Aquatic Mammals 2011, *37*(2), 167-174, DOI 10.1578/AM.37.2.2011.167

Nocturnal Haul-Out Patterns of Harbor Seals (*Phoca vitulina*) Related to Airborne Noise Levels in Bellingham, Washington, USA

Alejandro Acevedo-Gutiérrez[1] and Sara Cendejas-Zarelli[2]

[1]*Department of Biology, Western Washington University, 516 High Street, Bellingham, WA 98225-9160, USA;*
E-mail: acevedo@biol.wwu.edu
[2]*Department of Environmental Sciences, Western Washington University, 516 High Street, Bellingham, WA 98225-9181, USA*
Current address: P.O. Box 753, Bellingham, WA 98227, USA (SC-Z)

Abstract

Given their distribution, harbor seals (*Phoca vitulina*) are likely to interact with human activities and potentially be disturbed. However, it is unclear how human development affects the haul-out behavior of harbor seals near urban areas. Because disturbance related to human development may increase noise levels in air, one might expect seals to haul-out at times when airborne noise levels are low. This study examined the number of harbor seals hauled-out relative to time of day, noise levels in air, and tide level at two haul-out sites in the city of Bellingham, Washington, USA. Harbor seals were observed from May 2008 to April 2009. Two surveys were conducted every 1 to 2 wks—one during the day and one at night. Harbor seal counts and in-air noise levels were recorded approximately 100 m from each haul-out site with binoculars and a sound level meter, respectively. Given the strong correlation between time of day and noise levels, one set of linear mixed effects models examined the interactive influence of time of day and tide level on harbor seal numbers. Another set of models examined the effect of noise level and tide level on harbor seal numbers. Despite fluctuations in harbor seal numbers in relation to time of year and haul-out site, more harbor seals hauled-out during the night than during the day. The best model for the number of harbor seals hauled-out included an interaction between time of day and tide level, and an interaction between noise level and tide level. This study indicated that numbers of harbor seals hauling-out in Bellingham were correlated with time of day and in-air noise levels. However, it is unclear if the nocturnal haul-out behavior of harbor seals was a consequence of human development. It is still possible that an unknown factor associated with time of day was responsible for the observed results. To tease out the correlation between time of day and in-air noise levels, a future comparative study between nearby haul-out sites—one close to human activities and one away from them—is recommended.

Key Words: harbor seals, *Phoca vitulina*, haul-out behavior, nocturnal behavior, in-air noise, human disturbance

Introduction

Harbor seals (*Phoca vitulina*) are one of the most widespread and common pinniped species worldwide (Burns, 2009). Abundance estimates of this species are typically derived from counts of harbor seals hauled-out on land (Eberhardt et al., 1979; Thompson & Harwood, 1990). The factors influencing when harbor seals haul-out appear to be site-specific, but they include season, tide level, time of day, air temperature, wind speed, and precipitation (Pauli & Terhune, 1987; Huber et al., 2001; Reder et al., 2003; Hayward et al., 2005). Human disturbance is an additional factor that can affect the haul-out behavior of harbor seals.

Worldwide, over 37% of humans live ≤100 km of the seacoast, and this percentage is steadily increasing (Small & Cohen, 2004). Given the ubiquitous distribution of harbor seals in the highly developed northern hemisphere, interactions between harbor seals and human development are also likely to increase. Harbor seals typically rush into the water when disturbed by humans (Terhune & Almon, 1983; Allen et al., 1984; Johnson & Acevedo-Gutiérrez, 2007). Over longer periods of time, disturbance may result in seals hauling-out at times of day when disturbance is low (Grigg et al., 2002), avoiding areas of high disturbance (Montgomery et al., 2007), or abandoning a haul-out site (Newby, 1973). Because human activity varies with time of day, the haul-out behavior of harbor seals located near human development may also be related to time of day.

Typically, harbor seals haul-out primarily during daylight (Scheffer & Slipp, 1944; Boulva & McLaren, 1979; Thompson & Rothery, 1987), with the highest numbers usually recorded during the pupping and molting seasons, at low tide, during midday, or the afternoon (Pauli & Terhune, 1987; Yochem et al., 1987; Watts, 1996; Reder et al., 2003). Seasonal variations in the time of day at which most seals haul-out have been related to life history stages (Thompson et al., 1989; Cunningham et al., 2009); however, in San Francisco Bay, California, harbor seals haul-out most frequently at night, apparently in relation to high levels of daytime disturbance (Grigg et al., 2002). Because disturbance related to human development may increase noise levels above the water in the area, harbor seals might be expected to haul-out at times when noise levels are low. However, to our knowledge, no study has examined the influence of in-air noise level in the haul-out behavior of harbor seals. The downtown development of the City of Bellingham in Washington State, located in the Pacific Northwest, provides an opportunity to examine the hypothesis that airborne noise levels will influence the numbers of harbor seals hauled-out.

