State of the Estuary Report 2015

Summary and Technical Appendix

WILDLIFE – Harbor Seals

Prepared by
Denise Greig, California Academy of Sciences
Sarah Allen, Ocean and Coastal Resources Program, National Park Service

Living Resources: "Birds and Mammals"
Revised version, 13 May 2015
Sarah Allen and Denise Greig (reviewed by Nadav Nur)

Harbor Seal Indicator

1. Brief description of indicator and benchmark

Harbor seal abundance in the San Francisco Bay (SFB) estuary, excluding pups, is used as an indicator. The indicator is based on a time series of counts of harbor seals during the breeding season. The range that defines a Fair score is the historical average maximum number counted at select locations from 2000 to 2010 plus or minus one standard deviation. Good is defined as above the upper standard deviation. Poor is defined as below the lower standard deviation. The historical mean from 2000 to 2010 is 328 seals; the range for Fair is between 273 and 382 (i.e., 328 ± 54 [SD]) seals.

2. Indicator status and trend measurements

Fair. In the past three years, one year is within the range for Fair, one year is at the cut-point between Fair and Poor, and one year is in the Poor range. There has been no consistent trend, nor has there been a significant linear trend from 1998-2014 ($P > 0.1$; see Figure 1).

3. Brief write-up of scientific interpretation

Harbor seals are an apex predator within the SFB estuary and along the nearshore of the outer coast. They lead a dual existence in that they rest, molt, and nurse their pups on land at traditional terrestrial haul out sites, and so are easily surveyed, but forage at sea, often in close proximity to haul out sites.

Indicator of estuarine condition

An indicator of harbor seal abundance within the SFB estuary was used to reflect the health of the estuary:

- Number of harbor seals (excluding pups)

Harbor seal abundance is an excellent biological indicator of foraging conditions in the estuary and the outer coast. Seals are opportunistic predators of fish and invertebrate species that are seasonally abundant, and they respond quickly to changes in regional environmental conditions. For example, during El Niño years when many prey species moved away from warmer than usual waters, the number of total seals surveyed at colony sites in central California declined (Allen et al. 1989; Sydeman and Allen 1999). Marine mammals generally are used as sentinels of change in oceanic conditions (Moore 2008), and within SFB estuary harbor seals are the only year round resident marine mammal. Individual seal health has been linked to anthropogenic pollutants in the SFB estuary in several studies since the 1970s: these data have been used to understand health risks to humans using the estuary as well (for example, mercury levels in sport fish).

Seal numbers within the bay are important for understanding the ongoing impacts of humans on the bay ecosystem because the population is vulnerable to disturbance, habitat loss, contaminants and prey availability, as well as the cumulative effects of these factors on seal health and survival.

Benchmark and Scoring

The scoring approach is based on the mean of the annual maximum number of seals counted at two locations from 2000-2010 (excluding 2007 when we did not count one of the two sites), i.e., 328 seals. 1998 and 1999 were excluded from the historic mean because 1998 reflect the strong El Niño effects of that year, and there may have been some residual effects in 1999. From the 2000-2014 time series, a Standard Deviation (SD) about the mean was calculated, i.e., 54 seals. Good and Poor were defined relative to these historical data (i.e., above and below the mean ± 1 SD). A score of "Good" requires three most recent years all to be above the upper SD, i.e., all three years to be above mean plus 1 SD. A score of "Poor" requires three most recent years all fall 1 SD or more below the historic mean. If 1 to 3 of the most recent 3 years fall within the range of Fair, this is scored as Fair.

The indicator is based on counts of seals (excluding pups) during the breeding season. Pups are excluded from the indicator because their numbers are more variable and an occasional year with low pup numbers is not likely to impact the health of the population. Pup sensitivity to short term perturbations is illustrated in the Technical Appendix, where the pup numbers were dramatically decreased during the 1998 El Niño. However, data on pup trends are important ancillary information to interpret seal trends.

