Milesi-Gaches, David Pierre, and Alexandre Lhériau-Nice. 2024. "Assessing the Impact of Transportation on Seal Behaviour: A Case Study from Ísafjörður, Iceland." *Findings*, June. https://doi.org/10.32866/001c.120040.

TRANSPORT FINDINGS

Assessing the Impact of Transportation on Seal Behaviour: A Case Study from Ísafjörður, Iceland.

David Pierre Milesi-Gaches[1], Alexandre Lhériau-Nice[2]

[1] Zoologie, University of South Bohemia, [2] University of Auckland

Keywords: Ecology, seals, anthropogenic impacts, environment, multivariate analysis

https://doi.org/10.32866/001c.120040

Findings

This study explores the behavioural responses of seals to various disturbances while hauling out within a transport hub featuring diverse transport facilities. Utilising Factor Analysis of Mixed Data (FAMD) on observations from September 2021 to May 2023 in Ísafjörður, Iceland, the research reveals that watercraft, particularly kayaks, significantly affect seal haul-out behaviour, triggering vigilance and flush responses. Aerial vehicles also induce stress responses, whereas road-based vehicles have lower impacts. These findings highlight the substantial influence of human activities, especially transportation, on seal haul-out behaviour, suggesting a need for mitigating strategies to reduce these impacts.

1. QUESTIONS

Seals engage in a behaviour known as hauling-out, where they come ashore to rest, thermoregulate, moult, and evade predators. This behaviour has been extensively studied, indicating significant regional variations (S. Granquist and Hauksson 2016) influenced by factors such as habitat (Hauksson 2010), weather conditions (Pauli and Terhune 1987a, 1987b; Brasseur et al. 1996; Watts 1996), and human disturbances, including tourism (Henry and Hammill 2001; S. M. Granquist and Sigurjonsdottir 2014; Andersen et al. 2014). The surge in Icelandic tourism by 150% between 2003 and 2013 (Óladóttir 2013) has prompted research into its impacts (S. M. Granquist and Sigurjonsdottir 2014), revealing alterations in haul-out patterns (Hoover-Miller et al. 2013), reduced resting and foraging times, and negative physiological effects (Tyler 1991; Carney and Sydeman 1999; Dans et al. 2008; Jayakody et al. 2008). These findings necessitate further investigation into the effects of other anthropogenic factors, particularly transportation. How are transport means impacting seals? What is the ecology of seals resting close to a transport hub with features such as harbours or airports? A few studies investigated the impact of boats to pinnipeds, mostly referring to recreational or touristic use of boats. Studies have shown, for example, that kayaks, mimicking predatory behaviour more closely than motorboats without generating excessive noise or waves, exert greater disturbance on pinnipeds (Henry and Hammill 2001; Hoover-Miller et al. 2013). In this paper, we hypothesise that transport means impact seals similarly to tourism, particularly in transportation hubs where a wide range of transport solutions can be found, such as harbours, airports, regional or national roads. Focusing

on Harbour seals (*Phoca vitulina*, Linnaeus, 1758) and Grey seals (*Halichoerus grypus*, Fabricius, 1791), this research aims to examine the influence of transportation on seal populations in Ísafjörður, the Westfjords' regional capital, Iceland.

2. METHODS

Ísafjörður, with a population of nearly 3,000, serves as the primary touristic, nautical, industrial, and service centre in Northwest Iceland. It hosts three harbours and an airport facilitating connections to Reykjavík with two aircrafts DHC-8-200 and DHC-8-400 (Icelandair 2024a, 2024b) The city is a renowned preparation point for sailors embarking towards Greenland. Post-COVID-19, there has been a noted increase in cruise ship arrivals, with the summer months witnessing up to four ships simultaneously, bringing as many as 12,000 visitors (Ísafjarðarbær 2024). Popular tourist activities include bus tours, kayaking, biking, and hiking in the surrounding areas. Seals in Ísafjörður are observed resting near the fjord's base, adjacent to the main access road and airport, in proximity to the primary harbour servicing cruise and cargo ships.

