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Quantification of aggressive displays by wild, male grey seals (*Halichoerus grypus*) using seismic monitoring

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Abstract

Communication via substrate vibrations can convey information on conspecific presence, individual quality, group cohesion, and/or allow for predator avoidance. The grey seal (*Halichoerus grypus*) breeding colony at Donna Nook, UK, is part of a limited geographic region where the Body Slap (BS) behaviour is performed during male-male conflicts. This behaviour is thought to have a mechanical component. We examined if the magnitude of the BS substrate vibrations contained reliable information on male mass and size as measures of RHP, and if reliability varied across environmental conditions. Our results demonstrate the BS generates a stereotyped seismic signature, and we found a positive correlation between the maximum and mean magnitudes of the substrate-borne vibrations and a male's length. Dampness of the sand substrate had no effect on magnitude. Results of this study confirm that the maximum magnitude substrate vibrations generated by the Body Slap behaviour is an indicator of male size and that the substrate-borne vibrations are reliable across varying environmental conditions.

1. Background

Substrate vibrations generated by animal signalling are extensively documented across numerous animal taxa; conservative estimates suggest that in the order Insecta alone, a total of 195,000 species use this mode of communication. In comparison, the number of mammalian species known to use this form of communication is estimated at 32 species across 11 families. Recently, a geographically isolated addition to the male grey seal repertoire was noted: the Body Slap (BS), which is used during the breeding season in male-male conflict and male-female interactions at some beach breeding colonies in the UK (Bishop et al. 2014). In the performance of the BS, males lie prone, push their ventral surface off the ground with their flippers and then let their chest and stomach fall back to the substrate (Bishop et al. 2014, Figure 1). A Body Slap event typically consists of 2 to 3 repetitions of this general motor pattern in immediate sequence (Bishop et al. 2014). The display generates a distinct slapping noise as contact is made with the ground; the arching of the back potentially serves to display lateral area; and vibrations can be felt through the substrate by observers (AB, SDT pers. obs.) suggesting that the display likely serves as a multi-modal form of non-vocal communication.

Figure 1: Male grey seal Body Slapping with open mouth threat.

In this study, we investigate a specific behaviour performed by male grey seals (*Halichoerus grypus*) during the breeding season and investigate if the substrate vibrations generated convey reliable information regarding male resource holding potential (RHP), that could be used in contest assessment by receivers. To test this, we compared both the maximum magnitude of the substrate-borne vibrations a male produced while Body Slapping and the mean magnitude across all his Body Slap events, with his length, mass and dominance in order to determine which of the two measures of the substrate vibrations was more reliable in predicting known correlates to RHP. As any air-borne acoustic components of the BS would arguably vary by wind direction, air temperature, and surface dampness of the substrate, we also examined the effects of environmental variability on the reliability of the substrate-borne vibrations by testing to see if individuals' magnitudes varied with surface saturation of the substrate due to tidal fluctuations or rain on the beach breeding site.

2. Methods

2.1 Field Site

Data were collected on breeding male grey seals at the Donna Nook breeding colony on the North Lincolnshire coast, eastern England (53.47°N, 0.15°E, Figure 2). The colony produces approximately 1,500 pups annually and is managed as part of the Lincolnshire Wildlife Trust's wildlife refuge system and also spans the Ministry of Defence's (MOD) Royal Air Force (RAF) training range. Field observations were conducted across the autumn breeding season in 2013 (27 October – 12 December) during all daylight hours for an average of 8h 48min daily. The breeding colony was split into two study sites to cover the range of topography: the PUB (53.476°N, 0.155°E) and RAF (53.474°N, 0.155°E) sites. All observations for this study were conducted at the RAF site, characterized as tidal sand flats. While some colonies have restricted, or few, access points from the sea to the breeding grounds (e.g. North Rona; Twiss, 1991), Donna Nook is characterized by open access along the entire beach front. Males in the study area were identified daily via unique pelage markings or *post-hoc* from high resolution pictures.

