1998 and were both late in the pupping season, and 2) as noted above, 1998 was an El Niño year. In addition, the low number of seals recorded during the 1998 molting season may be related to El Niño's effect. Across all years, seal numbers at MS declined sharply during both the fall and winter seasons compared to pupping and molting.

As with YBI, detailed yearly information was not available for Newark Slough 1995-1997. In comparing seasonal counts between years, maximum counts at Newark Slough were comparable across all years. As with Mowry Slough, seal numbers peak at Newark Slough during the pupping and molting seasons.

DISTURBANCES

The frequency of disturbances (including those which caused head alerts, approaches to the water or flushes) at the three study sites varied (Table 7). YBI had the most disturbances reported per hour of field time, followed by CR day, CR night and MS. If only those disturbances that caused seals to flush into the water were considered, CR had the highest frequency of flushes/hour, followed by YBI, CR night and MS. The higher frequency of flushes/hr at Castro Rocks compared to YBI is likely related to the start of construction activity, and the coinciding construction disturbances that caused a flush over the past 6 months since the August 2001 Interim Report. Only those disturbances that caused seals to flush into the water will be analyzed for the remainder of this report unless otherwise noted.

Castro Rocks

Of all flush disturbances recorded at Castro Rocks during the day (n=1019), the major sources were watercraft (0.128 disturbances/hr field time) (e.g. motorboats, sailboats, tankers, kayaks and jet skis), wildlife (0.075 disturbances/hr field time) (seals and birds), "other man-made" (e.g. debris, workmen on the bridge) (0.040 disturbances/hr field time) and researchers (0.021 disturbances/hr field time) (Figure 9). Of the 164 disturbances due to wildlife, 36 were due to birds, and 128 were due to seals. Sixty-two of the seal disturbances were due to either 1.) a seal tagged with a time depth recorder seen at Castro Rocks in June 1998 (n=2), or 2.) seals tagged with radiotags or a satellite tag in January 2001 (n=45), July 2001 (n=10) or January 2002 (n=5). Disturbances were more frequent the first two months after the January 2001 tagging event, but have since subsided. The frequency of disturbances of unknown origin occurred 0.166 disturbances/hr field time of all recorded disturbances. Major sources of "other man-made" disturbances were other construction (0.0165 flushes/hr field time) other people (0.016 flushes/hr field time) and debris (0.015 flushes/hr field time) (Figure 10).

Few disturbances caused a flush during the Castro Rocks night surveys (n=52). Primary causes of nighttime disturbances were researchers (0.017 disturbances/hr field time), wildlife (0.013 disturbances/hr field time), watercraft (0.008 disturbances/hr field time) and disturbances of unknown origin (0.054 disturbances/hr field time) (Figure 9). Traffic noise on the bridge is greatly reduced at night and the seals are more able to hear the researchers descending onto the observation platform. In addition, the lack of available light makes detecting the source of many disturbances difficult. Disturbances due to watercraft, which are common during the daytime, are greatly reduced at night.

Yerba Buena Island

The majority of the disturbances at YBI (n=343) were caused by watercraft (0.159 disturbances/hr field time) (Figure 9). "Other man-made" sources caused 0.045 disturbances/hr field time of the recorded disturbances, researchers caused 0.033 disturbances/hr field time, wildlife caused 0.027 disturbances/hr field time, aircraft caused 0.018 disturbances/hr field time, and automobiles caused 0.001 disturbances/hr field time. Primary sources of "other man-made" disturbance sources included debris (0.023 disturbances/hr field time) and other people (0.011 disturbances/hr field time) (Figure 10). Other people at YBI typically were Coast Guard personnel or researchers conducting work for the San Francisco-Oakland Bay Bridge in the fall 2000. Disturbances of unknown origin occurred 0.122 disturbances/hr field time.

Mowry Slough

Disturbances were infrequent at MS (n=71), due to the relative inaccessibility of this site to the public and the methodology of data collection at this site. Much of this site is located on U.S. Fish and Wildlife Service land that is not open to the general public; the remainder is accessed through private lands and requires a permit from the landholder (Cargill Salt Company). In addition, since field biologists do not remain at each subsite for an extended period of time (like at Castro Rocks and YBI), disturbance sources common at this location, such as small aircraft in the area, are not recorded as often as they would be at the other research sites. Therefore, the number of disturbances at Mowry Slough likely represents an underestimate of the actual disturbances at this site. Of the disturbances to cause seals to flush at this site, 40 (0.046 disturbances/hr field time) of these were caused by researchers (Figure 9). Aircraft caused 0.019 disturbances/hr field time, 0.004 disturbances/hr field time were due to watercraft, and wildlife and other man-made accounted for 0.003 disturbances/hr field time. 0.008 disturbances/hr field time were attributed to unknown sources. The infrequency of human activity at this site may result in seals being more sensitive to human actions.

Disturbance Source:

Watercraft were a major source of disturbance at both Castro Rocks and YBI during the daytime. The average distance at which watercraft caused a flush at Castro Rocks (Mean = 165.0 m ± 7.2 SE) was not significantly different than the average distance at which watercraft elicited a head alert or approach water response (Mean = 177.0 m ± 4.5 SE). In contrast, the average distance at which watercraft caused a flush at YBI (Mean = 131.0 m ±9.5 SE) was significantly different than the average distance at which watercraft elicited a head alert or approach water response (Mean = 253.0 m ± 3.6 SE) ($t=12.05$, $p<0.0001$, $df=158$).

Overall, the average distance of watercraft which caused a flush at Castro Rocks (165.0 m) was significantly farther away compared to watercraft at YBI (131.0 m) ($t=2.80$, $p<0.01$, $df=262$) (Table 8). Jet skis and kayaks elicited a flush response from seals at a closer distance at YBI compared to at Castro Rocks, while "other boats", such as tugboats, elicited a flush response at farther distances at both sites (Table 8). However, caution should be used in interpreting disturbance data for several reasons. Depending upon the nature and behavior of the watercraft, the distance at which seals react can vary widely. For example, watercraft with erratic behavior, such as sudden changes in speed or direction, were more likely to cause a disturbance, whereas tankers maneuvering to the Chevron Pier located approximately 600 m from Castro Rocks typically do not cause a disturbance. In addition, the distance at which seals were able to perceive watercraft varied due to obstructions and angle of approach at each site. For example, watercraft approaching from under the bridge at Castro Rocks or from the east at YBI were frequently not noticed until they were close to the haul out site.

## CONSTRUCTION-RELATED DISTURBANCES

### Preconstruction Core Sampling (PCCS)

We recorded a total of 147 disturbances between January 24, 2001 and February 14, 2001, while preconstruction core samples were taken between piers 52 and 57. We recorded all disturbances when the tide height was $\leq$2 ft and all responses to disturbance sources (head alert, approach water, flush and wash off from wakes). Of those disturbances, 29.3% (43) were attributed to activities related to construction. Of the construction-related disturbances, watercraft in the area around the haul out site were responsible for most disturbances (60.5%), followed by sounds related to construction (30.2%), and boat wakes (9.3%). Two boats were seen most often during the PCCS: a tugboat with 2 6-cylinder Cummins engines ("Mudcat"), and a Crew-boat with 2 12V71 Detroit engines ("Pegasus").

Of the watercraft disturbances, 32.1% (n=9) resulted in seal flushes. Watercraft activity associated with flushes were movement within close proximity of the haul out site (of one or more boats), accelerations in boat speed, and boat work related to the set up of the boat exclusion zone around the haul out site. The average distance from the haul out site at which construction watercraft caused a disturbance or a flush was 233.0 m ± 23.1 SEM. In comparison, the average distance for other construction activities, such as jackhammering, that caused a disturbance was 172.9 m ±14.7 SEM. In comparing disturbance data from the preconstruction core sampling to past years, the overall frequency of flushes per hour of field time was significantly higher during the preconstruction core sampling than during the same time period in 1999 and 2000 ($F=5.73$, $p<0.01$, $df=46$) (Figure 11).

### Castro Rocks Work Period (August 1st – February 14th)

A total of 2986 disturbances (290 flushes; 9.7%) were recorded during the work period, compared to 548 (150 flushes; 27.4%) during the same time period in 1998 and 997 (236 flushes; 23.7%) in 1999. This represents a 3-5½ fold increase in the total disturbances recorded during the work period in 2001 (and 1.5-2 fold increase in disturbances to cause a flush). Of these disturbances, 2256 (76%) were due to construction-related disturbance sources (2144 (95%) day/112 (5%) night), of which 148 (7%) caused seals to enter the water (flush) (142 during the day and 6 at night).

Construction-related disturbance sources were recorded in the areas of Pier 49 through Pier 58. However, the majority of disturbances were caused by construction activity in the areas of Pier 54 (805 (36%) disturbances/55 (37%) flushes), Pier 55 (363 (16%) disturbances/37 (25%) flushes), Pier 56 (705 (31%) disturbances/41 (28%) flushes) and Pier 57 (247 (11%) disturbances/5 (3%) flushes). During the work period, construction activities at Pier 54 and 55 caused more disturbances during January and February, at Pier 56 during October – December, and at Pier 57 during December and January. Less than 40 disturbances and 5 flushes were recorded due to construction activities at each of the other piers in the immediate area.

Construction watercraft were responsible for 72.3% of the construction-related flushes, while other construction activities such as dredging, jackhammering and the movement of cranes on barges, accounted for the other construction-related disturbances which caused seals to flush (27.7%). The average distance from the haul out site at which construction watercraft caused a flush was 119.7.0 m $\pm$ 7.2 SE. Similarly, the average distance for other construction activities that caused a flush was 120.9 m $\pm$14.5 SE. "Other construction boats", such as pushboats, caused seals to enter the water when they were farther from the haul out site (mean=195.2 m) compared to construction motorboats (skiffs) (mean = 104.0 m). There was a significant difference in the frequency of flushes per hour of field time when analyzing disturbances recorded between August 1 – February 14, 1999-2002 ($F = 4.34$, $p<0.05$, df=296) (Figure 11), with more disturbances/hr during the 2001/2002 work period when construction activity was taking place.

Based on anecdotal information, disturbances due to watercraft were most likely caused by factors such as; 1) moving at varying speeds, 2) changing course, and 3) remaining within close proximity to the haul out site. In addition, when construction watercraft were traveling either close to the haul out site or at high speeds, the wake that was created washed over the haul out site and forced seals off of the rocks.

Several factors should be considered in evaluating the disturbance information. The frequency of construction-related disturbances recorded at each pier is dependent upon the amount of time and type of work conducted at each location. For example, although fewer disturbances were recorded at Pier 57 compared to Pier 54-56, delays in work at Pier 57, and the subsequent inability to complete the intended work scheduled during this work period, probably contributed to a lower number of potential construction-related disturbances from this pier. In addition, due to difficulties in accessing the normal survey platform at Pier 55, some surveys were conducted from locations that did not provide good visibility of the work area at all times. Of the 141 daytime surveys conducted during the work period, 34 (24%) were conducted from the upper deck of the bridge (during October and September) and 19 (13%) were conducted from the lower deck car level (during January and February). Both of these locations provided obstructed views of the work area compared to the Pier 55 platform and the base of Pier 55. Likewise, of the 72 night surveys conducted during the work period, 23 (32%) were conducted from the upper deck of the bridge (mainly in October) and 31 (43%) were conducted from the lower deck car level (December – January).

## AIR ACOUSTICS MONITORING

The $L_{eq}$ noise levels (the average A-weighted noise level during the measurement period) taken every 30-minutes during the day ranged from 72.7 – 73.9 dBA (maximum noise levels ranged from 76.9 – 87.7 dBA) (Figure 12) from November 2000 through February 2002. In contrast, the hourly nighttime $L_{eq}$ noise levels ranged from 65.9 – 72.9 dBA (maximum noise levels ranged from 74.2 – 86.2 dBA). There was a significant difference in the daytime and nighttime Leq levels at Castro Rocks, with the average daytime Leq (mean = 73.7 $\pm$ 0.09 SE) significantly greater than the average nighttime Leq (mean = 69.3 $\pm$ 0.51 SE) ($t=8.41$, $p<0.001$, $df = 23$). This may be biologically, as well as statistically meaningful, since decibels are based on a logarithmic scale; each one decibel increase is more substantial than if the information was not based on a logarithmic scale. The large drop in decibel levels at night is likely due to decreased automobile traffic on the Richmond-San Rafael Bridge.

When comparing the average $L_{eq}$ (dBA) sound levels recorded from November 2000 – February 14, 2001 to the Leq sound levels recorded during the same time period in 2001/2002, when construction was taking place (November 2001 – February 14, 2002), there was no significant difference in the overall average sound level recorded across the entire day. However, the $L_{eq}$ sound levels recorded during the late evening (approximately 23:30 until 04:30) were higher during the 2001/2002 work period. This is likely due to the construction activity that took place during the nighttime in the area of the haul out site.

When comparing monthly $L_{eq}$ levels within months when multiple years of information were available (November-February, 2001-2002), there was no significant difference in the average Leq levels recorded across the entire day within each month between years.

## RADIO- AND SATELLITE-LINKED TELEMETRY

A total of 27 seals were captured at Castro Rocks in January 2001 – January 2002. All seals captured were tagged on both rear flippers with lime green rototags. Of the 27 seals captured, a total of 10 seals were deployed with VHF radiotags, and 7 with satellite-linked PTT's. No pups were affixed with radio or satellite tags, but were flipper tagged. Data for these 17 seals are summarized in Table 9. One PTT-tagged seal still retains its tag; locations for this seal are shown in Figure 13. Locations for other PTT-tagged seals are shown in Figure 14. Locations for radiotagged seals are shown in Figure 15, including 5 radiotagged seals that still retain their tags at the time of this report.

Most seals tagged at Castro Rocks (10 of 17) used more than one haul out site in and around San Francisco Bay (Table 9; Figures 13-15). Six appeared to use Castro Rocks exclusively, although short tag duration for one of these seals (PTT 15440) should be considered when drawing conclusions about haul-out site use. All seals save two (VHF 1.652 and PTT 15437) used Castro Rocks as a primary haul-out site during at least part of the study period. Corte Madera Marsh, a small haul-out site located west of Castro Rocks, was used by three of the tagged seals. Depths utilized by seals in San Francisco Bay ranged from six to 18 m. Many seals appeared to use consistent feeding areas within and outside the SFB (Figures 13-15). When seals used Castro Rocks as their primary haul-out site, mean distances from the haul out site ranged from two to 33 km, although these distances for most seals (12 of 17) were ≤ 5 km.

Five seals tagged at Castro Rocks consistently used haul out sites outside San Francisco Bay, as far west as the Farallon Islands (37°42'04"N, 123°00'30"W) and as far north as Point Reyes National Seashore (38°01'42"N, 122°56'27"W) (Figures 13-15). At least two seals made >1 trip between the Farallon Islands and the California coast, and one seal (PTT 15437) appears to use a consistent feeding area between the coast and the Farallones. For example, one seal (PTT 19582) traveled to the Farallon Islands, remained at the Farallones for nine days, then returned to Duxbury Reef for two days, and then moved back to the Farallones. This seal lost its PTT four days later, while still at the Farallones, but has since been resighted at Castro Rocks. The Farallon Islands are located 45 km west of the entrance to SFB, in the Gulf of the Farallones National Marine Sanctuary, and serve as a haul out and breeding location for a number of pinniped species.

Initially, problems with tag attachment meant shorter tag attachment durations for some seals. With the refined attachment technique now in use, we are confident that the most recent set of tags (deployed in January 2002) will remain on the seals until the next molt (June-August).

### OTHER MARINE MAMMAL SIGHTINGS

Other marine mammal sightings are periodically documented while monitoring the three harbor seal haul out sites in San Francisco Bay. During the period of April 2000 – February 2002, observers noted 13 gray whale sightings within the Bay (11 live and 2 dead). Nine of the live whale sightings were from the Richmond-San Rafael Bridge, one from YBI and one was seen off of Tiburon. Both dead whale sightings were from the Richmond-San Rafael Bridge. In addition, from May 1998 – February 2002, a total of 33 California Sea Lions were seen near the Richmond-San Rafael Bridge and at least 20 were seen in the waters off of YBI. In addition, one dead sea lion was seen onshore at YBI, approximately 200 m northwest of the YBI haul out site. One sea otter was seen in March 2001 and 2 harbor porpoises were seen over the last several years.

## SUMMARY

Castro Rocks serves as an important harbor seal haul out site within SFB, utilized during low to medium low tides. Castro Rocks is also particularly important as a nighttime haul out site, with average nighttime counts surpassing daytime counts during the molting, fall and winter seasons. Previous reports have noted the importance of YBI as a winter haul out site. This study shows that this site is important year-round, but particularly during the molting and winter seasons. Historically, MS has been identified as an important pupping site and our data support that fact. In addition, MS appears to be an important haul out site during the molting season.

During the first "work period" of the construction activity within the area of the Castro Rocks haul out site (August 2001 – February 14, 2002), the total number of seals hauling out on Castro Rocks did not change compared to past years. However, we noted a shift in the pattern of subsite use at Castro Rocks compared to past years. There was a trend toward an increase in the number of seals hauling out on subsites C-F, which are located farther from the bridge, and a decrease in the number of seals hauling out on subsite A, located closest to the bridge.

Construction-related disturbances at Castro Rocks were attributed to two main factors; watercraft in the area of the haul out site and construction activities such as jackhammering and the movement of cranes on barges near the haul out site. The percentage of construction watercraft which caused seals to flush during the 2001/2002 work period (72.3%) was more than double the percentage of disturbances attributed to construction watercraft during preconstruction core sampling in January/February (32.1%). This increase in the percentage of construction watercraft which caused a flush is likely due to an increase in the number of watercraft in the area and the frequency of watercraft traveling to/from the launching dock located at the southeastern end of the bridge. The close proximity of watercraft to the haul out site, in addition to erratic movements and directionality, contributed to disturbances at Castro Rocks.

Although the overall Leq dBA levels recorded throughout the entire day has not changed significantly during construction activities, we have noted an increase in the late evening sound levels at Castro Rocks (~ 23:30 – 04:30). What effect, if any, that an increase in the nighttime sound levels may have on the haul out patterns of seals at Castro Rocks is unclear at this time.