Direct observations were selected over cameras for their superior flexibility and adaptability. Humans can quickly adapt to changes in the environment and cover a broader range of vision (Lancia et al. 2005). Human observers can also provide context to animal behaviour and a wide range of data types, understanding nuanced interactions within the ecosystem that cameras might miss due to limited field of view and resolution (Altmann 1974; Martin and Bateson 2007). Observations were conducted from 2nd September 2021 to 6th May 2023, totalling 43 hours of monitoring by a single observer over 31 sessions. Observation sessions were scheduled randomly, occurring between 3 hours before and 3 hours after the low tide peak. The observer recorded seal behaviours, as described in Table 1, using Observer Focus TM 10x34 binoculars and a Focus Hawk 20-60x60 spotting scope from a vantage point atop Hauganes hill (66°03'20.5"N 23°09'40.4"W, approximately 12 metres high). Data collection included the type of disturbance, the count of disturbance agents, and basic weather conditions. Data were recorded manually on paper before being organised into a .csv spreadsheet.

The behaviour of visitors was also recorded and labelled under three categories: Passive (moving slowly, without speaking or speaking in low voice level and without hand movements), Intermediate (walking and/or speaking normally and without hand movements) and Active (walking fast/running and/or speaking in a high voice level and/or big hand movements) (S. M. Granquist and Sigurjonsdottir 2014).

Table 1. Definitions of seal behaviours (amended from S. M. Granquist and Sigurjonsdottir 2014).

Behaviour	Definition
Resting	Lying either on the back, the stomach or on the side, without moving and with the head down.
Nursing	Pup laying with head close to the teats of the mother.
Vigilance	Lifting the head up with eyes open and/or moving the head from side to side.
Vocalising	Any vocal manifestation (e.g., crying, growling).
Antagonism	Fighting, biting, hitting with head/tail/flippers.
Locomotion	All visible movements within the colony, where an individual was moving from one place to another on land or in/out of the water.
Flush response	Rushing to the water.
Leaving	All visible movement where an individual is leaving the hauling area/colony without visible signs of stress, haste.
Other	All other behaviour.

In the specific case of a perceived impact approaching gradually, such as kayaks, flush responses were recorded up to 800 metres away, provided the disturbance was the only observable change and the seals remained alarmed as the disturbance approached.

With both qualitative and quantitative data, a Factor Analysis of Mixed Data (FAMD), using R, was used to explore the variability of the sample and reveal behavioural responses of seals to their co-specific, other species and various anthropogenic disturbances, with a focus on transportation (Pagès 2004). Factor analysis of mixed data (FAMD) analyses datasets with both quantitative and qualitative variables, combining PCA for quantitative variables and MCA for qualitative ones, with normalisation to balance their influence (Pagès 2004). This allows us to explore the associations between all variables, as well as the similarity between individuals (here seals).

3. FINDINGS

Figure 1 illustrates the impacts of transportation, specifically boats, on seal behaviour within their shared habitat.

The initial five dimensions of the FAMD account for 30.02% of the dataset's variability, with the first two dimensions explaining 23.60% of this variation (Table 2). Disturbance type emerges as the primary contributing variable across all dimensions. In the two main dimensions, seal behaviour, tide levels, and human presence significantly influence the analysis outcomes (Table 2). Weather conditions notably affect seal presence at the haul-out site, while anthropogenic disturbances, trigger vigilances or even flush responses (Figure 2). We chose not to name the dimensions to avoid oversimplification and maintain focus on the detailed variable loadings presented.

Figure 3 illustrates the impact of external stimuli on seals behaviour. We separated stimuli influence into 4 categories in Figure 3: A for vehicles, B for human presence, C for non-human elements (e.g. birds, weather) and D for unclear origins. Figure 3 (A) demonstrates the impact of transportation on seals, with boats exerting the most substantial effect by provoking flush

