Tidal and meteorological effects on Harbor Seals (Phoca Vitulina) and Gray Seals (Halichoerus Grypus) haul-out behavior in the Gulf of Maine

Introduction

Seals forage at sea but haul out onto land or ice for many reasons, including resting, sleeping, pupping, molting, reducing predation risks.

Many environmental effects are found to be associated with seal haul-out behaviors, such as wind speed, temperature, weather conditions. Haulout patterns differ between age, sex class, and the demands of mating and molting.

Rationale

Although haul-out behaviors have been investigated for years, the influence of environmental factors on seal haul-out number tends to be site-specific and contradictory.

Many studies rely on short-term data over 2-3 months.

Understanding of local seal haul-out patterns based on long-term data is important for preservation purposes.

This study utilized R programming to investigate the questions:

What are tidal and meteorological effects on Harbor Seals (Phoca vitulina) and Gray Seals (Halichoerus grypus) haul-out behavior in the Gulf of Maine?

Methodology

Data collection

3-day seal data during my field trip to Mount Desert Rock were recorded by a binocular on the seal blind spot.

Long-term seal data were collected by College of the Atlantic research students from 2016 to 2021 (excluding 2020).

Environmental variables collected are: tide levels (ft), air temperature (°C), water temperature(°C), and wind speed (m/s).

Data analysis

Generalized additive model (GAM) was used to analyze the data, with mgcv package of R, version 4.1.1.

Akaike Information Criterion (AIC) scores were used to determine the best-fit model.

ANOVA table was created and P-value was calculated to assess the significant association of each environmental variable.

Photo 1. Harbor seals and gray seals hauling out during low tide in Mount Desert Rock (Credit: Jamie Fogg)