In Bellingham, the largest numbers of hauled-out harbor seals are found downtown in the Georgia Pacific log pond (Farrer & Acevedo-Gutiérrez, 2010). In 2001, the Georgia Pacific paper mill was closed and, since then, anecdotal evidence suggests the amount of water traffic and noise in the area has been greatly reduced. Farrer & Acevedo-Gutiérrez (2010) suggested that reduced disturbance may have contributed to the preference of the log pond as a haul-out site for harbor seals in Bellingham. Recently, the Georgia Pacific site was purchased by the City of Bellingham, and in the spring of 2008, demolition began on a large-scale remediation project "to restore the health of the land and water, improve waterfront access, promote a healthy and dynamic waterfront economy, and reinforce the inherent qualities of the waterfront" (Port of Bellingham [POB], 2010). This remediation project includes demolition, construction, shipping of materials, and increased foot and vehicle traffic of workers, potentially causing an increase in noise levels during the day. Another haul-out site used by harbor seals in Bellingham is the fuel dock in Squalicum Marina, located a few hundred meters north of the log pond. Given the working hours at the dock, in-air noise levels are expected to be higher during the daytime than at nighttime. To determine if anthropogenic noise levels influenced the haul-out behavior of harbor seals in the City of Bellingham, the number of harbor seals hauled-out at the log pond and fuel dock were examined relative to time of day, in-air noise levels, and tide.

Materials and Methods

Study Sites

The City of Bellingham is found in northwest Washington State. The log pond haul-out site is located near downtown Bellingham at the former Georgia Pacific paper mill (48º 44' N, 122º 29' W). The haul-out site consists of several logs strung together by chains, forming a barrier around a small cove. Access from the water is unaffected by tide level, and the site covers an area of approximately 18,650 m^2. The paper mill has restricted human access with no known terrestrial predators.

The fuel dock haul-out is surrounded by an industrial area in Squalicum Marina (48º 45' N, 122º 30' W). The site consists of the dock where the fuel pumps are located and covers an area of approximately 45 m^2. Access from the water is unaffected by tide level; it has restricted human access and no known terrestrial predators.

Data Collection

Harbor seals and in-air noise levels were recorded from May 2008 through April 2009 once construction had already started. Hence, comparisons were conducted relative to time of day and not to a baseline dataset. Two surveys were conducted each week within 12 h of each other—one during the day and one at night—at both the log pond and at the fuel dock. We conducted surveys at both sites during the same day and night, randomly selecting which site would be counted first. Daytime harbor seal counts were conducted between 1100 and 1300 h to be consistent with previous observations at the site (Farrer & Acevedo-Gutiérrez, 2010). Nighttime counts were conducted between 2300 and 0100 h. The log pond and the fuel dock are separated by a distance of approximately 1 km; to ensure that harbor seals were not counted twice on the same date, the survey on the second site was conducted < 10 min from the end of the survey on the first site. Seal counts and noise level recordings were conducted from the same spot on land approximately 100 m from the harbor seals to comply with Marine Mammal Protection Act regulations. Surveys at the log pond were conducted from the Georgia Pacific site as the pond is sheltered on all other sides by water or other inaccessible industrial areas. Surveys at the fuel dock were conducted from land and from a pier running roughly parallel to the dock.

Observations were made using 10 × 40 binoculars during daytime hours and a combination of 10 × 40 binoculars, Rigel 2500 Night Vision binoculars (Rigel Optics, Inc., Washougal, WA, USA), and a million candlepower flashlight during nighttime surveys. The flashlight was briefly shone around the haul-out site to confirm the harbor seal numbers counted using the night-vision binoculars; we did not observe any reaction by the harbor seals to the flashlight. A 10-min scan was conducted at each site to record the maximum number of adult harbor seals and pups hauled out (Farrer & Acevedo-Gutiérrez, 2010). The total number of adult and pup seals observed are reported as one number for each site and for daytime vs nighttime observations.