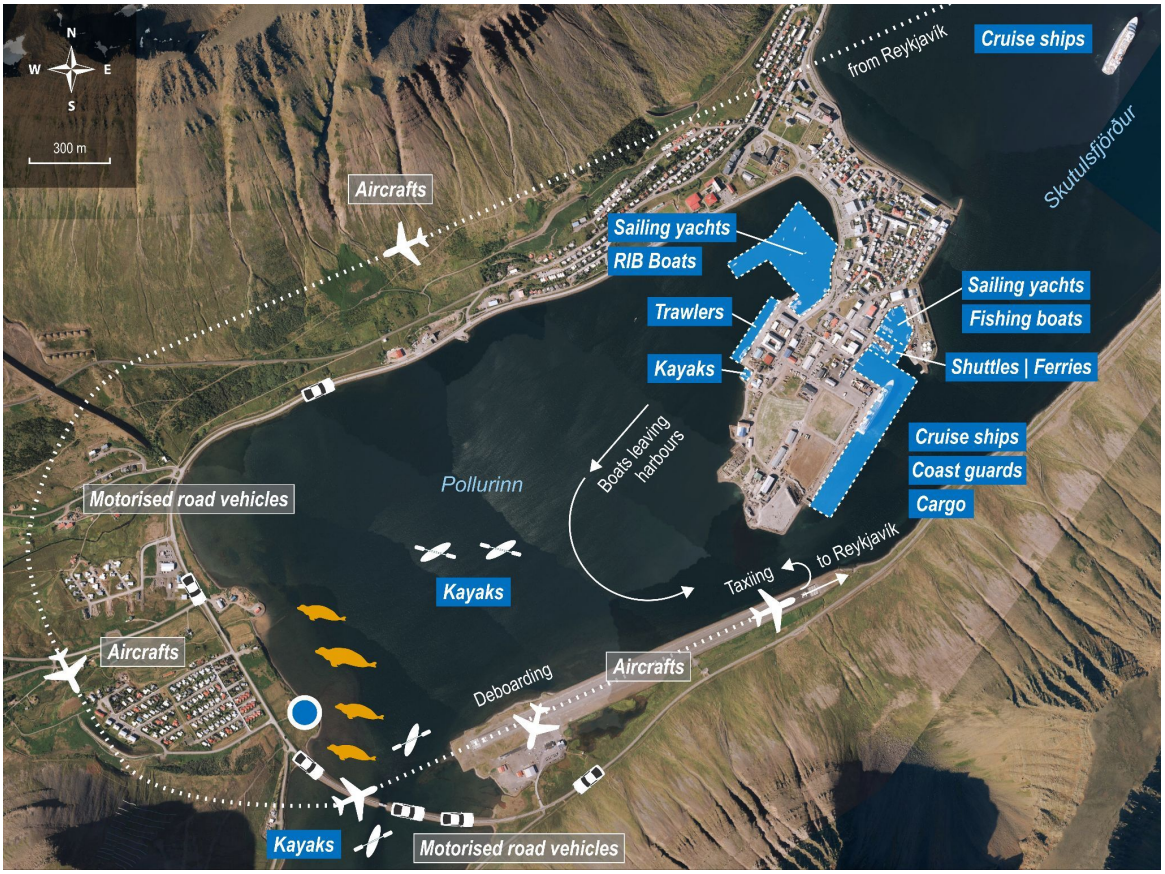

Figure 1. Localisation of the seal haul-out area and summary of observed transport means (Basemap: Loftmyndir ehf).

Table 2. Factor analysis of mixed data: percentage of explained variation per dimension and the contribution percentage of the most influential variable. The top five variables in each dimension are enumerated in brackets.

Variables	Dim. 1 | 17.0 %		Dim. 2 | 6.6 %		Dim. 3 | 5.7 %		Dim. 4 | 5.6 %		Dim. 5 | 5.0 %	
Seal number	1.83		3.11		3.25		4.29		17.47	(3)
Human number	9.30		9.21	(3)	21.16	(2)	3.16		2.29	
Tide	19.17	(2)	1.99		3.64		13.38	(3)	4.36	
Weather	9.40		4.99		5.99		1.57		27.79	(2)
Species	13.67		2.16		1.5		4.47		7.88	
Seal behaviour	15.95	(3)	36.43	(2)	19.53	(3)	34.55	(2)	10.73	
Type of disturbance	**30.68**	**(1)**	**42.11**	**(1)**	**44.94**	**(1)**	**38.59**	**(1)**	**29.48**	**(1)**

responses, as they are de facto linked to the seals' environment. Road and aerial transportation exhibit marginally lesser impacts through vigilances mostly. Human presence, particularly active behaviour, tends to induce vigilance or flush responses in seals (Figure 3, B). These impacts must be considered within the broader context of seals' behavioural ecology in the absence of anthropogenic influences, where seals predominantly engage in restful activities (Figure 3, C). Intra-specific interactions, such as vigilance towards other seals, birds, or competition for space, can affect seal behaviour to a similar extent as observed with aerial vehicles. Some behaviours remain tied to unexplained triggers (Figure 3, D) or result from rare events like construction noise from harbour expansion.

