Welfare outcomes for livestock transported on Northern Isles ferry routes

Final report

August 2024

Scottish Government
Riaghaltas na h-Alba

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Executive summary

Background

Transportation of livestock in Scotland can involve significant challenges, due to dispersed islands and movements through difficult terrain on narrow roads. A particular concern is the movement of animals from the Northern Isles to the mainland for marketing involving sea freight journeys of between 9-15 hours. Although some journeys are for slaughter, most journeys are made in the autumn, particularly to deal with the need to provide livestock with adequate nutrition during winter months, when available forage, housing and supplementary feeds are limited in the Northern Isles. Sheep and cattle regularly leave Orkney and Shetland and travel by ferry to Aberdeen in significant numbers (approximately 25,000 cattle and 140,000 sheep per annum). This trade is an integral part of the agricultural sustainability of these island communities. To deal with the retained EU legislative requirements for livestock journey times, the animals are loaded onto specially designed two-tier cassettes, which allow for feed and water to be given to the animals, and effluent to be contained. The current system has been in operation for over 15 years and is considered by stakeholders to be a substantial improvement for animal welfare and operational efficiency over the previous system. Scottish Government has designated the time on board the ferry as ‘neutral’, which does not count towards maximum allowable journey times. There is, however, little objective scientific evidence to understand the animals’ experience of these types of journeys.

The project’s aims and objectives were as follows:

Aim: Provide objective evidence on the behavioural responses of cattle and sheep to ferry transport from the Northern Isles to Aberdeen.

Objectives:

1. Stakeholder engagement and scoping
2. Historical data and modelling
3. Welfare outcomes attributable to the sea crossing

Outcomes:

Objective 1: Stakeholders from across the agricultural sector attended a stakeholder meeting at the beginning and end of the project. One-to-one discussions with 17 stakeholders gained deeper understanding of the practice of moving animals from the Northern Isles. A predominantly held view was that the current system is excellent and a substantial improvement for animal welfare and operational efficiency over the system used before the advent of the cassettes (the construction of which began in 2007). We do not doubt the veracity of this statement, but note that it was not possible to compare the livestock cassette system with the previous system in this study. Even well-functioning systems can be refined further and below we make recommendations for further refinement to the cassette system.

Objective 2: Movement data for 2022 during which 26,948 cattle and 126,613 sheep moved to the mainland from the Northern Isles showed that the predominant final destination for cattle was Aberdeenshire and Angus and for sheep was Aberdeenshire or Cumbria. The longest journey, experienced by a minority of animals, was the movement of sheep to Wales.

A small quantity of data was collected by Official Veterinarians on their impressions of the tiredness, thirst and hunger of animals arriving from ferry journeys at local abattoirs. Data from too few animals inspected immediately upon arrival at the abattoir was available to make meaningful conclusions, but this would be a useful source of data should Scottish Government wish to continue collecting it going forward.

Aberdeen City Council animal health inspection reports were available for a period of over 7 years during which a total of 299,060 animals passed through the Aberdeen port lairage during days in which inspection visits were made and on which wave height data were available. The number of casualties (animals that died on the journey, needed to be euthanised or receive veterinary intervention on arrival) that could be attributed to the journey with reasonable confidence was very low (23 animals; 0.0008% of animals transported). No effect of sea conditions on the casualty rate was found. This dataset was not designed to detect minor deviations in health/welfare.

Objective 3: Six journeys (three focusing on store cattle from Orkney and three on store lambs from Shetland) were accompanied. These journeys sampled a representative range of sea conditions and vessel motion recorded during the period from August to December 2023. High ambient temperature combined with high relative humidity (>25°C and 85% RH) occurred in around half of the cattle cassettes studied. A temperature of 25°C approximates the upper limit of the thermoneutral zone of store cattle and is the EFSA recommended limit for cattle transport. Temperature and humidity were lower in sheep cassettes. Cattle spent a mean of 14 hours and 54 minutes between entering the cassette and the vessel docking in Aberdeen, whilst lambs spent a mean of 19 hours and 40 minutes, such that animals spent several hours housed in the cassettes waiting to board the vessel (3 hours for cattle and around 5 hours for lambs). In lamb cassettes, hay was available for a mean of 3 hours and 4 minutes from entry to the cassette, leaving a mean of 16 hours and 36 minutes between the hay being consumed and docking in Aberdeen. For cattle, 25 of the 35 studied cassette compartments had hay remaining when the vessel docked in Aberdeen. Of the remaining 10 compartments, the hay was consumed within 6 hours of entering the cassette. On average, around 95% of cattle and 39% of lambs were observed to be standing at any moment in time. Behaviour of cattle was similar in each of the three journeys except the warmest when, on average, 24% of the cattle were showing rapid breathing at each observation point (1 and 7% in the other journeys). Open-mouthed panting was not seen. Few sheep showed rapid breathing (2-6% depending on the journey) but double the number of animals stood during the roughest sailing compared to the other journeys. Drinkers were only visible in around 40% of video segments in cassettes containing cattle, but cattle were not seen to drink when the drinkers were visible and drinking was rarely seen in the sheep cassettes (median 0% of visible animals). Cassette location on the vessel did not affect animal behaviour for either species. Only one animal was observed to fall during the sailings and the rate of involuntary movements by the animals caused by vessel motion was low. Currently the vessel master uses their experience to integrate the sources of information on weather and sea state and reach a decision on whether to transport each class of livestock. The low occurrence of involuntary movements by the animals indicates that the decisions made regarding the likely motion of the vessel and the impact of this on the animals were appropriate. Observations of animals on arrival in Aberdeen were problematic. Most cattle and lambs did not lie down within the first hour after unloading, but this may reflect the novelty of the lairage environment rather than a lack of fatigue. It was noted that animal handling was performed calmly by experienced staff at the lairages in Orkney, Shetland and Aberdeen.

Recommendations

The available data confirm the stakeholders' view that the system is efficient and no outcomes were recorded that would indicate a likely reduction in long-term animal welfare. Injuries observed were limited to lameness in lambs which was not significant enough to prevent the animals walking unaided at a normal walking speed. New injuries that could be confidently attributed to the journey were not found. As above, we noted that the animals were handled well at all three lairage facilities by experienced staff who moved the animals calmly. However, signs of heat stress during one cattle journey, the scarcity of lying behaviour in all three cattle journeys, the period without food in lambs and lack of rumination by both species suggest that short-term welfare is likely to be affected. Below are recommendations that would contribute to the continued refinement of the system and benefit short-term welfare.

1. A greater quantity of hay could be provided to sheep before loading to reduce the proportion of the journey spent without food.
2. This study only focussed on the two main classes of animals transported from the Northern Isles (store cattle and lambs). Specific effort should be made to assess

the welfare of other animals transported in smaller numbers but that are potentially less robust (e.g. cull adult animals and young stock).
3. Cattle were not observed to drink from the nipple drinkers in the port lairage in Kirkwall and drinkers are not provided for sheep at the lairage in Lerwick. As animals may wait in the lairage for prolonged periods, especially if the ship arrives late (>12 hours for some lambs in one journey), consideration should be given to providing water or improving the attractiveness of drinkers in the lairages.
4. Specific quantification of water use in the cassettes is recommended as a follow-up study to estimate the volume of water consumed. As lack of water use will exacerbate heat stress, quantifying water use by cattle would be particularly useful.
5. Methods to allow on-going monitoring and recording of ambient temperature within a sample of cassettes would provide valuable information to inform refinement of practices according to potential heat load. The current data suggests that effort to reduce heat load during summer cattle journeys would be valuable. For example, this may include reducing stocking density (with appropriate consideration given to maintaining postural stability), improving ventilation and (if water use is subsequently shown to be low) encouraging water consumption.
6. Within the course of a single journey, the wave and swell height, direction and period can fluctuate greatly (e.g. swell can move from the north and south and vary in height from 0.1 to 3.0m and period from 5 to 15 seconds in the course of a single journey; significant wave parameters may vary substantially also). Currently the vessel master uses their experience to amalgamate these sources of information and judge whether conditions are appropriate for the safe travel of animals. If a formalised rule-based approach was adopted (e.g. based on a maximum allowable wind speed or wave height) we note that this would need to be underpinned by studying a very large number of journeys (likely >100) to quantify how the duration and magnitude of each individual variable combines to affect animal welfare. The data indicate that vessel masters made appropriate decisions with respect to vessel motion on the accompanied journeys.

Objective 1: Stakeholder engagement and scoping

An initial stakeholder meeting was held in May 2023 and replicated in June 2023 which was attended by stakeholders representing the following sectors of the industry: Scottish Government, ferry operator, auction marts, agricultural consultancy, veterinary surgery, local government, industry associations, farmer unions, animal welfare NGOs, national and local animal health bodies and abattoirs. Stevedore operators were engaged with separately. A scoping visit was made to Aberdeen and Orkney. One-to-one discussions were held with 17 stakeholders for deeper insight and to engage with those unable to attend the stakeholder meetings (stevedores, lairage managers and vessel masters (two from freight vessels and two from passenger ferries which carry some cassettes)). A final stakeholder meeting is planned for February 2024. A predominant view from stakeholders was that the current system is excellent and a substantial improvement for animal welfare and operational efficiency over the system used before the advent of the cassettes. We do not doubt the veracity of this statement, but note that this study could only quantitatively explore the current cassette system and not the system it replaced. Furthermore, stakeholders commented that a functioning system is in place for staff in Aberdeen receiving animals to feed-back to those on the Isles to refine practice and that this process has improved animal welfare over the years. Stakeholders also reported a high degree of customer satisfaction with animals supplied from the Northern Isles.

Objective 2: Historical data and modelling

Animal journey length

Reports on animal movements involving cattle and sheep departing the Northern Isles were prepared by staff at the University of Glasgow and EPIC. Data for cattle were summarised for 2022 and for sheep between 2011 and 2022.

Cattle:

Number of journeys per animal: 26,948 cattle moved off Orkney or Shetland to the mainland during 2022. Of these, 14,662 experienced one journey in order to reach the mainland (directly from Orkney or Shetland to the mainland), 11,218 experienced two journeys (one within Orkney or Shetland and one to the mainland) and the remaining 596 experienced between three and six journeys, with the last being to the mainland. The interval between journeys is unknown, except that they occurred within 2022, and the number of journeys after reaching the destination on the mainland is also unknown.

Distance travelled per animal: The predominant final destination for cattle was Aberdeenshire and Angus. The straight-line distance between CPH of origin and CPH of destination on the UK mainland was: Cattle from Orkney to Aberdeenshire (median 123 miles, interquartile range 113-130 miles); cattle from Orkney to Angus (median 155, interquartile range 154-159 miles), cattle from Shetland to Aberdeenshire (median 204, interquartile range 189-214). No cattle from Shetland were delivered directly to Angus.

Sheep:

Number of journeys per animal: The EPIC data combined journeys that occurred within 7 days into a single journey, thus it is not possible to determine how many sheep were transported again within a few days of arrival at their first off-island destination. Around 30% of animals moved to a different holding more than 7 days after arrival.

Distance travelled per animal: Around 60-65% of sheep batches leaving the Northern Isles journeyed to another farm in Scotland, with around 20% sent to a market, and the remaining percentage being sent to abattoirs, to holdings in England or other premises. The large majority of movements occurred in the autumn. Data were analysed for 2022 in more detail, during which 126,613 sheep left Shetland and 67,111 sheep left Orkney. For sheep leaving Shetland, the large majority of animals were destined for Aberdeenshire or Cumbria or another of the Shetland islands, with much smaller numbers traveling elsewhere in Scotland or to England or Wales (Figure 1). The primary off-island destinations for sheep from Orkney were Lanarkshire, Cumbria and Aberdeenshire, again with smaller numbers destined for elsewhere in Scotland, England or Wales (Figure 2). The port lairage in Lerwick is a critical control point and visible in the movement data. The majority of sheep arrived at their destination within one day of leaving the lairage in Lerwick, although the period of time from leaving the farm of origin to departing the Lerwick lairage is likely to be an additional 10-12 hours in most instances.