The air sound pressure levels (SPLs) were measured as an indicator of the amount of human disturbance around each haul-out site. SPLs were recorded from land at the closest possible point to each haul-out site using a NM102 Sound Level Meter (Noise Meters USA, Houston, TX, USA). The NM102 sound level meter has a resolution and accuracy of 0.1 dB ± 1.5 dB (re: 94 dB @ 1 kHz, in air), a frequency range of 31.5 Hz to 8 kHz, and a selectable noise level range of 30 to 130 dB(A) and 35 to 130 dB(C) re 20 µPa. The A-weighting curve and the C-weighting curve are the most commonly used curves employed to measure SPLs. The NM102 sound level meter or comparable instruments have been employed to measure in-air noise in other studies (Wu et al., 1987; Hodge & Thompson, 1990; Asuquo et al., 2001; Best et al., 2008). During each survey, the minimum and maximum dB values were recorded with both the A and C sound level weightings using the omnidirectional microphone of the sound level meter. The maximum values using sound level filter C weighting are reported because it provides an almost linear response to a wide range of frequencies. At the log pond, SPL readings were taken in an area protected from the wind at the mid-point of the embayment. At the fuel dock, SPL readings were taken in an area protected from the wind at the top of the dock. Readings at both sites were taken approximately 100 m from the harbor seals. Human activity ≤ 100 m at each haul-out site was tallied as number of events according to type: foot, boat, and car traffic.

Data Analysis

The goal of this study was to examine the potential effect of human-generated airborne noise levels on the number of harbor seals hauled-out relative to time of day. However, there was a strong correlation between time of day and in-air noise levels (r = 0.690), thus we ran separate linear mixed effects (LME) models. Mixed-effects analyses are robust, powerful, and adaptable tests as they permit fixed and random effects to be estimated separately and associated error terms to be included in models independently (Cnaan et al., 1997; Faraway, 2005). They also allow for correlation between observations and can handle unbalanced datasets (Cnaan et al., 1997; Pinheiro & Bates, 2004). One set of LME models tested the effects of time of day (day, night) and tide level (negative, 0 to 79 cm, 80 to 159 cm, 160 to 239 cm, ≥ 240 cm), which was obtained from tide tables of the area, on the number of harbor seals hauled-out using the *R package lme4* (Bates & Maechler, 2009). In addition to these two fixed effects, the model also included the random effect of Julian date nested within the random effect of haul-out site (log pond or fuel dock). Given that the response variable was harbor seal counts, a Poisson distribution was used to model the number of harbor seals hauled-out (Bates & Maechler, 2009). Given that noise levels were a logarithmic variable, the link function relating the model with the response variable was set to logarithm; additionally, the scatterplot of noise levels against the logarithm of the response variable was linear, as desired. The fit of models that contained an interaction between the fixed effects and models containing each separate main effect were compared. Model fit was compared using Akaike Information Criterion (AIC), and the model with the lowest AIC value is reported.

A second set of LME models was used to test the effects of in-air noise level and tide level on the number of harbor seals hauled-out using the *R package lme4* (Bates & Maechler, 2009). The model also included the random effect of Julian date nested within the random effect of haul-out site, and employed a Poisson distribution to model the harbor seal counts. The fit of models was compared as described above. All values are reported as a mean ± SE.

Results

Despite fluctuations in harbor seal numbers in relation to time of year and haul-out site, more harbor seals hauled-out during the night than during the day throughout the study (Figure 1). Overall, the average number of harbor seals was lower during the day than at night at both the log pond (5.3 ± 1.3 [day] vs 17.5 ± 2.5 [night] harbor seals; n = 41 counts each) and the fuel dock (0.1 ± 0.1 vs 1.9 ± 0.4 harbor seals; n = 41 counts each). Based on AIC values (Table 1), the best model fit for the variable number of harbor seals hauled-out included an interaction between time of day and tide level (Figure 2). The interaction between these two explanatory variables was slightly different at the log pond than at the fuel dock. At the pond, the number of harbor seals hauled-out during the day was small at different tide levels, except for a large increase during the 0 to 79 cm tide level. At night at the pond, the number of harbor seals hauled-out increased along with tide level, decreasing

Table 1. Linear mixed effects (LME) model results for number of harbor seals hauled-out in Bellingham relative to time of day and tide level from May 2008 through April 2009

Model	df	AIC	ΔAIC	logLik
Time of day * tide level	13	529.88	0.00	-251.94
Time of day + tide level	9	542.41	12.53	-262.20
Time of day	5	567.16	37.28	-278.58
Tide level	8	819.67	289.79	-401.83
Intercept	4	907.85	377.97	-449.92