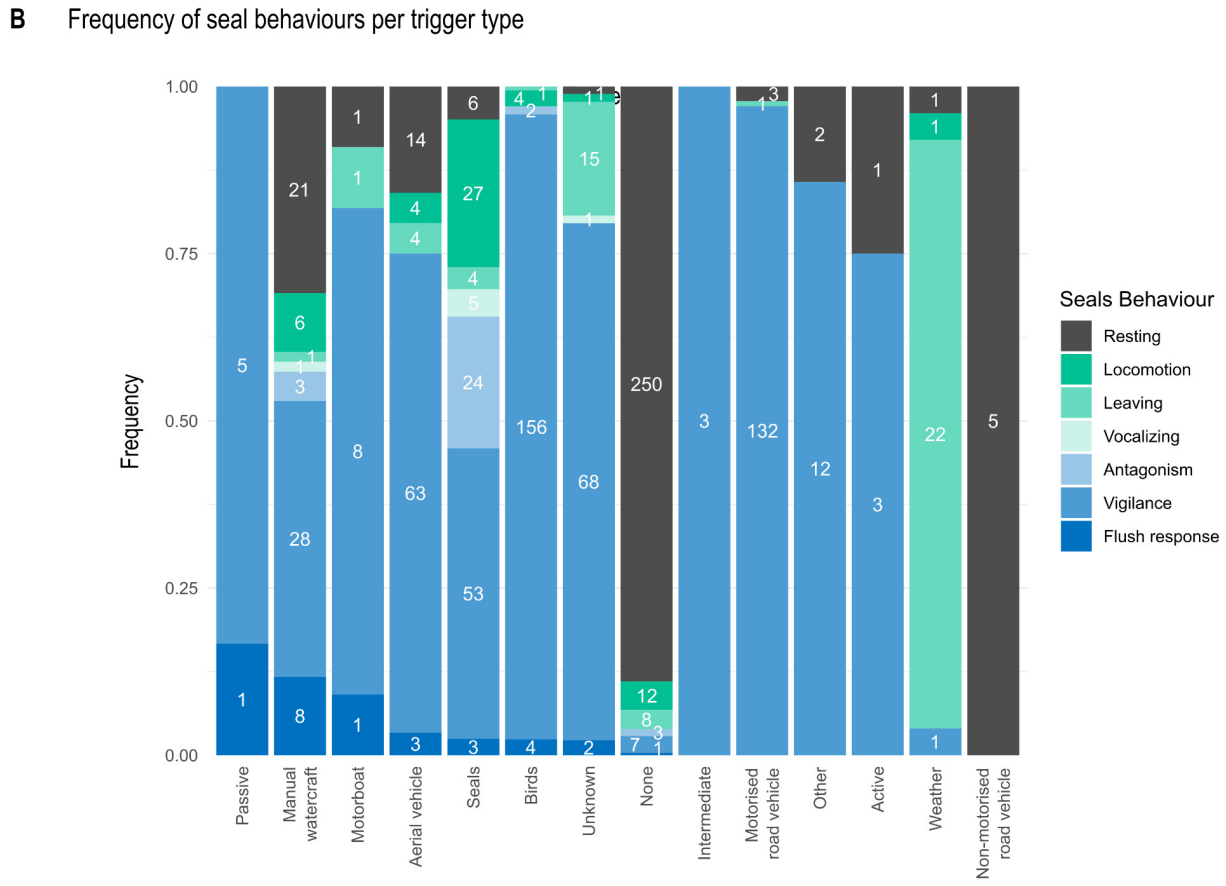

Figure 2. Frequency of seal behaviours per trigger type.

The most adverse behavioural response observed in seals (i.e. flush response) occurred 23 times. Of these incidents, 8 can be attributed to non-human factors such as bird attacks, while 13 were attributed to humans or vehicles, especially kayaks approaching within a range of 800m to 10m from the haul-out area. Only 2 flush response origins remain unknown. While flush responses are the most alarming responses possible to external stimuli, it only accounted for 2,3% of the observed behaviours, whereas vigilances accounted for 53,0% (Table 3). The latter, predominantly triggered by birds (15,3%) and motorised vehicles (13,0%), hindered the seals from resting (Table 3).