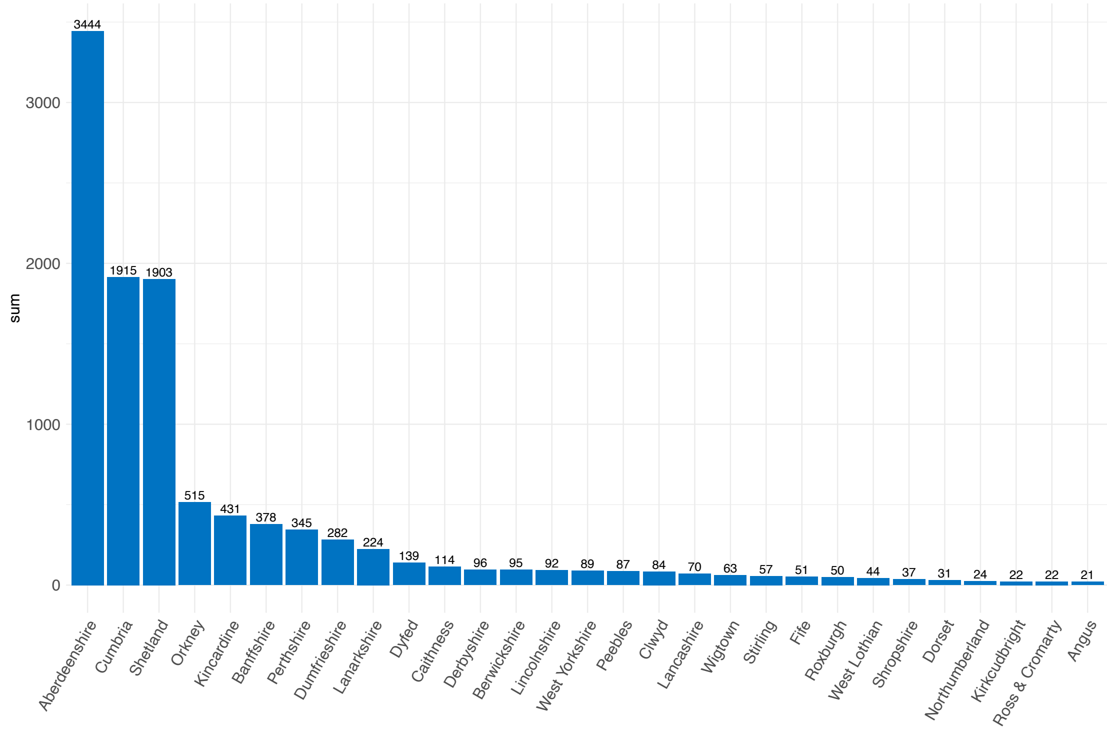


Figure 1: First destination of sheep leaving Shetland in 2022

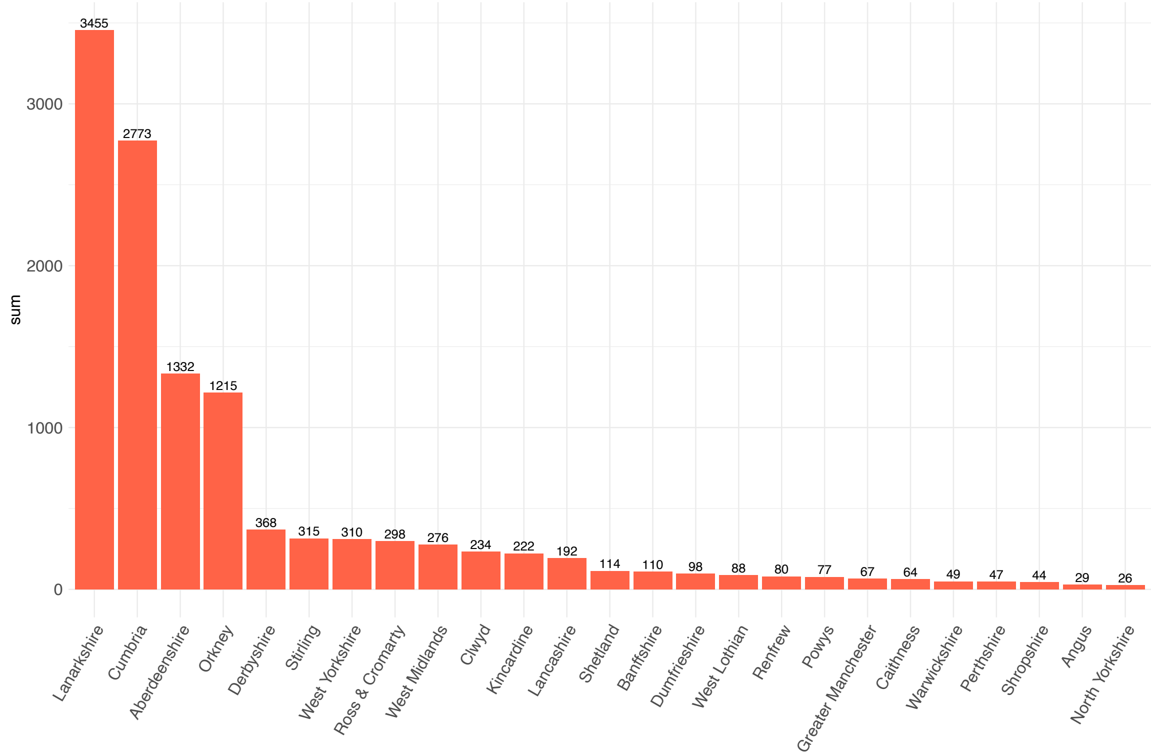


Figure 2: First destination of sheep leaving Orkney in 2022

Official Veterinarian inspections in abattoirs

Official Veterinarians in two abattoirs within approximately 40 miles of Aberdeen kindly noted the date, hour of arrival, number of animals in the consignment, and whether animals appeared unusually (a) tired or (b) thirsty or hungry on arrival compared to animals arriving from elsewhere (based on subjective impression).

Observations were made on 523 cattle over 20 days (2 abattoirs) and 114 sheep over 4 days (1 abattoir). Cattle that had experienced a ferry journey appeared more tired than animals from other sources on two observation days and hungrier on one day. They showed normal levels of thirst on all observation days. Sheep appeared to be moving slower than animals from other sources on one observation day. They showed a normal level of tiredness on the remaining three days and showed normal levels of thirst on all four days. Wave data for the corresponding dates (minimum and maximum significant wave height and swell height) showed that the days when animals appeared to deviate in behaviour from the norm were not unusual with respect to sea conditions. The predominant wave direction on the dates with abnormal behaviour was from the SW, corresponding to the prevailing wind direction.

This is potentially a valuable source of data, but the quantity of data collected for the purposes of the current study is extremely limited, especially for sheep considering the number of animals transported by ferry during a season. Sheep were also not observed immediately upon arrival at the abattoir. This is a form of data collection that the Scottish Government may wish to continue collecting, together with data on duration since leaving the farm of origin to determine whether abnormal behaviour most likely reflects lack of rest or the sea conditions.

Historical data from animal inspections on arrival in Aberdeen

We explored whether there was any evidence in historical data for an effect of sea conditions on animal casualties evident on arrival in Aberdeen. Casualty data was provided by Aberdeen City Council which holds responsibility for inspection of the port lairage facility. Seven complete years of data plus two years represented by only 3 months each were available, beginning in 2014. Data were filtered to remove inspection visits when fewer than 100 animals were observed. The original inspection notes were not designed to attribute causation of health problems to the journey versus farm of origin. Therefore, ascribing cause was challenging in our analysis and is not without error. It was assumed that any animal which was unable to walk out of a cassette, was dead-on-arrival or needed to be euthanised on arrival was a casualty of the journey. Animals with obvious pre-existing conditions (e.g. poor body condition, pregnancy) were not included as casualties of the journey. Some cases were ambiguous (lameness which did not prevent onward travel; prolapse). These could have existed before loading into the cassettes and these animals were not counted as casualties of the journey. On almost all journeys with a casualty, only one animal was affected rather than multiple animals. Therefore, the occurrence of casualty animals was treated as a binary outcome (yes/no) rather than as a proportion of the animals observed.

Significant wave height (Hs) data were taken from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) database. As the closest wave recording station to the ferry journeys, wave height was taken from the Claymore buoy owned by UK Oil and Gas Ltd located 161km NE of Aberdeen in the Claymore oil field. Wave height was recorded at midnight on the morning of the day of inspection, approximately when vessels would be at their closest point to this buoy.

A total of 299,060 animals passed through the Aberdeen port lairage during days in which inspection visits were made and on which wave height data were available. The number of casualties that could be attributed to the journey with reasonable confidence was 23 (0.0008% of animals transported). The median significant wave height on journeys with no casualties was 1.80m and that during journeys with casualties was 1.90m. A Mann Whitney U test showed that these medians were not statistically significantly different from chance ($p=0.26$).

It should be noted that this analysis was significantly limited in a number of respects: Health outcomes that were not deemed severe enough to warrant recording by inspectors may have occurred but are not visible in the data (e.g. lameness that did not require intervention). The wave data from the Claymore buoy was the only retrospective data available for analysis and is not located directly on the journey from Shetland and is a significant distance off-route from Orkney. Furthermore, it provides only a snap-shot of one part of the journey and the effects of wave height are likely to be influenced by other metrics (e.g. wave direction and period; swell height, direction and period; vessel speed and heading).

Objective 3: Welfare outcomes attributable to the sea crossing

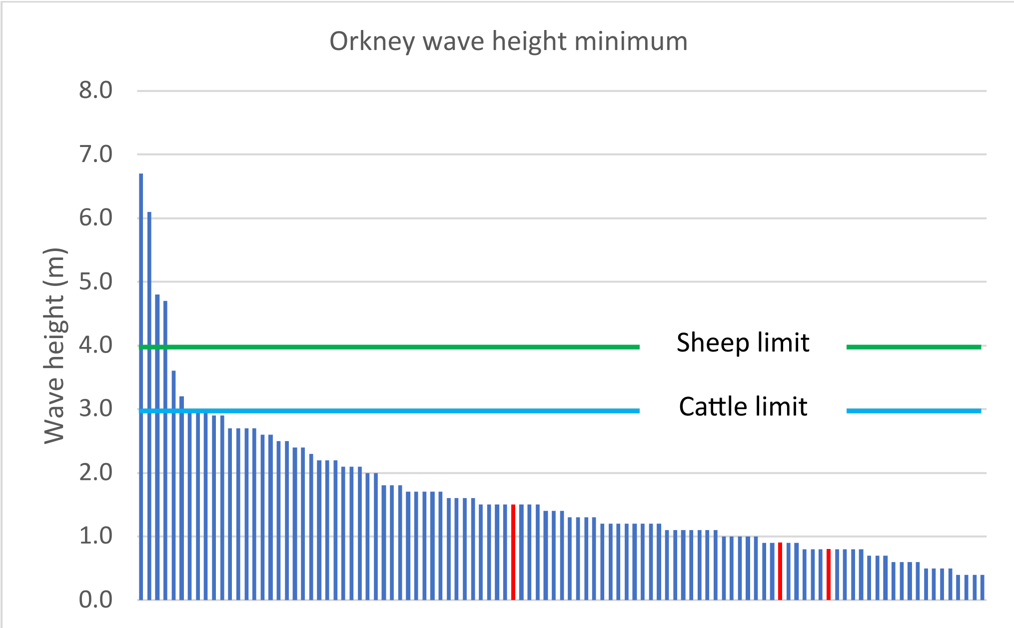
Three journeys focusing on store cattle from Orkney and three journeys focusing on store lambs from Shetland were accompanied and the animals' behaviour and welfare assessed. These stock types were chosen as they represent the major types shipped from the Northern Isles. Lambs varied in weight from store Shetland breed animals of around 25kg to prime lambs (e.g. of Suffolk/Texel cross) of around 40kg. These weights were estimated by eye.

Accompanied journeys in the context of seasonal variation in sea conditions

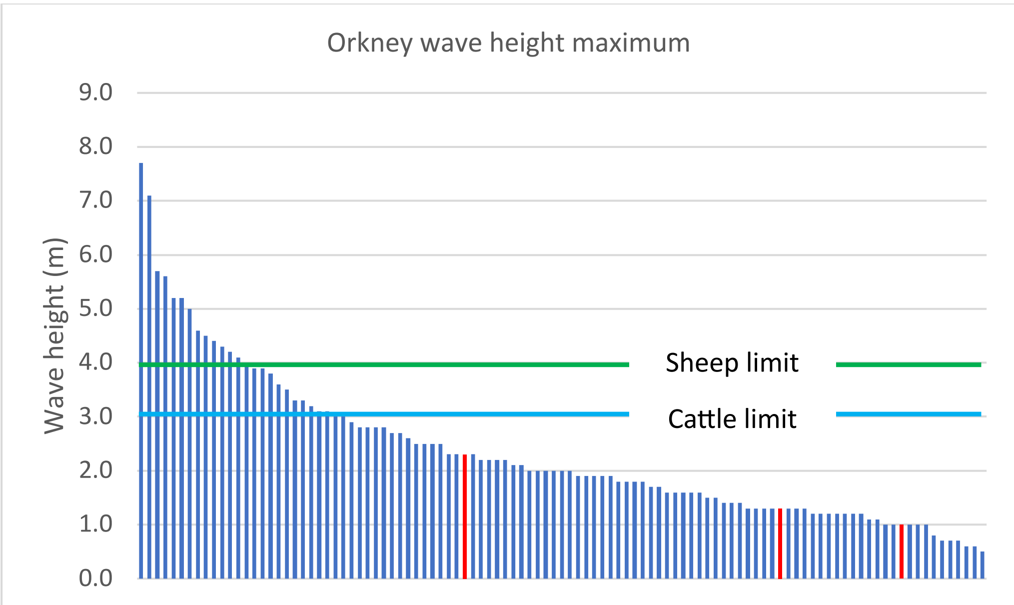
Two methods were used to place the accompanied journeys into the wider context of the sea conditions which occurred during the late summer to early winter period of 2023: (1) daily records of sea condition; (2) vessel motion recorded on samples of journeys throughout the season.

(1) Sea conditions
Significant wave height (Hs: min, max; m), period (min, max; seconds) and predominant wave direction together with the same attributes for swell were recorded daily from 27th August to 10th December 2023, encompassing the main livestock movement period, using the Windy App (a tool recommended by two of the ships' masters interviewed). Conditions were recorded at a time of day when vessels would be approximately at the mid-point of their journey. Data from dates when accompanied journeys were made were compared to the seasonal distribution. The accompanied journeys sampled a representative range of sea conditions recorded across the season (Figures 3 and 4). The vessel masters exercised their discretion in restricting the types of livestock transported and in delaying or cancelling journeys according to sea conditions. Therefore, Figures 3 and 4 include days when livestock were not accepted, when restrictions were placed on the class of livestock moved or the journey was delayed or cancelled (see below for a quantification of these events). All four masters interviewed independently gave the same wave height limits as the maximum for accepting cattle (3m) and sheep (4m). These limits are highlighted on Figures 3 and 4. As the sea state data were only recorded as a snap-shot approximately when the vessel would be mid-journey, it is not possible to determine with accuracy exactly what maximum sea state a vessel actually experienced on a given journey. However, matching the available sea state data to the ship movement logs (which include cancellations, delays and limits on animal carriage) gives no reason to doubt that these limits were adhered to. It should be noted that, within the course of a single journey, the wave and swell height, direction and period can fluctuate greatly, and this within-journey complexity is not captured in Figures 3 and 4.