Tagging seals with radiotags and satellite PTT's enables us to track the movements of seals within and around the Bay. Specifically, if seal haul out patterns at Castro Rocks are disturbed due to construction activities, tracking tagged animals will add valuable information to our understanding of how Bay seals respond to these disturbances. Tracking of tagged seals is still underway, and thorough analyses of individual seal movements during construction periods have not been completed. Visual surveys conducted at the three primary SFB haul out sites will allow us to detect major shifts in numbers of seals using these sites, should seals' use of Castro Rocks decrease. Radio- and satellite-linked telemetry will allow us to track seals that either use smaller or new haul out sites in the Bay, and/or leave the Bay, and tracking allows us to document the movements and haul-out patterns of individual seals. Tracking known individuals may allow us to detect changes in movement and/or haul out patterns not detectable in haul out survey numbers alone. In addition, we will be able to track changes in foraging patterns that could be linked to changes in haul out patterns or to activities around the Richmond-San Rafael Bridge related to the seismic retrofit.

Given that the SFB harbor seal population is estimated at 500 seals (Robert Read, pers. comm. 2000, California Department of Fish and Game), the number of seals using Castro Rocks, as well as YBI and MS, represent a substantial proportion of the seals in SFB. In addition, as this study and data provided by Kopec (unpublished data) show, Castro Rocks, along with YBI and MS, serve as important sites for an increasing number of mother/pup pairs during the pupping season (and possibly a slight increase in overall seal numbers over the year). Castro Rocks, along with YBI and MS, serve as important haul out sites for an increasing number of mother/pup pairs during the pupping season (and possibly a slight increase in overall seal numbers over the year). Castro Rocks is an important harbor seal haul out site in SFB, and protecting this site is important for the protection of harbor seal in the Bay.

## RECOMMENDATIONS

Continued monitoring of the Castro Rocks harbor seal haul out site throughout the retrofit work on the Richmond-San Rafael Bridge is important in order to properly assess what impacts the retrofit work has on the SFB harbor seal population. Currently, we have only documented a shift in subsite use at Castro Rocks, to areas farther from the bridge; no decline has been documented in overall seal numbers at this site. However, monitoring should be continued in order to examine the effects as retrofit work progresses.

In order to alleviate watercraft-related disturbances during construction, we recommend that, whenever possible, watercraft maintain a slow steady speed when passing by the haul out site, and that, unless necessary, boats not travel close to the haul out site. In addition, if boats are traveling within the area of the haul out site; they will likely elicit fewer disturbances if they travel parallel to the haul out site rather than toward the haul out site.

Results to date from the radio- and satellite-linked telemetry of harbor seals tagged at Castro Rocks are very promising. We are learning much about the daily movements of seals within SFB (encompassing time spent at Castro Rocks, other haul out sites used in SFB, and feeding areas), and about possible linkages between the SFB population and coastal harbor seals. Continued tagging work will allow us to monitor spatial shifts in seal distributions around the retrofit site and around SFB, comparing seal movements during the work closure period with seal movements during work periods. Monitoring seal movements may be particularly important as the retrofit work progresses, for example when full-scale piledriving is underway at the bridge.

## LITERATURE CITED

Alcorn, D., Fancher, L. (1980) Report on harbor seals of the San Francisco Bay National Wildlife Refuge, South San Francisco Bay, California. Final Report to U.S. Dept. of Interior, Fish and Wildlife Service 57p.

Allen, S.G., Waber, S. and Press, D. (2002) Long-term monitoring of harbor seals at Point Reyes, CA. Five year annual report: 1997 – 2001, National Park Service Technical Report.

Allen, S. (1991) Harbor seal habitat restoration at Strawberry Spit, San Francisco Bay. Report to the U.S. Marine Mammal Commission. 44 pp.

Allen, S.G., Ainley, D.G., Page, G.W., and Ribbic, C.A. (1984) The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, California. Fishery Bulletin 82(3): 493-500.

Bartholomew, G.A. (1949) A census of harbor seals in San Francisco Bay. Journal of Mammalogy 30: 34-35.

Bonner, W.N. (1982) Seals and man: A study of interactions. University of Washington Press, Seattle, WA. 170 p.

Calambokidis, J., Bowman, K., Carter, S., Cubbage, J., Dawson, P., Fleischner, T., Schuett-Hames, J., Skidmore, J., and Taylor, B. (1978) Chlorinated hydrocarbon concentrations and the ecology and behavior of harbor seals in Washington State Waters. NSF funded project provided by Cascadia Research Collective. 121 pp.

Clifton, D. (1971) The effect of construction on the harbor seal in Diablo Cove, San Luis Obispo County, California. California State Polytechnic College. P.G. & E. Report.

Da Silva, J. and Terhune, J.M. (1988) Harbour seal grouping as an anti-predator strategy. Animal Behaviour. 36:1309-1316.

DeLong, R.L., Melin, S.R., Allen, S.G., and Lowry, M.S. (1999) Impacts of the 1997 El Niño on Marine Mammals in the California Current. California Cooperative Oceanic Fisheries Investigations (CalCOFI) Meeting (presentation).

Department of Commerce, National Oceanic and Atmospheric Administration (1997). Incidental Harassment Authorization, "Small takes of marine mammals incidental to specified activities; seismic retrofit of the Richmond-San Rafael Bridge, San Francisco Bay". Federal Register 62 (246) (Notices): 67045-67051.

Feltz, E.T. and Fay, F.H. (1966) Thermal requirements in vitro of epidermal cells from seals. Cryobiology. 3(3): 261-264.

Green, D.E., Grigg, E., Markowitz, H., and Allen, S. (2001) Monitoring the potential impact of the seismic retrofit construction activities at the Richmond-San Rafael Bridge on harbor Seals (*Phoca vitulina*): May 1998 – August 2001. Draft Interim Report. National Marine Fisheries IHA # FR14JA00-38.

Hoover, A.A. (1988) Harbor seal *Phoca vitulina*. p. 125-157 *In*: J.W. Lentfer (ed.), Selected marine mammals of Alaska/Species accounts with research and management recommendations. U.S. Marine Mammal Commission, Washington, D.C. 275 p. NTIS PB88-178462.

Johnson, B.W. (1977) The effects of disturbance on a population of harbor seals. Appendix I from: Pitcher, K. and D. Calkins. Biology of the harbor seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. In: Annual Reports, Environmental Assessment of the Alaskan Continental Shelf (March, 1977), vol. 1.

Johnson, S.R., Burns, J.J., Malme, C.I., and Davis, R.A. (1989) Synthesis of information on the effects of noise and disturbance on major haulout concentrations of Bering sea pinnipeds. LGL Alaska Research Associates Report MMS 88-0092.

Kopec, D., Harvey, J. (1995) Toxic pollutants, health indices, and population dynamics of harbor seals in San Francisco Bay, 1989-91: a final report. Technical publication. Moss Landing, CA: Moss Landing Marine Labs.

Paulbitski, P. (1975) The seals of Strawberry Spit. Pacific Discovery 28: 12-15.

Risebrough, R.W., Alcorn, D., Allen, S.G., Alderlini, V., Booren, L., DeLong, R., Fancher, L., Jones, R.E., McGinnis, S., and Schmidt, T. (1979) Population biology of harbor seals in San Francisco Bay. NTIS PB-81-107963.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I., and Thomson, D.H. (1995) Marine Mammals and Noise. Academic Press, San Diego. 576 p.

Spencer, C.L. (1997) Seasonal haul out patterns of *Phoca vitulina richardsi* in San Francisco Bay. M.A. Thesis. San Francisco, CA: San Francisco State University, 99 pp.

Spratt, J.D. (1981) Status of the Pacific Herring, Clupea harengus pallasii, Resource in California 1972 to 1980. Fish Bulletin. State of California, Department of Fish and Game, 107 pp.

Stein, J.L. (1989) Reproductive parameters and behavior of mother and pup harbor seals, *Phoca vitulina richardsi*, in Grays Harbor, Washington. M.S. Thesis, San Francisco State University, San Francisco, CA, 110 p.

Sullivan, R.M. (1979) Behavior and ecology of harbor seals, *Phoca vitulina*, along the open coast of Northern California. M.S. Thesis. Humbolt, CA: California State University, Humbolt. 115 pp.

Sydeman, W.J. and Allen, S.G. (1999) Pinniped population dynamics in Central California: correlations with sea surface temperature and upwelling indices. Marine Mammal Science 15(2):446-461.

Terhune, J.M. (1985) Scanning behavior of harbor seals on haul-out sites. Journal of Mammalogy 66:392-395.

Watts, P. (1993) Possible lunar influence on hauling-out behavior by the Pacific harbor seal (*Phoca vitulina richardsi*). Marine Mammal Science 9(1):68-76.

| | Work Closure Period | | Work Period | |
|---|---|---|---|---|
| **Location** | 2/15-7/24 | 7/25-7/31 | 8/1-8/31 | 9/1-2/14 |
| **Castro Rocks (day)** | 3 until 3/99 - currently 4 | 5 | 7 | 7 |
| **Castro Rocks (night)** | 2 | 2 | 2 | 2 |
| **Yerba Buena Island** | 2 | 5 until 9/99 - currently 2 | 5 until 9/99 - currently 2 | 3 until 9/99 - currently 2 |
| **Mowry Slough** | 2 | 5 | 7 | 3 |

**Table 1. Number of days per week surveys were taken at each location during each time period.**

| | | CRD | CRN | YBI | MS |
|---|---|---|---|---|---|
| Pup 1998 (May Only) | Time in Field hrs(# Surveys) | 96(174) | 9.47(21) | 26.83(60) | 5(2) |
| | # Surveys -Tide Height ≤2' | 117 | 12 | 52 | N/A |
| Molt 1998 | Time in Field hrs(# Surveys) | 311.6(615) | 29.47(56) | 136(299) | 129(32) |
| | # Surveys -Tide Height ≤2' | 244 | 45 | 143 | N/A |
| Fall 1998 | Time in Field hrs(# Surveys) | 631(1322) | 64.92(148) | 184(414) | 168(42) |
| | # Surveys -Tide Height ≤2' | 261 | 141 | 114 | N/A |
| Winter 1998 | Time in Field hrs(# Surveys) | 661(1410) | 59.48(147) | 187.5(416) | 149.22(37) |
| | # Surveys -Tide Height ≤2' | 438 | 84 | 208 | N/A |
| Pup 1999 | Time in Field hrs(# Surveys) | 314.33(675) | 30.95(77) | 72(161) | 99.42(27) |
| | # Surveys -Tide Height ≤2' | 457 | 41 | 137 | N/A |
| Molt 1999 | Time in Field hrs(# Surveys) | 361.75(775) | 32.97(80) | 120(270) | 160.55(42) |
| | # Surveys -Tide Height ≤2' | 352 | 50 | 140 | N/A |
| Fall 1999 | Time in Field hrs(# Surveys) | 587.5(1264) | 26.43(123) | 166.00(374) | 209.22(54) |
| | # Surveys -Tide Height ≤2' | 230 | 122 | 106 | N/A |
| Winter 1999 | Time in Field hrs(# Surveys) | 595.00(1268) | 63.00(162) | 132.00(289) | 120.07(32) |
| | # Surveys -Tide Height ≤2' | 452 | 75 | 125 | N/A |
| Pup 2000 | Time in Field hrs(# Surveys) | 308.27(666) | 37.12(74) | 87.5(195) | 124.68(33) |
| | # Surveys -Tide Height ≤2' | 464 | 24 | 161 | N/A |
| Molt 2000 | Time in Field hrs(# Surveys) | 359.25(772) | 29.50(78) | 79.00(177) | 158.78(43) |
| | # Surveys -Tide Height ≤2' | 376 | 50 | 113 | N/A |
| Fall 2000 | Time in Field hrs(# Surveys) | 606.50(1301) | 45.5(118) | 106.5(240) | 157.2(41) |
| | # Surveys -Tide Height ≤2' | 252 | 112 | 72 | N/A |
| Winter 2000 | Time in Field hrs(# Surveys) | 646.2(1380) | 70.7(180) | 123.0(277) | 111.9(34) |
| | # Surveys -Tide Height ≤2' | 488 | 112 | 93 | N/A |
| Pup 2001 | Time in Field hrs(# Surveys) | 283.0(666) | 31.0(82) | 91.0(206) | 84.7(25) |
| | # Surveys -Tide Height ≤2' | 448 | 43 | 171 | N/A |
| Molt 2001 | Time in Field hrs(# Surveys) | 371.0(795) | 32.0(84) | 94.0(205) | 106.5(30) |
| | # Surveys -Tide Height ≤2' | 372 | 53 | 107 | N/A |
| Fall 2001 | Time in Field hrs(# Surveys) | 537.08(1149) | 20.75(123) | 99.5(214) | 57.75(33) |
| | # Surveys -Tide Height ≤2' | 219 | 121 | 57 | N/A |
| Winter 2001 | Time in Field hrs(# Surveys) | 464.52(1003) | 79.0(189) | 127.5(287) | 40.18(27) |
| | # Surveys -Tide Height ≤2' | 271 | 113 | 117 | N/A |

**Table 2. Field summary for each research location May 1998 – February 2002. Fewer surveys were conducted at the Mowry Slough alternate site compared to YBI. Only one survey can be conducted per day at Mowry Slough (to cover all 6 subsites), while 9 surveys are typically conducted per day at YBI.**

| | | Castro Rocks Day | Castro Rocks Night | Yerba Buena Island | Mowry Slough |
|---|---|---|---|---|---|
| **Pup 1998** | Mean ± SEM | 62.5 ± 6.15 | 58.2 ± 10.97 | 66.9 ± 9.90 | 43.5 ± 33.52 |
| | Max | 121 | 81 | **129** | 77 |
| **Molt 1998** | Mean ± SEM | 69.2 ± 4.44 | 94.6 ± 4.88 | 75.1 ± 9.25 | 67.7 ± 7.12 |
| | Max | 125 | 128 | **213** | 129 |
| **Fall 1998** | Mean ± SEM | 56.4 ± 3.9 | 89.6 ± 5.34 | 30.2 ± 5.35 | 22.5 ± 2.16 |
| | Max | 136 | **145** | 98 | 49 |
| **Winter 1998** | Mean ± SEM | 68.8 ± 4.64 | 57.7 ± 9.95 | 77.0 ± 9.96 | 17.2 ± 3.11 |
| | Max | 160 | 143 | **296** | 64 |
| **Pup 1999** | Mean ± SEM | 68.8 ± 3.96 | 38.0 ± 7.91 | 62.1 ± 8.37 | 91.3 ± 9.01 |
| | Max | 150 | 93 | 136 | **243** |
| **Molt 1999** | Mean ± SEM | 79.4 ± 4.12 | 95.0 ± 6.96 | 96.6 ± 10.11 | 89.0 ± 7.11 |
| | Max | 141 | 143 | 198 | **205** |
| **Fall 1999** | Mean ± SEM | 56.8 ± 4.26 | 117.5 ± 8.94 | 72.8 ± 6.69 | 25.9 ± 2.36 |
| | Max | 154 | **203** | 141 | 59 |
| **Winter 1999** | Mean ± SEM | 77.0 ± 5.49 | 69.8 ± 7.59 | 93.7 ± 11.39 | 14.9 ± 3.41 |
| | Max | 179 | 145 | **193** | 69 |
| **Pup 2000** | Mean ± SEM | 79.2 ± 3.59 | 26.2 ± 5.99 | 62.4 ± 7.65 | 90.9 ± 10.43 |
| | Max | 161 | 56 | 128 | **230** |
| **Molt 2000** | Mean ± SEM | 88.0 ± 3.19 | 95.8 ± 7.88 | 81.6 ± 10.85 | 81.1 ± 7.62 |
| | Max | 155 | 148 | **204** | 197 |
| **Fall 2000** | Mean ± SEM | 72.7 ± 5.88 | 125.3 ± 8.35 | 80.4 ± 10.10 | 18.6 ± 1.87 |
| | Max | 201 | **212** | 151 | 49 |
| **Winter 2000** | Mean ± SEM | 59.8 ± 5.00 | 76.7 ± 8.84 | 93.1 ± 14.01 | 31.4 ± 5.06 |
| | Max | 156 | 166 | **277** | 105 |
| **Pup 2001** | Mean ± SEM | 85.9 ± 4.02 | 45.4 ± 7.22 | 61.0 ± 5.88 | 145.7 ± 15.10 |
| | Max | 172 | 112 | 156 | **300** |
| **Molt 2001** | Mean ± SEM | 100.4 ± 4.06 | 114.8 ± 6.92 | 71.8 ± 10.65 | 107.0 ± 11.98 |
| | Max | 172 | 152 | 184 | **228** |
| **Fall 2001** | Mean ± SEM | 75.74 ± 6.04 | 124.6 ± 7.89 | 69.84 ± 9.22 | 31.3 ± 2.92 |
| | Max | **205** | 200 | 135 | 67 |
| **Winter 2001** | Mean ± SEM | 86.53 ± 6.95 | 85.7 ± 8.19 | 102.1 ± 10.50 | 27.7 ± 6.91 |
| | Max | **225** | 198 | 238 | 128 |

**Table 3. Summary statistics (Mean ± SD, Max) for each research site, considering only those surveys taken with a tide height ≤2 feet; May 1998 – February 2002. (*Mowry Slough statistics were calculated regardless of tide height due to varying haul out patterns at this site.)**

| | | MSN | MSS | MF | NW | NSP | SSP |
|---|---|---|---|---|---|---|---|
| Pup 1998 (May Only) | Mean | 16.0 | 0 | 0 | 25 | 0 | 15.0 |
| | Max | 27 | 0 | 0 | 25 | 0 | 25 |
| | N | 2 | 1 | 1 | 1 | 1 | 2 |
| | Tide Height of Max | 0.3 | 2.2 | -- | 3.3 | -- | 1.5 |
| Molt 1998 | Mean | 16.1 | 1.0 | 3.3 | 20.6 | 0 | 28.7 |
| | Max | 59 | 33 | 22 | 51 | 0 | 78 |
| | N | 30 | 31 | 30 | 32 | 31 | 31 |
| | Tide Height of Max | 2.2 | 4.1 | 0 | 5.1 | -- | 4.1 |
| Fall 1998 | Mean | 0.2 | 0 | 5.2 | 13.9 | 0 | 3.3 |
| | Max | 6 | 0 | 21 | 41 | 0 | 13 |
| | N | 41 | 42 | 41 | 42 | 42 | 42 |
| | Tide Height of Max | 3.1 | -- | 1.9 | 2.9 | -- | 4.1 |
| Winter 1998 | Mean | 0.3 | 0 | 4.1 | 6.6 | 0 | 8.4 |
| | Max | 8 | 1 | 27 | 26 | 0 | 49 |
| | N | 30 | 37 | 20 | 36 | 36 | 37 |
| | Tide Height of Max | 1.2 | 2.7 | 2.2 | 3.2 | -- | 7.4 |
| Pup 1999 | Mean | 26.3 | 16.9 | 8.3 | 22.8 | 2.5 | 24.4 |
| | Max | 126 | 47 | 32 | 47 | 11 | 70 |
| | N | 24 | 27 | 16 | 23 | 24 | 27 |
| | Tide Height of Max | 0.1 | 0.1 | -1.6 | 6.2/6.8 | -0.8/2.7 | 4.7 |
| Molt 1999 | Mean | 38.8 | 0.2 | 2.6 | 22.9 | 0 | 29.3 |
| | Max | 118 | 6 | 52 | 62 | 0 | 118 |
| | N | 40 | 42 | 38 | 40 | 43 | 43 |
| | Tide Height of Max | 2.7 | 3.3 | -1.0 | 4.0 | -- | 7.3 |
| Fall 1999 | Mean | 9.5 | 0.04 | 2.5 | 10.1 | 0 | 5.4 |
| | Max | 37 | 1 | 15 | 32 | 0 | 22 |
| | N | 51 | 54 | 46 | 50 | 52 | 54 |
| | Tide Height of Max | 5/6.6 | 2.9/5.2 | 3.4 | 6.7 | -- | 7.5 |
| Winter 1999 | Mean | 3.9 | 0 | 1.4 | 5.0 | 0 | 5.7 |
| | Max | 32 | 0 | 18 | 18 | 0 | 45 |
| | N | 32 | 30 | 21 | 29 | 27 | 31 |
| | Tide Height of Max | 2.2 | -- | 1.5 | 9 | -- | 4.7 |
| | Tide Height of Max | -- | 4.4 | 3.7 | 7.9 | 4.4 | 8.1 |