Protocols for monitoring harbor seals are well established and have been implemented in the SF estuary since 1998 at two prime locations for breeding harbor seals. This approach provides an index of abundance that can be consistently replicated.

Status and Trend

Status: Fair
We consider the harbor seal population status to be fair: there has not been a substantial drop in numbers, however numbers have not improved substantially since the 1970's as they have for harbor seal populations along the adjacent coast after passage of the Marine Mammal Protection Act (1972). In addition, there remain ongoing concerns regarding their health as a result of pollutants introduced to the bay by humans (oil, mercury, pesticides, and other contaminants) and habitat loss.

Trend: No distinct trend.
The numbers have been variable: numbers were Poor in 2011 and 2012, but back within range in 2014 and nearly so in 2013. There is no significant linear or quadratic trend in the data from 1998 -2014 ($t_{16} = -0.86$, $P > 0.4$ for linear; $t_{15} = -1.25$, $P > 0.2$, for quadratic) analyzing ln-transformed counts), nor was a linear or quadratic trend significant when analyzing just 2000-2014 ($P > 0.1$; $P > 0.9$, respectively), omitting the El Niño year of 1998 and the year following, 1999.

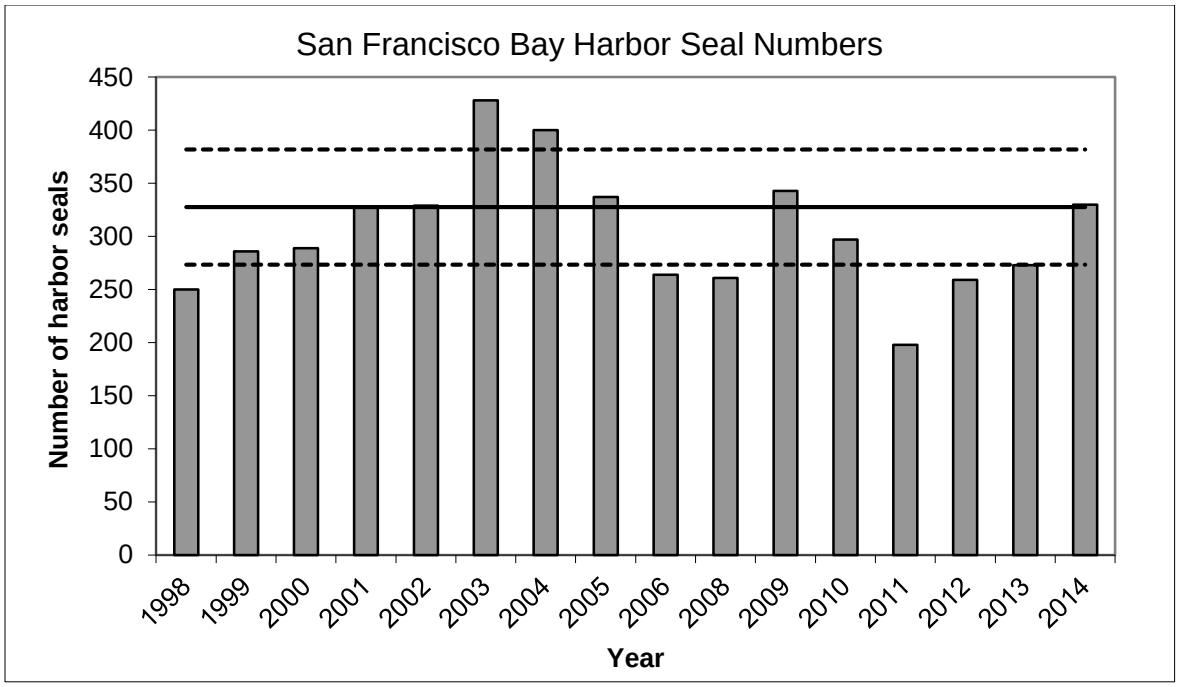
SIGNIFICANCE/INTERPRETATION

While there is no clear trend to the data between 1998 and 2014, seal abundance is a useful indicator for understanding the population of harbor seals within the estuary. Adult harbor seal numbers decreased in 2011, but the pup numbers were not as depressed.
If numbers are consistently depressed below Fair, then this will be a reflection of changes within the estuary that are likely affecting other species as well the seals. If the numbers increase, that would signal that the SFB estuary environment has improved (either more productive or improved habitat).