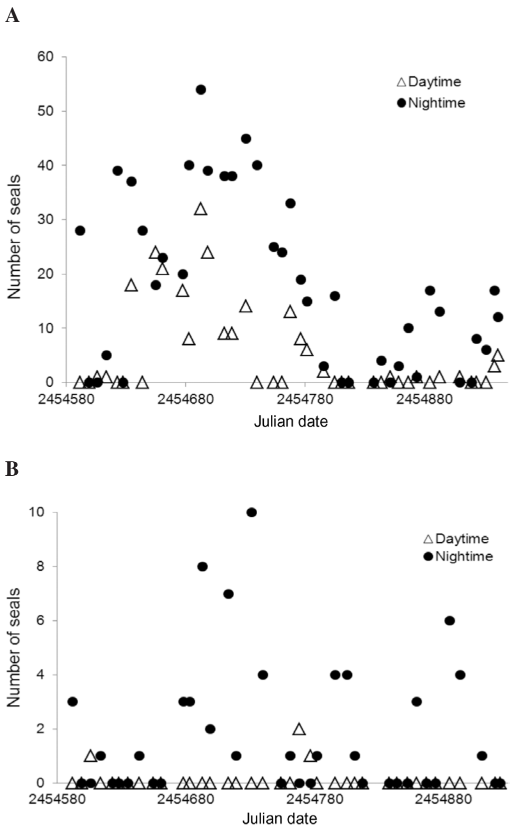

Figure 1. Number of harbor seals hauled-out relative to Julian date (May 2008 to April 2009) and time of day in Bellingham; (a) log pond and (b) fuel dock.

during the highest tides (≥ 240 cm level). As a result, more harbor seals hauled-out at night than during the day at different tide levels, except at the 0 to 79 cm level (Figure 2a). At the dock, the number of harbor seals hauled-out during the day was small at all tide levels, while the number of harbor seals hauled-out at night increased along with tide level, decreasing during the highest tides (≥ 240 cm level). As a result, more harbor seals hauled-out at night than during the day at different tide levels, except the ≥ 240 cm level (Figure 2b).

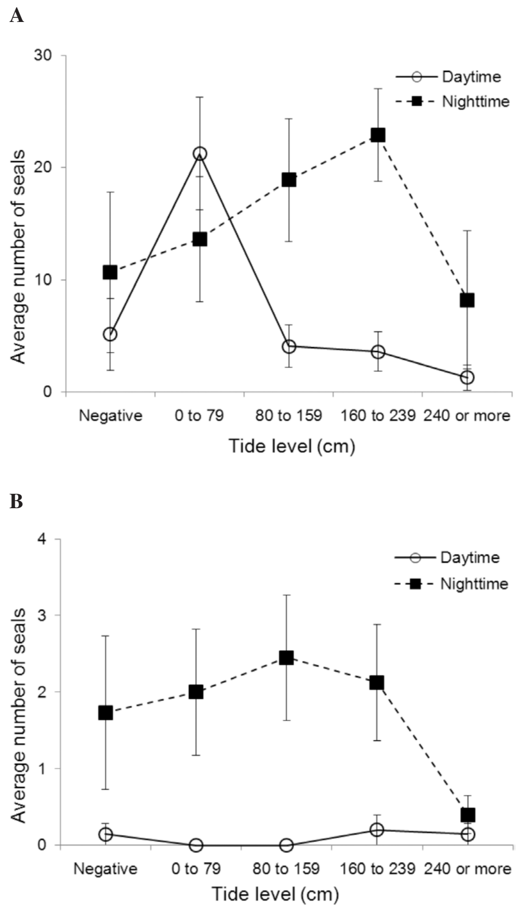

Figure 2. Number of harbor seals hauled-out relative to time of day and tide level in Bellingham; mean ± SE. (a) log pond and (b) fuel dock.