(a)


Orkney wave height minimum
Wave height (m)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Sheep limit
Cattle limit

(b)


Orkney wave height maximum
Wave height (m)
9.0
8.0
7.0
6.0
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4.0
3.0
2.0
1.0
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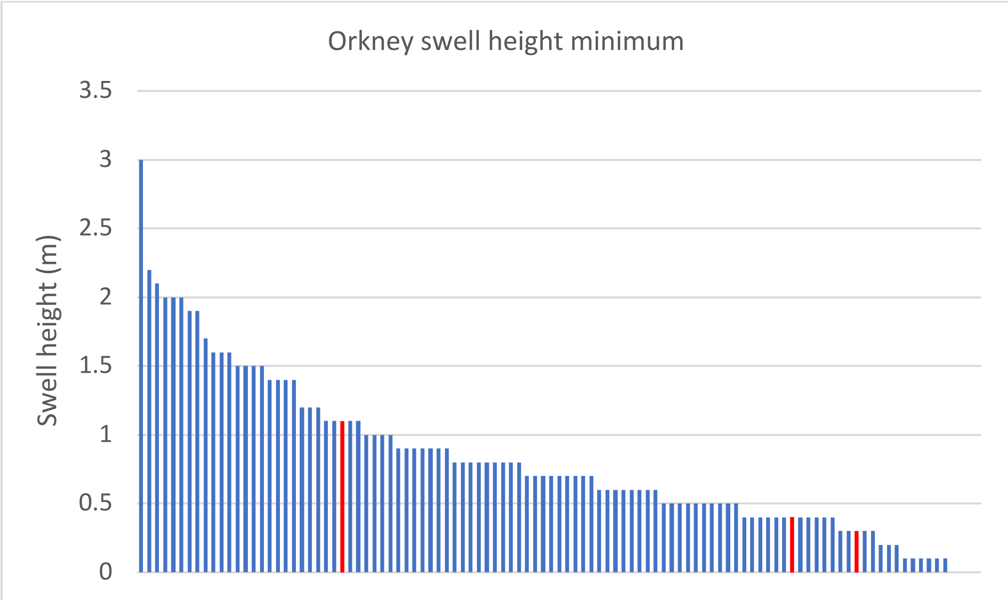
Sheep limit
Cattle limit

(c)



(d)

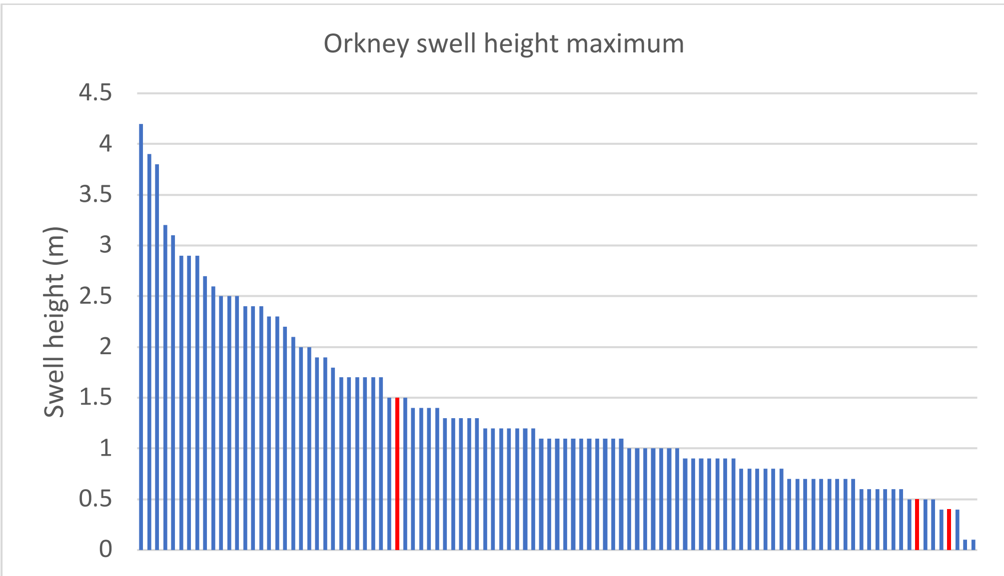
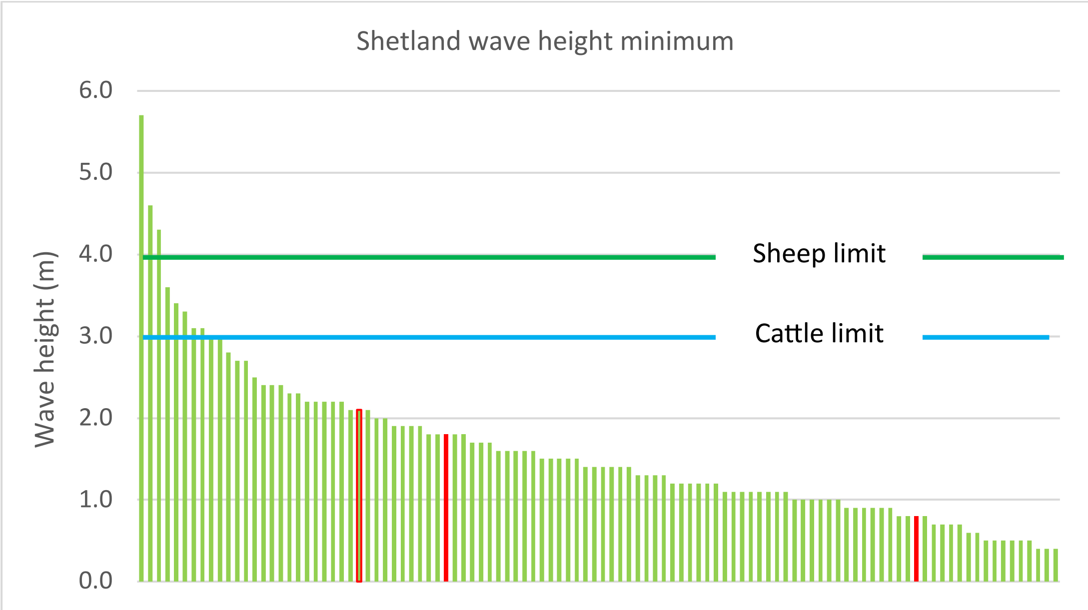
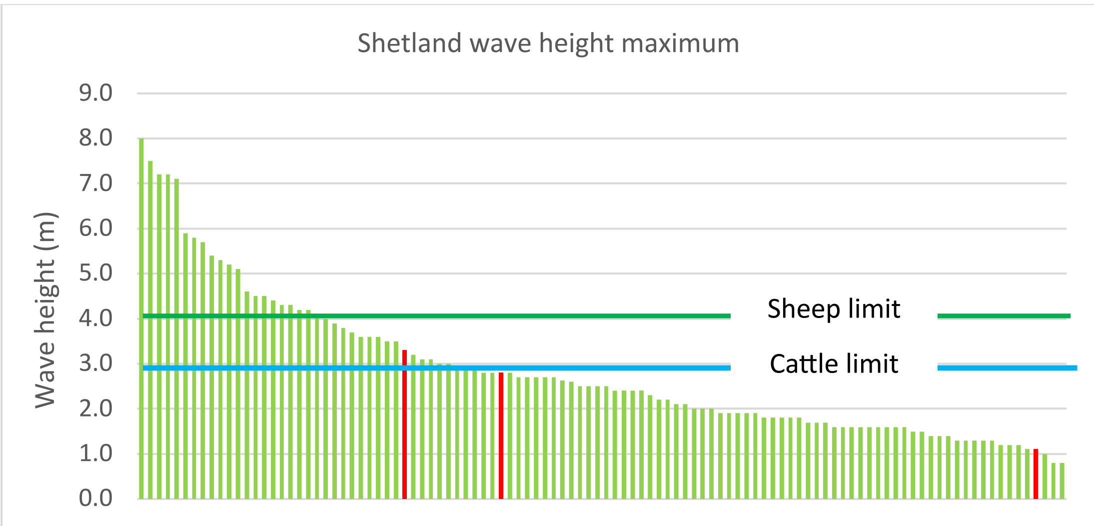


Figure 3 a-d: (a) Minimum significant wave height (Hs); (b) maximum significant wave hight; (c) minimum swell height; (d) maximum swell height in the route between Kirkwall and Aberdeen. Each bar represents a single day. Days are organised from the roughest on the left to calmest on the right. Accompanied journeys are highlighted in red. **Sailings were cancelled on the roughest days on the Master's judgement, and therefore the vessel did not sail on all of the days depicted.** On figures a and b 'Sheep limit' and 'cattle limit' refer to the thresholds indicated independently by four vessel masters as being the maximum wave height beyond which these livestock would denied boarding.

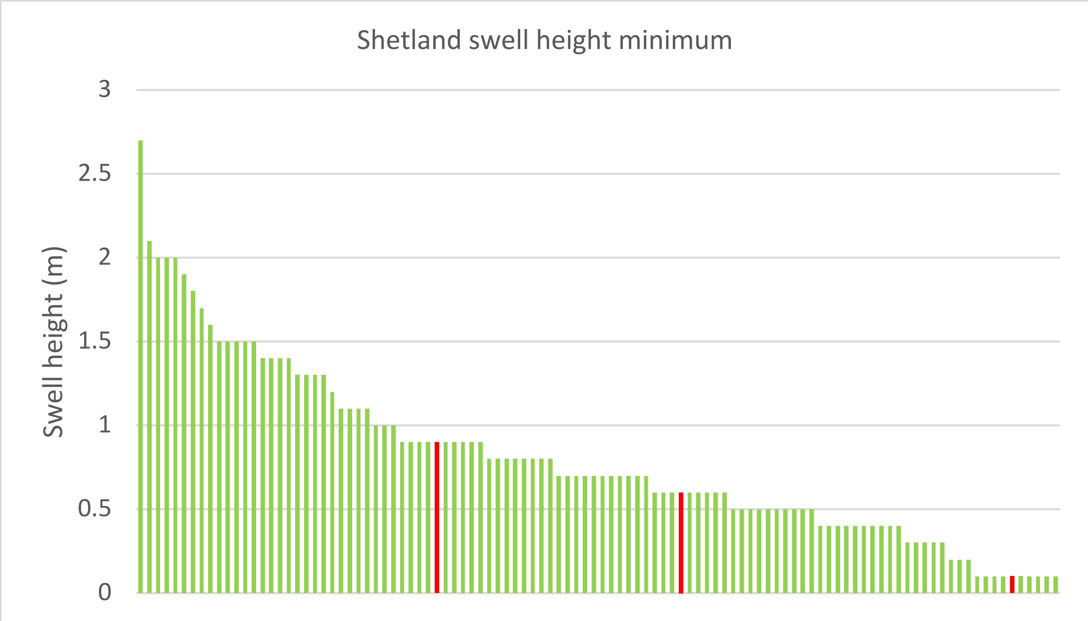
(a)


Shetland wave height minimum
Wave height (m)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Sheep limit
Cattle limit

(b)


Shetland wave height maximum
Wave height (m)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Sheep limit
Cattle limit

(c)



(d)

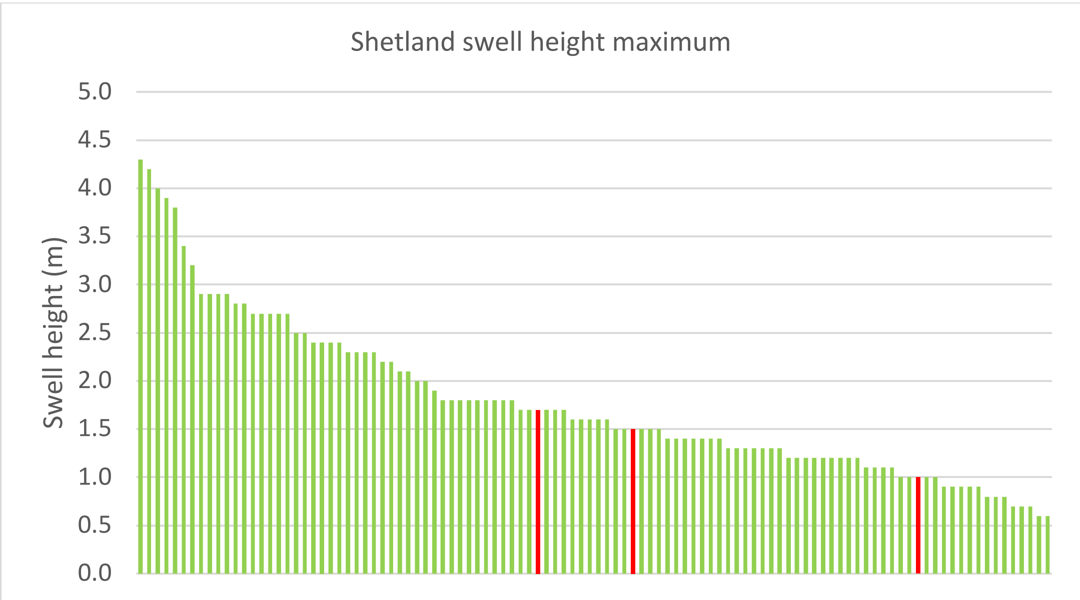
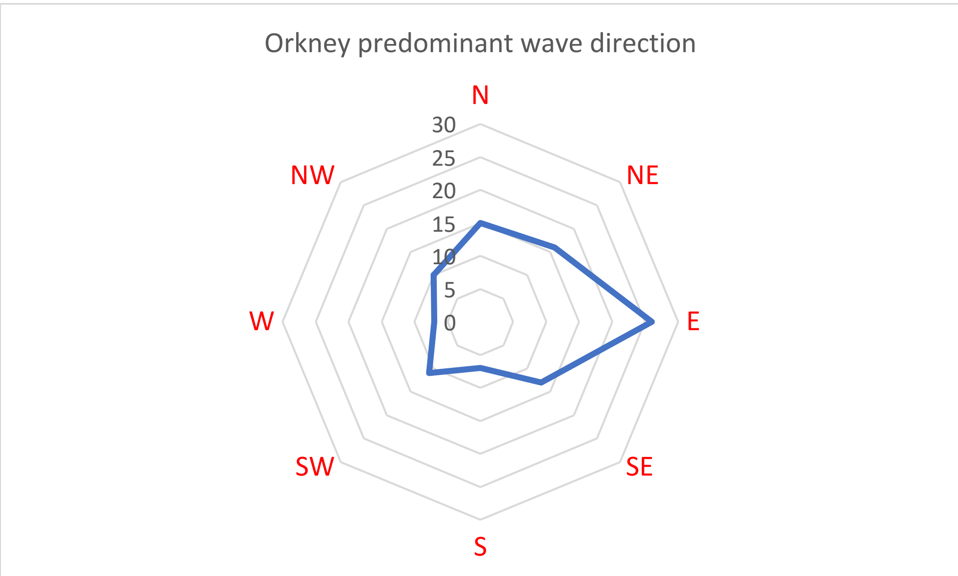


Figure 4 a-d: (a) Minimum significant wave height (Hs); (b) maximum significant wave hight; (c) minimum swell height; (d) maximum swell height in the route between Lerwick and Aberdeen. Each bar represents a single day. Days are organised from the roughest on the left to calmest on the right. Accompanied journeys are highlighted in red. **Sailings were cancelled on the roughest days on the Master's judgement, and therefore the vessel did not sail on all of the days depicted.** On figures a and b 'Sheep limit' and 'cattle limit' refer to the thresholds indicated independently by four vessel masters as being the maximum wave height beyond which these livestock would denied boarding.