There is a strong ecological linkage between the SFB estuary and the regional coastal conditions to which the seals within the SFB estuary are responding. The SFB plume of fresh water and sediments extends out of the Golden Gate and drifts north and south, depending upon tides and winds. The plume provides significant nutrients to the coastal waters and contributes to the biological diversity. Conversely, colder and saltier coastal waters extend far up into the SFB estuary contributing equally to the biological diversity within the SFB. When anomalies in weather patterns occur, these linkages are altered as occurs during El Niño years. NOAA documented 2015 as an El Niño year because of unusual warm ocean conditions. The warm conditions are often associated with a breakdown in food webs with less krill and anchovies present in nearshore coastal waters that provide prey to seals and seabirds; however within SFB estuary, resident seals forage more on resident prey species, which might lessen the El Niño effects on the seals within the bay. The intensity and frequency of El Nino events is predicted to increase in the future in response to changes in climate. Monitoring in SFB estuary is important to identify the potential effects of these events on sentinel species such as seals and to provide opportunities to react to these new types of events as they unfold.

4. Related figures

Figure 1. Maximum harbor seal numbers (excluding pups) counted during the breeding season at two locations in the SFB estuary (Castro Rocks and Yerba Buena Island). The solid line is the mean from 2000 to 2010; the dotted lines are 1 SD above and below the mean. The area between the dotted lines is scored as Fair. 2007 is omitted from the figures and the calculation of the mean because YBI was not sampled that year. Estimated linear trend for 2000 to 2014 is -1.4% (SE = 1.0%) per year ($P > 0.1$); trend for 1998-2014 also was not significant. Poor is below the lower dotted line. Fair is between the dotted lines. Good is above the upper dotted line.



5. Technical appendix

Harbor seals are marine carnivores that rest ashore daily, and therefore, seal numbers are indicative of both prey availability and suitable harbor seal habitat within the SFB estuary. Harbor seals have been studied in the SFB estuary since the early seventies when concerns were raised about the connection between pollutants in the bay and premature harbor seals births (Risebrough et al. 1980). Studies have investigated pollutants (Kopec and Harvey 1995, Neale et al 2005, Greig et al. 2011), levels of mercury and selenium (Kopec and Harvey 1995, Brookens et al 2007, McHuron et al 2014), food habits and movements (Harvey and Torok 1994, Nickel 2005, Grigg et al 2009, Gibble and Harvey 2015), disturbance (Allen 1991) and survival (Greig 2011, Manugian 2013). These studies showed that harbor seals do forage within the bay (Harvey and Torok 1994, Nichol 2003, Gibble and Harvey 2015) and the amount of time that they spend on local haul-outs (Green et al. 2006) as well as some of the factors affecting health and survival and therefore seal numbers (Kopec and Harvey 1995, Grigg et al. 2004, Greig 2011, McHuron et al 2014).

The studies above do not, however, provide a consistent, easily replicated indicator for monitoring perturbations in the seal population over time. State and federal agencies do aerial surveys, but not every year (Carretta et al 2013). From 1998 to the present, harbor seals have been counted consistently through the pupping and molt seasons at the same locations by a network of citizen scientists with data managed by the National Park Service. The proposed count data provide the best index of seal numbers and pup production, and thus, indicate the ability of the estuary to support seals and these activities.

- Benchmark
    - Describe the benchmark and why it was chosen.

The scoring is based on the mean of the annual maximum number of seals counted at two haul-out locations from 2000-2010 (excluding 2007 when we did not count one of the two sites), i.e., 328 seals. The Fair scoring range encompasses one standard deviation above or below the mean. This metric was chosen because seals have been consistently counted at two of their larger haul out sites within the estuary and we think the variability around the mean of the historical dataset provides a good reference point for evaluating natural variability and for detecting any deviation away from that mean.