This study did not specifically measure long-term changes in seal responses to human disturbances, despite the increase in cruise ships and tourists post-COVID-19. Seals use multiple resting spots, and their behaviour is influenced by various dynamic factors.

While the impacts of birds on seals cannot be mitigated, disturbances caused by transportation should be considered for the conservation of pinnipeds, particularly in the case of harbour seals, whose population is declining in Iceland (S. Granquist 2022). As these transportation disturbances are seemingly twice more disrupting to seal hauling than other natural phenomena.

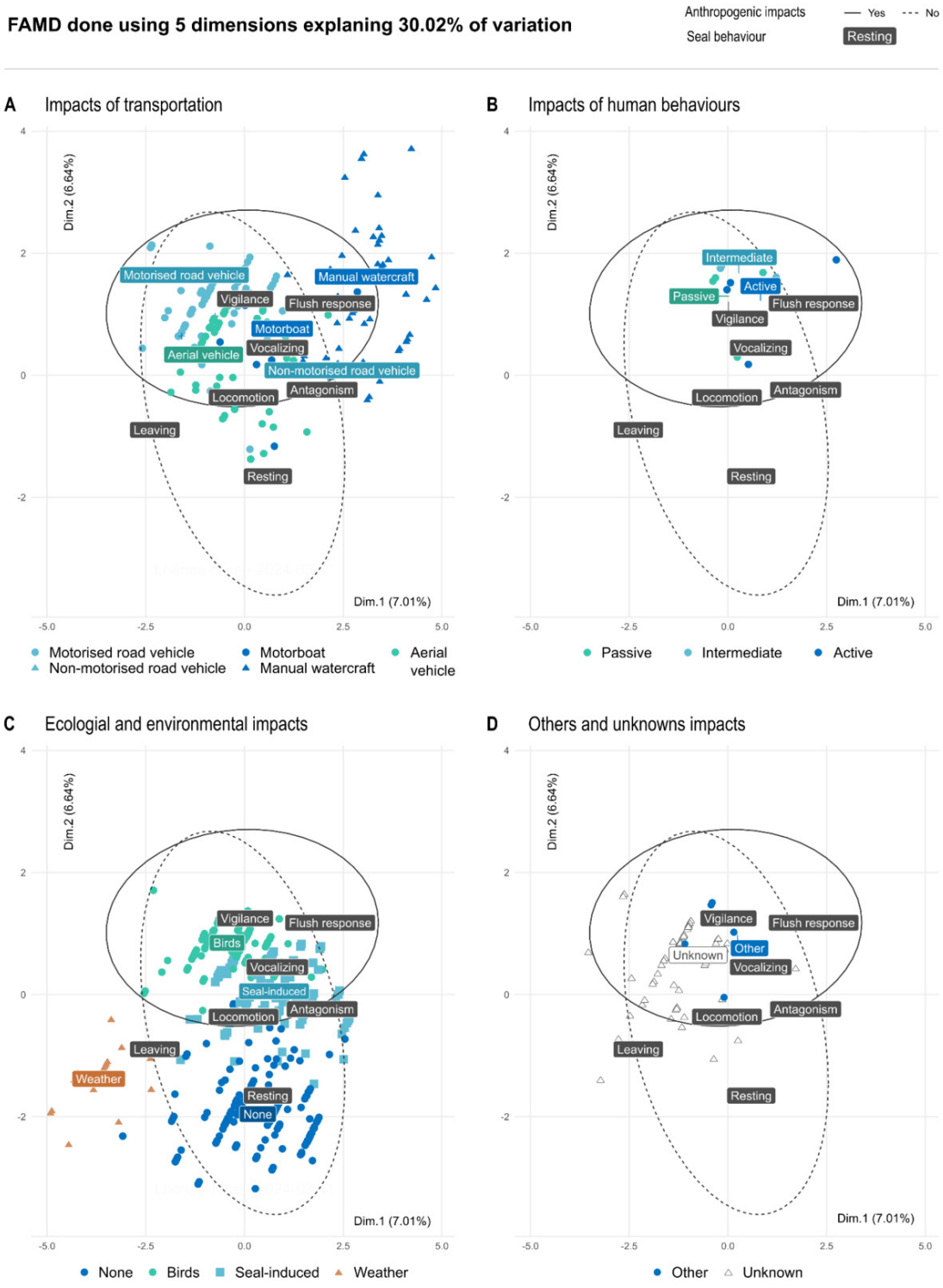

Figure 3. Factor Analysis of Mixed Data: representation of the first two dimensions, in terms of how seals are impacted by transportation **(A)**, human behaviour **(B)**, ecological and environmental variables **(C)**. **(D)** represents specific, unclear or unknown impacts. Overlapping ellipses indicate variability in individual seal responses to disturbances and transitional states influenced by varying degrees of human activity, reflecting the complex and dynamic nature of their behaviour.