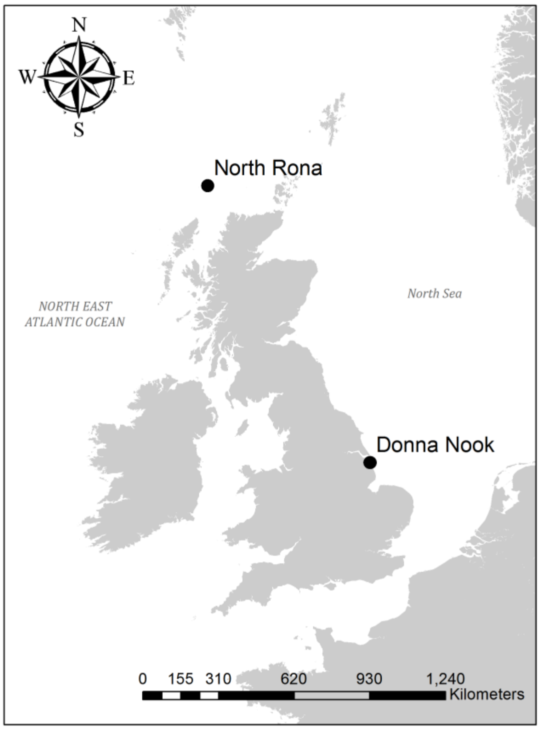

Figure 2: Location of the Donna Nook field site (with the North Rona grey seal breeding colony for reference; Twiss 1991).

2.2 Seismometer Deployment & Behavioural Data Collection

We deployed 2 Guralp 6TD seismometers (Guralp Systems Ltd) from 30 October to 23 November 2013. The seismometers were both buried at 53.47491 N, 0.15503 E, at a depth of 1 m. Continuous seismic data were recorded over 24 h encompassing a frequency bandwidth of 0.03Hz-500Hz (Brisbourne 2012). Velocity was measured in 3 axes (X, Y and Z); however, for the purpose of this study we chose to follow the methods of previous work on northern elephant seals (Shipley, Stewart, & Bass, 1992) and focus on the vertical movement axis only. During daylight hours, field observers recorded BS events, noting ID of male and time of event to the second (h:m:s). An event was defined as a bout of displaying, usually comprised of 2 repetitions of the motor pattern, but the range varied from 1 - 6 repetitions. Events were labeled as being performed on 'wet' or 'dry' sand; wet sand being any sand exposed to tidal inundation within the past 12 h or with visibly pooled water. Locations of events were mapped onto aerial photographs of the study area using a Nikon laser 550 rangefinder (6x21), with accuracy of 0.5 m up to 100m and ±1m at >100m distance, along with horizon reference points. Maps were digitized and distance (km) of each BS event to the seismometer was calculated using ArcMap 10 (ESRI, 2011). We recommend that for future deployments, solar panels are used for a power source.

2.3 Post-processing Seismic Data

Post deployment, we matched the time of an observed event to the seismic record of vertical velocity traces using *Scream!* v4.5 (Guralp Systems Ltd). The unfiltered peak to peak amplitudes (nm/s) of the displays were extracted (see Figure 3 for example of hourly raw trace without (a) and with (b) helicopter activity). To minimize potential false positive matches, only displays that were at least double in amplitude relative to the background were considered positive matches (Shipley et al. 1992). As males performed BSs at different distances from the seismometer, in order to compare their relative magnitudes, the amplitudes had to be distance corrected. The seismometer measures amplitudes as velocity in nm/s

(v); however the distance correction formula required this measure to first be converted into vertical displacement in nm (A) using the formula

$$A = \left(\frac{[v]}{f * 2\pi}\right) \quad \textbf{(1)}$$

where v is the vertical velocity in nm/s of an event, and f is the frequency in Hz. Frequency analysis of the displays indicated that the bulk of the energy contained in these signals lay within the 20Hz band. To ensure that all calculations were carried out using the same formula, we used this frequency to convert peak-peak velocity amplitudes to displacement. From this, magnitude values, which could be compared relative to each other, were then calculated using Booth's (2007) distance correction equation generated specifically for seismic activity in the UK. The maximum magnitude generated per male, mean magnitude per male (for males with 4 or more events), and the variation in magnitude (standard error around the mean for males with 4 or more events) were calculated and used in further analyses.