- Discuss any limitations of the benchmark and how it might be improved in the future.

The breadth of the Fair score range is affected by the degree of variability in the dataset from sources not associated with the seal population (such as the observer differences, poor weather and reduced visibility). In addition, only two sites are monitored consistently, so increases or decreases could result from seals moving to or from other locations in the bay, or from the seals using the two index sites differently (for example, increased use of Yerba Buena Island as nursery area). Improvements to the scoring could include additional sites (especially if haul out patterns in the south bay change with restoration efforts) as well as an expanded seal monitoring program within the SF estuary.

- Provide any further related information about goals, reference conditions and targets.

Indicator values below Fair for three consecutive years would be cause for concern and should result in management action. For example, a management action might include an estuary-wide aerial survey program to document if seals moved somewhere else within the estuary or were gone from the estuary's population. An increase above Fair for three years in a row would indicate that the seals and the SFB estuary were healthy and the status of this indicator would then be scored as "Good".

- Data Sources
    - Describe the data used and where they came from.

Data are collected by volunteers for the National Park Service's San Francisco Area Network Inventory and Monitoring Program. The data are curated and validated at Point Reyes National Seashore and published each year in a peer reviewed annual report (Adams et al. 2009).

- Methods
    - Describe the calculation methods.
    - Include a brief description of the assumptions and uncertainties.

Sampling locations consist of two of the largest breeding and resting sites in the estuary: Castro Rocks under the Richmond/San Rafael Bridge and Yerba Buena Island in the middle of the San Francisco/Oakland Bay Bridge. Pupping occurs at other locations and new sites may be colonized by seals, but the sites that make up the indicator have been surveyed consistently since

1998. Note that pup numbers are not included in the harbor seal population index but serve as ancillary data for interpretation of the index.

Breeding season surveys are conducted every other week (coinciding with the low tides) from March through May and every week for the three weeks surrounding peak pupping (late April/early May). The maximum number of non-pups counted on any survey during the season is used as the indicator. Numbers can vary dramatically with weather and disturbance, and this sampling regime is designed to account for that variation, although it is possible that no good counts are acquired in a given season due to weather or other factors.

Because not all locations within the estuary are monitored and because seals spend seasonally varying proportions of their time at sea, these counts are an index of seal abundance rather than an attempt to estimate total numbers of seals in the estuary.

Harbor seal count data from 1998 through 2005 were collected as part of the Richmond Bridge Harbor Seal Survey (Green et al 2006, Grigg et al. 2004). Data from 2006 to the present have been collected by volunteers using the same protocols and datasheets as before, but less effort in terms of time. From 1998 through 2005, paid survey shifts lasted six hours and were distributed across time of day and tidal cycle. Now, volunteers survey from 30 minutes to 2 hours during low tides in concert with the region-wide harbor seal survey (which includes Point Reyes Peninsula and locations along the Sonoma and San Mateo coastline).

- Peer Review
    - Describe how the indicator was vetted with other experts in the community.

See Data Sources section above – the regional count data are reviewed and made public each year (http://www.sfnps.org/harbor_seals/).

Work precedents for this indicator include 30 years of previous monitoring under different programs including Marine Mammal Commission in 1980s, CalTrans and other sources. See references including Risebrough et al. 1980, Allen 1991, Kopec and Harvey 1995, Grigg et al. 2004, and Green et al. 2006).

- Additional Information

Seal mortality is also documented during surveys, therefore an outbreak of disease or other health problem might be detected if carcasses were evident during the survey period. NOAA documents Unusual Mortality Events (UME) of marine mammals and such events are indicators of potential health issues in populations. In the past two decades, two harbor seal mortality events have occurred in the SF Bay Area (Nollens et al. 2010).

- Literature Cited

Adams, D., D. Press, M. Hester, H. Nevins, D. Roberts, B. Becker, H. Jensen, E. Flynn, M. Koenen, and S. Allen. 2009. San Francisco Bay Area Network pinniped monitoring protocol. Natural Resource Report NPS/SFAN/NRR—2009/170. National Park Service, Fort Collins, Colorado.