In-air noise levels were higher during the day than during the night throughout the study (Figure 3). Overall, SPLs were higher during the day than at night at both the log pond (75.3 ± 1.5 vs 62.5 ± 1.5 dB re 20 μPa; $n = 41$ measurements each) and the fuel dock (71.0 ± 1.4 vs 59.4 ± 1.4 dB re 20 μPa; $n = 41$ measurements each). Based on AIC values (Table 2), the best model fit

Table 2. LME model results for number of harbor seals hauled-out in Bellingham relative to in-air noise level and tide level from May 2008 through April 2009

Model	df	AIC	ΔAIC	logLik
In-air noise * tide level	11	1,586.7	0.00	-782.34
In-air noise + tide level	7	1,650.6	63.9	-818.31
Tide level	6	1,652.8	66.1	-820.42
In-air noise	3	1,718.7	132.0	-856.36
Intercept	2	1,742.7	156.0	-869.34

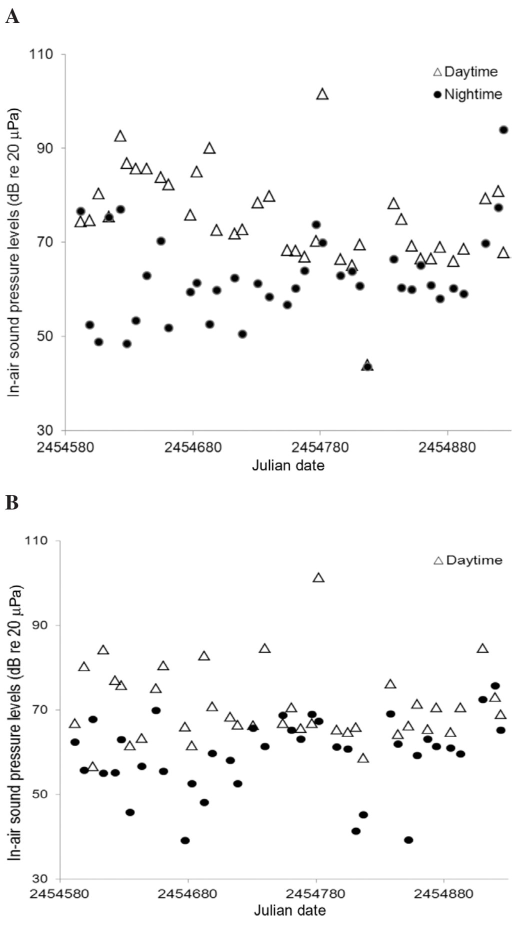

Figure 3. In-air sound pressure levels (SPLs) in dB re 20 µPa (dB C weighting) relative to Julian date (May 2008 to April 2009) and time of day in Bellingham; (a) log pond and (b) fuel dock.

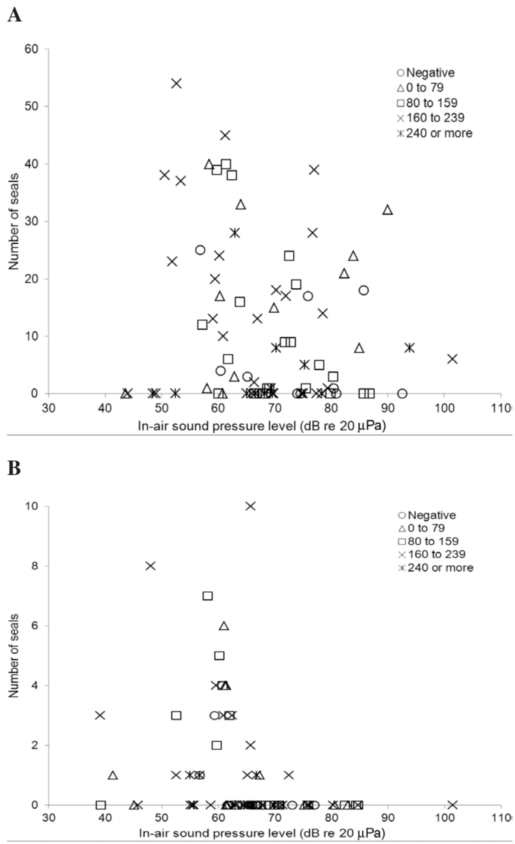

Figure 4. Number of harbor seals hauled-out relative to SPLs in dB re 20 µPa (dB C weighting) and tide level (cm) in Bellingham; (a) log pond and (b) fuel dock.

for the variable number of harbor seals hauled-out included an interaction between noise level and tide level (Figure 4). The interaction between these two explanatory variables was slightly different at the log pond than at the fuel dock. At the pond, the number of harbor seals hauled-out during the day decreased as SPLs increased at most tide levels; however, at the 0 to 79 cm tide level, the number of harbor seals remained relatively high at all noise levels; and at the ≥ 240 cm tide level, the number of harbor seals remained low at all noise levels (Figure 4a). At the dock, the number of harbor seals hauled-out decreased as noise levels increased, regardless of tide level, except the ≥ 240 cm level in which the number of harbor seals remained low at all noise levels (Figure 4b).