The natural ecology of seals involves disturbances from birds and human activities (e.g. kayaking, walking), but transportation adds further impacts. Although roads do not directly intersect seal habitats, vehicles generate noise

Table 3. Percentage distribution of seal behaviours in response to observed triggers.

	Resting	Locomotion	Leaving	Vocalizing	Antagonism	Vigilance	Flush response	TOTAL
None	**24.6**	1.2	0.8	0	0.3	0.7	0.1	**27.6**
Passive	0	0	0	0	0	**0.5**	0.1	**0.6**
Intermediate	0	0	0	0	0	**0.3**	0	**0.3**
Active	0.1	0	0	0	0	**0.3**	0	**0.4**
Weather	0.1	0.1	**2.2**	0	0	0.1	0	**2.5**
Seal	0.6	2.7	0.4	0.5	2.4	**5.2**	0.3	**12.0**
Birds	0	0	0.1	0.4	0.2	**15.3**	0.4	**16.4**
Non-motorised road vehicle	**0.5**	0	0	0	0	0	0	**0.5**
Motorised road vehicle	0.3	0	0.1	0	0	**13.0**	0	**13.4**
Manual watercraft	2.1	0.6	0.1	0.1	0.3	**2.8**	0.8	**6.7**
Motorboat	0.1	0	0.1	0	0	**0.8**	0.1	**1.1**
Aerial vehicle	1.4	0.4	0.4	0	0	**6.2**	0.3	**8.6**
Other	0.2	0	0	0	0	**1.2**	0	**1.4**
Unknown	0,1	0.1	1.5	0.1	0	**6.7**	0.2	**8.7**
TOTAL	**30.0**	**5.0**	**5.6**	**1.1**	**3.1**	**53.0**	**2.3**	**100.0**

(sudden acceleration, sport cars, studded winter tyres, etc.) and distraction (acceleration, movement, ambulance emergency light, air ambulance, etc.). Aircrafts fly over haul-out areas at low altitudes and, after landing, taxi towards the airport (Figure 1), which makes them appear to approach the seals. Additionally, boats entering or leaving Ísafjörður harbours sail towards the seals before turning (Figure 1), causing the animals to perceive an approach and potentially become agitated. While they were not observed during this study, wakeboarding and jet skiing are activities that might occur in the lagoon. All these transportation impacts are in addition to other natural disturbances, such as those caused by birds or weather conditions.

ACKNOWLEDGEMENTS

We express our gratitude to the landowner of Hauganes, from whose property the observations were conducted.

Submitted: March 21, 2024 AEST, Accepted: June 12, 2024 AEST

REFERENCES

Altmann, J. 1974. "Observational Study of Behavior: Sampling Methods." *Behaviour* 49: 227–67. https://doi.org/10.1163/156853974X00534.

Andersen, S. M., J. Teilmann, R. Dietz, N. M. Schmidt, and L. A. Miller. 2014. "Disturbance-Induced Responses of VHF and Satellite Tagged Harbour Seals." *Aquatic Conservation: Marine and Freshwater Ecosystems* 24 (5): 712–23. https://doi.org/10.1002/aqc.2393.

Brasseur, S., J. Creuwels, B. Van der Werf, and P. Reijnders. 1996. "Deprivation Indicates Necessity for Haul-out in Harbor Seals." *Marine Mammal Science* 12 (4): 619–24. https://doi.org/10.1111/j.1748-7692.1996.tb00077.x.

Carney, K. M., and W. J. Sydeman. 1999. "A Review of Human Disturbance Effects on Nesting Colonial Waterbirds." *Waterbirds: The International Journal of Waterbird Biology* 22 (1): 68–79. https://doi.org/10.2307/1521995.

Dans, S. L., E. A. Crespo, S. N. Pedraza, M. Degrati, and G. V. Garaffo. 2008. "Dusky Dolphin and Tourist Interaction: Effect on Diurnal Feeding Behavior." *Marine Ecology Progress Series* 369: 287–96. https://doi.org/10.3354/meps07629.