**Table 4. Summary data for Mowry Slough subsites; May 1998 through August 2001. MSN = Mowry Slough North, MSS = Mowry Slough South, MF = Mud Flats, NW = Newark, NSP= North Salt Pile, SSP = South Salt Pile** **(continued on next page)**

| | | MSN | MSS | MF | NW | NSP | SSP |
|---|---|---|---|---|---|---|---|
| Pup 2000 | Mean | 35.4 | 12.0 | 6.8 | 13.4 | 0.9 | 28.3 |
| | Max | 131 | 75 | 41 | 45 | 6 | 73 |
| | N | 32 | 30 | 26 | 28 | 27 | 33 |
| | Tide Height of Max | 0.6 | 2.4 | 0.7 | 7 | 2 | 6.2 |
| Molt 2000 | Mean | 39.5 | 0 | 2.5 | 138.0 | 0 | 26.8 |
| | Max | 118 | 0 | 48 | 33 | 0 | 126 |
| | N | 42 | 43 | 32 | 43 | 36 | 43 |
| | Tide Height of Max | 3.3 | -- | 0.4 | 6.3 | -- | 6.1 |
| Fall 2000 | Mean | 4.2 | 0.5 | 5.0 | 8.1 | 0 | 2.0 |
| | Max | 26 | 12 | 27 | 24 | 0 | 12 |
| | N | 41 | 41 | 37 | 37 | 37 | 41 |
| | Tide Height of Max | 4.3 | 5.0 | 5.2 | 3.9 | -- | 4.7 |
| Winter 2000 | Mean | 0.625 | 2.94 | 11.75 | 6.14 | .48 | 15.94 |
| | Max | 20 | 45 | 36 | 26 | 11 | 107 |
| | N | 32 | 33 | 30 | 29 | 23 | 33 |
| | Tide Height of Max | 3.0 | 4.4 | 3.7 | 5.3 | 4.1/6.6 | 3.9 |
| Pup 2001 | Mean | 53.12 | 14.60 | 36.37 | 22.04 | 1.68 | 28.8 |
| | Max | 144 | 94 | 75 | 59 | 11 | 160 |
| | N | 25 | 25 | 19 | 23 | 19 | 25 |
| | Tide Height of Max | 4.0 | 1.5 | 0.2 | 5.9 | 3.5 | 5.7 |
| Molt 2001 | Mean | 32.63 | 0.69 | 11.23 | 13.68 | 0 | 55.0 |
| | Max | 99 | 15 | 81 | 34 | 0 | 184 |
| | N | 30 | 29 | 22 | 31 | 20 | 28 |
| | Tide Height of Max | 3.6 | 3.6 | 1.6 | 6.5 | -- | 5.5 |
| Fall 2001 | Mean | 3.2 | 1 | 5.1 | 9.7 | 0 | 12.6 |
| | Max | 20 | 22 | 41 | 31 | 0 | 34 |
| | N | 33 | 33 | 32 | 31 | 31 | 34 |
| | Tide Height of Max | 3.6 | 5.5 | 2 | 8.1 | -- | 6.3/7. |
| Winter 2001 | Mean | 2 | 1.4 | 3.0 | 5.8 | 0.1 | 23.4 |
| | Max | 32 | 30 | 71 | 22 | 2 | 111 |
| | N | 29 | 30 | 28 | 25 | 30 | 30 |
| | Tide Height of Max | 0.7 | 6.7 | 0.8 | 4.2 | 2.2 | 7.3 |

**Table 4 continued. Summary data for Mowry Slough subsites; May 1998 through August 2001. MSN = Mowry Slough North, MSS = Mowry Slough South, MF = Mud Flats, NW = Newark, NSP= North Salt Pile, SSP = South Salt Pile**

| | CRD | | CRN | YBI | MS |
|---|---|---|---|---|---|
| | Max # pups hauled out | Estimated # of mother/pup pairs* | Max # pups hauled out | Max # pups hauled out | Max # pups hauled out |
| **Pup 1998** | 9 | ---- | 6 | 6 | 6 |
| **Pup 1999** | 21 | 35 | 13 | 7 | 78 |
| **Pup 2000** | 27 | 40 | 15 | 8 | 90 |
| **Pup 2001** | 35 | 40 | 34 | 9 | 102 |

**Table 5. Summary of the number of pups seen each season at each research site.**
*** Estimate of the total number of mother/pup pairs (Bohorquez, pers. comm.)**

## Maximum Harbor Seal Count

**CRD**

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| Pupping | 89 | 119 | 187 | 121 | 150 | 161 | 172 |
| Molting | 161 | 96 | 113 | 125 | 141 | 155 | 172 |
| Fall | 98 | 69 | 88 | 136 | 154 | 201 | 205 |
| Winter | 128 | 106 | -- | 160 | 179 | 156 | 225 |

**YBI**

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| Puppin g | 117* | | | 129 | 136 | 128 | 156 |
| Molting | 230* | | | 213 | 198 | 204 | 184 |
| Fall | 236* | | -- | 98 | 141 | 151 | 135 |
| Winter | 242* | | -- | 296 | 193 | 231 | 238 |

**MS**

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| Pupping | 117 | 63 | 239 | 52** | 201 | 273 | 270 |
| Molting | 199 | 158 | 168 | 105 | 177 | 302 | 213 |
| Fall | 29 | 26 | -- | 26 | 60 | 31 | 53 |
| Winter | 70 | 26 | -- | 60 | 69 | 87 | 112 |

**Newark**

| | 1995-1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|
| Pupping | 53* | 25** | 47 | 45 | 59 |
| Molting | 69* | 51 | 62 | 33 | 34 |
| Fall | 35* | 41 | 32 | 24 | 31 |
| Winter | 34* | 26 | 18 | 23 | 22 |

**Table 6. Maximum harbor seal count during each season from 1995-2002 at Castro Rocks (day) (CRD), Yerba Buena Island (YBI), Mowry Slough (MS) and Newark Slough (Newark). Not all of the data provided by D. Kopec (1995-1997) could be broken down by year. * From D. Kopec, not all of the data provided could be broken down by year. **Only two counts were taken during the 1998 pupping season at Mowry/Newark Sloughs.**

| Location | Total # Disturbances/Flushes (includes construction-related) | Total # Construction-Related Disturbances/Flushes | Disturbances/Flushes Per Hr Field Time (includes construction-related) | Construction-Related Disturbances/Flushes Per Hr Field Time |
|---|---|---|---|---|
| Castro Rocks (day) | 4329/1004 | 2188/153 | 1.98/0.46 | 1.00/0.07 |
| Castro Rocks (night) | 244/52 | 112/6 | 0.52/0.11 | 0.24/0.01 |
| Yerba Buena Island | 3718/343 | -- | 3.21/0.40 | -- |
| Mowry Slough | 381/71 | -- | 0.33/0.08 | -- |

**Table 7. Summary of the total disturbances and flushes recorded at each research site. In addition, the frequency of disturbances and flushes per hour of field time (May 1998 – February 2002) is provided. Only those disturbances which took place when the tide height was $\leq$ 2 ft are included (except at Mowry Slough, where all disturbances were included). Construction-related disturbances include disturbances recorded during the preconstruction core sampling in January/February 2001, as well as disturbances recorded during the 2001/2002 work period (August 2001 – February 14, 2002).**

| | Castro Rocks Day | | | | YBI | | | |
|---|---|---|---|---|---|---|---|---|
| | n | Proportion of Overall Source | Average Distance (m) | Range (m) | n | Proportion of Overall Source | Average Distance (m) | Range (m) |
| Jet Ski | 1 | 0.5 | 150.0 | 150 | 6 | 4.9 | 86.8 | 25-200 |
| Kayak/Canoe | 53 | 19.3 | 152.4 | 10-500 | 22 | 17.9 | 77.1 | 20-150 |
| Sailboat | 7 | 3.0 | 241.9 | 70-444 | 10 | 8.1 | 145.3 | 30-225 |
| Motorboat | 121 | 44.0 | 162.5 | 10-595 | 78 | 63.4 | 127.9 | 15-550 |
| Construction Motorboat | 37 | 13.5 | 104.0 | 20-362 | -- | 0 | -- | -- |
| Other Boat | 2 | 0.1 | 80.4 | 45-150 | 7 | 5.7 | 190.0 | 30-510 |
| Construction "Other Boat" | 54 | 19.6 | 195.2 | 37-430 | -- | 0 | -- | -- |
| Overall | **275** | | **164.5** | **10-536** | **123** | | **131.1** | **15-550** |

**Table 8. Summary of the watercraft disturbances that caused seals to flush from the haul out site at Castro Rocks Day and YBI (May 1998 – February 2002). Only those disturbances that took place when the tide height was ≤ 2 ft are included in order to make comparisons between the two sites. The category "other boats" includes watercraft such as tugboats, ferries, tankers and Bay tour boats.**

| Seal ID | Date tagged (mm/dd/yy) | Tag type | Age class | Sex | Tag days | Haul-out sites used | Maximum distance from CR (km) | Mean distance from CR[a] (km) | Mean depth used in SFB (m) | Mean depth used outside of SFB (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| **1.310** | 01/07/01 | VHF | Adult | F | 44 | CR, MS, BI | 59.6 | 3.2 ± 2.3 | 6 ± 4 | N/A |
| **1.652**[b] | 01/08/01 | VHF | Subadult | F | 13 | YB | -- | -- | -- | -- |
| **1.221** | 01/08/01 | VHF | Subadult | F | 50 | CR | 10.6 | 3.3 ± 2.1 | 11 ± 6 | N/A |
| **15345** | 01/09/01 | PTT | Adult | M | 153 | CR | 37.9 | 7.3 ± 0.4 | 7 ± 1 | N/A |
| **0.320** | 07/15/01 | VHF | Subadult | F | 124 | CR, PB, LE | 25.6 | 3.2 ± 1.7 | 15 ± 9 | N/A |
| **1.611** | 07/15/01 | VHF | Subadult | M | 98 | CR, CM, PB | 8.7 | 4.9 ± 0.6 | 18 ± 6 | N/A |
| **15440** | 07/15/01 | PTT | Subadult | F | 34 | CR | 16.1 | 5.0 ± 0.5 | 8 ± 1.7 | N/A |
| **15436** | 07/16/01 | PTT | Subadult | F | 31 | CR, CM, BI | 40.6 | 2 ± 0.2 | 8 ± 0.7 | N/A |
| **19580** | 07/16/01 | PTT | Adult | F | 233 | CR, CM, BI | 46.8 | 3.6 ± 0.1 | 6 ± 0.2 | 18 ± 2.7 |
| **19582** | 07/17/01 | PTT | Adult | M | 22 | CR, DR, FI | 73.2 | 3.3 ± 0.5 | 11 ± 2.9 | 37 ± 2.8 |
| **15439** | 07/19/01 | PTT | Adult | F | 69 | CR | 18.2 | 3.3 ± 0.4 | 8.5 ± 0.7 | N/A |
| **1.361** | 01/24/02 | VHF | Yearling | F | 102[d] | CR | 5.5 | 3.5 ± 1.1 | 8 ± 4 | N/A |
| **1.371** | 01/24/02 | VHF | Yearling | F | 102[d] | CR, RR | 5.3 | 2.5 ± 1.2 | 9 ± 3 | N/A |
| **1.631** | 01/24/02 | VHF | Yearling | M | 102[d] | CR, FI, LE | 57.1 | 33.4 ± 12.6 | 14 ± 10 | 44 ± 13 |
| **1.641** | 01/24/02 | VHF | Yearling | M | 102[d] | CR | 6.1 | 3.5 ± 1.2 | 8 ± 2 | N/A |
| **1.727** | 01/24/02 | VHF | Yearling | F | 102[d] | CR, PB, DR, DP, PP | 49.0 | 3.3 ± 1.1 | 8 ± 3 | 17 ± 13 |
| **15437**[c] | 01/24/02 | PTT | Adult | M | 102[d] | DE, DP, BL, PT, YB, SB, PB | 69.8 | N/A | 14.0 ± 2.1 | 23 ± 1.5 |

[a]when CR was being used as the primary haul-out site
[b]insufficient data was collected on this seal due to early tag loss; mean depth etc. could not be evaluated
[c]seal only used CR haul-out site immediately after tagging (1/24/02); CR not used as a primary haul-out site
[d]tag still attached to seal at the time of this report

*Haul out sites, with distances (across water) from Castro Rocks (tagging site) in km:*

| | | | |
|---|---|---|---|
| BI = Brooks Island (7.0) | DE = Drake's Estero (64.4) | LE = Land's End (21.2) | PT = Point Bonita (20.7) |
| BL = Bolinas Lagoon (38.5) | DP = Double Point (48.3) | MS = Mowry Slough (64.4) | RR = Red Rock (1.4) |
| CM = Corte Madera Marsh (7.5) | DR = Duxbury Reef (39.0) | PB = Point Blunt, Angel Island (8.7) | SB = Sausalito Boatdocks (11.2) |
| CR = Castro Rocks (--) | FI = Farallon Islands (65.0) | PP = Pillar Point (58.5) | YB = Yerba Buena Island (15.7) |

**Table 9: Summary information on radiotagged (VHF) and satellite-linked tagged (PTT) harbor seals, 2001-2002.**

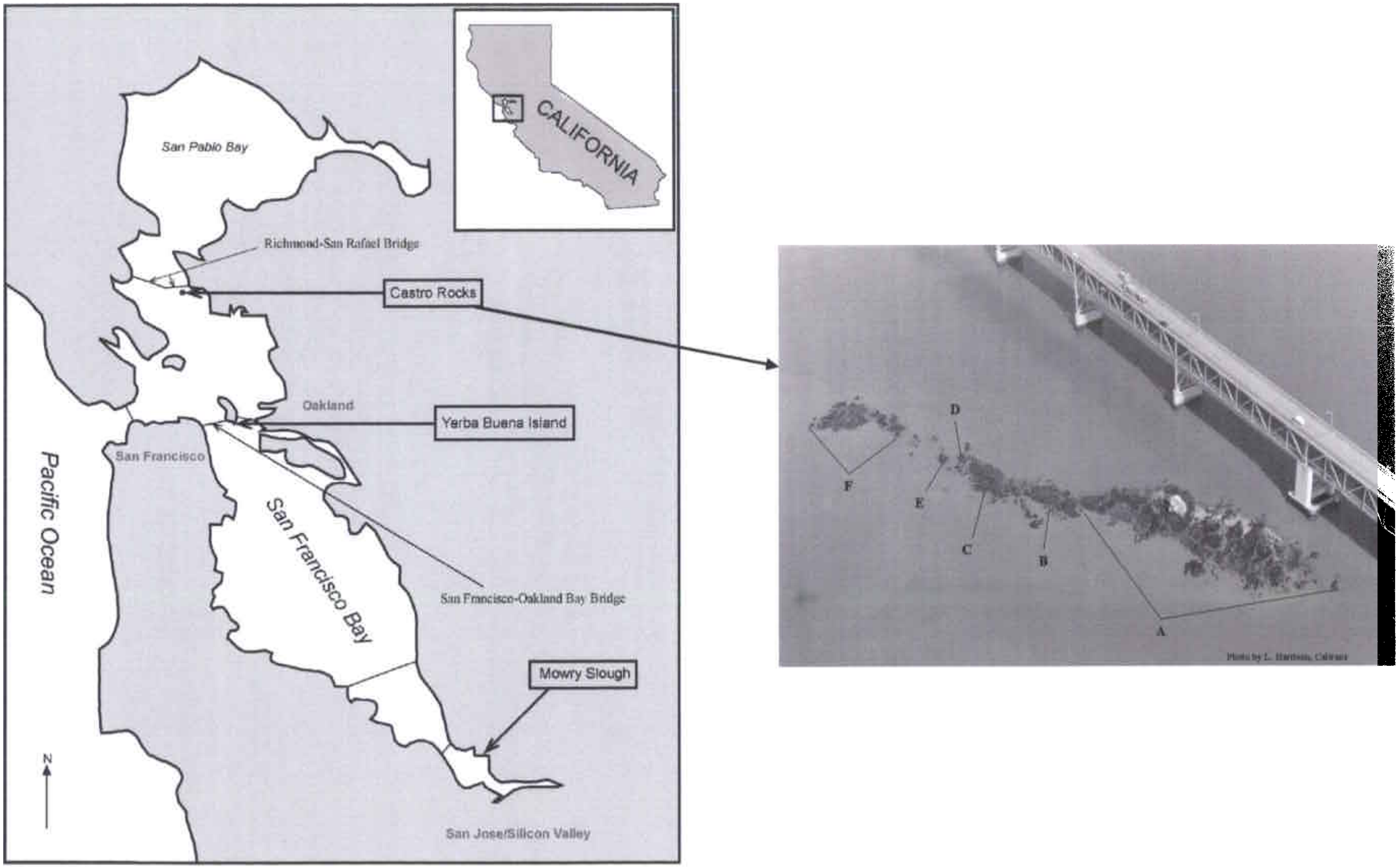



Figure 1. Map of study sites: Castro Rocks, Yerba Buena Island and Mowry Slough, with additional map of subsites A-F at Castro Rocks, Richmond- San Rafael Bridge (San Francisco Bay, CA).