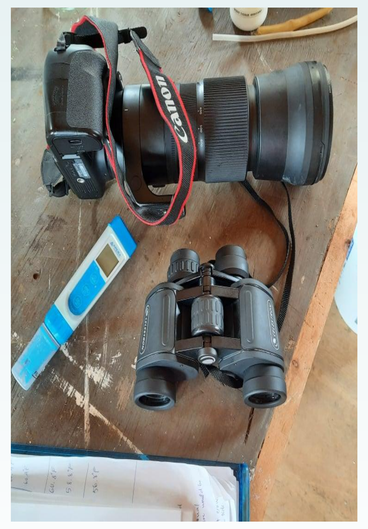


Photo 2. Binocular and camera for seal count

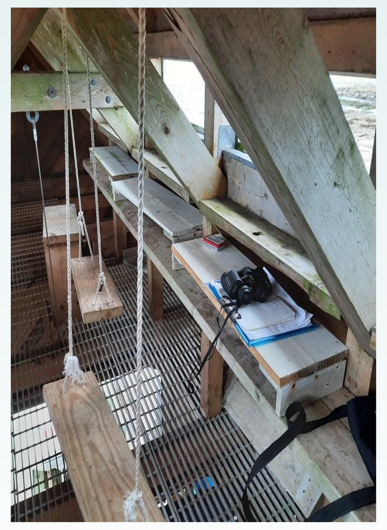


Photo 3. Seal blind spot

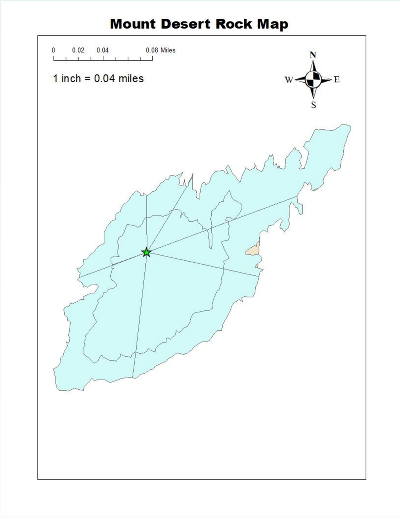


Photo 4. Study site: Map of Mount Desert Rock, situated in the Gulf of Maine

Data

Gray Seal

Model	df	AIC
1. seal_count ~ s(water_temp) + s(water_level)	7.338029	4610.892
2. seal_count ~ s(air_temp) + s(water_temp) + s(water_level)	8.38447	4611.563
3. seal_count ~ s(water_temp) + s(water_level) + s(wind_speed)	8.262203	4612.447
4. seal_count ~ s(air_temp) + s(water_temp) + s(water_level) + s(wind_speed)	9.273284	4612.549
5. seal_count ~ s(air_temp) + s(water_level)	7.33553	4615.447
6. seal_count ~ s(air_temp) + s(water_level) + s(wind_speed)	8.295942	4617.392
7. seal_count ~ s(water_level) + s(wind_speed)	7.313619	4617.578
8. seal_count ~ s(water_temp) + s(wind_speed)	8.296477	4646.622
9. seal_count ~ s(air_temp) + s(water_temp) + s(wind_speed)	11.685667	4648.832
10. seal_count ~ s(air_temp) + s(wind_speed)	8.540896	4651.614
11. seal_count ~ s(air_temp) + s(water_temp)	8.244811	4759.028

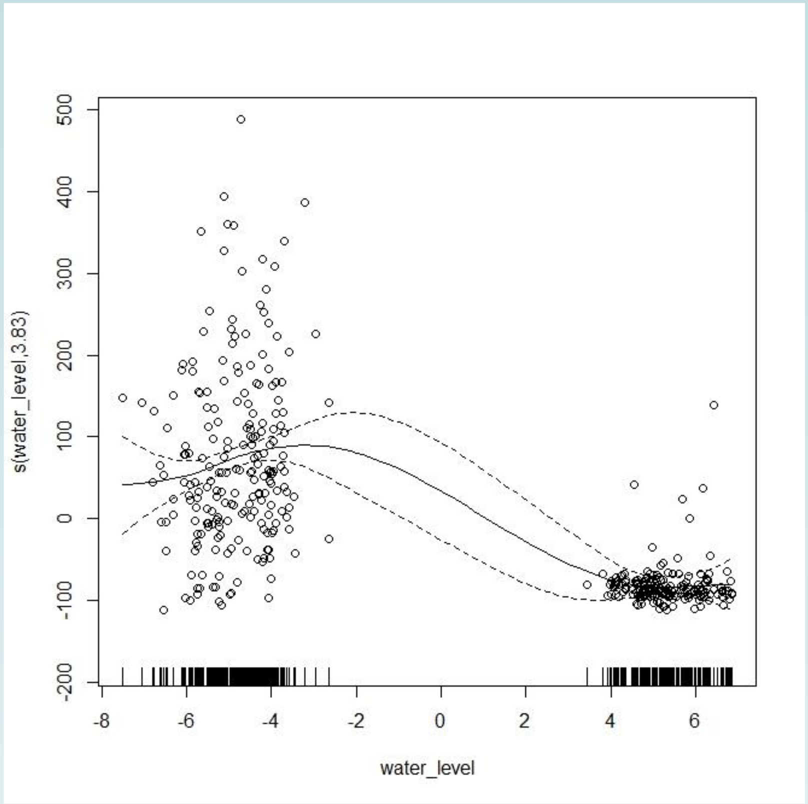
Table 1.1 All generalized additive models fitting number of gray seals hauling out with different combinations of explanatory factors of water temperature, air temperature, water level and wind speed. Model 1 is the best fit model for the number of gray seals hauling out.

Model: seal_count ~ s(water_level) + s(water_temp)

Parameter	edf	Ref.df	F-value	P-value
Water level	3.826	4.621	58.801	< 2e-16 ***
Water temperature	1.002	1.004	6.908	0.00884 **

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 1.2 ANOVA table for the best-fit model explaining number of gray seals hauling out (Water level + Water Temperature)