Wave and swell direction impact vessel movement. For both the routes from Orkney and Shetland, the wave direction was from east to west and swell direction from east or west or north to south on a disproportionate number of days (Figures 5 and 6). The normally prevailing south-westerly wind direction occurred on relatively few days in the 2023 season and hence days in which waves or swell were from this direction were few. The routes are exposed to rougher conditions for a greater portion of their length when the sea motion is from the east or north as the Scottish mainland offers no protection. Therefore, the 2023 season can be regarded as unusually rough with a greater number of timetable changes than normal. Nine sailings to/from Aberdeen and the Northern Isles were cancelled during the period from the beginning of August to the end of November 2023 (plus an additional three sailings between Orkney and Shetland). Additionally, sheep but no other livestock were accepted on 5 further journeys and no livestock were accepted on three further journeys. The large majority of animals experience a southbound sailing, and all accompanied journeys in this study were southbound. Four of the southbound sailings were cancelled or the master accepted no livestock onboard, and a further two sailings accepted sheep but no other classes of livestock.

(a)



(b)

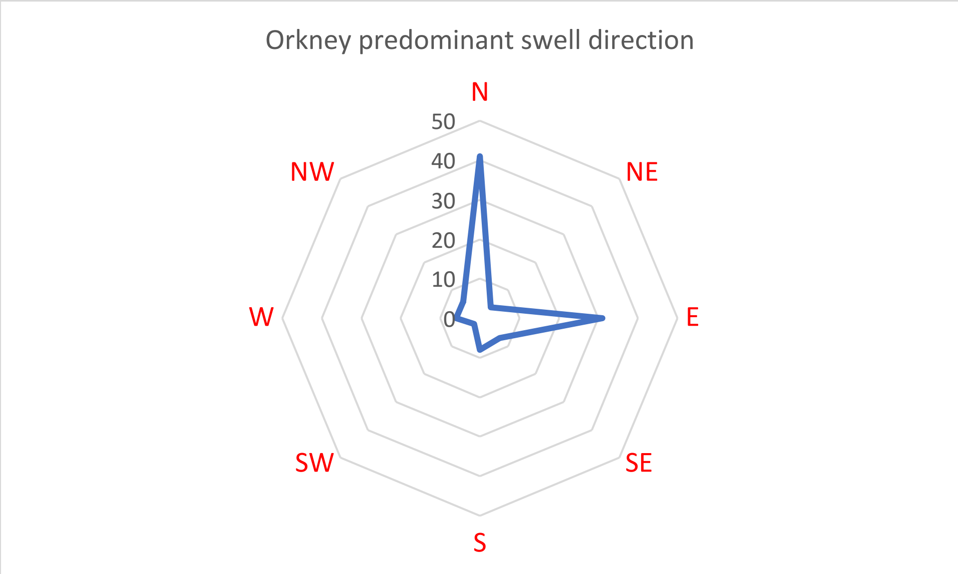
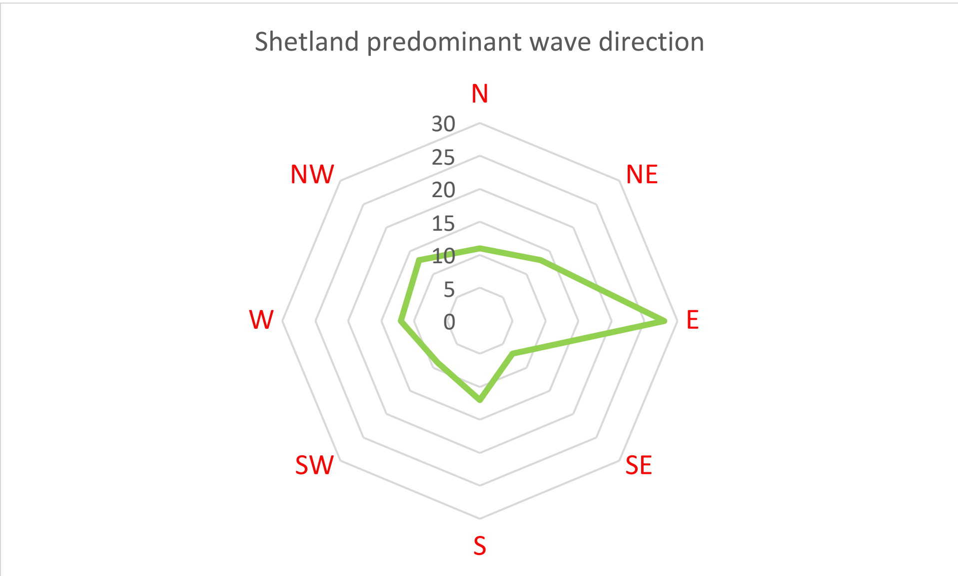


Figure 5 a, b: Predominant wave (a) and swell (b) direction recorded daily for the route between Kirkwall and Aberdeen. Numbers refer to number of days. The blue trace indicates the frequency of days in which the wave or swell direction was from each point of the compass.

(a)



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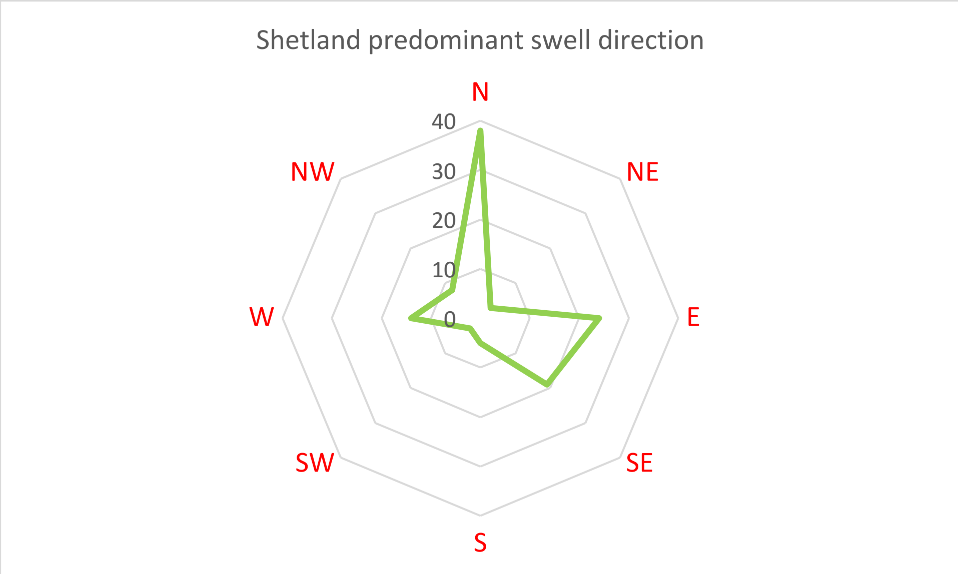


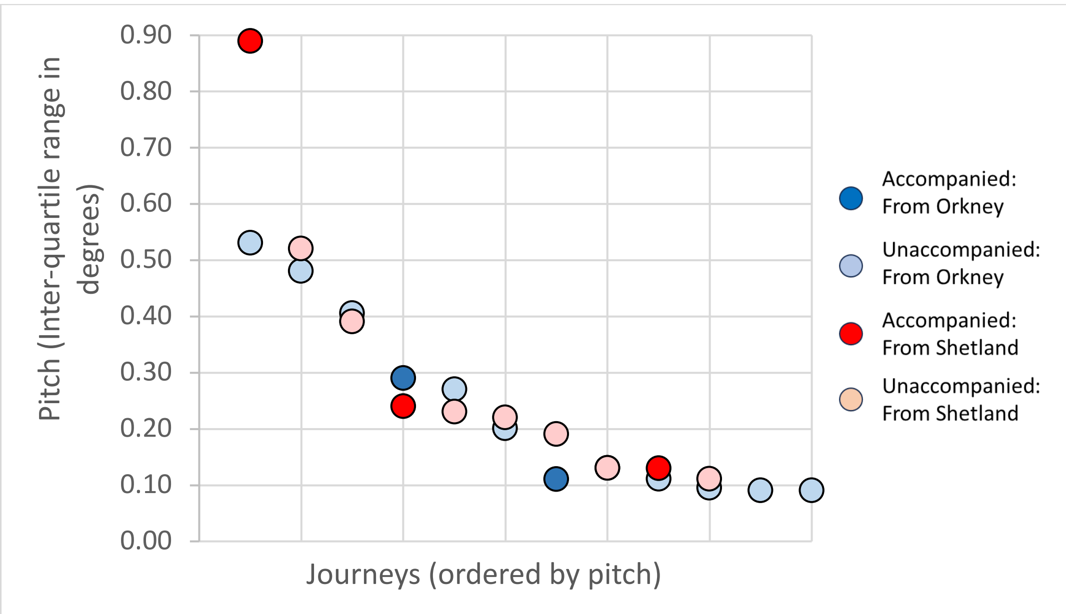
Figure 6 a, b: Predominant wave (a) and swell (b) direction recorded daily for the route between Lerwick and Aberdeen. Numbers refer to number of days. The green trace indicates the frequency of days in which the wave or swell direction was from each point of the compass.

(2) Vessel motion

Lateral and vertical motion both contribute to motion sickness and instability in humans. Roll (tilting motion from side to side), pitch (the vertical movement of the bow and stern around a point of rotation in the centre of the vessel) and heave (linear vertical movement of the vessel; represented by acceleration in the vertical z plane here) movements independently influence motion sickness in humans but a combination of these movements is most problematic. A Lowell Mat1B motion sensor measuring roll and pitch in degrees (as these are rotational axes) and acceleration in g in the x, y and z plane was installed on the vessel during each accompanied journey in which animal behaviour was observed (described below). Blocks of additional motion data (when animals were not accompanied by project staff) with the sensor located at the same point in the ship were accumulated for three periods of approximately two weeks duration each at the beginning, middle and end of the peak livestock transport season. These blocks of data were trimmed to focus on only periods when the vessel was in motion southbound from Orkney (9 unaccompanied journeys) or Shetland (7 unaccompanied journeys). Motion during the accompanied journeys was compared to the distribution from these unaccompanied journeys to place the accompanied journeys into the context of the seasonal variation.

Figure 7 illustrates the pitch and roll motion (in degrees) during accompanied (bold coloured data points) and unaccompanied (lighter coloured data points) from Orkney and Shetland. In both cases the Y axis shows the inter-quartile range representing the degrees of rotation around the resting point. In the case of roll for example, quartile 1 reflects the amount of movement to port where the 25% of records closest to the resting point were found, and quartile 3 reflects the amount of movement to starboard where the 25% of records closest to the resting point were found. An inter-quartile range of 1 degree means that 50% of the records were within plus or minus 0.5 degrees of the resting point, and 50% of the records were at a roll value greater than this. This approach was taken to account for the skewed distribution of the data and to discount erroneous data points caused by short-lived sensor error. The data logger sampled the vessel rotation every tenth of a second and then averaged these observations to give a value per second. In interpreting the small inter-quartile range in roll or pitch, it should be noted that most records made by the logger will have occurred part-way through a roll or pitch cycle and not at the moments of maximum rotation. Furthermore, the effects of a small rotational movement in terms of metres of vertical or horizontal displacement will be amplified as distance increases from the centre of gravity of the vessel. Data are only available for the three accompanied journeys from Shetland and two of the accompanied journeys from Orkney. As Figure 7 indicates, the accompanied journeys were reasonably representative of the variation present in motion recorded during the larger number of unaccompanied journeys.