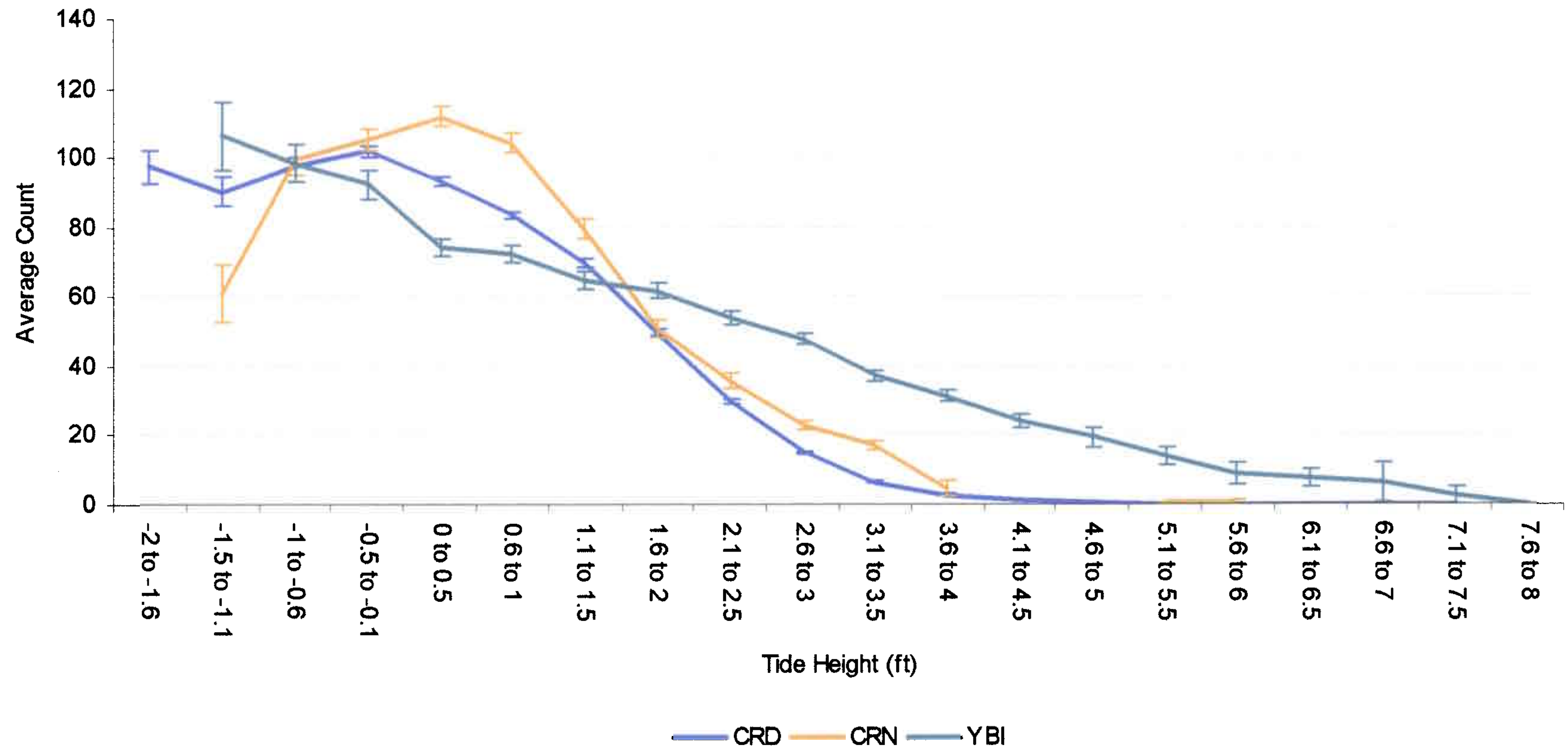



Figure 2. Average count (±SEM) at each survey tide height for Castro Rocks Day, Castro Rocks Night, and Yerba Buena Island; May 1998 – February 2002.

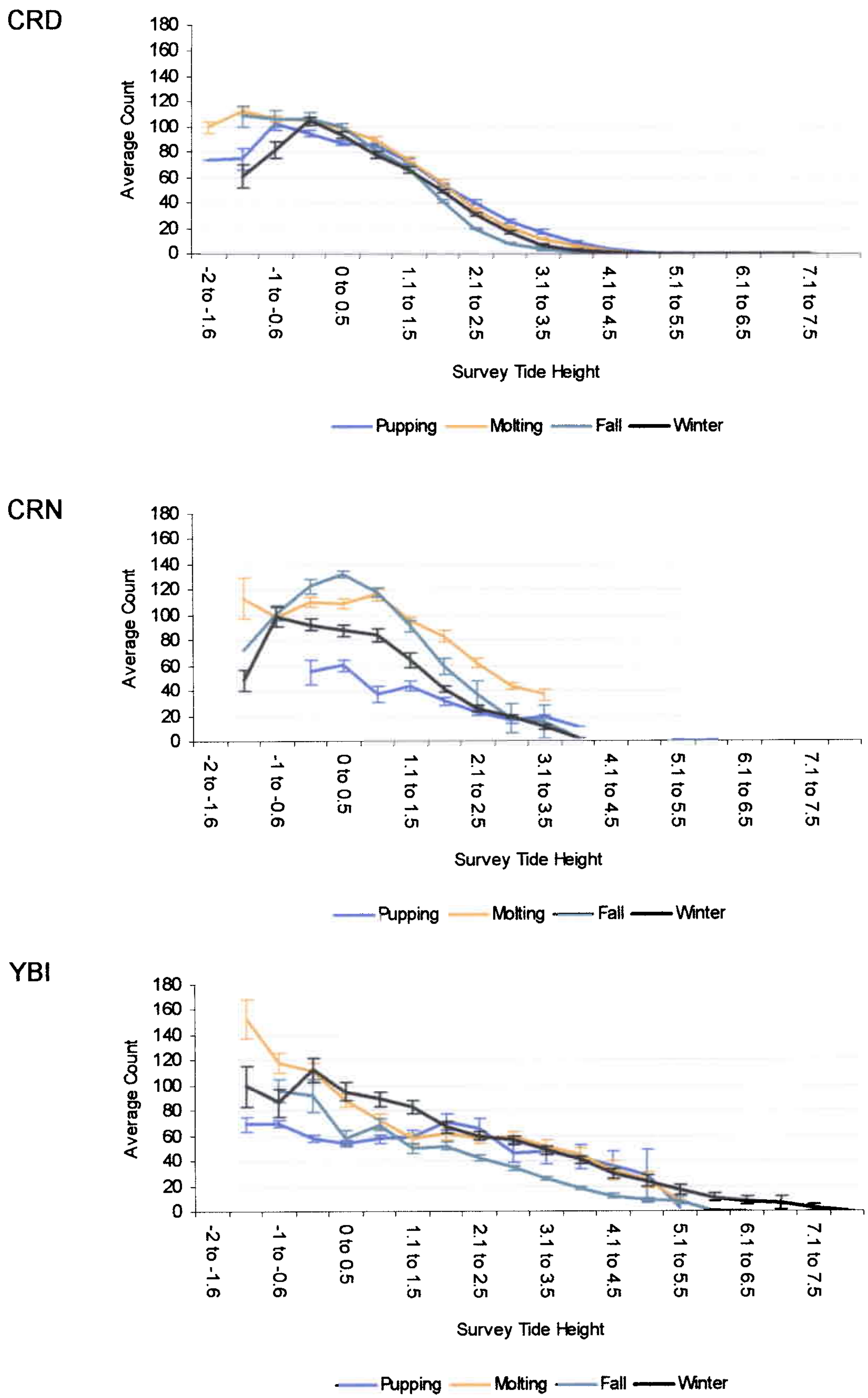



**Figure 3. Average count (±SEM) by survey time tide height at Castro Rocks Day (CRD), Castro Rocks Night (CRN) and Yerba Buena Island (YBI) during the pupping, molting, fall and winter seasons; May 1998 – February 2002**

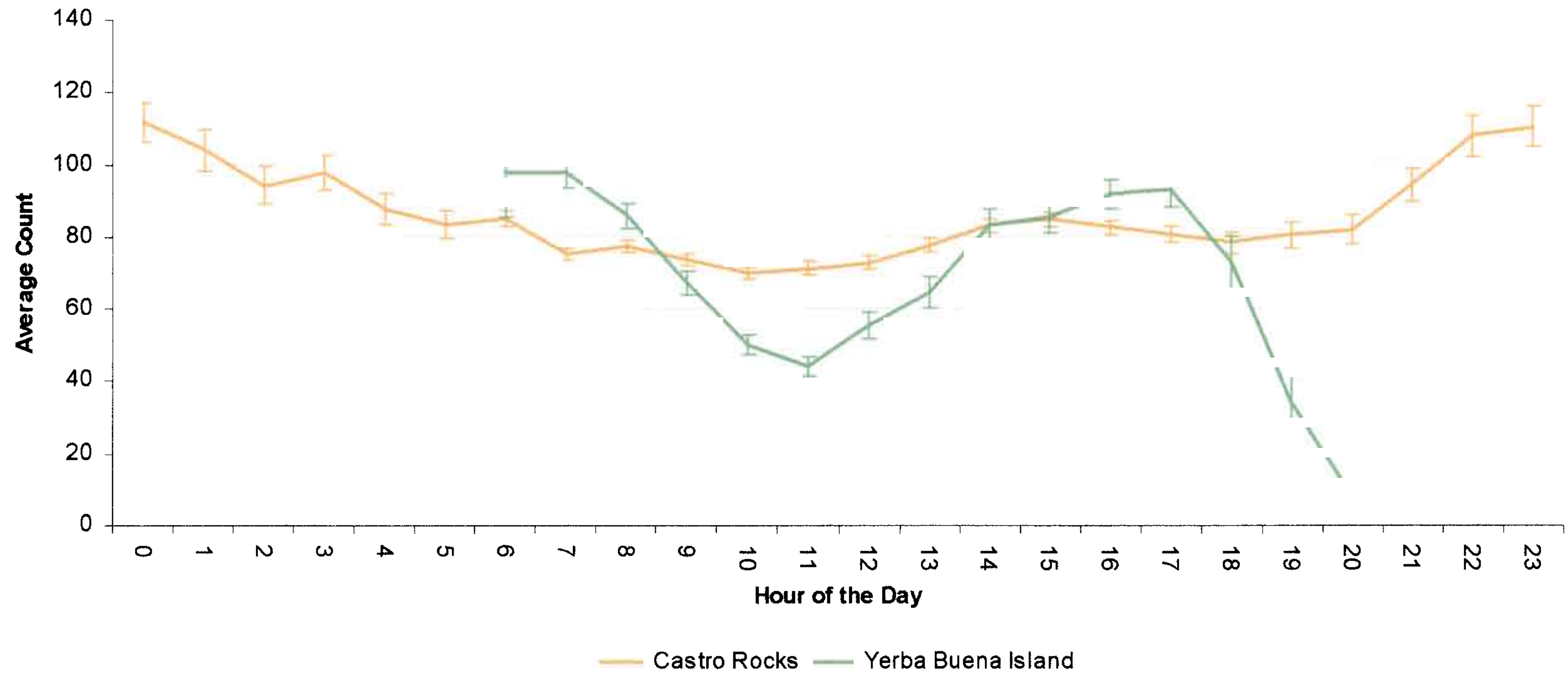
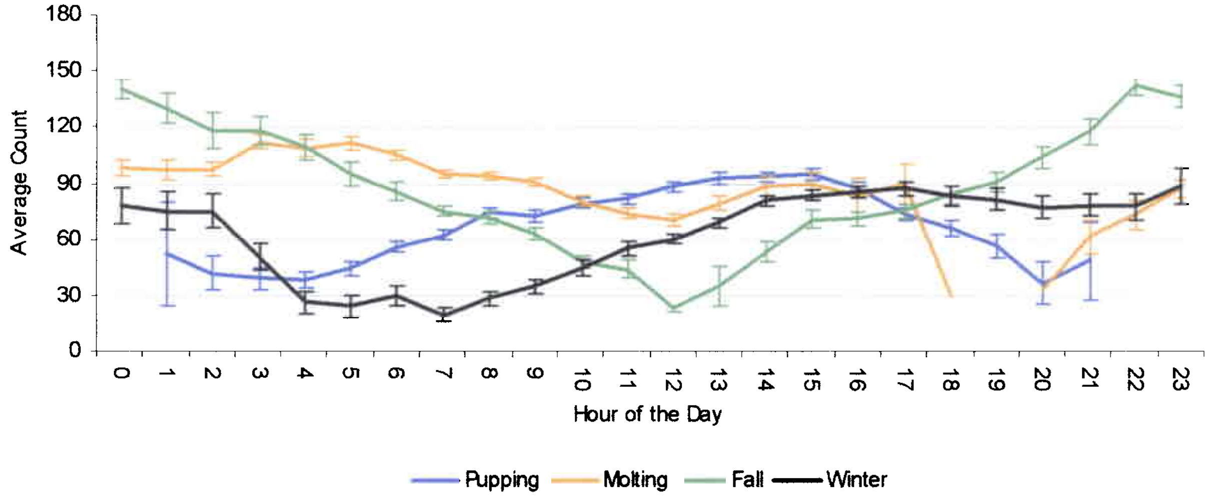



**Figure 4. Average count (± SEM) by hour of the day (May 1998 – February 2002) at Castro Rocks and Yerba Buena Island. Only those surveys taken when the tide height was 2 ft or less were used.**

CR




YBI

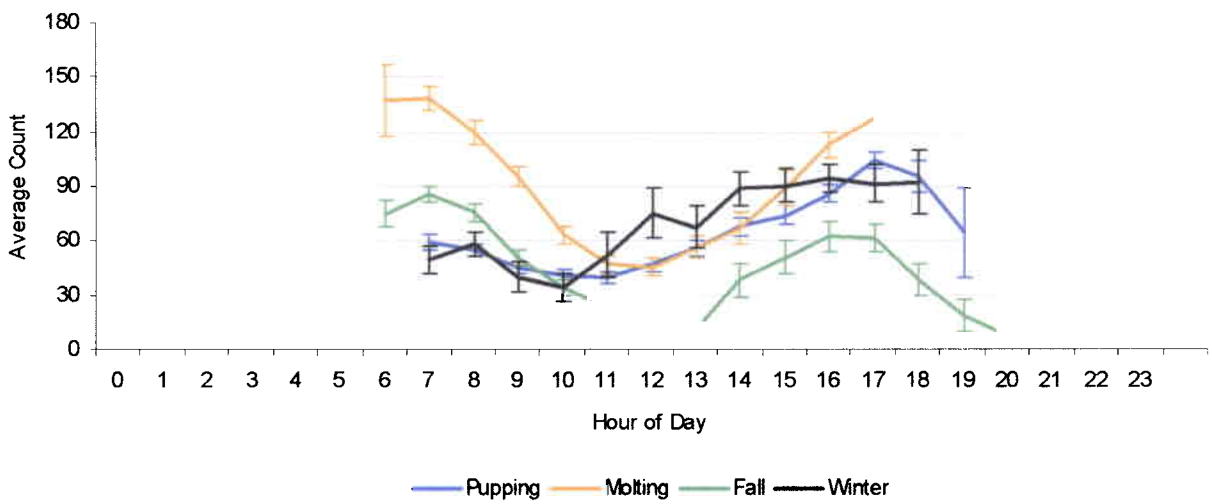



**Figure 5. Average count (± SEM) by hour of the day for Castro Rocks (CR) and Yerba Buena Island (YBI) during the pupping, molting, fall and winter seasons, May 1998 – February 2002.**

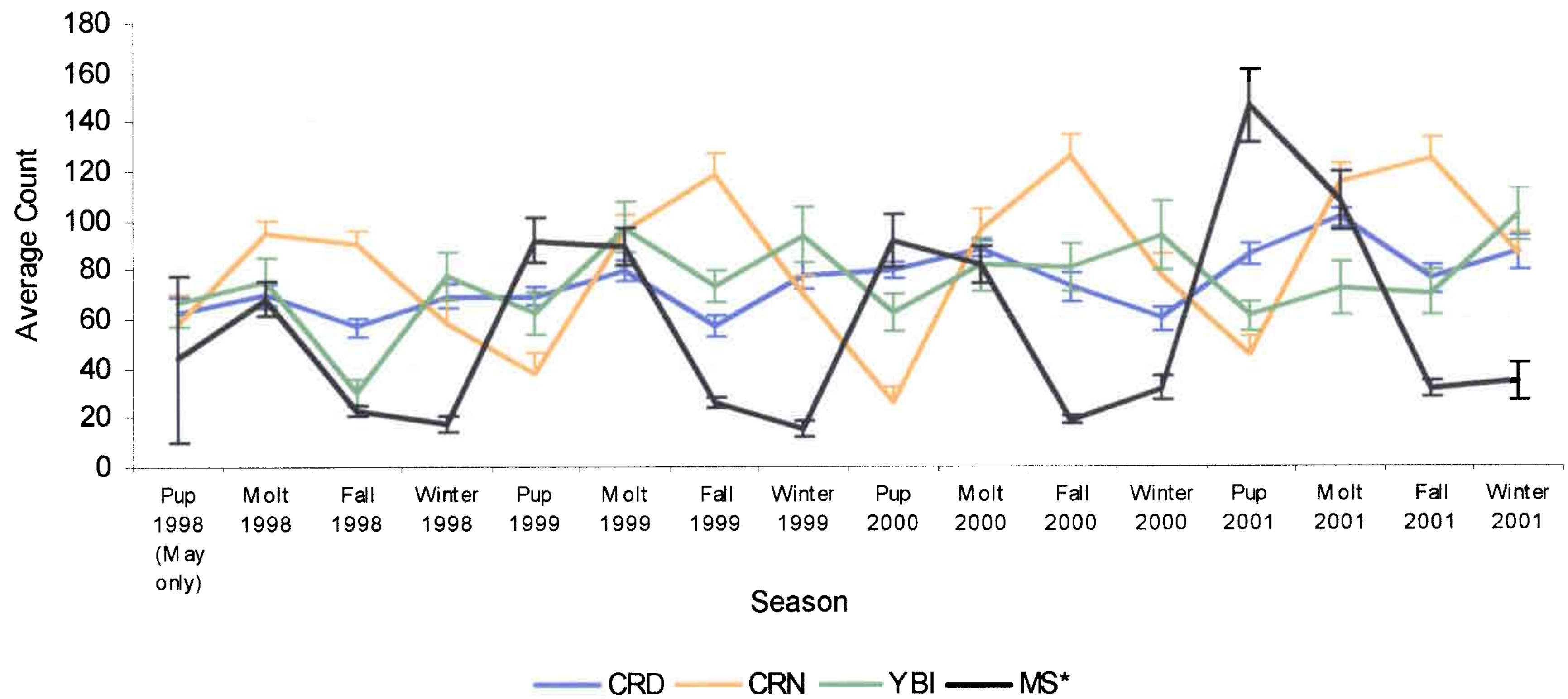



**Figure 6. Average seasonal count (± SEM) at Castro Rocks Day (CRD), Night (CRN), Yerba Buena Island (YBI), and Mowry Slough (MS). Only those surveys taken when the survey tide height was 2 ft or less were used. * Averages for Mowry Slough were calculated regardless of tide height.**