At the log pond, construction-related humans and visitors ≤ 100 m from harbor seals were observed 13 times during the day and 10 times at night, representing 31% and 24% of surveys, respectively. Humans on a boat comprised 69% of the daytime occurrences of human sightings and 100% of the occurrences at nighttime. Harbor seals only visibly reacted to humans once. During a daytime survey, they flushed into the water when a boat approached them to observe them at close range (< 50 m). At the fuel dock, humans ≤ 100 m from harbor seals were only observed during the day (10 times, representing 24% of surveys). Moving boats comprised all those observations, but none elicited a reaction from the harbor seals. Anecdotal evidence indicates that during the day, a few boats lingered near the haul-out site and approached the harbor seals, a situation that did not occur at night.

Discussion

The number of harbor seals hauled-out in Bellingham was related to both time of day and in-air SPLs (Tables 1 & 2; Figures 2 & 4). More harbor seals hauled-out at night throughout the year at both the log pond and the fuel dock (Figures 1 & 2) when airborne SPLs and human traffic were lower than during the day (Figures 3 & 4). Because overall human activity in Bellingham was higher during the day than at night and because construction activity only occurred during the day, our results indicate that higher in-air SPLs during daytime were related to human activity. However, given the strong correlation between time of day and in-air SPLs, we could not conclusively determine if SPLs, and hence human activity, were the primary cause of the nocturnal haul-out behavior observed in the harbor seals. It is still possible that an unknown or unmeasured factor associated with time of day, such as prey availability or temperature, was responsible for the observed results.

The choice of haul-out sites in harbor seals is related to the degree of isolation (Brown & Mate, 1983; Suryan & Harvey, 1998). Given that the haul-out sites in Bellingham are embedded in an urban area, looking for isolation at night may have been a strategy followed by harbor seals in Bellingham. In San Francisco Bay, levels of daytime disturbance apparently contributed to the preference for nighttime haul-out behavior, with the greatest source of disturbance from watercraft and other human activity (Grigg et al., 2002). In Bellingham, human traffic decreased greatly at night at the fuel dock and only slightly at the log pond. In addition, boats approached harbor seals during the day but not at night. Harbor seals are disturbed by boats that linger and approach the haul-out site rather than by boats that pass through the area, regardless of their distance to the haul-out site (Johnson & Acevedo-Gutiérrez, 2007). Hence, we believe that human activity, such as boat traffic during the day, may be more disturbing to harbor seals than indicated by the rate of occurrence that was documented during this study.

Besides time of day and noise levels, tide level also partially explained the haul-out behavior of harbor seals (Tables 1 & 2; Figures 2 & 4). In this study, harbor seal numbers decreased at the highest tide levels at both haul-out sites and increased at the 0 to 79 cm level at the log pond. The log pond and the fuel dock as well as boat access to them are unaffected by tides, hence an unknown variable associated with tide level is likely responsible for the observed results. Access to the haul-out sites from land is restricted, which, combined with the heavy human presence in the marina, makes it unlikely that terrestrial predators move to the haul-out sites at low tide levels as occurs in other areas (Cottrell, 1995). It is possible that prey availability explains the relationship between seal numbers and tide levels (Patterson & Acevedo-Gutiérrez, 2008). However, no data on harbor seal diet or prey distribution are currently available for Bellingham to examine this alternative hypothesis.

The harbor seal counts in this study are similar to those reported recently by Farrer & Acevedo-Gutiérrez (2010), suggesting that human development has not affected the presence of seals in the area between 2007 and 2009. Likewise, the numbers of harbor seals hauled-out in Bellingham varied with time of year (Figure 1). Yet, despite this variation, harbor seals hauled-out preferably at night and when noise levels were low. The largest overall number of harbor seals occurred during the summer, when 62 individuals were counted. The seasonal variation in harbor seal abundance may be related to the pupping and mating seasons. Harbor seals use the log pond and fuel dock as pupping, breeding, and molting sites (Farrer & Acevedo-Gutiérrez, 2010). In this study, peak harbor seal numbers coincided with these three life-history stages (June to October). Studies in the Pacific Northwest report similar findings: the peak number of hauled-out harbor seals occurred during the pupping and molting seasons (Brown & Mate, 1983; Huber et al., 2001; Jeffries et al., 2003). Hence, the seasonal use of haulouts as reproductive and molting areas may explain the abundance of harbor seals at haul-out sites in Bellingham during the summer months.