3. Results

The Body Slap generated a stereotyped seismic trace with raw amplitudes ranging from 10 752 nm/s to 475 136 nm/s, and after distance corrections, magnitudes ranged from –1.62 to -0.14 (Figure 4a). Frequency was broadband and ranged from 10-80Hz. Other male behavioural events were observed *ad lib* and matched to the seismic record for comparison, including male locomotion (Figure 4b). BS displays were measurable up to 126.3 m from the source; of the observed BS events in the field, 94.3% were positively matched in the seismic record up to 70m distance, but proportion matched dropped to 71.7% from 80-100m and to 37% on average beyond 100m (Figure 5). We recorded events for 39 individual males (within-male sample sizes ranging from 1-255 events, median for males with >4 events = 22.5) for a total of 470 observed events comprised of 990 individual slaps matched in the seismic trace. Similar to findings of Bishop et al. (2014), 9.45% of events consisted of a single slap, 61.5% consisted of 2 slaps, and 28.9% consisted of >3 repetitions. Inter-repetition intervals were typically 1s apart and separately distinguishable (Figure 4a). Our findings confirm that male grey seals generate substrate-borne vibrations associated with a specific, stereotyped display and this study suggests that the magnitude of the BS contains information regarding RHP that could be used by opponents in assessment (Figure 6). The results of this study also indicate that, while the breeding colonies at which the BS has been observed are all open-access beach sites with variable surface water pooling due to tidal and rain fluctuations, individuals' maximum and mean magnitudes were not significantly different across wet or dry surface sand conditions (Bishop et al. 2015). [For additional statistical results please see: Bishop et al. 2015].

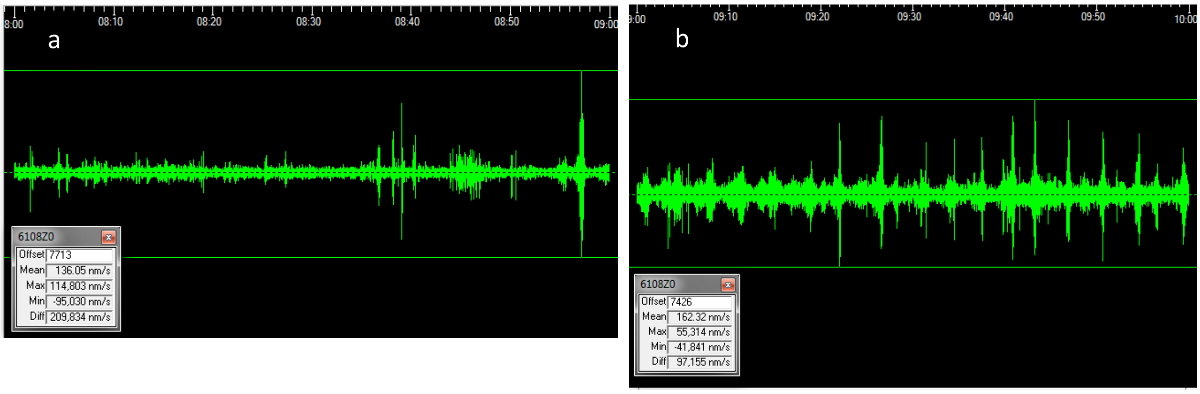

Figure 3: Oscillogram recorded at 0.03-500Hz and viewed in *Scream!* (a) One hour long trace on 1-Nov-13 when there was a lack of anthropogenic activities; barring a tractor driving past at 8:57, (b) One hour long trace on 1-Nov-13 when military helicopters were flying overhead.

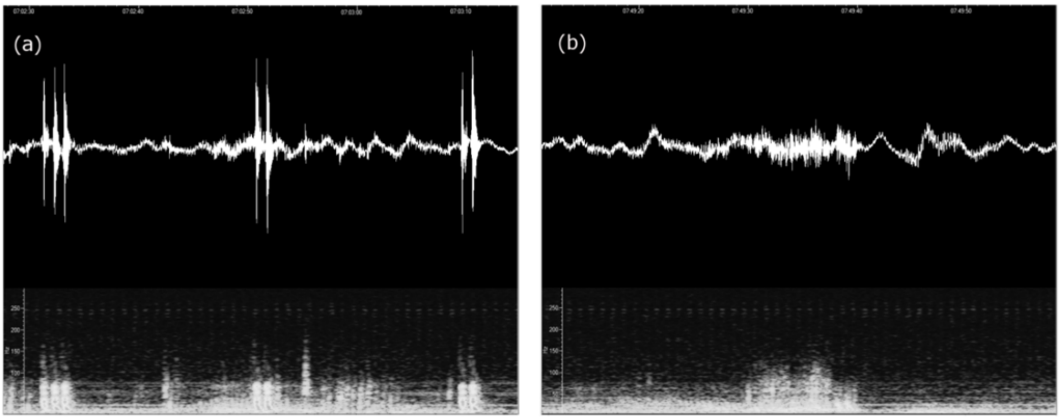

Figure 4: Traces zoomed in to 50 seconds; Oscillogram (top) and spectrogram (bottom) recorded at 0.03-500Hz and viewed in *Scream!*. (a) 3 BS events (3 repetitions at 7:02:31; 2 repetitions at 7:02:50; 2 repetitions at 7:03:09). Distance from source = 50 m. All three events presented between 10-80Hz with highest energy at 20-40Hz.; (b) Male locomotion at 7:49:30. Distance from source = 40 m.