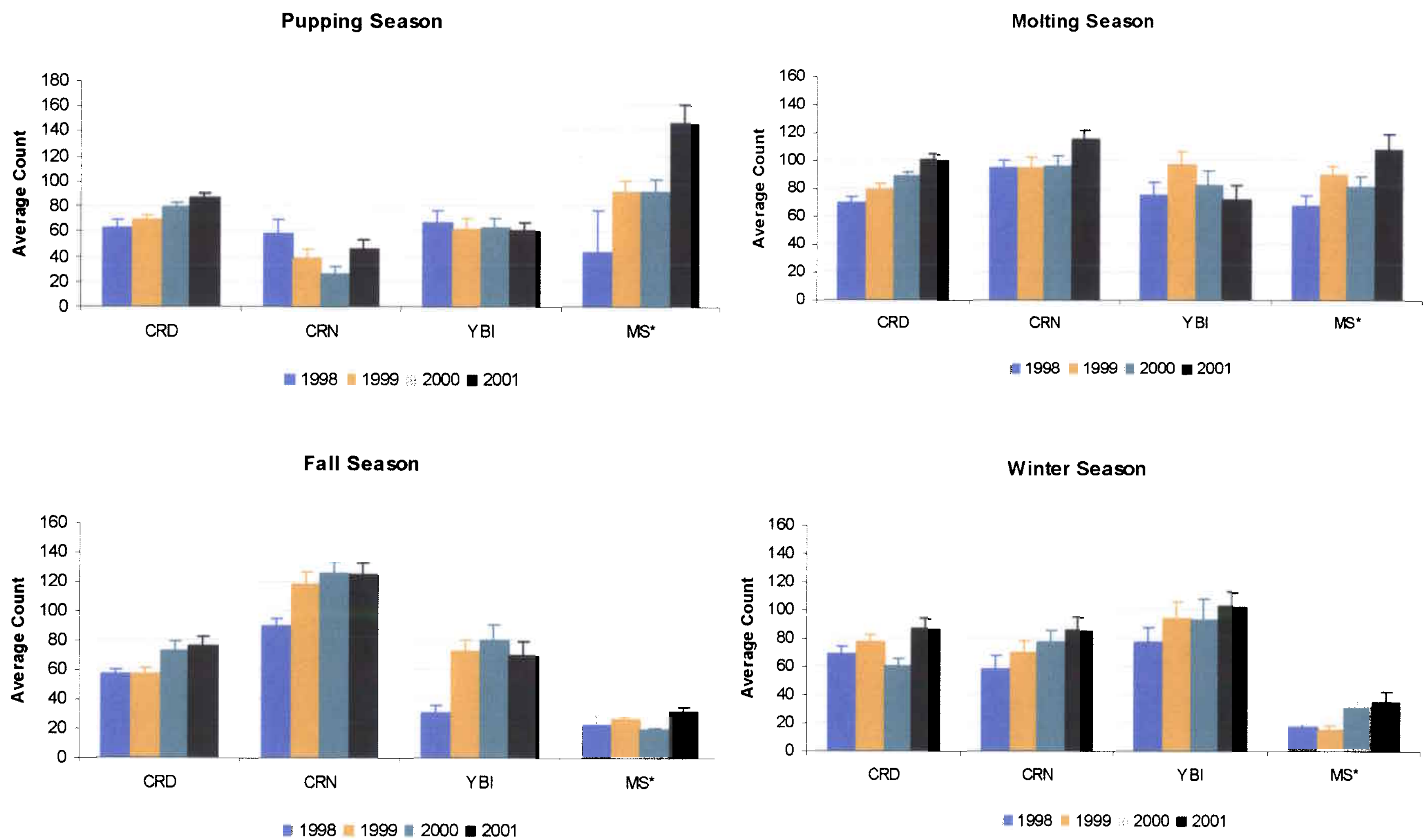
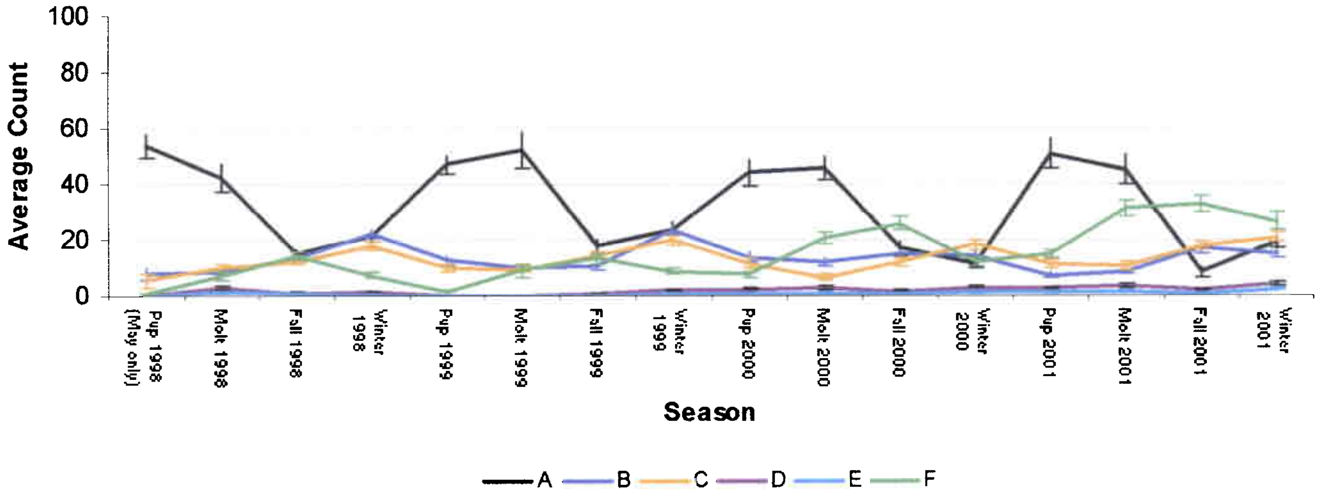



**Figure 7. Maximum seasonal harbor seal counts at Castro Rocks Day (CRD), Night (CRN), Yerba Buena Island (YBI), and Mowry Slough (MS), May 1998 – February 2002. Only those surveys taken with a tide height of ≤2 ft were used.**



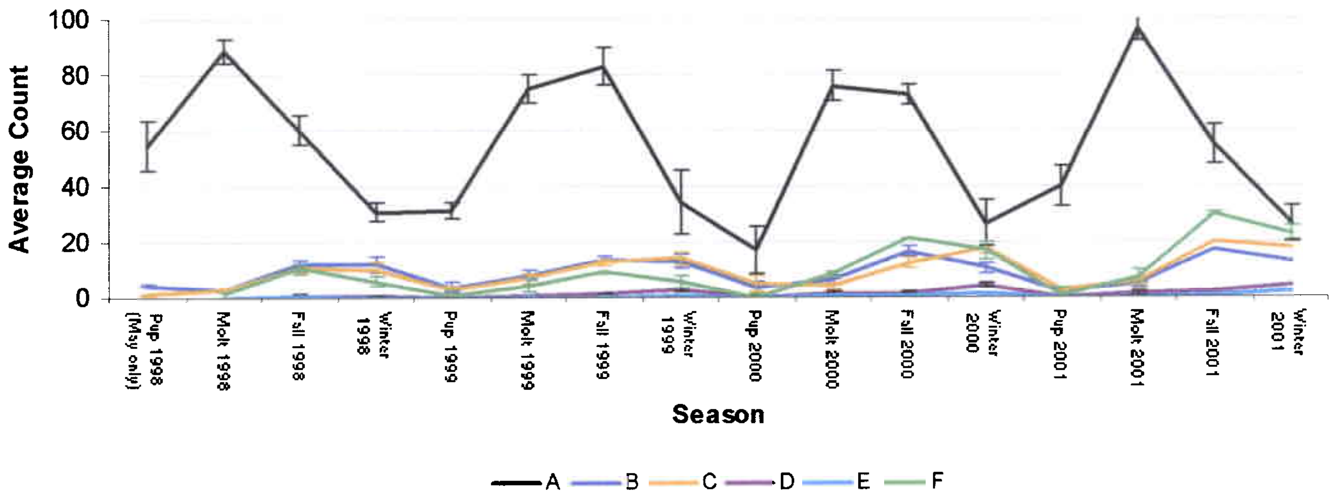




**Figure 8. Average number (± SEM) of seals hauled out on each subsite at Castro Rocks Day (CRD) and Night (CRN) during each season, May 1998 – February 2002. Only those counts taken when the survey tide height was ≤ 2 ft were used.**

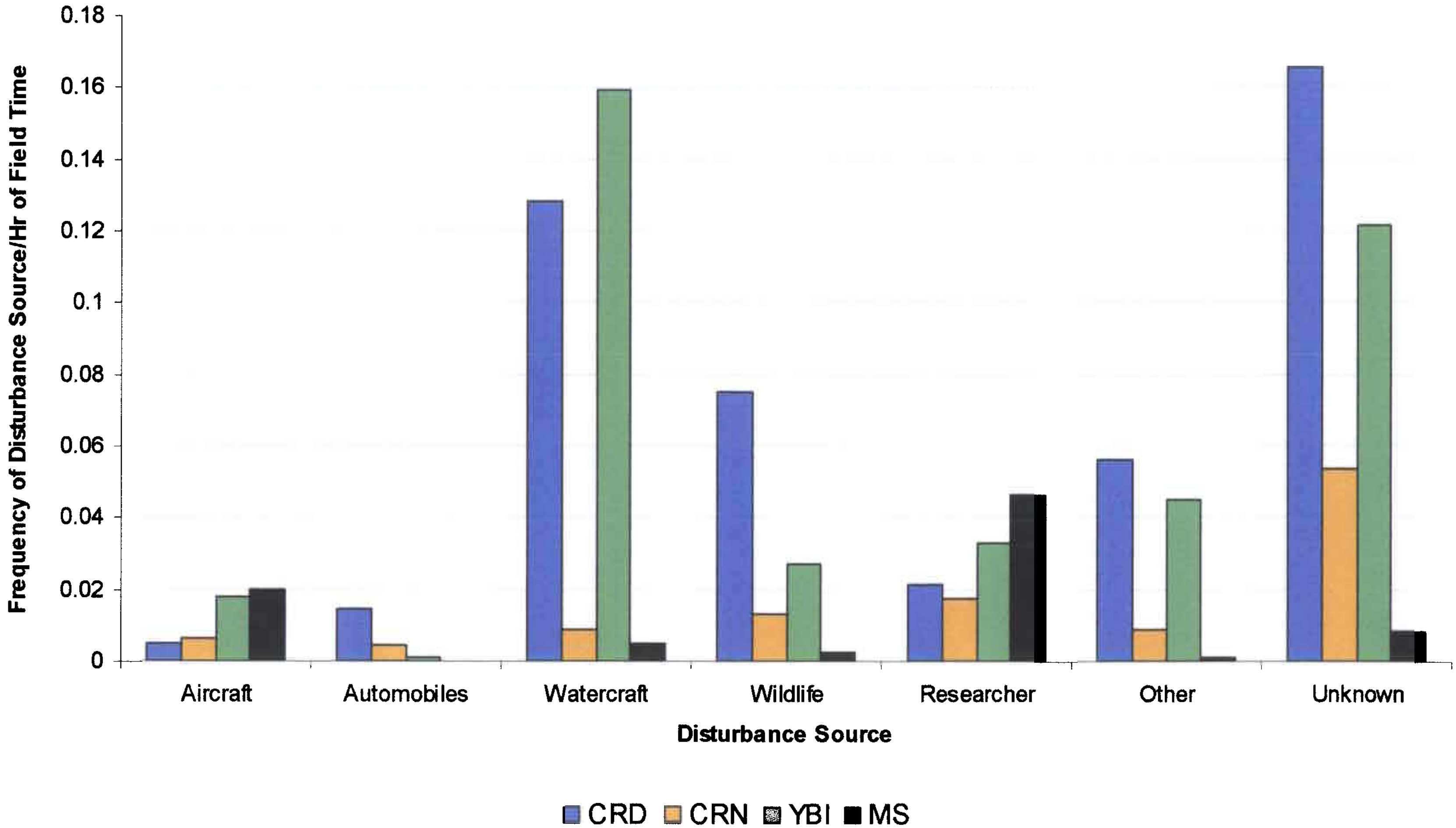



**Figure 9. Frequency per hour of field time for disturbance sources at Castro Rocks Day (CRD), Night (CRN), Yerba Buena Island (YBI), and Mowry Slough (MS). Only those disturbances to cause a flush are included in the figure.**

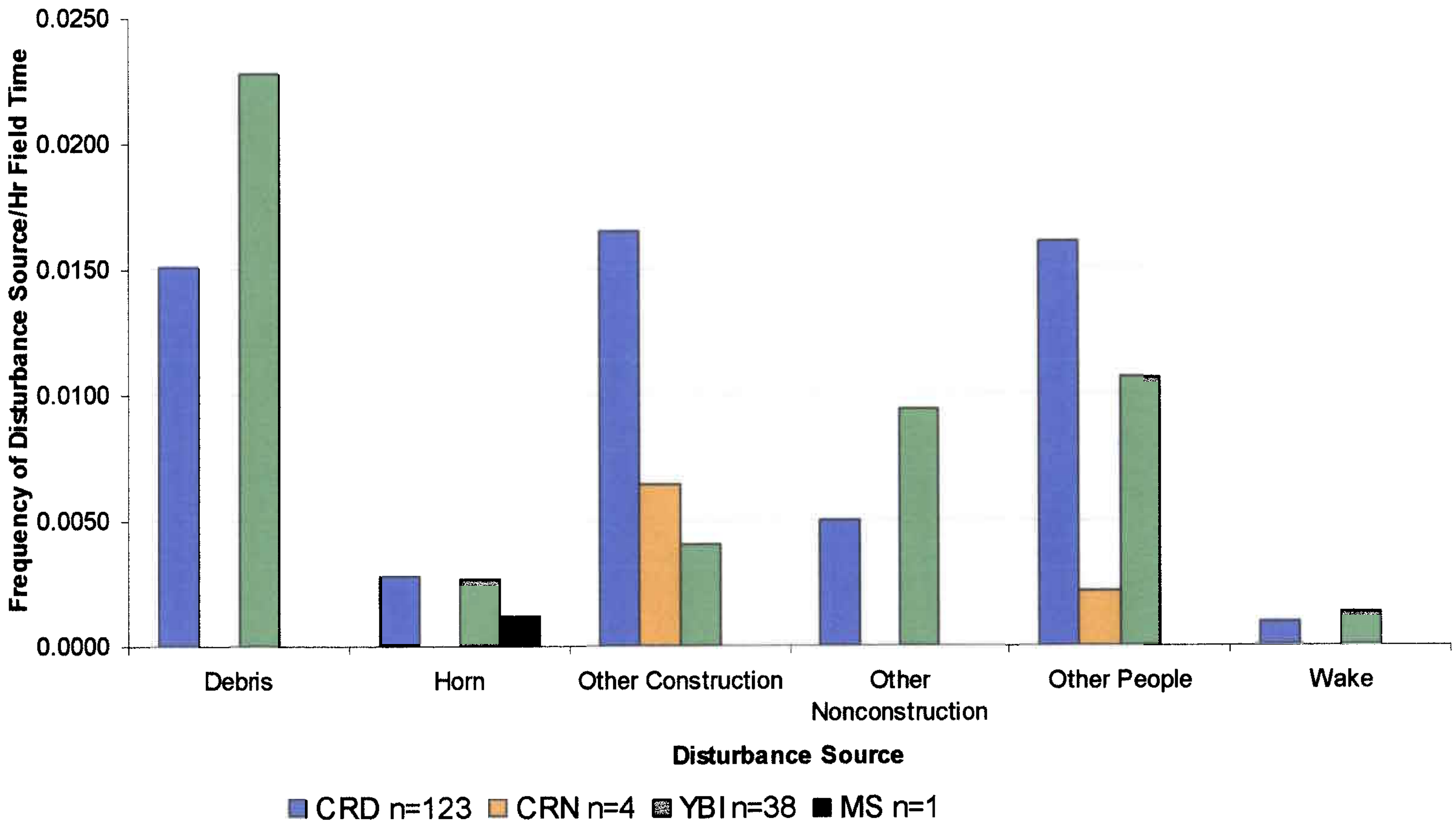



**Figure 10. Frequency per hour of field time for disturbance sources included in the "other" category at Castro Rocks Day (CRD), Night (CRN), Yerba Buena Island (YBI), and Mowry Slough (MS). Only those disturbances to cause a flush are included in the figure.**