This study indicated that harbor seal numbers at the log pond and the fuel dock were related to time of day and in-air noise levels. It supports the hypothesis that higher nocturnal haul-out behavior of harbor seals is a consequence of human activity. However, to tease out the correlation between time of day and noise levels, a comparative study between nearby haul-out sites—one close to human activities and one with no human activities—is recommended.

Acknowledgments

We thank the Port of Bellingham, particularly A. Birdsall and M. Stoner, for providing access to the log pond. We appreciate D. Perry from Georgia Pacific for allowing our presence in the demolition site. We are most grateful to P. Zarelli for his enduring support during nighttime surveys. Funding for Sara Cendejas-Zarelli was provided by the North Cascades Audubon Society.

Literature Cited

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

Asuquo, U. E., Menkiti, A. I., Onuu, M. U., & Opaluwa, E. H. O. (2001). Environmental noise studies in some areas of Calabar and Uyo, Nigeria. *Global Journal of Pure and Applied Sciences, 7,* 339-344.

Bates, D., & Maechler, M. (2009). *lme4: Linear mixed-effects models using S4 classes* (R package version 0.999375-31).

Best, J. D., Berghmans, S., Hunt, J. J. F. G., Clarke, S. C., Fleming, A., Goldsmith, P., & Roach, A. G. (2008). Non-associative learning in larval zebra fish. *Neuropsychopharmacology, 33,* 1206-1215. doi:10.1038/sj.npp.1301489

Boulva, J., & McLaren, I. A. (1979). Biology of the harbor seal, *Phoca vitulina*, in eastern Canada. *Bulletin of the Fisheries Research Board of Canada, 200,* 1-22.

Brown, R., & Mate, B. (1983). Abundance, movements, and feeding habits of harbor seals, *Phoca vitulina*, at Netarts and Tillamook Bays, Oregon. *Fishery Bulletin, 81,* 291-301.

Burns, J. J. (2009). Harbor seal and spotted seal. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd ed., pp. 533-542). San Diego: Academic Press.

Cnaan, A., Laird, N. M., & Slasor, P. (1997). Tutorial in biostatistics: Using the general linear mixed model to analyse unbalanced repeated measures and longitudinal data. *Statistics in Medicine, 16,* 2349-2380. doi: 10.1002/(SICI)1097-0258(19971030)16:20<2349::AID-SIM667>3.0.CO;2-E

Cottrell, P. E. (1995). *Diet, activity budgets, and movement patterns of harbour seals (*Phoca vitulina*) in Cowichan Bay and adjacent areas.* Unpublished Master of Science thesis, University of Victoria, Victoria, BC.

Cunningham, L., Baxter, J. M., Boyd, I. L., Duck, C. D., Lonergan, M., Moss, S. E., & McConnell, B. (2009). Harbour seal movements and haul-out patterns: Implications for monitoring and management. *Aquatic Conservation: Marine and Freshwater Ecosystems, 19,* 398-407. doi: 10.1002/aqc.983

Eberhardt, L. L., Chapman, D. G., & Gilbert, J. R. (1979). A review of marine mammal census methods. *Wildlife Monographs, 63,* 3-46.

Faraway, J. J. (2005). *Extending the linear model with R: Generalized linear, mixed effects and nonparametric regression models*. Boca Raton, FL: Chapman & Hall/CRC.

Farrer, J., & Acevedo-Gutiérrez, A. (2010). Use of haul-out sites by harbor seals (*Phoca vitulina)* in Bellingham: Implications for future development. *Northwestern Naturalist, 91,* 74-79. doi: 10.1898/NWN08-46.1

Grigg, E. K., Greene, D. E., Allen, S. G., & Markowitz, H. (2002). Nocturnal and diurnal haul-out patterns of harbor seals (*Phoca vitulina richardsi)* at Castro Rocks, San Francisco Bay, California. *California Fish and Game, 88,* 15-27.

Hayward, J., Henson, S., Logan, C., Parris, C., Meyer, M., & Dennis, B. (2005). Predicting numbers of hauled-out harbour seals: A mathematical model. *Journal of Applied Ecology, 42,* 108-117. doi: 10.1111/j.1365-2664.2005.00999.x

Hodge, B., & Thompson, J. F. (1990). Noise pollution in the operating theatre. *Lancet, 335,* 891-894. doi: 10.1016/0140-6736(90)90486-O

Huber, H. R., Jeffries, S. J., Brown, R. F., DeLong, R. L., & Vanblaricom, G. (2001). Correcting aerial survey counts of harbor seals (*Phoca vitulina richardsi*) in Washington and Oregon. *Marine Mammal Science, 17,* 276-293. doi: 10.1111/j.1748-7692.2001.tb01271.x