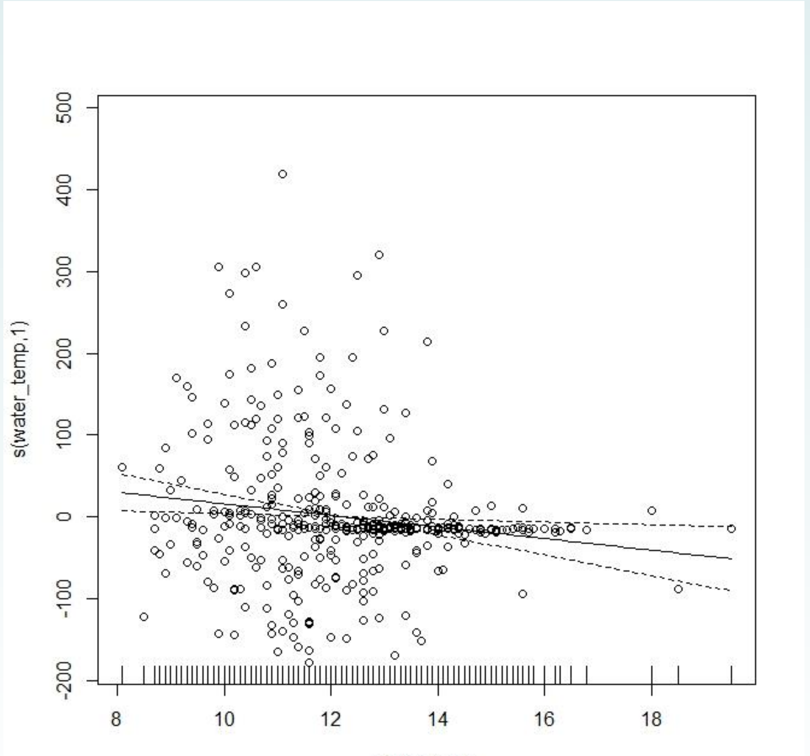


Figure 1. Estimated smoother for water level (top), water temperature (bottom) obtained by the GAM applied on the number of gray seals indicated by unbroken lines. Broken lines indicate 95% confidence interval and dots indicate residuals.

Harbor Seal

Model	df	AIC
1. seal_count ~ s(air_temp) + s(water_temp) + s(water_level) + s(wind_speed)	10.504715	5020.368
2. seal_count ~ s(water_temp) + s(water_level) + s(wind_speed)	8.163044	5021.939
3. seal_count ~ s(air_temp) + s(water_temp) + s(water_level)	7.188977	5022.783
4. seal_count ~ s(water_temp) + s(water_level)	4.509041	5024.494
5. seal_count ~ s(air_temp) + s(water_level) + s(wind_speed)	8.812074	5028.503
6. seal_count ~ s(air_temp) + s(water_level)	5.687483	5031.494
7. seal_count ~ s(water_level) + s(wind_speed)	5.721542	5032.012
8. seal_count ~ s(water_temp) + s(wind_speed)	9.819054	5048.638
9. seal_count ~ s(air_temp) + s(water_temp) + s(wind_speed)	8.286469	5048.045
10. seal_count ~ s(air_temp) + s(wind_speed)	10.962484	5054.674
11. seal_count ~ s(air_temp) + s(water_temp)	7.557963	5067.069

Table 2.1 All generalized additive models fitting number of harbor seals hauling out with different combinations of explanatory factors of water temperature, air temperature, water level and wind speed. Model 1 is the best fit model for the number of harbor seals hauling out.