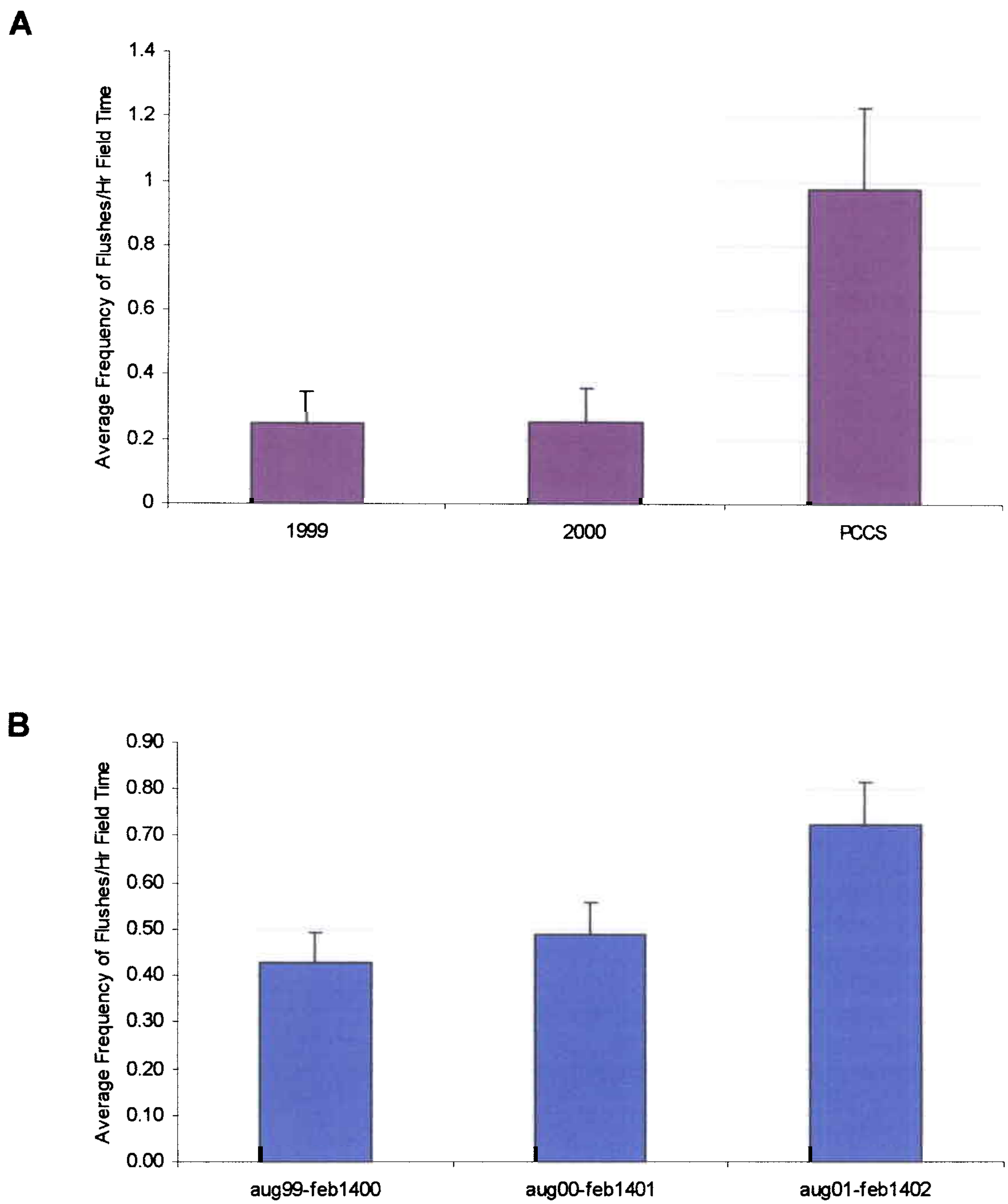



**Figure 11. Average frequency of disturbances/hr of field time to cause a flush during (A) Preconstruction core sampling (PCCS) in January/February 2001 compared to the same time period in 1999 and 2000, and (B) August 1 – February 14 1999, 2000, 2001; the "work period" when construction activities are permitted in the area of the haul out site. Construction activities occurred during January /February 2001 PCCS work and for the duration of the work period in 2001/2002.**

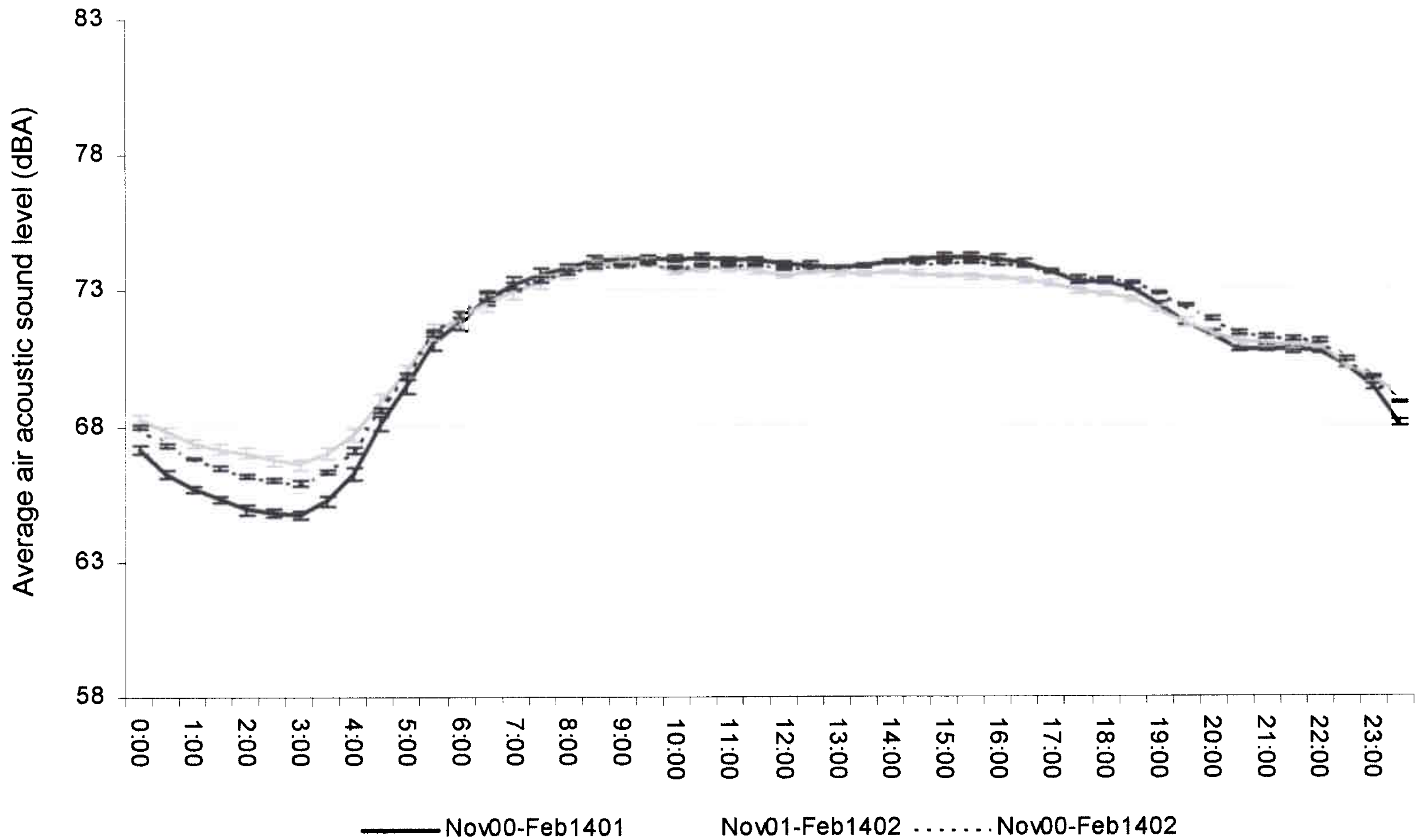



**Figure 12. Average Leq (± SEM) levels at Castro Rocks throughout the day comparing all air acoustic data available (November 2000 – February 2002) with portions of the "work period" when data are available for comparison (November 2000 – February 14, 2001 versus November 2001 – February 14, 2002). Leq represents the level of a constant sound over a period of time that has the same sound energy as the actual (unsteady) sound over the same time period.**

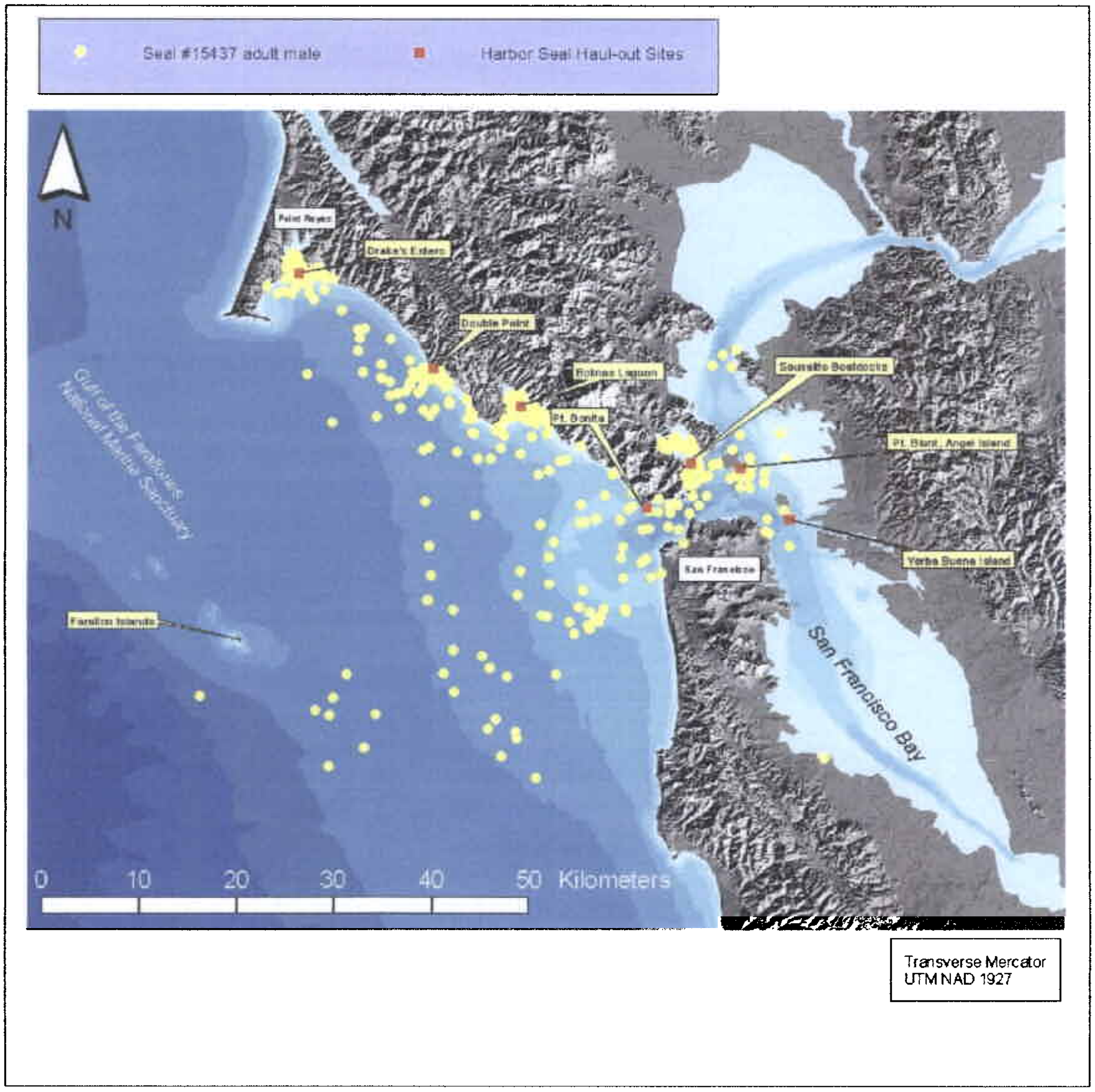



Figure 13: Locations of harbor seal 15437 in and around San Francisco Bay, California, based on satellite-linked telemetry. Seal was tagged in January 2002, and tag duration was 102 days to date.

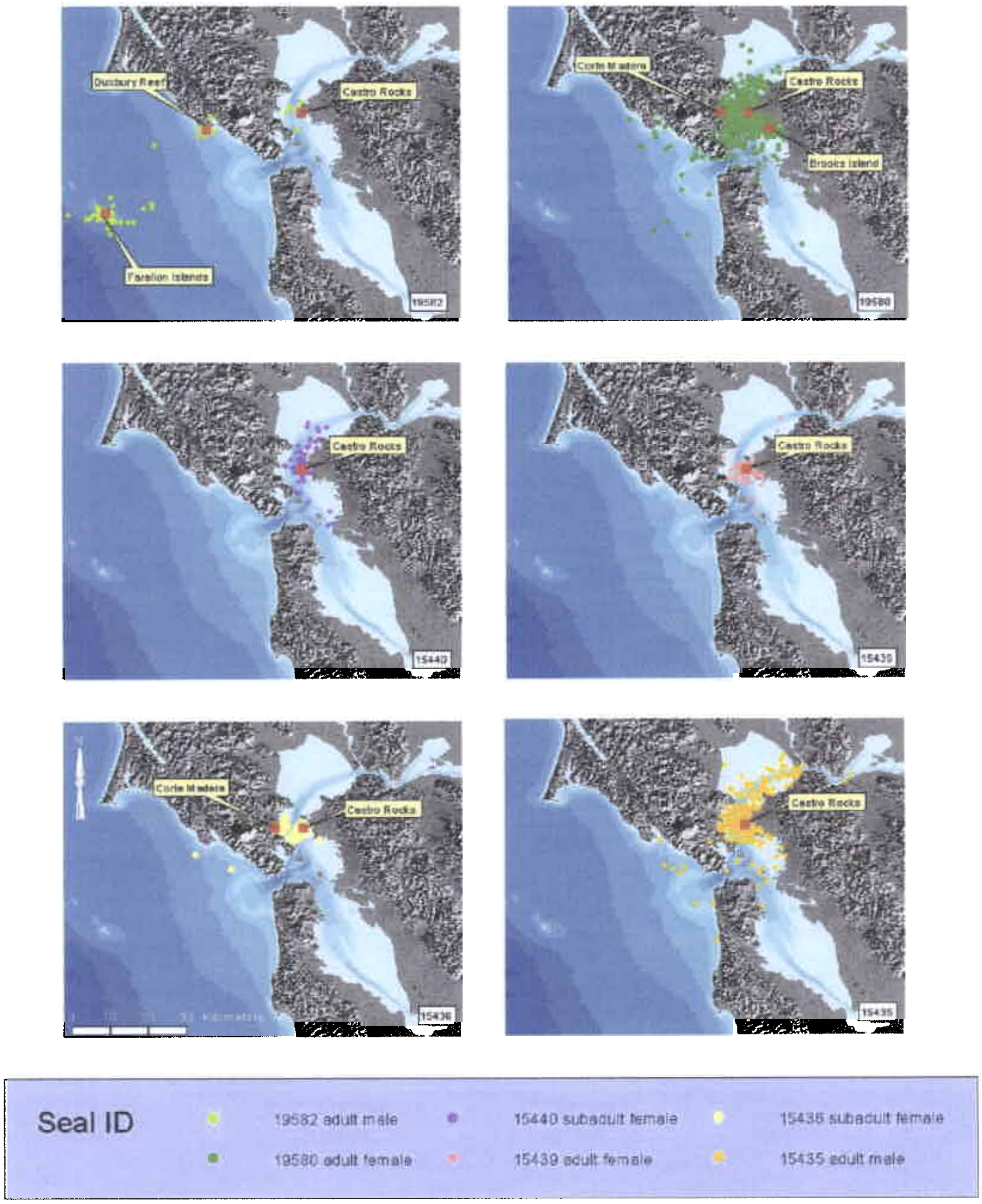



Figure 14: Harbor seal locations in and around San Francisco Bay, based on satellite-linked telemetry. Haul out sites used by each seal are shown in red. Seal 15435 was tagged in January 2001; all other seals were tagged in July 2001. Tag durations for PTT seals ranged from 22 days (19582) to 233 days (19580).

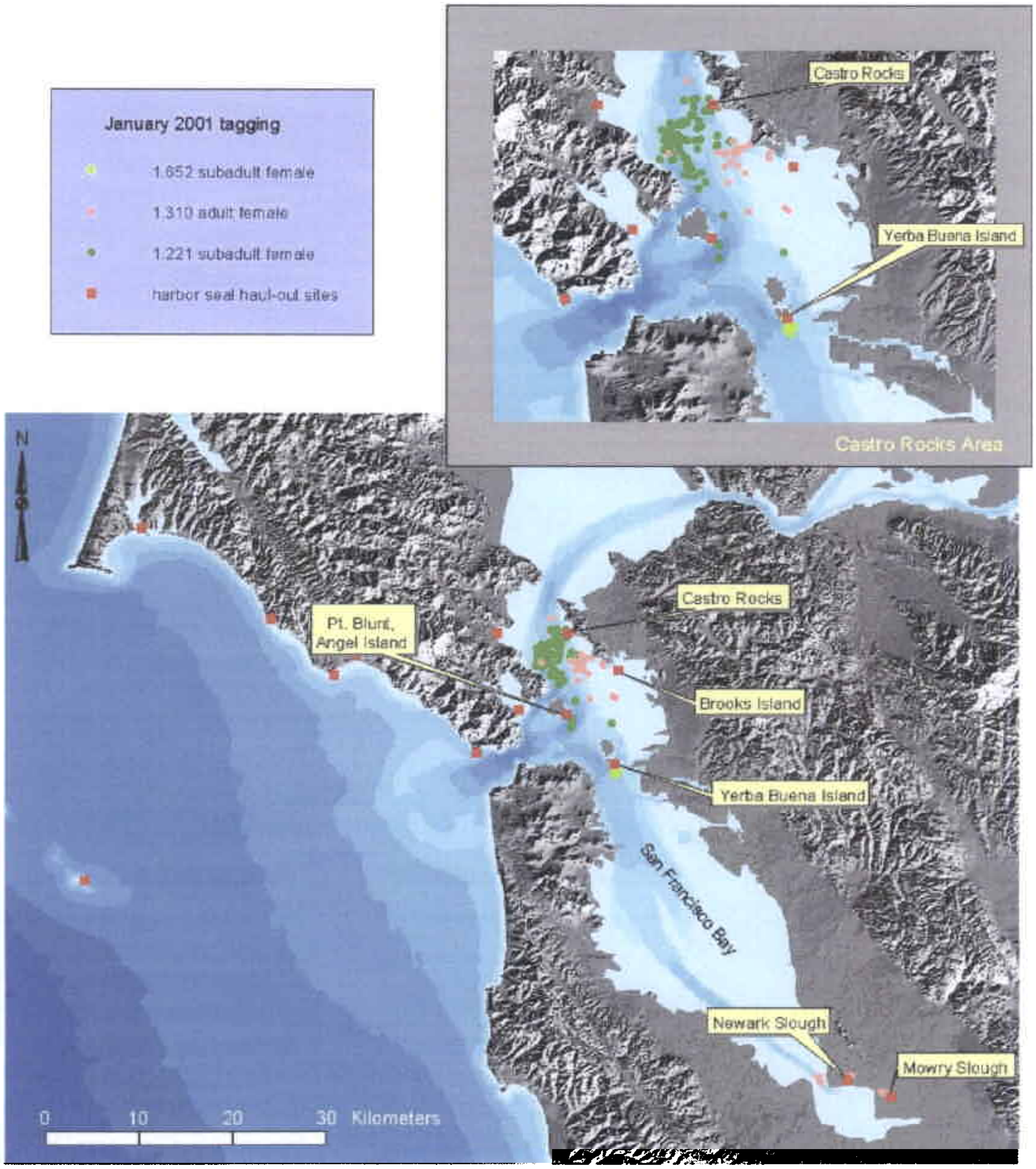



Figure 15 (A): Locations in and around San Francisco Bay, California, of VHF-radiotagged harbor seals tagged at Castro Rocks in January, 2001. Primary haul out sites are shown in red. Maximum tag duration was 50 days.