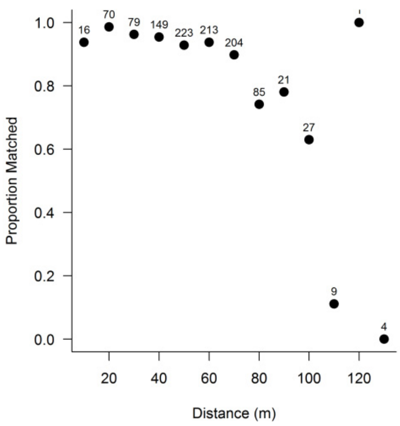

Figure 5: Proportion of BS events positively matched in the seismic record to the number observed in the field across distance (10m bins). Labels represent number of events observed in field. Detectability dropped off after 80m from source and maximum distance detected was 126.3 m.

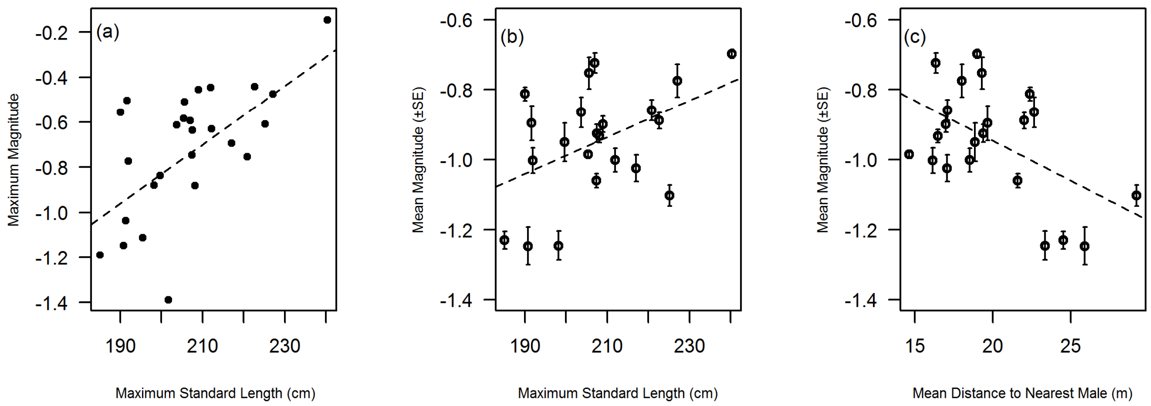

Figure 6: Results of best models. Correlations for maximum (a) and mean magnitude (b) indicated a positive relationship with maximum standard length. Mean magnitude also shared a negative relationship with mean nearest neighbor distance (c). See Bishop et al. 2015 for coefficient estimates.

4. Discussion

This work represents the first look into the substrate vibrations generated by male pinnipeds in the UK. Our results have demonstrated a positive relationship between the magnitude of the BS's substrate-borne vibrations and proxies for RHP, but how the receiver responds to the information in the BS still requires further examination and is likely context dependent. Further work utilizing playback manipulations (*e.g.* observations of receivers' response when presented with a range of substrate-borne vibration magnitudes) could be done to investigate the honesty of the information in the BS display and if active or passive receivers are deriving the information regarding size from the BS substrate vibrations and basing decisions on that information. Given the BS is a behaviour that has only been noted within the past 30 years and is at present geographically isolated (Bishop et al. 2014), it is interesting to consider the evolutionary history of this species. Grey seals in the UK have experienced increased terrestrialization of breeding colonies since the last glaciation. At present, grey seals breed on a variety of substrates; however, the BS display has only been observed at colonies with flat sandy beaches (Bishop et al. 2014). Other colonies across their range exhibit similar substrate types and conditions but observers have not reported usage of this behaviour. Furthermore, the usage of this behaviour appears to have evolved in a reasonably short period of time. An exciting aspect of these findings therefore is that while it is likely the BS originated as an extension of the locomotor pattern (Bishop et al. 2014), it is possible the substrate and local environmental conditions at Donna Nook and nearby colonies promoted the use of this behaviour.