(a)



(b)

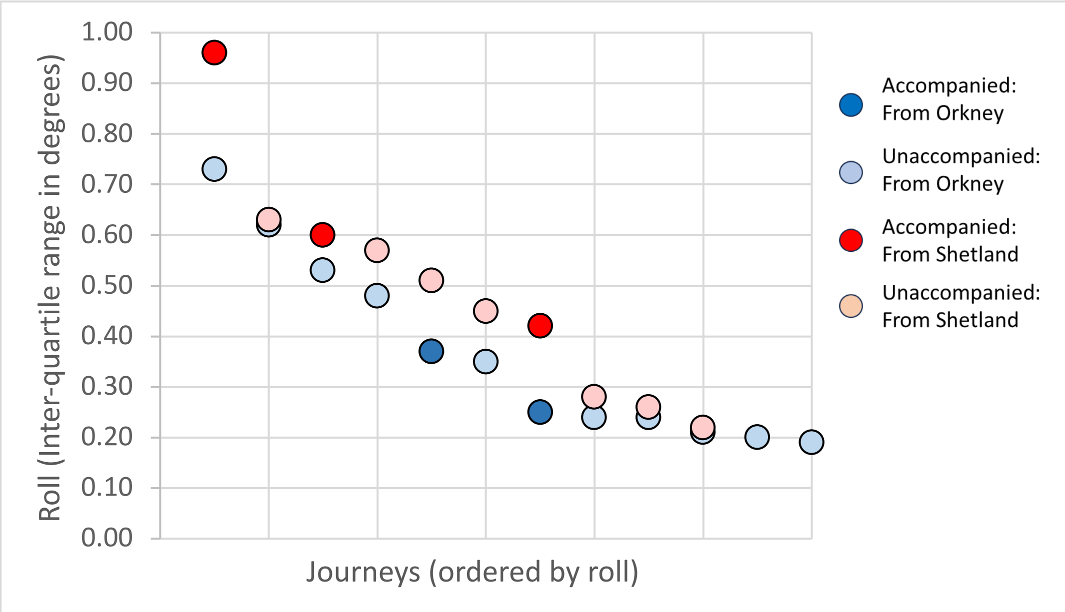


Figure 7 a, b: Vessel motion recorded as pitch (a) and roll (b) for two accompanied journeys from Orkney (motion data was not available for one journey) and three accompanied journeys from Shetland. Motion during a random sample of unaccompanied journeys is provided as a comparison. Measurements were angular motion recorded in degrees at 10^{th} of a second frequency and then averaged per second by the sensor. In a pitch or roll cycle, only a minority of sampling points will have been timed to coincide with the inflexion point of the movement (e.g. maximum roll to starboard/port). Additionally, the metres of vertical or horizontal movement created per degree of roll or pitch will vary according to distance from the centre of gravity of the vessel. Therefore, these values indicate the pitch and roll recorded by the sensor rather than the overall maximum movement in degrees that occurred nor the amount of vertical or horizontal movement in metres experienced. Please see the text for an explanation on how to interpret the inter-quartile range values.

Animal behavioural responses to the ferry journey

Data collection

Data were collected from six livestock cassettes (LCs) during each journey. Cattle were only located on the lower floor of the LCs and two compartments (middle compartment plus one end compartment) were sampled from each of 6 LCs for two journeys and one end compartment was sampled from a final journey. Sheep were located on both the lower and upper floor of the LCs and the central compartment on both the upper and lower floor of each LC was sampled. In total, 30 compartments containing 192 cattle were observed and 36 compartments containing approximately 1236 lambs were observed (mean animals per compartment = 6.4 (cattle) and 34.3 (lambs)). Video equipment failed in one compartment of sheep and two compartments of cattle.

Data collection before the ferry journey: Cattle and sheep were inspected immediately before loading into LCs. Evidence of existing injuries and lameness was recorded to ensure that these were not erroneously attributed to the subsequent journey. Few cattle (n=4) showed signs of injury, and these were minor. Other minor pre-existing injuries may have been masked by coat soiling. Sheep showed no visible signs of injury apart from lameness which did not prevent them walking unassisted into the LCs (n=28).

Data collection during the ferry journey: The following environmental measurements were made: LC location on the vessel; vessel motion using the Lowell Mat1B sensor described above (continuously throughout the journey at a frequency of 10 Hz); acceleration of the sampled LCs (g in the x, y and z planes) using Omni MSR sensors (continuously throughout the journey; 4 times per second); temperature and humidity within the lower compartment of five LCs per journey (continuously; every 5 minutes); temperature and humidity on the exterior of one LC per journey (continuously, every 5 minutes); sound (for the first 9 hours of 4 journeys, every second). Attempts were made to sample ammonia at the end of journeys immediately before docking but repeated equipment failure prevented collection of meaningful data. Other gases (e.g. carbon dioxide, carbon monoxide, hydrogen sulphide) were deemed unlikely to be significantly elevated based on previous transport research and were not sampled.

Observations of animals from video images: Animal behaviour was recorded from video images of 1 minute duration sampled every 20 minutes from the time that the vessel departed until unloading in Aberdeen (a mean of 32 sample points per LC for journeys from Orkney and 46 from Shetland). The behaviours listed in Table 1 below were recorded by scan sampling from these segments of video, and involuntary movements caused by vessel motion (described in Table 2 below) were recorded by continuous observation of the same video segments. Analysis of video clips was performed by a single observer. It should be noted that the low roof height in the lower compartments of the LCs prevented a comprehensive view of the cattle. Most significantly, this prevented a view of the drinkers. Live observations by frequent visits to the cargo decks at sea was not feasible or allowable for safety reasons.

Data collection after the ferry journey: Animals were observed for obvious signs of injury when unloaded. In reality this was challenging as the stocking density in the lairage pens was high. Many cattle and most lambs were unloaded from the LC and immediately moved onto waiting livestock vehicles within 1 to 5 minutes of unloading. Observations were not made from these animals. Those animals from the focal LCs which remained in the lairage for more than 5 minutes were observed by scan sampling every 5 minutes for two hours (or until onward travel if this occurred within 2 hours of entering the lairage) for the following behaviours: drinking, lying, ruminating (recorded as a proportion of those animals whose mouth could be readily seen). Food was not provided and therefore feeding was not recorded. Vocalisations could not be reliably attributed to specific pens of animals and were not recorded.

Statistical analysis approach: The proportion of visible animals exhibiting each behaviour from the videos recorded during the ferry journey was quantified at each observation time (i.e. every 20 minutes). From this, the average proportion was calculated for each LC for the journey. The data did not meet the assumptions of parametric analysis and Kruskal Wallis tests were used to estimate the effect on animal behaviour of (a) journey conditions and (b) location of the LC in the vessel. Kruskal Wallis tests are analogous to analyses of variance on ranked data. To account for the risk of type I errors (i.e. false positive significant effects) resulting from performing multiple statistical tests, Bonferroni corrections were applied to increase the stringency of the p value accepted as statistically significant. It should be noted that each journey was unique (e.g. a unique combination of temperature, duration waiting before boarding the vessel, sea conditions etc). The sample size did not allow the relative contributions of each of these environmental determinants of animal behaviour to be disentangled. Additionally, Spearman rank correlations explored the relationship between the proportion of animals standing or lying and acceleration (g) of the LC recorded in the x, y and z planes.

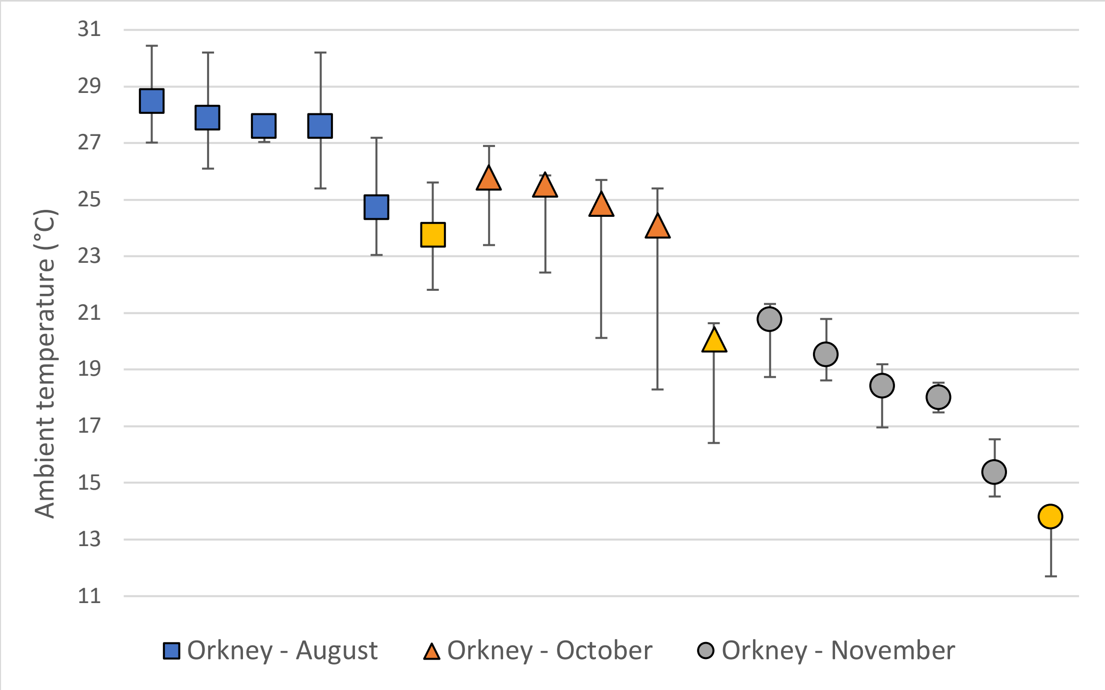
Results

Ambient conditions: During the period that the vessel was at sea, the ambient temperature in the LCs was higher than that immediately outside of the LCs. The temperature recorded immediately outside of one sentinel LC varied substantially according to the journey (gold symbols in Figure 8 below). The temperature recorded at this location was a median or 23.8, 20.1 and 13.8°C for the August, September and November cattle journeys and 17.4, 15.9 and 13.8°C for the August, September and October lamb journeys. Temperature was also recorded by the Mat1 motion sensor located approximately 10m from the closest LC and this showed similar deck temperature variation by journey, although 1-2°C cooler than the sensor attached to the exterior of the sentinel LCs.

Only two LCs were located in the lower hold of the vessel (one on each of two journeys from Orkney). The average temperature recorded within these two LCs was within 0.5°C of the temperature of other LCs on the same journey located on the main deck. Five LCs with available temperature data were located on the main deck surrounded by LCs on all sides, distributed between two journeys from Orkney and two from Shetland. Contrary to what was expected, the temperature within these centrally located LCs was, on average, 0.6°C cooler than within other LCs.

Temperature within the LCs was affected by the month in which the journey took place (Figure 8). For half of the cattle LCs, the median temperature was 25°C or above which approximately corresponds to the upper limit of the thermoneutral zone for cattle of this weight and is the limit recommended by EFSA for cattle during transport. For lambs, temperature was only recorded inside the lower deck of the LC and not on the top deck, but in most LCs the median was below 20°C.

(a)



(b)

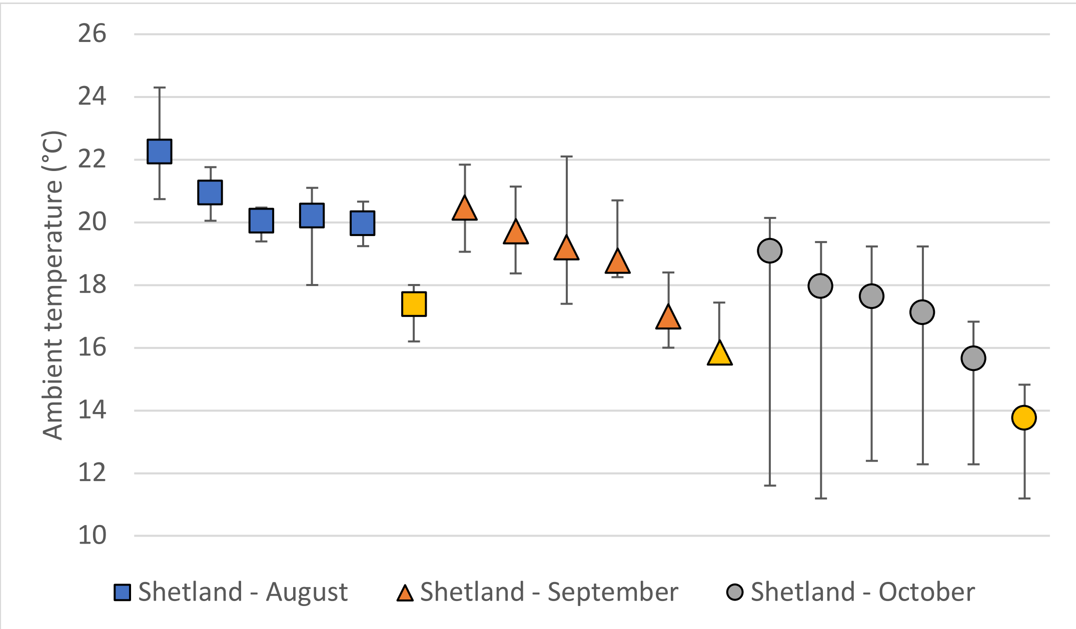


Figure 8 a, b: Median (symbol), minimum and maximum (whiskers) ambient temperature inside LCs during three journeys from (a) Orkney and (b) Shetland between the ship departing and docking. Each data point is a separate LC. Gold symbols represent temperature recorded outside of the LC as a measure of deck temperature. All other symbols represent temperature recorded within the LC. For LCs with lambs, temperature was only recorded on the lower deck of the LC.

To give context to the temperatures recorded during the three cattle journeys from Orkney, the minimum, mean and maximum daily outdoor ambient temperatures on the journey dates were compared with the broader period from the start of August to the end of November 2023 (Figure 9). Data were extracted from an independent weather station in Kirkwall as Met Office data for 2023 were not available in the MIDAS database at the time of writing. The available data agree closely with ambient temperatures recorded by the temperature logger fitted to the exterior of one sentinel LC per journey before cattle entered the LC. The journey with the warmest average temperature recorded within the LCs and during which the majority of rapid breathing was observed occurred in August. The specific date was amongst the warmest of the period considered, although six days had greater maxima.