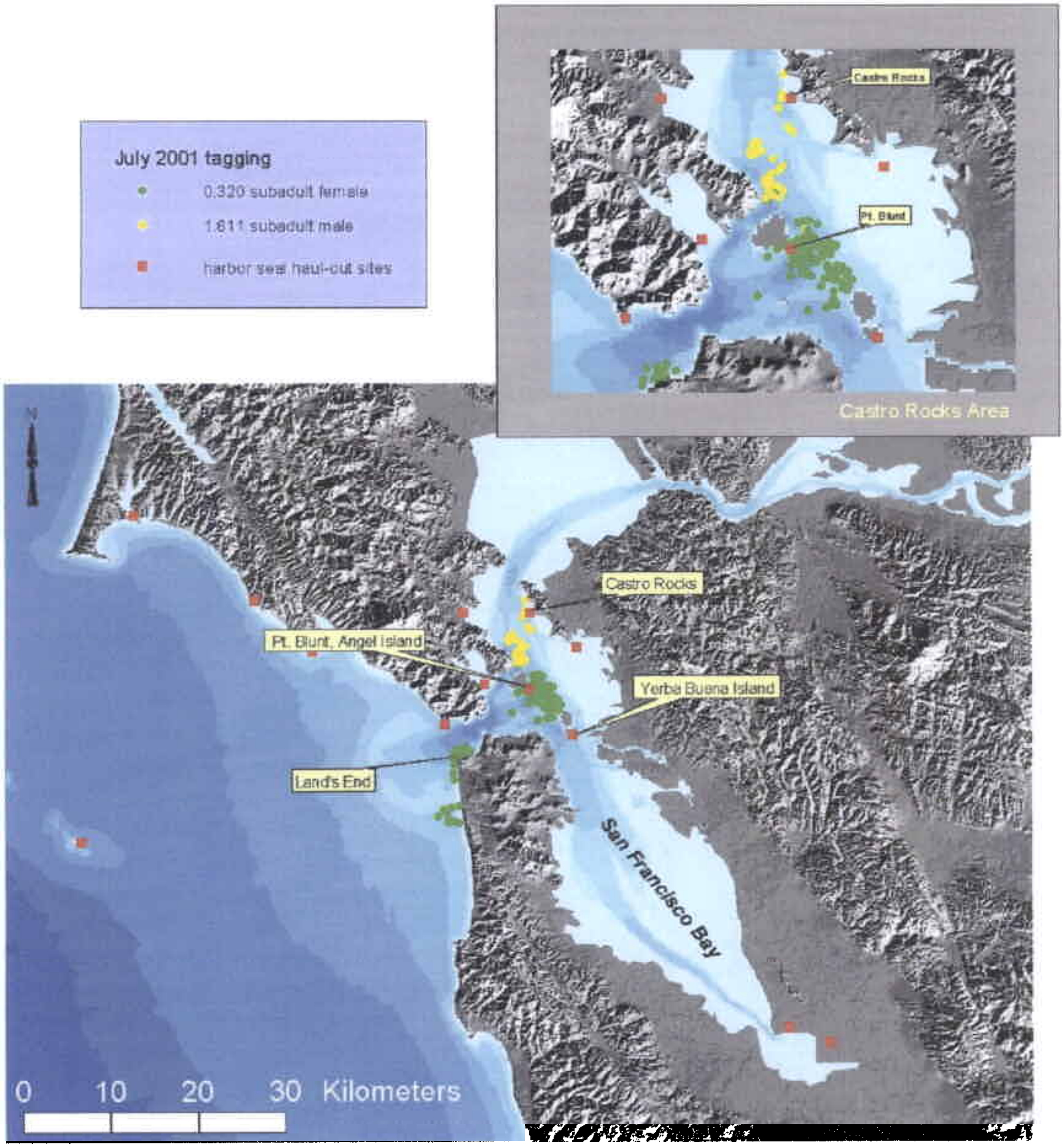



Figure 15 (B): Locations in and around San Francisco Bay, California, of VHF-radiotagged harbor seals tagged at Castro Rocks in July, 2001. Primary haul out sites are shown in red. Maximum tag duration was 124 days.

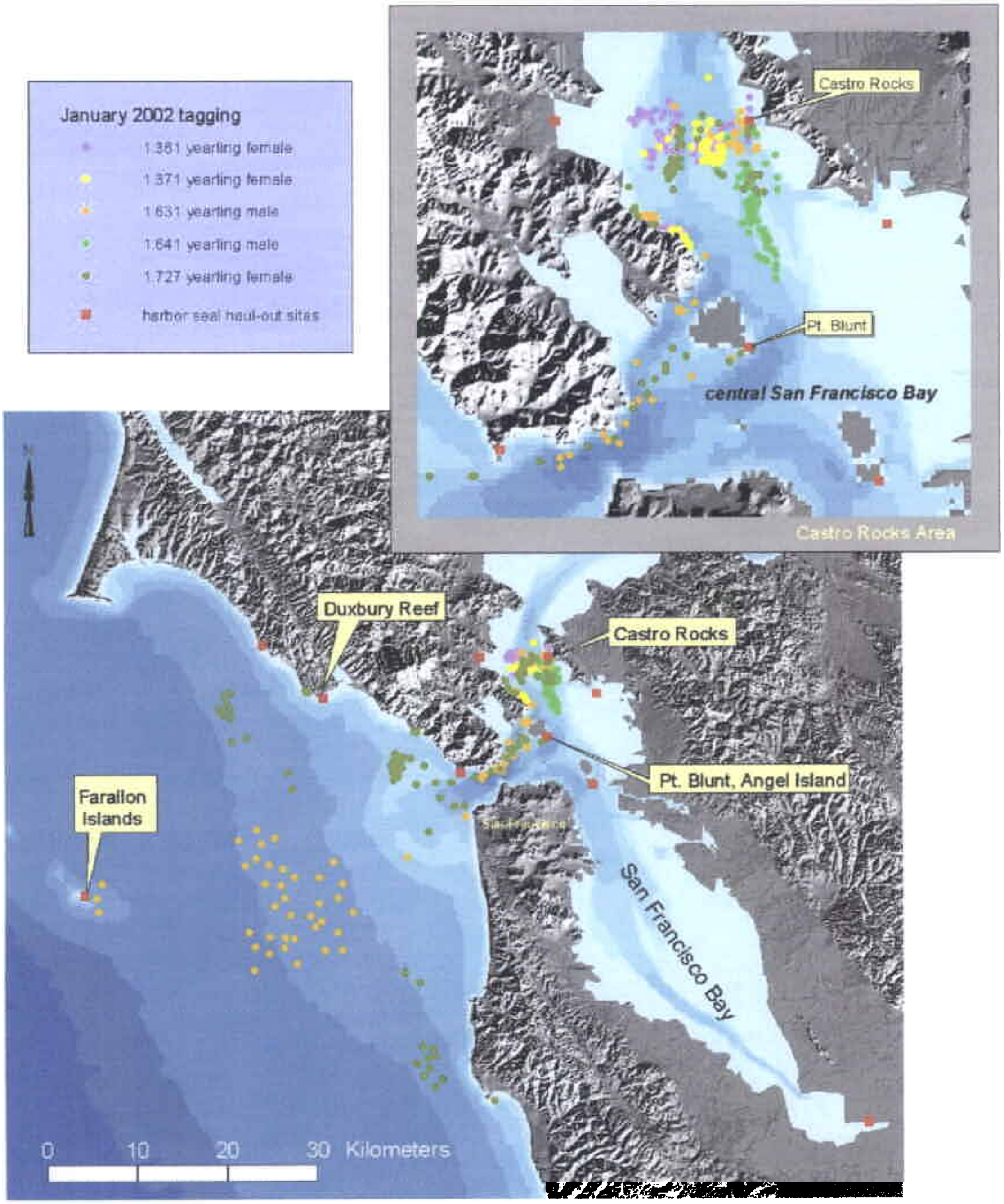



Figure 15 (C): Locations in and around San Francisco Bay, California, of VHF-radiotagged harbor seals tagged at Castro Rocks in January, 2002. Primary haul out sites are shown in red. Maximum tag duration (to date) was 102 days.

## Appendix A – Publications, Posters and Presentations

**Publications:**

Grigg EK, Green DE, Allen SG, Markowitz H, (2002) Diurnal and Nocturnal Haul Out Patterns of Harbor Seals (*Phoca vitulina richardsi*) at Castro Rocks, San Francisco Bay, California, Accepted 2002: California Fish and Game Journal

Surveys of harbor seals, *Phoca vitulina richardsi*, at Castro Rocks, San Francisco Bay (SFB), California, were conducted from May 1998 through April 2001. Surveys were conducted at all hours of the day, and disturbance data and seal responses were recorded continuously during these surveys. Harbor seals hauled out at Castro Rocks during the daytime and nighttime throughout the year. Over the course of the study period, mean nighttime counts were significantly higher than mean daytime counts. Maximum daytime and nighttime seal counts were recorded during the fall season. Tidal dependence alone was not a clear predictor of fluctuations in seal numbers hauling out during the daytime compared to the nighttime. Seals at this site experienced high levels of disturbance from a variety of sources during the daytime, and significantly lower levels of disturbance at night. We believe that, in this highly urbanized environment, high levels of daytime disturbance contribute to the higher use of this haul out site at nighttime, versus daytime. Given projected increases in the number of people living and working around SFB, protecting the integrity of haul out sites in SFB is an important facet of protecting the harbor seal population.

**Posters:**

Grigg EK, Green DE, Allen SG, Markowitz H, Disturbances to Harbor Seals (*Phoca vitulina richardsi*) in San Francisco Bay, California, an Urbanized Estuary. Society for Marine Mammalogy Biennial Conference, Maui HI, November 26 – December 3, 1999

We monitored disturbances to two primary harbor seal haul out sites within San Francisco Bay, from May 1998 through April 1999: Castro Rocks (CR), and Yerba Buena Island (YBI). The major causes of disturbance were human-related: watercraft, aircraft and automobiles. We examined watercraft disturbances in order to evaluate the effects of distance on seal reactions. Watercraft within 200 m of the CR and YBI haul out sites elicited a response from seals 73.1% and 74.4% of the time, respectively, and flushed seals off the haul out sites 29.0% and 10.8% of the time, respectively. Despite the significantly higher occurrence of watercraft near the haul out site at YBI than at CR ($p<0.0001$), animals at YBI were less prone to flush off the haul out site ($p<0.006$). Watercraft close to the haul out site were more likely to flush seals during the pupping season at CR, and during the fall season at YBI. At both sites, watercraft disturbed seals more frequently on weekends than on weekdays (CR: $p<0.05$; YBI: $p<0.006$).

We suggest that the differences in seal reactions at these two locations are due to 1) reproductive status, 2) varying disturbance levels, and 3) habituation. CR is a major pupping site in San Francisco Bay and females with pups may have an increased tendency to flush during the pupping season. Only a few pups occur at YBI and seals were more prone to flush during the fall at YBI, when counts were low and transient animals may be present. Habituation to disturbance by YBI seals may account for the significantly reduced tendency to flush (compared to CR, $p<0.005$). Furthermore, habituation may explain why weekend and weekday seal numbers at YBI were not significantly different, but were significantly different at CR ($p<0.01$).

Green DE, Grigg EK, Petersen HM, Galloway M, Bohorquez AS, Sanders AM, Allen SG, Markowitz H, Trends in harbor seal (*Phoca vitulina richardsi*) haul out patterns at Castro Rocks and Yerba Buena Island in San Francisco Bay, California. Society for Marine Mammalogy Biennial Conference, Maui HI, November 26 – December 3, 1999

*We examined two primary harbor seal haul out sites within San Francisco Bay, California, from May 1998 through April 1999, in order to determine the effects of tide height and time of day on the haul out patterns of the seals. The mean number of seals present at Castro Rocks (CR) and Yerba Buena Island (YBI) varied with tide height. Mean number of seals on the haul out declined as tide height rose at both sites, with the greatest number of seals present when the tide height was ≤2 ft. CR is a mid- to low-tide haul out site, and space on the haul out site is unavailable at high tides. However, haul out space is available at YBI at much higher tides, and we recorded seals at this site up to a 6.5 ft tide height.*

Time of day also influenced the number of seals seen on both haul out sites. At CR, there was a slight drop in mean number of seals using the site from approximately 0500 until 1200, with high mean numbers of seals present on the haul out during the night (2100-0300). At YBI, there appears to be a stronger relationship between time of day and haul out site use, with a sharp drop in the numbers from 1000-1200. Based on surveys taken between 0600-2000, we suggest that there is a bimodal haul out pattern at this site, with high numbers present in the early morning hours (prior to 0800) and in the mid-afternoon (1300-1700).

Tide height appears to be a stronger factor in haul out patterns at CR, due to the geography of that site. The relationship between time of day and haul out numbers may be due to the role of human-related disturbance to seals at both sites.

Bohorquez A, Grigg EK, Green DE, Markowitz H, Allen S, Red Pelaged Harbor Seals in the San Francisco Bay. Society for Marine Mammalogy Biennial Conference, Maui HI, November 26 – December 3, 1999

Red pelage in the northern pacific harbor seal (*Phoca vitulina richardsi*) in San Francisco Bay has been recorded in the bay since 1969. There have also been sightings in Oregon and Washington, Japan, Ireland and Maine, but not in the numbers seen within the San Francisco Bay. Allen et al. (1993) reported that red-pelage resulted from iron oxide adherence to the keratin surface on the shaft of the hairs, possibly related to flocculation of ferrous iron in the water column. Red-pelage occurs in all sex and age classes, except for pups. In May of 1999, a higher proportion of red pelaged harbor seals were recorded in the San Francisco Bay seal population (42.9% at Castro Rocks, 49.3 at Yerba Buena Island) using the highest proportion of red pelaged animals in the maximum total count. Using the average proportion of red pelaged animals over the month of May, however, we see similar proportion to those previously recorded (28% in 1999, 27% in the 1980s; Allen et al. 1993). At Yerba Buena Island, we also see a drop in the proportion of red pelaged animals in the winter months (6.4% in December), this may correspond to the Herring migration through the area surrounding the island, which may attract more seals from the coastal colonies. In spring 1999, at Castro Rocks, a higher daily proportion of red pelaged mothers were seen in April (67%). The daily proportion of red pelaged mothers dropped significantly in the month of May (18%). Comparison of daily proportions for the two months showed a significant difference ($p<0.02$) for the two months. Individual mothers were identified and followed throughout the breeding season. Many red pelaged mothers were seen with late stage pups, suggesting successful pupping.

Galloway MJ, Grigg EK, Green DE, Markowitz H, Allen, SG, Differential Scanning between Male and Female *Phoca vitulina richardsi* Hauled-Out at Yerba Buena Island, California. Animal Behaviour Society Conference, Georgia, August 5-10, 2000.

Previous studies have shown conflicting results in scanning behavior between adult male and female harbor seals. Scanning refers to movements that increase the seals visual field. This study compares differences in scanning bouts by hauled-out seals at Yerba Buena Island, CA (YBI) between October 1998 and September 1999. YBI is primarily utilized by males at all times of the year. Up to three seals at different locations of the site were selected. Seal behavior was recorded for 15 seconds per minute for up to 8 10-minute observations during the 45 4-hour surveys. The number of scanning bouts from focal male and female seals was analyzed. Overall results suggest that females scan more frequently. The differences between scanning bouts were significant when comparing seals near the water. Females near the water scanned significantly more than males on surveys with below average disturbance levels and above average seal counts indicating that several factors may have an influence on female scanning behavior.

Green DE, Grigg EK, Markowitz H, Allen SG, Update on the population status of harbor seals (*Phoca vitulina richardsi*) in San Francisco Bay, California. Marine Conservation Biology Institute 2nd Symposium, San Francisco, CA, June 2001.

Since May 1998, we have been surveying the San Francisco Bay harbor seal population. We evaluated population numbers and percent pups at three major Bay haul out sites (Castro Rocks, Mowry/Newark Slough and Yerba Buena Island) and compared our current data to historical harbor seal counts for the Bay. Our data support the theory of a stable Bay population, in contrast to the dramatic rise in harbor seal numbers along the coast of California. Although our maximum harbor seal counts at Castro Rocks are significantly higher than seal counts at that site in the 1980's, a nearby haul out site (Strawberry Spit) was abandoned by harbor seals in the early 1980's. Consequently, some seals may have shifted from the Strawberry Spit site to Castro Rocks. Seal numbers have remained stable at Mowry Slough, the Bay's largest harbor seal rookery, since the 1970's. Yerba Buena Island is not generally recognized as a harbor seal rookery, and data at that site is limited prior to 1995. However, we have noted stable seal numbers, with a slight increase in pup numbers, at Yerba Buena Island. The lack of growth in the Bay seal population may be due to one or more of the following: limited food availability, pollutants in the Bay waters affecting female reproductive success, limited suitable haul out space in the face of increased shoreline development, and increases in human disturbance around haul out areas.

Bohorquez, AS, Nickel BA, Grigg EK, Green DE, Bouse RM, Jaffe BE, Allen SG, Markowitz H. The high price of gold: possible effects of hydraulic mining on harbor seals in San Francisco. Conservation Biology Conference, Hilo, HI, July 2001.

The Gold Rush of the 1853 brought prosperity to California; however, the costs of the methods used to extract that gold are still being assessed today. The use of highly pressurized water washed over one billion tons of sediment from the Sierra Nevada foothills, a portion of which remains in the San Francisco Bay (SFB). The SFB also has the highest proportion of harbor seals with a red discoloration of their pelage. The red color results from iron oxide adherence to the keratin surface on the shaft of the coat hairs. This iron may adhere while seals are foraging in sediment contaminated by re-exposed hydraulic mining debris. In order to test this hypothesis, a model will be developed from a collaborative approach integrating behavioral, geological and chemical methods by, (1) synthesizing behavioral information obtained from VHF radio and satellite tagged harbor seals into a Geographic Information System (GIS); (2) classifying habitat from a digital terrain model based on bathymetric and hydraulic mining sediment data; and (3) chemically analyzing the red pelage for the hydraulic mining signature and other metals that may be linked to the debris. We present this plan to demonstrate the benefits of collaborative analysis for conservation issues.

## Grigg EK, Green DE, Allen SG, and Markowitz H Population Status and Trends of Harbor Seals (*Phoca vitulina richardsi*) in San Francisco Bay, CA, 1970-2000, State of the Estuary Biennial Conference, San Francisco, CA , October 2001.