Jeffries, S. J., Huber, H. R., Calambokidis, J., & Laake, J. (2003). Trends and status of harbor seals in Washington State: 1987-1999. *Journal of Wildlife Management, 67,* 208-219. doi:10.2307/3803076

Johnson, A., & Acevedo-Gutiérrez, A. (2007). Regulation compliance by vessels and disturbance of harbour seals (*Phoca vitulina*). *Canadian Journal of Zoology, 85,* 290-294. doi: 10.1139/Z06-213

Montgomery, R. A., Ver Hoef, J. M., & Boveng, P. L. (2007). Spatial modeling of haul-out site use by harbor seals in Cook Inlet, Alaska. *Marine Ecology Progress Series, 341,* 257-264. doi: 10.3354/meps341257

Newby, T. C. (1973). Changes in the Washington State harbor seal population, 1942-1972. *The Murrelet, 54,* 4-6. doi:10.2307/3535680

Patterson, J., & Acevedo-Gutiérrez, A. (2008). Tidal influence on the haul-out behavior of harbor seals (*Phoca vitulina)* at a site available at all tide levels. *Northwestern Naturalist, 89,* 17-23. doi:10.1898/1051-1733(2008)89[17:TIOTHB]2.0.CO;2

Pauli, B. D., & Terhune, J. M. (1987). Tidal and temporal interaction on harbour seal haul-out patterns. *Aquatic Mammals, 13*(3)*,* 93-95.

Pinheiro, J. C., & Bates, D. M. (2004). *Mixed-effects models in S and S-PLUS*. New York: Springer.

Port of Bellingham [POB]. (2010). *The waterfront district, Bellingham, Washington. Draft sub-area plan 2010.* Retrieved 25 March 2011 from www.portofbellingham.com/index.aspx?NID=172.

Reder, S., Lyderson, C., Arnold, W., & Kovacs, K. (2003). Haulout behaviour of High Arctic harbour seals (*Phoca vitulina vitulina*) in Svalbard, Norway. *Polar Biology, 27,* 6-16. doi: 10.1007/s00300-003-0557-1

Scheffer, V. B., & Slipp, J. W. (1944). The harbor seals in Washington State. *American Midland Naturalist, 32,* 372-416. doi:10.2307/2421307

Small, C., & Cohen, J. E. (2004). Continental physiography, climate, and the global distribution of human population. *Current Anthropology, 45,* 269-288. doi: 10.1086/382255

Suryan, R. M., & Harvey, J. T. (1998). Variability in reactions of Pacific harbor seals, *Phoca vitulina richardsi*, to disturbance. *Fishery Bulletin, 97,* 332-339.

Terhune, J. M., & Almon, M. (1983). Variability of harbor seal numbers on haul-out sites. *Aquatic Mammals, 10*(3), 71-78.

Thompson, P. M., & Harwood, J. (1990). Methods for estimating the population size of common seals, *Phoca vitulina*. *Journal of Applied Ecology, 27,* 924-938. doi:10.2307/2404387

Thompson, P. M., & Rothery, P. (1987). Age and sex differences in the timing of moult in the common seal, *Phoca vitulina*. *Journal of Zoology, 212,* 597-603. doi: 10.1111/j.1469-7998.1987.tb05958.x

Thompson, P. M., Fedak, M. A., McConnell, B. J., & Nicholas, K. S. (1989). Seasonal and sex-related variation in the activity patterns of common seals (*Phoca vitulina*). *Journal of Applied Ecology, 26,* 521-535. doi:10.2307/2404078

Watts, P. (1996). The diel hauling-out cycle of harbor seals in an open environment: Correlates and constraints. *Journal of Zoology, 240,* 175-200. doi: 10.1111/j.1469-7998.1996.tb05494.x

Wu, T-N., Ko, Y-C., & Chang. P-Y. (1987). Study of noise exposure and high blood pressure in shipyard workers. *American Journal of Industrial Medicine, 12,* 431-438. doi: 10.1002/ajim.4700120408

Yochem, P. K., Stewart, B. S., DeLong, R. L., & DeMaster, D. P. (1987). Diel haul-out patterns and site fidelity of harbor seals (*Phoca vitulina richardsi)* on San Miguel Island, California, in autumn. *Marine Mammal Science, 3,* 323-332. doi: 10.1111/j.1748-7692.1987.tb00319.x