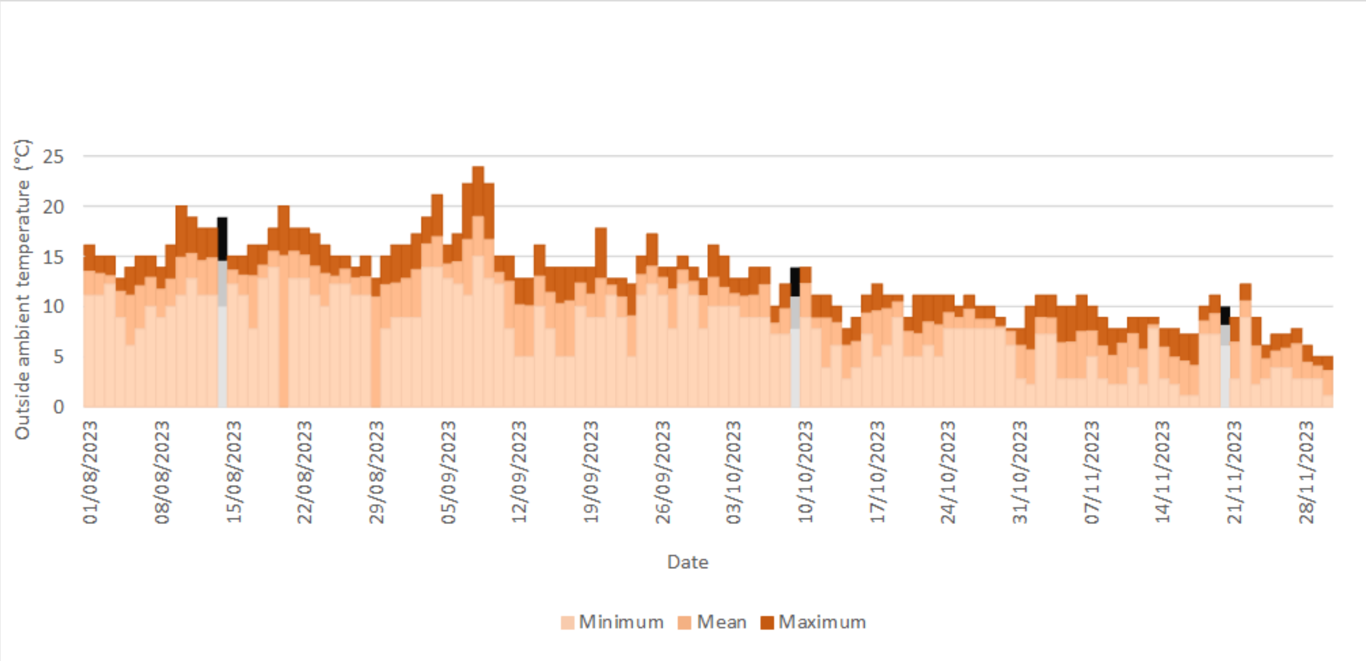


Figure 9: Minimum, mean and maximum outdoor ambient temperatures recorded in Kirkwall for the period 1st August to 30th November 2023. Dates on which cattle were observed during accompanied journeys are identified in grey.

Humidity is defined as the mass of water vapour per unit of air volume. Conventionally, humidity is quantified by the relative humidity which is a relative quantity.

Relative Humidity is defined by the ratio:

$$RH = \frac{Water\ Vapour\ Pressure}{Saturation\ Water\ Vapour\ Pressure} \times 100\%$$

The relative humidity is a consistent measurement of the humidity only if combined with the corresponding temperature. This quantity represents the relative amount of moisture that can be held by a sample of air at a specific temperature.

In animal environments, such as during transportation, as air dry bulb temperature increases there is an increased demand for heat loss from the animals in order to avoid increases in deep body temperature. This is often achieved by increasing evaporative heat loss, e.g. panting, or sweating which adds water vapour to the local air. So, in such situations the local absolute humidity increases but RH potentially increases as well dependent upon the balance between increased addition of water and the rise in temperature. Thus, whilst caution must be exercised in the interpretation of RH values in the absence of the accompanying dry bulb temperature, RH can still be a useful indicator of the local humidity load.

Relative humidity was consistently high (Figure 10), particularly within LCs containing cattle, which will have increased the heat load associated with the ambient temperature.

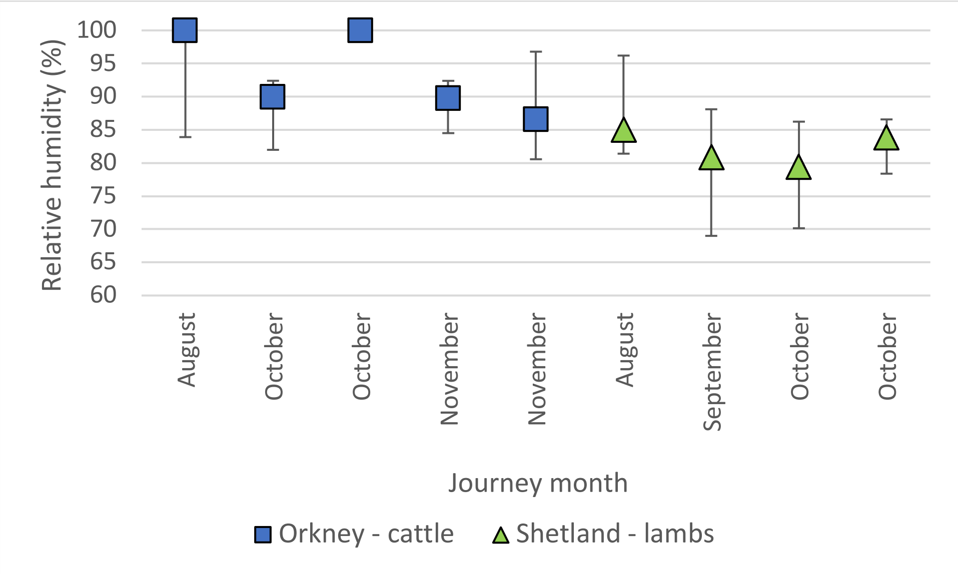
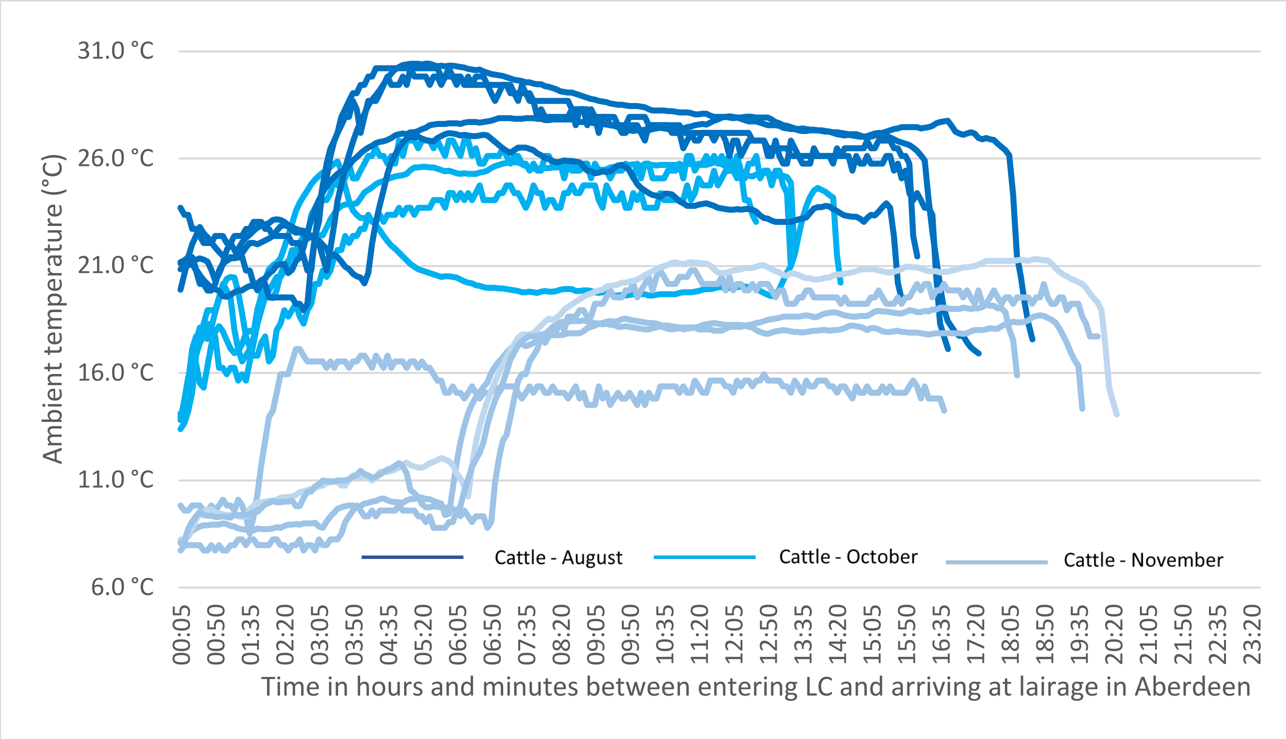


Figure 10: Relative humidity (%) sampled from within the lower compartments of 1-2 LCs during each journey. The period represented is from the time of vessel departure to docking. Each data point represents a separate LC. Squares or triangles represent the median and whiskers show the minimum and maximum.

The ambient temperature and relative humidity inside LCs were fairly stable during the period that the LCs were on the vessel, but showed a marked increase at the point of boarding and a decrease at disembarkation (Figures 11 and 12).

(a)



(b)

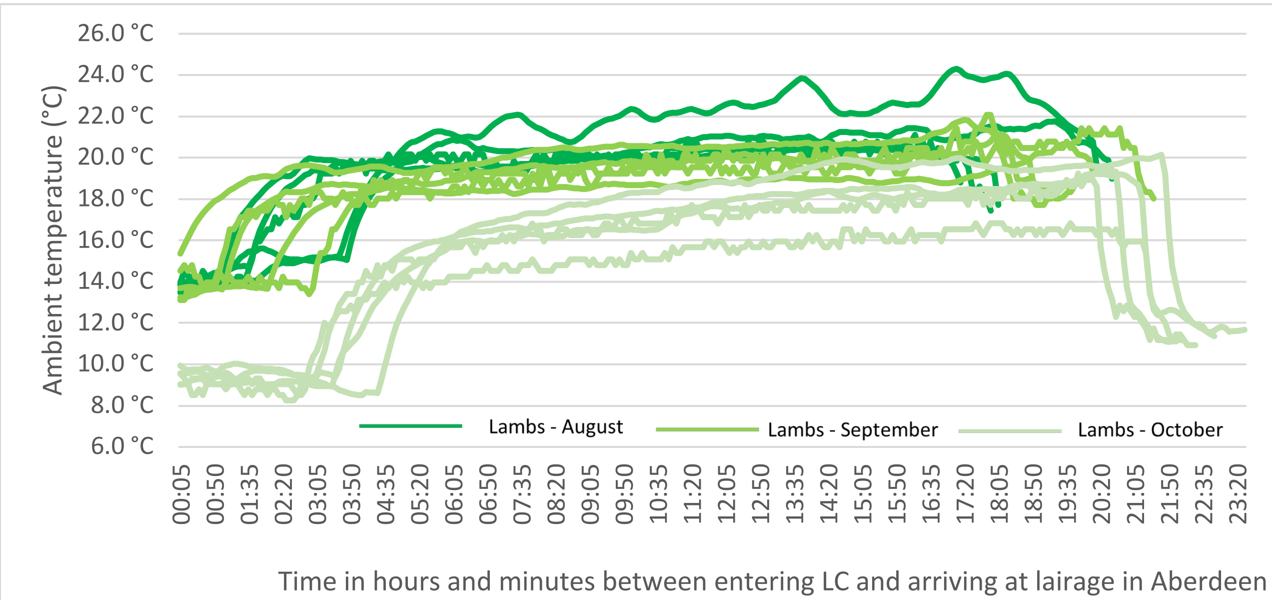
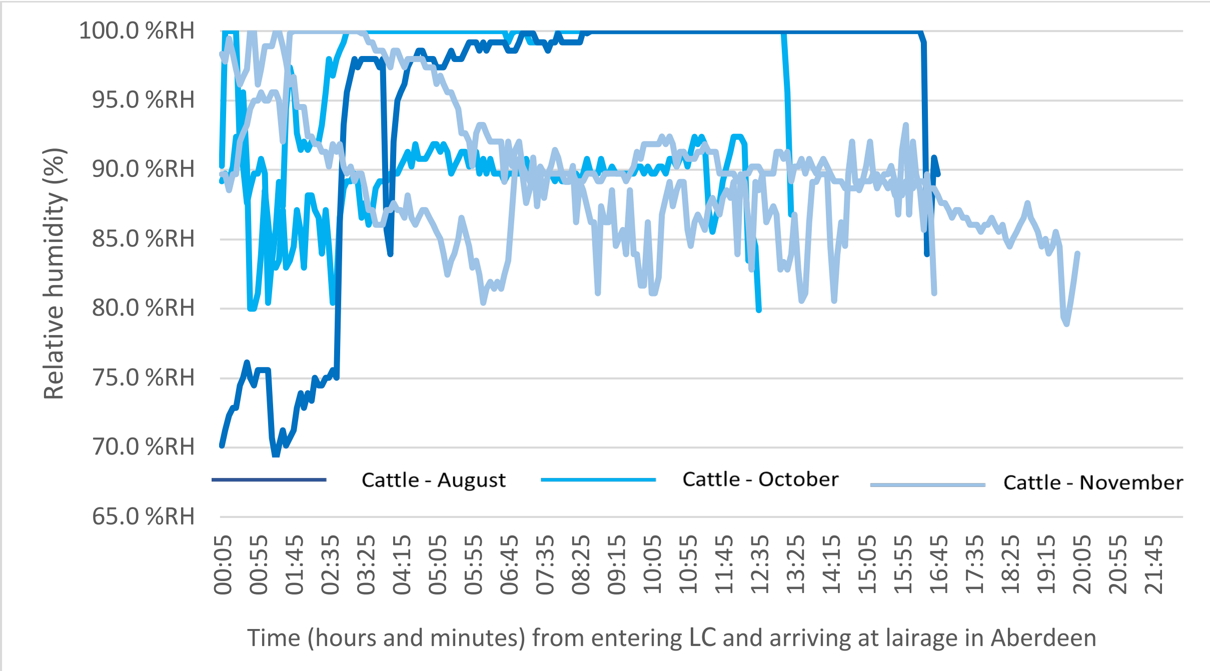


Figure 11: Ambient temperature profiles inside LCs with (a) cattle and (b) lambs recorded at 5 minute resolution from entry to the LC to arrival at the lairage in Aberdeen, including time in LC before boarding.