Numerous large-scale construction activities are scheduled for San Francisco Bay (SFB) over the next decade, including two bridge retrofit projects and the San Francisco Airport runway expansion. These projects have the potential to affect the population of harbor seals, the only resident marine mammals in SFB. Ground-based counts were used to evaluate population numbers and population changes between 1970 and 2000. Since May 1998, we have been surveying three major harbor seal haul out sites in San Francisco Bay (SFB), California: Mowry Slough (MS), Castro Rocks (CR) and Yerba Buena Island (YBI). We evaluated current data against historical harbor seal counts for the Bay, including an additional SFB haul out site (Strawberry Spit, SS) that was abandoned in the early 1980's due to development and a shift in food resources. In addition, we developed a model of population trends of seals in SFB using stepwise polynomial regressions on the natural logarithm of maximum yearly seal counts. Although the SFB population has remained stable over the past 30 years, there have been shifts in the number of seals using each site during both the pupping and non-pupping seasons. During the pupping season, maximum counts increased at both CR and YBI, while counts at MS decreased. During the non-pupping season, maximum counts increased at all sites. We believe that increases at these sites were influenced by the abandonment of the SS haul out site and by increases at nearby coastal sites. A cubic regression provided the best fit for data during both the pupping and non-pupping seasons. We plan to use this model to compare predicted and actual seal counts in SFB during future large-scale construction activities over the next decade. Harbor seals are a top predator species in SFB, and are faced with high levels of anthropogenic stress. Evaluating long-term population trends is an essential component in understanding and protecting this resident species.

## Nickel B, Grigg KE, Green DE, Allen SG, Markowitz H, Pacific harbor seal (*Phoca vitulina richardsi*) distribution, movement, and foraging activities within an urban estuary: implications for the effects of seismic retrofitting in San Francisco Bay, California. Society for Marine Mammalogy Biennial Conference, Vancouver, CA, November 2001.

Continual urban development and human population growth in San Francisco Bay (SFB), California, increases the possibility that harbor seals will abandon preferred breeding habitat due to anthropogenic disturbance and habitat degradation. A primary harbor seal haul-out site and rookery, Castro Rocks (CR), is adjacent to the Richmond-San Rafael Bridge (RSRB) in northern SFB. From January to May, 2001, we conducted a pilot study on harbor seal movements and foraging activities using a combination of VHF and satellite-linked telemetry. This study complements an ongoing monitoring program investigating the effects of a large-scale seismic retrofit of the RSRB on the SFB harbor seal population.

Four harbor seals were captured and tagged (VHF: 1 adult female, 2 subadult females; PTT: adult male) at CR in January 2001. Three of four tagged harbor seals showed high site fidelity to CR and used consistent foraging areas within the study area. An adult female and one sub-adult female were recorded at CR 60% and 90% of study days, respectively; an adult male hauled out at CR during 81% of haul-out site surveys. Harbor seals consistently foraged in areas within a mean distance of 6 km from the primary haul out site. Home range estimates varied widely from 50 km2 (sub-adult female) to 638 km2 (adult female). These results support previous studies indicating harbor seals exhibit high haul-out site fidelity in and around the pupping season, and illustrates the importance of CR as a significant site for resident seals of SFB. With preferred habitat shrinking at an accelerated rate, the potential loss of important SFB sites poses a threat to the sustainability of the resident harbor seal population. Further research on the movements and foraging activities of harbor seals in relation to the seismic retrofit is required to accurately assess potential effects to the resident population.

Austin K, Bohorquez A, Green D, Grigg E, Markowitz H, and Allen S. Observations of epimeletic behavior in Northern Pacific harbor seal mothers toward their dead pups at Castro Rocks, San Francisco Bay, California. Society for Marine Mammalogy Biennial Conference, Vancouver, CA, November 2001.

Occurrences of epimeletic behavior of mothers toward their dead offspring have been frequently documented in cetaceans, especially prominent in bottlenose dolphins, yet this phenomenon has rarely been observed in pinnipeds. Further, the few existing records of this care-giving behavior in pinniped mothers directed to their dead pups only lasted for short durations. While unavoidable factors may cause the death of the offspring, the response of the mother may be to continue nurturance regardless of the cost. Data concerning mother-pup interactions of Northern Pacific harbor seals were gathered at Castro Rocks, San Francisco Bay, California throughout the 2001 pupping season. During this time period, two adult females were observed carrying their dead pups in the water surrounding the site, placing the dead pups onto the site and following the dead pups back into the water after they had been washed away with the rising tides. Unlike previous observations, in both of our cases the mother-pup pairs were seen for extremely prolonged periods of time. In the first instance, the pup survived for 3 days although it was born with a partial lanugo coat. The mother exhibited the aforementioned behaviors toward the pup for at least 4 weeks after it had died. In the second case, the pup was not observed while alive but the pair was seen together for at least 3 weeks. Photographic records established the identity of the mother and pup and confirmed that these were two distinct instances. We believe that this is the longest recorded observation of epimeletic behavior of mothers toward their offspring in pinnipeds.

Green DE, Grigg EK, Markowitz H, Allen SG, The Impacts of Preconstruction Core Sampling at the Richmond-San Rafael Bridge, CA on Harbor Seal (*Phoca vitulina*) Haul Out Patterns. Society for Marine Mammalogy Biennial Conference, Vancouver, CA, November 2001.

Castro Rocks (CR), the second largest rookery in San Francisco Bay, is located next to the Richmond-San Rafael Bridge. Prior to a large-scale seismic retrofit of the bridge, preconstruction core sampling (PCCS) was conducted from January 24 through February 14, 2001 near CR. We examined changes in harbor seal site use during PCCS and summarized PCCS-related disturbances. We have been monitoring harbor seals at CR since May 1998. During surveys, biologists recorded 1) total count of seals present on CR and 2) behavioral data pertaining to disturbances to seals. Mean number of seals on CR during PCCS was significantly less than during the same time period in 1999 and 2000 ($F=4.29$, $p<0.05$, $df=46$), as well as during the 3 weeks following PCCS work ($t=2.75$, $p<0.05$, $df=15$). The frequency of disturbances/hr of field time was significantly higher during the PCCS compared to the same time period in 1999 and 2000 ($F=6.43$, $p<0.005$, $df=46$). In addition, the number of disturbances to cause a flush/hr was significantly higher during the PCCS than during the same time period in 1999 and 2000 ($F=5.73$, $p<0.01$, $df=46$). Mean number of disturbances/hr and mean number of flushes/hr were greater during PCCS compared to the 3 weeks prior to and following PCCS, although not statistically significant. Taken collectively, these data suggest that seal haul out patterns at CR will be impacted when the seismic retrofit construction is conducted near the haul out site. What, if any, long term effects construction activities will have on harbor seal haul out patterns at CR remains unclear at this time.

Grigg EK, Nickel B, Green DE, Allen S, Markowitz H. Spatial Analysis of Habitat Use Patterns of Harbor Seals (*Phoca vitulina richardsi*) in San Francisco Bay, California. Society for Marine Mammalogy Biennial Conference, Vancouver, CA, November 2001, GIS Remote Sensing Workshop.

A Geographic Information System (GIS) was used to investigate relationships between harbor seals and hydrographic features in San Francisco Bay (SFB), California. From January to May 2001, we conducted a pilot study on harbor seal habitat use in SFB, using VHF and satellite-linked telemetry. Analysis was done on an integrated database of behavioral and environmental data. Four harbor seals were captured and tagged (1 adult female, 2 subadult females; PTT: 1 adult male) at a major SFB haul-out site in January 2001. Using ArcView GIS, we overlaid harbor seal locations onto a digital elevation model (USGS DEM) of bathymetric features. We calculated distances traveled from primary harbor seal haul-out sites to foraging areas, as well as the farthest distance traveled by each seal from its primary haul-out site. Fixed kernel utilization distributions were estimated in order to define individual home ranges and foraging areas. Additionally, a spatial dive model (interpolated from point locations of mean dive length) was created to investigate dive patterns within individual home ranges. Three of four seals tagged in the pilot study used consistent foraging areas, within a mean distance of 6 km from each individual's primary haul-out site. Maximum distance traveled by any seal tracked was 59.58 km, representing a shift by the adult female to an alternate rookery. Home range estimates varied widely from 50 km2 (subadult female) to 638 km2 (adult female). There was some overlap of harbor seal foraging areas with prominent SFB bathymetric features, such as major shipping channels. Mean water depths in which seals were located ranged from 6-11 m. This study complements an ongoing monitoring program investigating the effects of a large-scale seismic retrofit of the Richmond-San Rafael Bridge on the SFB harbor seal population. The use of GIS to analyze spatial patterns of habitat use within SFB greatly enhances the ability to assess effects on the resident population. Research continues on harbor seal movements and foraging activities using VHF and satellite-linked telemetry. Future analysis will incorporate vegetation and prey distribution, sediment type, and primary productivity in order to accurately model environmental features encountered by the SFB harbor seal population.

Bohorquez A., Markowitz, H., Allen, S. Factors Influencing harbor Seal Pupping Behaviors at Castro Rocks, San Francisco Bay, California. Society for Marine Mammalogy Biennial Conference, Vancouver, CA, November 2001.

The seismic retrofit of the Richmond-San Rafael Bridge (RSRB) in the San Francisco Bay, poses many threats to the local colony of Pacific harbor seals (Phoca vitulina richardsi) in San Francisco Bay (SFB). Effects may be as obvious as site abandonment, or as subtle as slight changes in haul out pattern. For mother-pup pairs, availability of optimal haul out space is important for pup growth and survival. In this study, haul out patterns of mother-pup pairs were monitored at Castro Rocks, a haul out site adjacent to the RSRB. We sectioned Castro Rocks into different quadrants to determine if there was a correlation between environmental variables and use of each quadrant by the mother-pup pairs. Over three years, we found a significant difference in quadrant usage by mother-pup pairs ($F=15.6$, $p<0.02$, $df=16$). The reasons for these differences may have multiple causes including weather, topography, depth, or proximity to human activities. We considered the effects of environmental factors (temperature, rain, cloud coverage, wind speed and direction) each day on the number of pups in each quadrant, to determine if there was a significant relationship. From this, we designed a model for the number of pups that we predict to be in each quadrant, given existing environmental and anthropogenic factors. In the upcoming years, if we see a change in quadrant use by mother-pup pairs after the seismic-retrofitting of the RSRB begins, we can eliminate environmental factors as a cause by using this model.

**Presentations**:

Green DE, Grigg E, Allen S, and Markowitz H, Nocturnal Haul Out Patterns of Harbor Seals (*Phoca vitulina richardsi*) at Castro Rocks, San Francisco Bay, California. The Wildlife Society Western Conference, Monterey CA, January 1999

Night counts of harbor seals hauled out at Castro Rocks, located near the eastern end of the Richmond-San Rafael Bridge, were collected from May 1998 through September 1998. This work was conducted as part of a project monitoring the effects of Caltrans' seismic retrofit of the bridge on this seal population. This information serves as baseline data against which future counts, collected during and following the bridge construction work, will be compared.

Seals were consistently present in high numbers on the haul out at night. The maximum monthly night count steadily increased over the five-month period from 81 in May to 140 in September. These numbers are comparable to maximum monthly daytime seal counts, which ranged from 114 to 134 during the study period, with no obvious trend such as is seen with the night counts.

This site is subject to higher levels of human disturbance during the day due to watercraft, and the higher volume of vehicular traffic on the bridge. The consistent nighttime use of Castro Rocks by seals may reflect a response to high daytime disturbance levels.

Bohorquez AS, Galloway MJ, Green DE, Grigg EK, and Allen SG, Markowitz H, Differential Response of Pacific Harbor Seals (*Phoca vitulina richardsi*) Towards Kayaks Compared to Other Watercraft. Animal Behaviour Society Conference, Georgia, August 5-10, 2000.

Previous studies have considered the effects of various types of watercraft disturbances on the haul-out patterns and behavioral responses of harbor seals. We considered the variation in occurrence of kayaks within 200m in comparison with other types of watercraft at two harbor seal haul-out sites within San Francisco Bay, California. Since kayaks are more maneuverable they often advance closer to the haul out site than other types of watercraft. A higher proportion of kayaks elicit a disturbance response from the seals than all other types of watercraft within 200m of the haul-out sites. Kayaks within 200m also caused a higher proportion of flushes. This differential response to the kayaks is a consequence of the proximity of the kayaks to the seals. Kayaks are more likely to elicit disturbance responses from hauled-out harbor seals because they are quiet and low to the water. These factors may not allow the seals to detect kayaks until they are much closer to the haul-out site and may lead to a higher startle response.

Grigg EK, Green DE, Allen SG, Markowitz H, An Analysis of Relationships between Environmental Variables and Harbor Seal (*Phoca vitulina richardsi*) Haul Out Patterns at Castro Rocks, San Francisco Bay, CA. The Wildlife Society Western Section Annual Meeting, Feb. 22-24, 2001. Sacramento, CA.

We surveyed a primary harbor seal haul-out site in San Francisco Bay, California, May 1999 - August 2000, in order to examine seasonal relationships between environmental variables and seal haul out patterns. Since tide height was correlated with seal counts, we used a subset of our data to control for this relationship while examining other variables. Multiple regressions were run to identify relationships between total seal number and air temperature, water temperature, solar radiation, wind speed and wind chill. In addition, a t test was used to compare seal counts on rainy days vs. nonrainy days.

As harbor seal haul out patterns vary by season, we examined data from each season (pupping, molting, fall, winter) independently. During the pupping season, all environmental variables, except for rain, influenced the number of harbor seals hauled out: the higher the air temperature, the lower the number of seals hauled out, whereas increases in water temperature, solar radiation, wind speed and wind chill were all related to increases in seal counts. During molting season, increases in both wind speed and wind chill were related with increases in seal counts. In contrast, when each weather variable was taken independently, there were no significant relationships between weather variables and the number of harbor seals hauled out during fall and winter. Overall, rain effected the number of seals hauled out – with fewer seals present on rainy days. The influence of weather variables should not be generalized across sites or seasons since each location, season and even population has its own unique set of characteristics to be considered.

Bohorquez, AS, Green DE, Grigg EK, Markowitz H, Allen SG. Current status of red-pelaged harbor seals within the San Francisco Bay. Conservation Biology Conference, Hilo, HI, July 2001.

A previous study of the San Francisco Bay (SFB) red-pelaged harbor seals suggests a significant difference in haul out use by these seals at three sites within the bay. Allen et al. (1993) reported that red pelage resulted from iron oxide adherence to the keratin surface on the shaft of the hairs, likely related to foraging behavior. This coloration tends to make the red fur more brittle, leading to the loss vibrissae. Using several methods of comparison, a significant difference in the number of seals with red pelage was found between the central bay and the north and south bays. Continued analysis of this population from June 1999 to December 2000 showed significantly more of red-pelaged seals used the north and south bay haul out sites ($p<0.05$). We found red-pelaged mothers gave birth earlier in both pupping seasons ($p<0.05$). These results may indicate that red-pelaged mothers are older or foraging in nutrient rich areas, presenting a possible balance between foraging efficiency and the cost of the red-pelage. We recommend using this demographic data and the red-pelage as an indicator of optimal foraging areas and therefore identifying these areas from protecting.

Grigg, E.K.[1], Green, D.E.[1], Allen, S.G.[1,2], Nickel, B.[1], Markowitz, H.[1] and Gulland, F.[3] Overview of current monitoring of harbor seals (*Phoca vitulina richardsi*) in San Francisco Bay, CA, 6th Biennial Conference on Research in the Gulf of Farallones. San Francisco, CA, October 2001.

Numerous large-scale construction activities are scheduled for San Francisco Bay (SFB) over the next decade, including two bridge retrofit projects and the San Francisco Airport runway expansion. These projects have the potential to affect the population of harbor seals, the only resident marine mammals in SFB. Ground-based counts were used to evaluate population numbers and population changes between 1970 and 2000. Since May 1998, we have been surveying three major harbor seal haul out sites in San Francisco Bay (SFB), California: Mowry Slough (MS), Castro Rocks (CR) and Yerba Buena Island (YBI). We evaluated current data against historical harbor seal counts for the Bay, including an additional SFB haul out site (Strawberry Spit, SS) that was abandoned in the early 1980's due to development and a shift in food resources. In addition, we developed a model of population trends of seals in SFB using stepwise polynomial regressions on the natural logarithm of maximum yearly seal counts. Although the SFB population has remained stable over the past 30 years, there have been shifts in the number of seals using each site during both the pupping and non-pupping seasons. During the pupping season, maximum counts increased at both CR and YBI, while counts at MS decreased. During the non-pupping season, maximum counts increased at all sites. We believe that increases at these sites were influenced by the abandonment of the SS haul out site and by increases at nearby coastal sites. A cubic regression provided the best fit for data during both the pupping and non-pupping seasons. We plan to use this model to compare predicted and actual seal counts in SFB during future large-scale construction activities over the next decade. Harbor seals are a top predator species in SFB, and are faced with high levels of anthropogenic stress.

Evaluating long-term population trends is an essential component in understanding and protecting this resident species.

Green, DE, Grigg, EK, Allen, SG, Markowitz, H. San Francisco Bay Harbor Seals. Monthly district-wide meeting for Caltrans, Oakland, CA, December 2001.
Presentation on the current findings of the project for the monthly district meeting. No abstract available.

Grigg, EK, Green, DE, Allen, SG, Markowitz, H. The Richmond Bridge Harbor Seal Survey. 8th Annual Wildlife and Aquatic Animal Medicine Symposium, University of California at Davis, January 2002.
One-hour presentation summarizing the work of the Richmond Bridge Harbor Seal Survey. No abstract available.

Green DE, Grigg EK, Markowitz H, Allen SG, San Francisco Bay Harbor Seals. Bishop O'Dowd High School, Oakland. Outreach Presentations. April 2002.
Four one-hour discussion groups about harbor seals in San Francisco Bay, California. No abstract available.

APPENDIX B
LIST OF ACRONYMS

| Acronym | Definition |
|---|---|
| BEZ | Boat Exclusion Zone |
| Caltrans | California Department of Transportation |
| CRD | Castro Rocks Day |
| CRN | Castro Rocks Night |
| DEM | Digital Elevation Model |
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| IHA | Incidental Harassment Authorization |
| MF | Mud Flats (Mowry Slough Subsite) |
| MSN | Mowry Slough North (Mowry Slough Subsite) |
| MS | Mowry Slough |
| MSS | Mowry Slough South (Mowry Slough Subsite) |
| NSP | North Salt Pile (Mowry Slough Subsite) |
| NW | Newark Slough (Mowry Slough Subsite) |
| PTT | Platform Terminal Transmitter |
| SFB | San Francisco Bay |
| SSP | South Salt Pile (Mowry Slough Subsite) |
| VHF | Very High Frequency |
| USCG | United States Coast Guard |
| YBI | Yerba Buena Island |