Granquist, S. 2022. "The Icelandic Harbour Seal (Phoca Vitulina) Population: Trends over 40 Years (1980–2020) and Current Threats to the Population." *NAMMCO Scientific Publications* 12. https://doi.org/10.7557/3.6328.

Granquist, S., and E. Hauksson. 2016. "Seasonal, Meteorological, Tidal and Diurnal Effects on Haul-out Patterns of Harbour Seals (Phoca Vitulina) in Iceland." *Polar Biology* 39: 1–3. https://doi.org/10.1007/s00300-016-1904-3.

Granquist, S. M., and H. Sigurjonsdottir. 2014. "The Effect of Land Based Seal Watching Tourism on the Haul-out Behaviour of Harbour Seals (Phoca Vitulina) in Iceland." *Applied Animal Behaviour Science* 156: 85–93. https://doi.org/10.1016/j.applanim.2014.04.004.

Hauksson, E. 2010. "Monitoring Trends in the Abundance of Harbour Seals (Phoca Vitulina) in Icelandic Waters." *NAMMCO Scientific Publications* 8: 227–44. https://doi.org/10.7557/3.2687.

Henry, E., and M. O. Hammill. 2001. "Impact of Small Boats on the Haulout Activity of Harbour Seals (Phoca Vitulina) in Métis Bay, Saint Lawrence Estuary, Québec, Canada." *Aquatic Mammals* 27 (2): 140–48.

Hoover-Miller, A., A. Bishop, J. Prewitt, S. Conlon, C. Jezierski, and P. Armato. 2013. "Efficacy of Voluntary Mitigation in Reducing Harbor Seal Disturbance." *The Journal of Wildlife Management* 77 (4): 689–700. https://doi.org/10.1002/jwmg.510.

Icelandair. 2024a. "De Havilland Canada (DHC) Aircraft | Icelandair." https://www.icelandair.com/about/our-fleet/dhc-8-400/.

———. 2024b. "De Havilland Canada (DHC) Aircraft | Icelandair." https://www.icelandair.com/about/our-fleet/dhc-8-200/.

Ísafjarðarbær. 2024. "Skemmtiferðaskip." Ísafjarðarbær. https://www.isafjordur.is/is/thjonusta/samgongur/hafnir/skemmtiferdaskip.

Jayakody, S., A. M. Sibbald, I. J. Gordon, and X. Lambin. 2008. "Red Deer Cervus Elephus Vigilance Behaviour Differs with Habitat and Type of Human Disturbance." *Wildlife Biology* 14 (1): 81–91. https://doi.org/10.2981/0909-6396(2008)14[81:RDCEVB]2.0.CO;2.

Lancia, R. A., W. L. Kendall, K. H. Pollock, and J. D. Nichols. 2005. *Estimating the Number of Animals in Wildlife Populations*.

Martin, P., and P. Bateson. 2007. *Measuring Behaviour: An Introductory Guide*. 3rd ed. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511810893.

Óladóttir. 2013. "Tourism in Iceland in Figures." https://www.ferdamalastofa.is/static/files/ferdamalastofa/talnaefni/tourism-in-iceland-in-figures-april-2013.pdf.

Pagès, J. 2004. "Analyse factorielle de données mixtes." *Revue de Statistique Appliquée* 52 (4): 93–111.

Pauli, B. D., and J. Terhune. 1987a. "Meteorological Influences on Harbour Seal Haul-Out." *Aquatic Mammals* 13: 114–18.

———. 1987b. "Tidal and Temporal Interaction on Harbour Seal Haul-out Patterns." *Aquatic Mammals* 13: 93–95.

Tyler, N. J. C. 1991. "Short-Term Behavioural Responses of Svalbard Reindeer Rangifer Tarandus Platyrhynchus to Direct Provocation by a Snowmobile." *Biological Conservation* 56 (2): 179–94. https://doi.org/10.1016/0006-3207(91)90016-3.

Watts, P. 1996. "The Diel Hauling-out Cycle of Harbour Seals in an Open Marine Environment: Correlates and Constraints." *Journal of Zoology* 240 (1): 175–200. https://doi.org/10.1111/j.1469-7998.1996.tb05494.x.