(a)



(b)

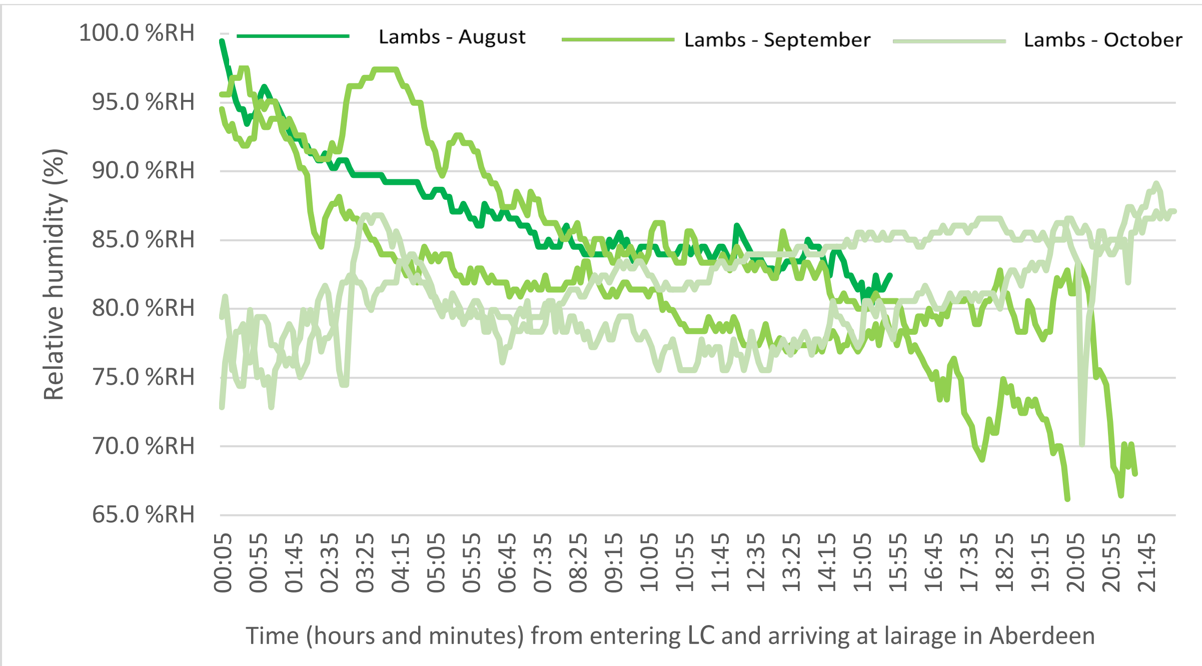


Figure 12: Relative humidity profiles in LCs with (a) cattle and (b) lambs recorded at 5 minute resolution from entry to the LC to arrival at the lairage in Aberdeen, including time in LC before boarding.

Sound recordings were made at 1 second frequency from approximately 1 hour before the LC was loaded onto the vessel until the logger's storage capacity was reached (just under 9 hours). The logger was positioned near a ventilation opening on one LC on each of four journeys (two with cattle; two with lambs). All four LCs were located on the main deck of the vessel. The mean sound volume was 81 and 84dB on the two cattle journeys and 74 and 76dB on the two lamb journeys (Figure 13). To place these values in context, The Control of Noise at Work Regulations (2005) require employers to perform risk assessment when employees are exposed daily or weekly average sounds >80dB and to provide hearing protection at >85dB. In the cattle LCs, the peak noise level was possibly created by animals kicking the metal sides of the cassette.

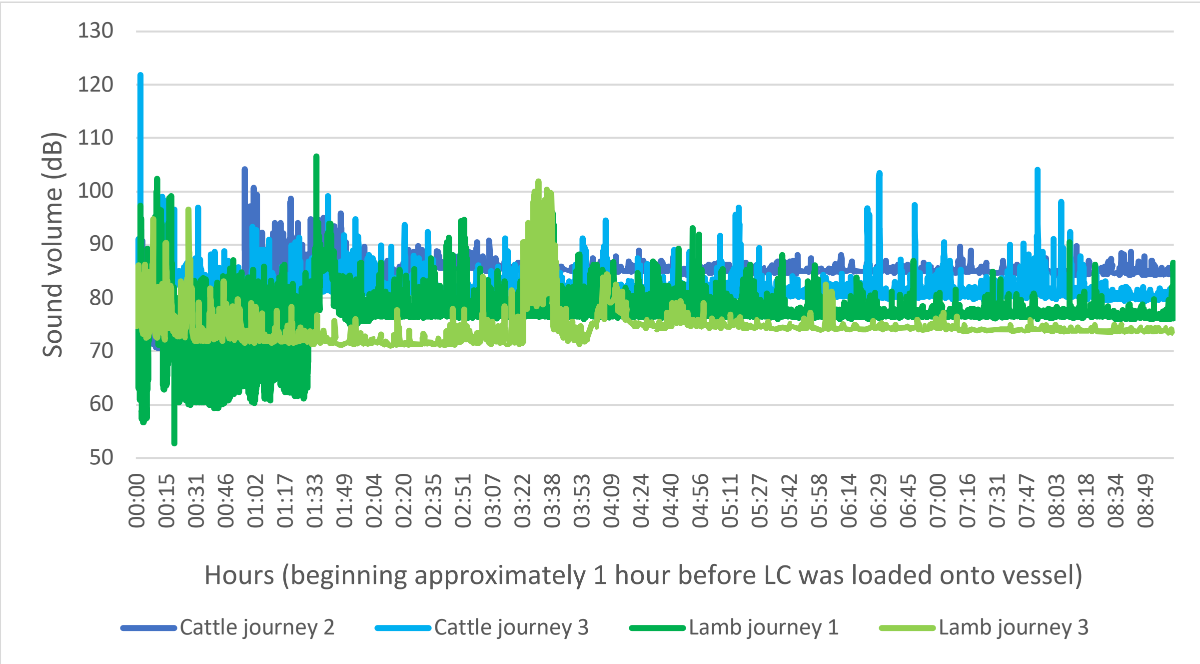


Figure 13: Sound volume (dB) profiles for four journeys (two with cattle from Orkney and two with lambs from Shetland). Recording started within an hour of loading the LC onto the vessel.

Journey duration and food and water availability: Animals were typically sold at the Kirkwall or Lerwick mart in the morning or early afternoon and loaded into LCs during the afternoon or evening before the vessel sailed in the evening or night. Cattle spent a mean of 4 hours 46 minutes between arriving at the port lairage and boarding the vessel. No cattle were observed to use the nipple drinkers in the lairage. The exact time of arrival of lambs at the lairage is unknown but many were seen to arrive in the morning prior to boarding the vessel in the evening, during which time water was unavailable.

Cattle spent a mean of 14 hours and 54 minutes between entering the LC and the vessel docking in Aberdeen, whilst lambs spent a mean of 19 hours and 40 minutes (an additional period, typically of between 10 minutes and 2 hours was required between the vessel docking and the animals being unloaded from the LC). There was considerable variation around these means as shown in Figure 14. The mean duration between the animals entering the LC and the LC being loaded onto the vessel was 3 hours and 0 minutes for cattle and 4 hours and 54 minutes for lambs.

Hay in all studied lamb LCs was consumed before docking in Aberdeen. Hay was available for a mean of 3 hours and 4 minutes from entry to the LC, leaving a mean of 16 hours and 36 minutes between it being consumed and docking in Aberdeen. The lairage in Aberdeen does not provide food. For cattle, 25 of the 35 studied LC compartments had hay remaining when the vessel docked in Aberdeen. Of the remaining 10 compartments, the hay was fully consumed within a mean of 5 hours and 47 minutes after entering the LC, and 10 hours and 21 minutes before docking in Aberdeen. A long period without food for a grazing ruminant is unnatural and would reasonably be expected to induce some degree of hunger. It is acknowledged that withdrawal of food before transport, usually to slaughter, is sometimes practiced. As most of the animals transported from the Northern Isles were destined for onward travel to farms rather than slaughter, provision of additional hay is likely to be preferable unless future research indicates that it contributes to motion sickness or other negative animal welfare outcomes.

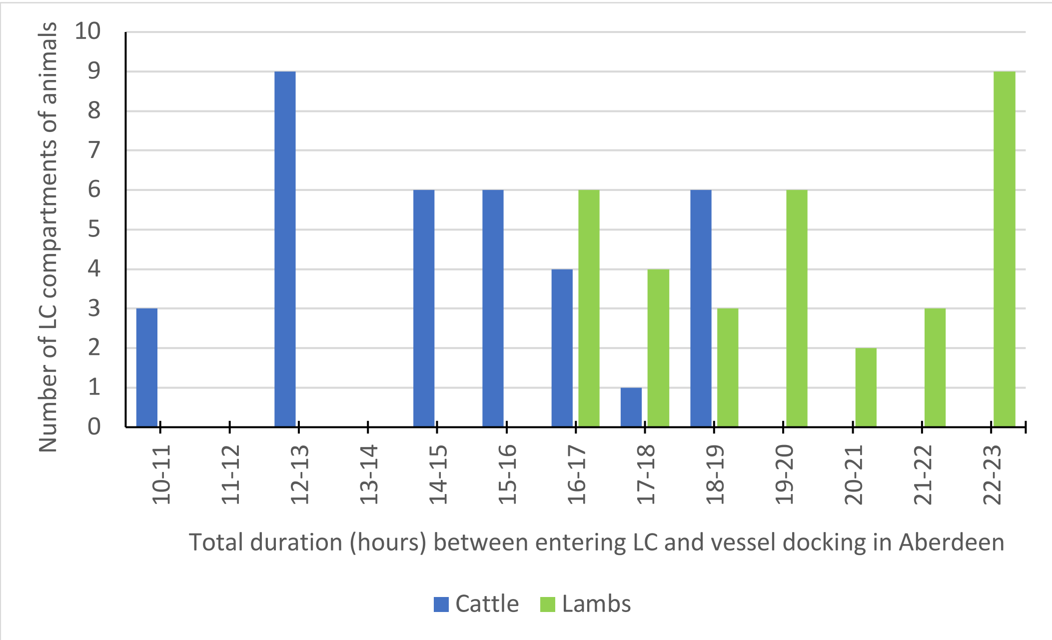


Figure 14: Frequency distribution of the duration that cattle and lambs spent in LCs between loading into the LC and the vessel docking in Aberdeen. The duration between docking and unloading from the LC typically varied between 10 minutes and 2 hours.

Animal behaviour: On average, around 95% of cattle were observed to be standing at any moment in time (Table 1 and Figure 15) which is unusual behaviour for a species which shows high motivation to lie after a period of standing. This is a substantially greater proportion of time spent standing than observed when cattle are at pasture or housed indoors in a building when around a quarter to a third of daylight time is spent lying. It is also higher than the amount of standing seen in other transported animals (e.g. beef cattle of a mean 269 kg weight were observed to lie for 63.5% of the time when transported for 23 hours by sea from Ireland within livestock road vehicles at 8-11°C). Observations of eating and ruminating were uncommon. A lack of rumination may have resulted from a reduced food intake, but rumination has also been reduced in previous studies that imposed movement in different planes and has been suggested to indicate motion sickness.

Rapid breathing was observed in the cattle, but disproportionately so in one journey (see below). Open-mouthed panting, however, was not observed. The drinkers were only visible in around 40% of the 1 minute video segments for the cattle as the animals blocked the line-of-sight of the camera. However, drinking was not observed when the drinkers were visible. Eating was uncommon in all three cattle journeys and largely absent in two journeys, although, as noted above, hay was fully consumed in some LCs. Some of the hay consumption may have occurred before the LC was loaded onto the vessel.

Lambs lay considerably more often than cattle, and with the exception of one journey (see below), lay for the majority of the journey. As described above, available hay was consumed by the lambs whilst waiting for the LC to board the vessel or during the early hours of the sailing. The drinker was visible to the camera, but drinking and ruminating were largely absent. Signs of rapid breathing were less common in lambs.

The effects of vessel motion on involuntary movements of cattle and lambs are described below.

	Cattle		**Lambs**	
	Median	Inter-quartile range	**Median**	Inter-quartile range
All standing behaviours	**0.95**	0.85-0.99	**0.39**	0.32-0.56
Stand idle	**0.76**	0.61-0.81	**0.33**	0.24-0.51
Stand rapid breathing	**0.08**	0.01-0.25	**0.04**	0.01-0.06
Stand ruminating	**0.06**	0.05-0.11	**0.01**	0.01-0.02
Stand eating	**0.00**	0.00-0.01	**0.00**	0.00-0.01
Stand drinking	**0.00**	0.00-0.00	**0.00**	0.00-0.00
All lying behaviours	**0.05**	0.00-0.13	**0.61**	0.39-0.67
Lying idle	**0.04**	0.04-0.11	**0.53**	0.38-0.60
Lying ruminating	**0.00**	0.00-0.01	**0.06**	0.01-0.07
Lying rapid breathing	**0.00**	0.00-0.00	**0.01**	0.00-0.02
Vocalising	**0.00**	0.00-0.06	**0.00**	0.00-0.00

Table 1: Median proportion of visible animals performing various behaviours.