5. Location of archived data

Data has been archived at the School of Biological and Biomedical Sciences, Durham University, Durham DH1 3LE. Requests for access: please contact Dr. Sean Twiss (s.d.twiss@durham.ac.uk, Tel: +44 (0)191 334 1350) or Dr. Amanda Bishop (ambishop2@uaa.alaska.edu, Tel: +1 907 786 6953).

6. Publications

Bishop AB, Denton P, Pomeroy PP, and Twiss SD. 2015. Good vibrations by the beach boys: magnitude of substrate vibrations is a reliable indicator of male grey seal size. Animal Behaviour, 100, 74-82.

Bishop AB. 2015. Behavioural mechanisms of conflict and conflict reduction in a wild polygynous pinniped. PhD Thesis, Submitted March 2015, Durham University

7. References

1) Bishop, A.B., Lidstone-Scott, R., Pomeroy, P.P., & Twiss, S.D. (2014). Body Slap: An innovative aggressive display by breeding male gray seals (*Halichoerus grypus*). Marine Mammal Science. 30, 579-593.
2) Booth, D.C. (2007). An improved UK local magnitude scale from analysis of shear and Lg-wave amplitudes. Geophysical Journal International, 169, 593–601.
3) Brisbourne, A. (2012). How to store and share geophysical data. Astronomy & Geophsyics, 53, 19-20.
4) Shipley, C., Stewart, B.S., & Bass, J. (1992). Seismic communication in northern elephant seals. In Marine mammal sensory systems. Supin, Plenum Press, New York, NY. pp 553–562.
5) Twiss, S.D. (1991). Behavioural and energetic determinants of individual mating and success in male grey seals (*Halichoerus grypus*). Ph.D. thesis, University of Glasgow, Glasgow, U.K. 337 pp.

8. A table of instrument deployment details including locations

Sensor	Digitizer	Flash Memory	GPS	Lacie
6305	1373	8	3258	L2032
6108	946	16	3398	

Device	GPS cycle	Tap0	Tap2	Tap4	Tap6	Recording	Baud rate	Trans Mode	O/S and Drift
6305	1	*1000*	*100*	10	*1*	ZNE mass/temp	115200	Duplicate	10, 26
6108	1	*1000*	*100*	10	*1*	ZNE mass/temp	115200	Duplicate	-57, 17

	DATE	ARRIVAL TIME	Site Name	Team	Soil Description	Depth to top?	Battery type	Flush Successful?	O/S and Drift?	Comments
Deployed	30-Oct-13	12:13	Donna Nook	PD, AB	sand	30cm	D-cells	na	yes	
Servicing/Data Download	7-Nov-13	16:00	Donna Nook	AB, JS	sand	30cm	D-cells	Y (20min)	yes	No water damage, no cable damage, security satisfactory, everything secured, masses OK
Servicing/Data Download	15-Nov-13	16:00	Donna Nook	AB, JS	Sand	30m	D-cells	No	No	No response from either device in Scream!; Decided to replace batteries the next day and try again
Servicing/Data Download	16-Nov-13	07:15	Donna Nook	AB, JS	Sand	30m	D-cells	Y (20min)	yes	Double checked baud-rate, after resetting it, the 6108 device responded and downloaded. Mass positions, streams looked okay. Still no response from 6305. Changed batteries but still no response (emailed David Hawthorne for assistance)
Servicing/Data Download	21-Nov-13	16:00	Donna Nook	AB, JS	Sand	30m	D-cells	Y (20min)	yes	6108 still responding okay; 6305 didn't try.
Recovery	1-Dec-13	07:30	Donna Nook	PD, AB	sand	30cm	D-cells	Y (20min)	yes	Packed up all equipment; no damage to cables; no signs of water damage. Did final data download at the office. I was able to get the non-responsive device (6305) to register in Scream using the other device's breakout box, wires and battery box so I am assuming it was some sort of voltage/cable problem but still am not sure what the exact issue was.

*Batteries were changed weekly on both devices—might be more cost effective/precautionary in any future deployments to use solar panels.