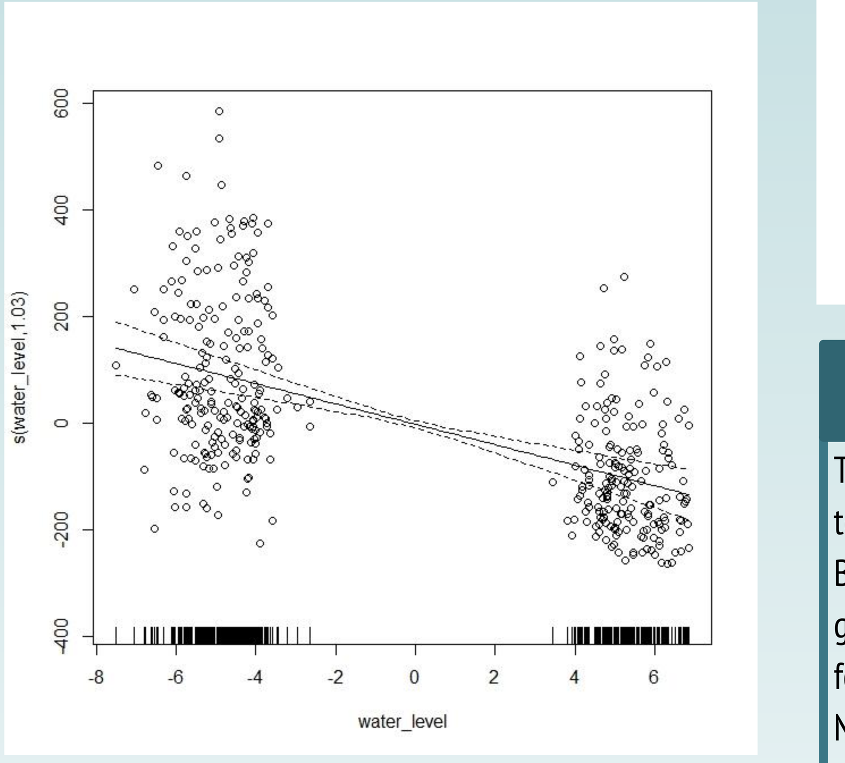
Model: seal_count ~ s(wind_speed) + s(water_temp) + s(air_temp) + s(water_level)

Parameter	edf	Ref.df	F-value	P-value
Air temperature	2.580	3.274	1.686	0.15335
Water temperature	1.001	1.001	9.886	0.00179 **
Water level	1.028	1.055	31.163	< 2e-16 ***
Wind speed	2.504	3.175	2.087	0.09232

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2.2 ANOVA table for the best-fit model explaining number of harbor seals hauling out (Wind speed + Water temperature + Air temperature + Water level)

Figure 2. Estimated smoother for water level (top), water temperature (bottom) obtained by the GAM applied on the number of harbor seals indicated by unbroken lines. Broken lines indicate 95% confidence interval and dots indicate residuals.



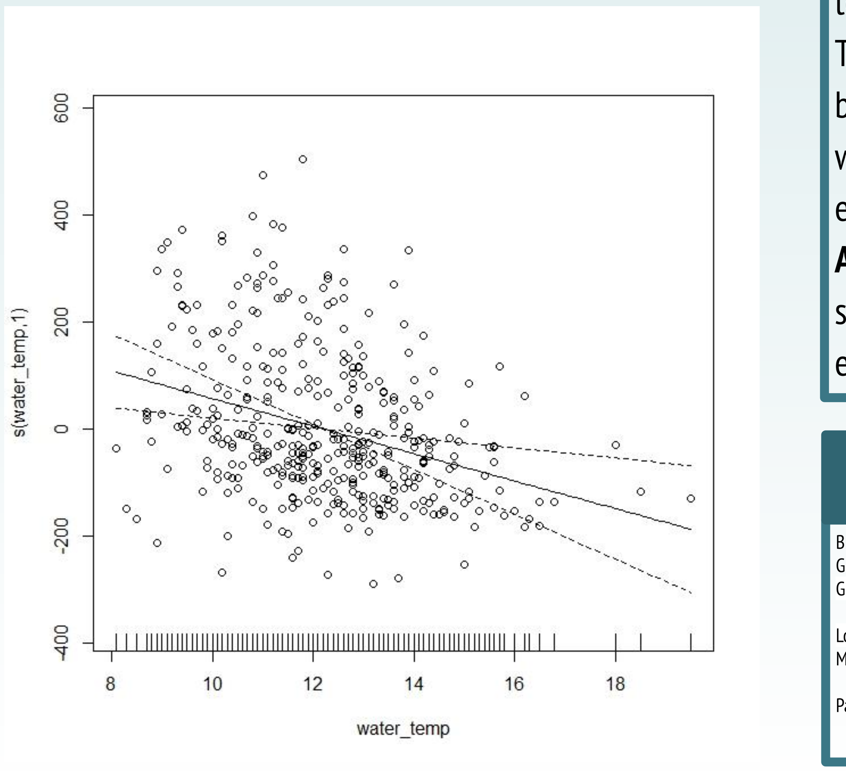


Photo 5. A close-up photo of a harbor seal hauling out in Mount Desert Rock (Credit: Jamie Fogg)

Results

11 models with different combinations of environmental factors for both gray seals and harbor seals were tested. The model with the lowest AIC was the best-fit model.