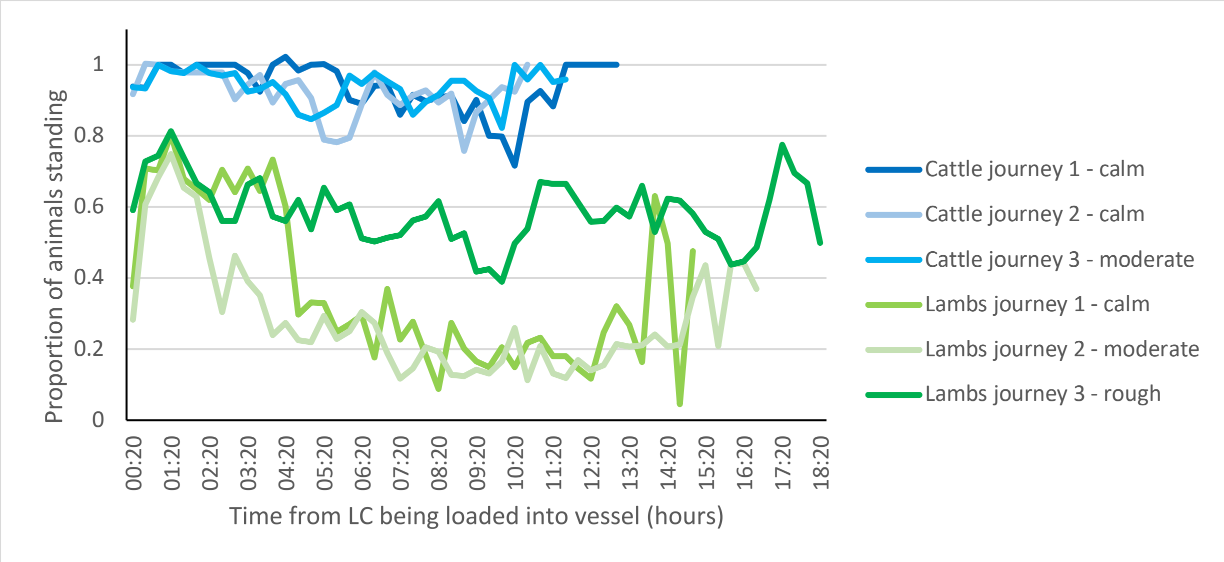


Figure 15: Variation in proportion of animals standing. Time on the x axis is from 20 minutes after LC was loaded onto the vessel until disembarkation in Aberdeen.

Effect of journey conditions on animal behaviour: Only one animal was observed to fall. Other involuntary responses to motion occurred rarely considering the quantity of video footage analysed combined with the number of animals viewed. Involuntary adjustment of position and involuntary contact with walls or other animals were absent on calm journeys and, as expected, most common on the roughest journey (from Shetland; Table 2).

Around a quarter of cattle had rapid breathing during one journey (the warmest; Table 2). Around two-thirds of lambs were observed to be lying during the calm and moderate journeys but this dropped to around a third during the rough journey. Lambs were observed to use the drinker infrequently and meaningful statistical analysis was not possible.

	Cattle from Orkney				**Lambs from Shetland**			
	Journey			p	Journey			p
	1	2	3		1	2	3	
Sea conditions:	**Calm**	**Calm**	**Moderate**		**Calm**	**Moderate**	**Rough**	
Median ambient temperature within LC (°C):	27.3	25.1	18.4		20.7	19.0	17.5	
Median relative humidity (%)	100	95.0	88.1		85.0	80.9	81.7	
Involuntary response to motion (counts)								

Involuntary adjustment of position	0	0	2.8/hr (n=16)		0	9.1/hr (n=87)	13.9/hr (n=126)	
Involuntary contact with walls or other animals	0	0	2.8/hr (n=16)		0	5.5/hr (n=53)	6.2/hr (n=56)	
Falls	0	0	0		0	0.1/hr (n=1)	0	
All standing behaviours	0.97	0.94	0.95	0.694	0.38	0.31	0.62	**0.000**
Stand idle	0.62	0.76	0.80	**0.001**	0.30	0.23	0.60	**0.001**
Stand rapid breathing	0.24	0.07	0.01	**0.000**	0.05	0.04	0.02	0.103
Stand ruminating	0.08	0.06	0.06	0.286	0.016	0.008	0.009	**0.004**
Stand eating	0.000	0.006	0.000	0.079	Not analysable			
Stand drinking	Not analysable				Not analysable			
All lying behaviours	0.03	0.06	0.05	0.898	0.62	0.68	0.38	**0.000**
Lying idle	0.03	0.06	0.03	0.915	0.55	0.60	0.36	**0.000**
Lying ruminating	0.00	0.00	0.00	0.987	0.07	0.06	0.009	**0.000**
Lying rapid breathing	Not analysable				0.01	0.03	0.00	**0.000**
Vocalising	Not analysable				Not analysable			

Table 2: Comparison of the behaviour of animals during each of the three journeys per species. Values for involuntary response to motion are counts (number of observed occurrences per hour of video footage and total number of observed occurrences during the journey). In other rows, the values are the median proportion of visible animals. P values are derived from Kruskal-Wallis tests, adjusted for type I error by Bonferroni correction. Bold p values indicate a statistically significant difference between journeys within the same species. The following behaviours occurred too infrequently for meaningful analysis: standing drinking (lambs and cattle), standing eating (lambs) or vocalising (lambs and cattle).

The linear acceleration in the x, y and z plane, measured in g, was slight. This reflects that motion on the sea is typically gradual, unless heading into oncoming waves/swell. The maximum acceleration was measured in the z (vertical) plane corresponding to heave of the vessel together with the vertical movement associated with pitch and roll. Even in this plane the median was close to 1g (reflecting a resting body on the earth's surface) and the inter-quartile range was only 0.07g for journeys from Orkney and 0.04g for journeys from Shetland. As the median was close to zero motion, the inter-quartile range was used for analysis of the association between x, y and z plane acceleration and animal behaviour. For cattle, no significant correlation was found between the proportion of animals standing and acceleration in the x, y or z plane (Spearman's rho ranging from r=0.18-0.30; p=0.194-0.428). For lambs, a larger inter-quartile range in acceleration in the vertical plane (indicating greater deviation from 1g and greater heave) was associated with a greater proportion of animals standing (Spearman's rho r=0.49, p=0.003; Figure 16). Acceleration in the x and y planes was not correlated with standing behaviour in lambs.

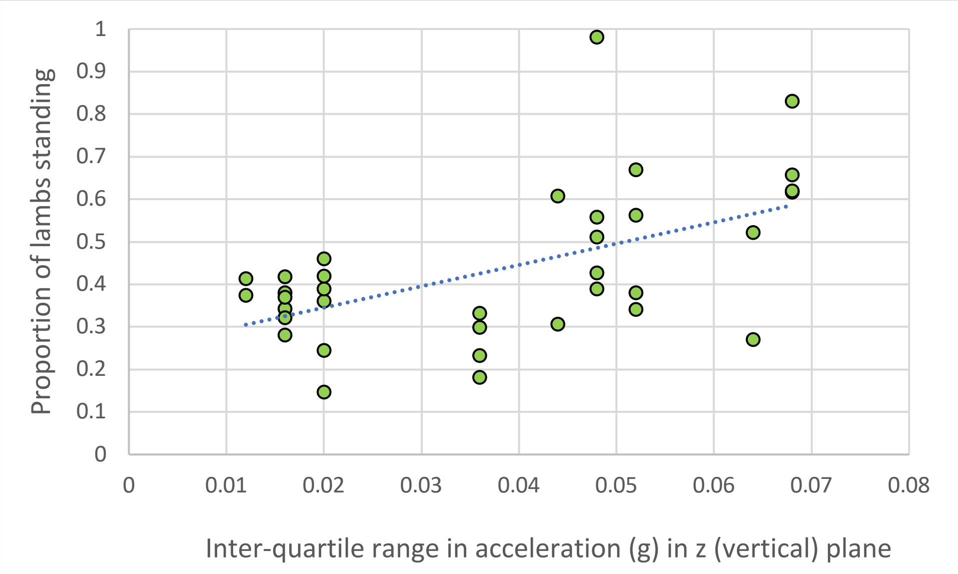


Figure 16: Relationship between proportion of lambs standing and variation in acceleration in the z (vertical) plane caused by vessel motion (corresponding to heave). A larger inter-quartile range in acceleration indicates greater deviation from 1g experienced by resting bodies on the earth's surface.

Effect of deck location on animal behaviour: Deck location was firstly categorised as being on the main deck or lower hold (the lowest cargo deck) and, in the case of the main deck towards the bow, amidships or stern. All LCs from Shetland were located on the main deck and only two LCs were located towards the stern. Therefore, the effect of deck location on animal behaviour was only statistically analysed for amidships versus bow on the main deck. Behaviour of animals in the two LCs located towards the stern was quantitatively similar to that of other animals on the same journey.

Only two LCs from Orkney were located in the lower hold (one LC during each of two journeys). Of the remaining LCs, only one was towards the stern on the main deck and all others were either amidships or towards the bow. Again therefore, only the effect on animal behaviour of LCs being towards the bow versus amidships was statistically analysed. The behaviour of animals in the two LCs in the lower hold and one LC towards the stern of the main deck were quantitatively similar to other animals on the respective journeys.

The location of the LC (near the bow or amidships) did not affect acceleration in g in the x, y or z planes (Mann Whitney W=159-223; p=0.221-0.805). LCs located towards the stern or in the lower hold experienced quantitatively similar acceleration to those elsewhere on the main deck.

No statistically significant differences were found in the behaviour of either cattle or sheep when located towards the bow as compared to towards the centre of the vessel (Table 3).

	Cattle from Orkney			**Lambs from Shetland**		
	Main deck location		p	Main deck location		p
	Bow	**Amidships**		**Bow**	**Amidships**	
All standing behaviours	0.95	0.97	0.322	0.38	0.38	0.554
Stand idle	0.63	0.80	0.066	0.30	0.31	0.371
Stand rapid breathing	0.10	0.02	0.059	0.04	0.04	0.866
Stand ruminating	0.07	0.06	0.254	0.01	0.01	0.719
Stand eating	0.00	0.01	0.039[‡]	Not analysable		
Stand drinking	Not analysable			Not analysable		
All lying behaviours	0.05	0.04	0.184	0.62	0.62	0.473
Lying idle	0.05	0.03	0.184	0.55	0.53	0.220
Lying ruminating	0.00	0.00	0.920	0.05	0.06	0.499
Lying rapid breathing	0.00	0.00	0.194	0.02	0.01	0.397
Vocalising	Not analysable			Not analysable		

Table 3: Comparison of the behaviour of animals located towards the bow or centre of the main deck. Values are median proportion of visible animals. P values are derived from Kruskal-Wallis tests, adjusted for type I error by Bonferroni correction. The following behaviours occurred too infrequently for meaningful analysis: standing drinking (lambs and cattle), standing eating (lambs) or vocalising (lambs and cattle). [‡]Not statistically significant after Bonferroni correction.

LCs were usually orientated in three rows on the main deck, with their long axis parallel to that of the vessel. LCs were categorised as being located in the centre row (i.e. above the keel) or in one of the outer rows (i.e. towards port or starboard). Only three LCs for cattle (one on each journey) were located in the central row. Four LCs for lambs were located in the central row (two on one journey and one each on the other journeys). The behaviour of animals in the central LCs was quantitatively similar to that of animals in the other rows.

Observation of animals on arrival at Aberdeen: Observations at Aberdeen port lairage were challenging. Many groups of animals moved directly from LCs to a waiting road vehicle, or did so after less than 30 minutes in lairage. Other groups were moved between pens and/or mixed with neighbouring groups of animals which disturbed their behaviour. Furthermore, group sizes were large for the lambs and expressing behavioural occurrences per individual rather than per group was difficult.

Meaningful data were collected for nine LCs of cattle (two from journey 1, five from journey 2 and two from journey 3) and nine LCs of lambs (four from journey 1, three from journey 2 and two from journey 3). For the purposes of summarising the data, the behaviour of cattle during the first two hours in lairage was included and the behaviour of lambs for the first 1 hour was included (the large majority of lambs left the lairage within 2 hours). Group sizes and stocking densities were higher for the lambs and the duration in the lairage was shorter, therefore it should not be attempted to compare behaviour between the species. Given the small number of LCs sampled per journey and variation in factors such as location in the lairage and movement of animals in/out of neighbouring pens, it would also be unwise to draw conclusions about the impact of specific journeys on animal behaviour.

Broad trends can be highlighted from Table 4 below. The drinker was used during the first scan sample point in most lairage pens for both species. The first scan sample was at 5 minutes after the animals entered the pen, therefore the minimum latency for animals to drink or lie in Table 4 was 5 minutes. It is possible that animals drank within the first 5 minutes of entering the pen, but this was not captured by the scan sampling. For cattle it took over an hour for the first animal to lie down and over 1.5 hours for five animals to lie simultaneously. As few cattle lay down in the lairage pens in Kirkwall or during the sailing, this was surprising. It also varies from earlier work which shows that cattle spend around 40 mins of the first 60 minutes lying after a 20 hour road journey, although the conditions in the present study are not directly comparable (being on store cattle transported by sea rather than recently weaned calves transported by road). However, it is likely that this long latency to lie after disembarking results from the novel environment and stimuli of the busy lairage in Aberdeen and may not indicate a lack of fatigue. In both species, rumination was shown by only a small proportion of animals during each scan.

Observation of injuries was also difficult both before loading into the LCs and on arrival in Aberdeen due to the lairage pens being highly stocked and the period moving to/from pens providing a very short period of time to observe individual animals. No significant new injuries were present in Aberdeen that could be confidently ascribed to the journey which likely reflects the calm handling observed at all lairages and the scarcity of slips or falls during the sailings.

	Journey	Mean latency to first animal drinking (mins)	Mean latency to first animal lying (mins)	Mean latency to 5 animals lying simultaneously	Mean number of animals drinking per scan	Mean number of animals lying per scan	Mean proportion of visible animals ruminating per scan
Cattle	1	5	67	92	0.13	1.77	0.07
	2	6	69	102	0.43	1.07	0.08
	3	15	87	90	0.30	1.38	-
Lambs	1	6	36	47	1.44	5.91	0.09
	2	5	31	55	1.39	0.94	0.04
	3	17	50	60 (maximum)	0.15	0.21	0.02

Table 4: Behaviours recorded by scan sampling at 5 minute intervals in Aberdeen port lairage. Please refer to Table 2 above for a description of the ambient conditions during each journey, but also note the caution above about the unsuitability of the data to allow robust comparison between journeys.

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