Allen, S.G., H.R. Huber, C.A. Ribic, and D. G. Ainley. 1989. Population dynamics of harbor seals in the Gulf of the Farallones, California. Calif. Fish and Game, 75:224-232.

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

Brookens, T., et al. (2007). "Trace element concentrations in the Pacific harbor seal (*Phoca vitulina richardii*) in central and northern California." Science of the Total Environment **372**: 676-692.

Codde, S. and S. Allen (2013). Pacific Harbor Seal (*Phoca vitulina richardsi*) Monitoring at Point Reyes National Seashore and Golden Gate National Recreation Area: 2012 annual report.

Gibble, C. M. and J. Harvey (2015). Food habits of harbor seals (*Phoca vitulina richardsii*) as an indicator of invasive species in San Francisco Bay, CA. Marine Mammal Science doi: 10.1111/mms.12214.

Green, D. E., et al. (2006). Monitoring the potential impact of the seismic retrofit construction activities at the Richmond San Rafael Bridge on harbor seals (*Phoca vitulina*): May 1, 1998-September 15, 2005, Richmond Bridge Harbor Seal Survey**:** 99 pp.

Greig, D.J. (2011). Health, disease, mortality and survival in wild and rehabilitated harbor seals (Phoca vitulina) in San Francisco Bay and along the central California coast. PhD. University of St Andrews. 168 pp.

Greig, D. J., et al. (2011). "Geography and stage of development affect persistent organic pollutants in stranded and wild-caught harbor seal pups from central California." Science of the Total Environment **409**(18): 3537-3547.

Greig, D. J., et al. (2014). "Surveillance for zoonotic and selected pathogens in harbor seals (*Phoca vitulina*) from central California." Diseases of Aquatic Organisms **111**(2): 93-106.

Grigg, E. K., et al. (2009). "Spatial and seasonal relationships between Pacific harbor seals (*Phoca vitulina richardii*) and their prey, at multiple scales." Fishery Bulletin **107**(3): 359-372.

Grigg EK, Allen SG, Green DE, Markowitz H (2004) Harbor seal, Phoca vitulina richardii, populationrends in the San Francisco Bay Estuary, 1970-2002. California Fish and Game 90(2):51-70.

Grigg, E. K., et al. (2012). "Foraging distribution of Pacific harbor seals (*Phoca vitulina richardii*) in a highly impacted estuary." Journal of Mammalogy **93**(1): 282-293.

Harvey, J. and M. Torok (1994). Movements, dive behaviors, and food habits of harbor seals (*Phoca vitulina richardsi*) in San Francisco Bay, CA, Department of Water Resources**:** 89 pp.

Kopec, A. D. and J. T. Harvey (1995). Toxic pollutants, health indices, and population dynamics of harbor seals in San Francisco Bay, 1989-1992. Moss Landing, CA, Moss Landing Marine Laboratories**:** 138.

Manugian, S. C. (2013). Wild harbor seal (*Phoca vitulina*) population dynamics and survival in Northern California. M.S., Moss Landing Marine Laboratories, San Jose State University, 85 pp.

McHuron, E. A., et al. (2014). "Selenium and mercury concentrations in harbor seals (*Phoca vitulina*) from central California: Health implications in an urbanized estuary." Marine Pollution Bulletin **83**: 48-57.

Neale, J. C. C., et al. (2005). "Contaminant loads and hematological correlates in the harbor seal (*Phoca vitulina*) of San Francisco Bay, California." Journal of Toxicology and Environmental Health, Part A **68**: 617-633.