Gray Seal

The best-fit model included 2 factors: water temperature, water level (AIC = 4610.892, table 1.1).

Water temperature and water level were significant descriptors for model fit (ANOVA, P < 0.01, table 1.2).

Harbor Seal

The best-fit model included 4 factors: wind speed, water temperature, air temperature, water level (AIC = 5020.368, table 2.1).

Water temperature and water level were significant predictors (ANOVA, P < 0.01, table 2.2).

Interaction between gray seals and harbor seals

When gray seal number was added as another explanatory factor to the best-fit model of harbor seal number, this model had the lowest AIC, becoming the new best-fit model compared to 11 previously tested models (AIC = 4984.85, figure 3).

This indicated gray seal could be a significant predictor of hauled-out harbor seals.

Gray Seal and Harbor Seal Interaction

seal_count ~ s(wind_speed) + s(water_temp) + s(air_temp) + s(water_level) + s(gray_seal)

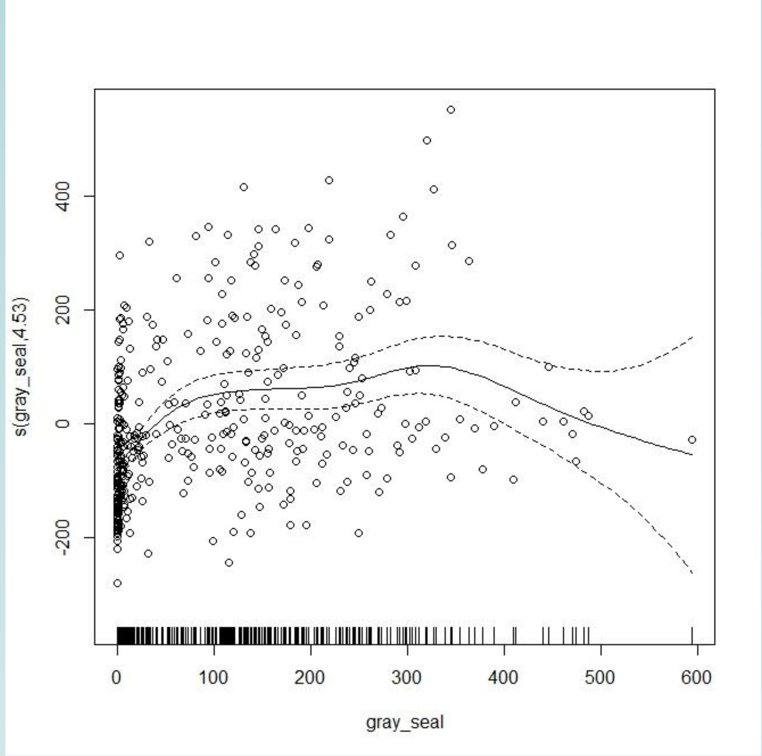


Figure 3. Estimated smoother for gray seals obtained by the GAM applied on the number of harbor seals indicated by unbroken lines. Broken lines indicate 95% confidence interval and dots indicate residuals.
AIC: 4984.85
P-value of the gray seal factor: 0.000134

Conclusion

The number of gray seals and harbor seals hauling out were both significantly associated to water level and water temperature.

Both gray seals and harbor seals hauled out the most during the low tides. The number of gray seals hauling out was at its peak when the water level is between -4 and -2 ft, while for harbor seals, the water level was between -6 and 4 ft.

Number of gray seals and harbor seals hauling out decreased with increasing water temperature. Gray seal and harbor seal number both reached its peak at 8 to 10 °C.

The highest number of harbor seals hauling out was recorded when gray seal number was between 300 and 400. However, as the number of gray seals exceeded 400, harbor seals were less likely to haul out. The aggressive behaviors of gray seals could be a possible explanation for this observation.

Applications: The findings suggest that aerial census of both gray seals and harbor seals should be conducted during low tides and at mildly cold weather. This can be applied for estimating seal population size in the Gulf of Maine and even more broadly.

References

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