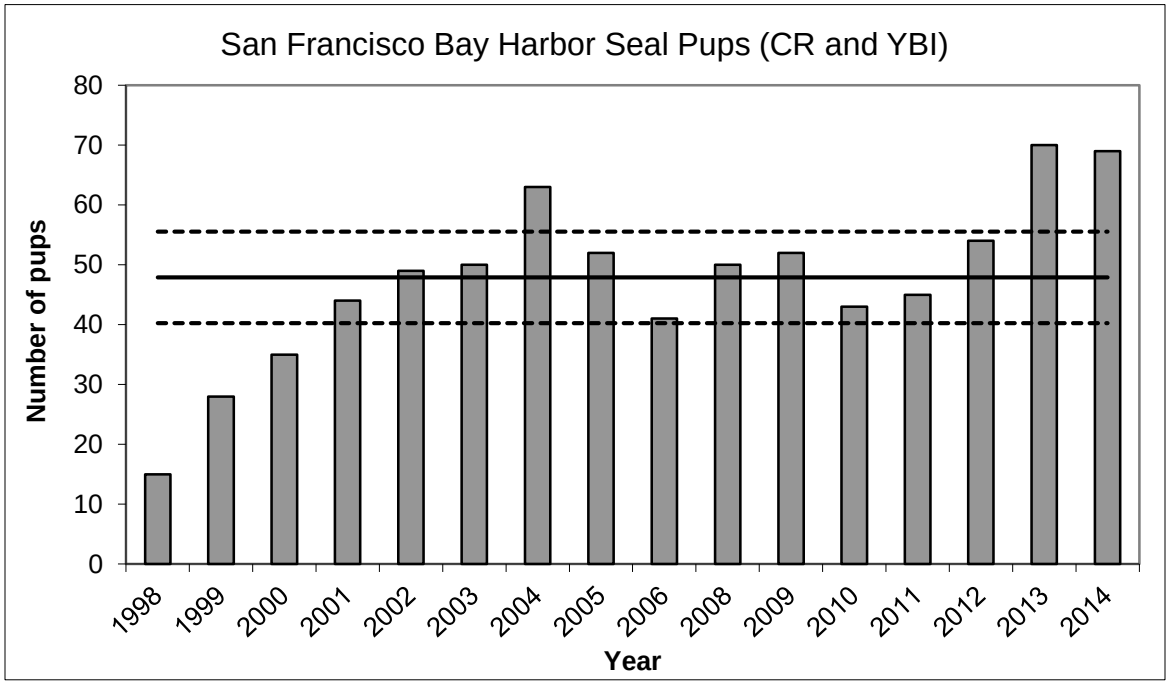
Nickel, B. A. (2003). Movement and habitat use patterns of harbor seals in the San Francisco Bay Estuary, California. Biology. San Francisco, San Francisco State University. **MS:** 121.

Nollens, H. H., J. F. X. Wellehan, L. Archer, L. J. Lowenstine and F. M. D. Gulland (2010) Detection of a respiratory coronavirus from tissues archived during a pneumonia epizootic in free-ranging Pacific harbor seals *Phoca vitulina richardsii*. Diseases of Aquatic Organisms **90**:113-120.

Risebrough, R. W., et al. (1980). "Population Biology of Harbor Seals in San Francisco Bay, California." US Department of Commerce, National Technical Information Service **Report No. MMC-76/19**: 67.

Sydeman, Wm. And S. G. Allen. 1999. Pinnipeds in the Gulf of the Farallones; 25 years of monitoring. Marine Mammal Science. 15:446-461

Figure TA-1. Maximum harbor seal numbers (pups only) counted during the breeding season at two locations in the SFB estuary (Castro Rocks and Yerba Buena Island). This metric is provided for additional information and is not used in the calculation of scoring. The solid line is the mean from 2000 to 2010 and the dotted lines are 1 SD above and below the mean. Seals were not counted in 2007.



A degraded pier in Alameda is a harbor seal haul out site and an example of the shortage in SFB of preferable habitat for seals to rest on land near foraging areas. The haul out site, though marginal habitat for seals, will likely be lost due to proposed replacement, which will make the pier inaccessible to the seals. Future restoration of the South Bay will potentially provide high quality habitat for seals where they can give birth and rest on land undisturbed and near feeding areas.