live export

Stocking density in cattle shipments and animal health and performance – an assessment of existing data

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Abstract

This pilot project used currently available data from a sample of recent short-haul voyages from Australia conducted by two cattle exporting companies, to assess the potential for using this type of data in future observational studies and controlled trials to evaluate effects of varying stocking densities on various indicators of welfare. Nineteen live cattle export voyages were selected by two exporting companies and relevant records for these voyages studied. The project showed that both case series and cohort studies could be conducted using existing data routinely collected by exporting companies. However, such studies conducted using existing data would face several major constraints that would preclude reaching scientifically sound conclusions. Prospective studies offer the possibility of addressing these limitations and potentially reaching scientifically sound conclusions. Expert advice should be sought from epidemiologists, the export industry and animal welfare experts when designing any future studies assessing effects of stocking density on animal welfare.

Executive summary

This pilot project used currently available data from a sample of recent short-haul voyages from Australia conducted by two cattle exporting companies, to assess the potential for using this type of data in future observational studies and controlled trials to evaluate effects of varying stocking densities on various indicators of welfare. Nineteen live cattle export voyages were selected by two exporting companies and relevant records for these voyages studied.

Key conclusions are as follows:

1. *Data recording methods and availability of data vary between voyages.*

Studies comparing cattle exposed to different stocking densities such as cohort studies and controlled trials are much preferred to case series (where no control cattle are studied) when assessing effects of stocking density on animal welfare. Controlled trials may result in greater control of bias than that afforded by cohort studies but may pose greater logistic problems.

Comparisons between stocking densities on live cattle voyages can be performed at various levels of organisation. Studies assessing effects of stocking density on animal welfare should be conducted at the animal level rather than at pen, deck, class of cattle or voyage levels. Such studies require data for each animal rather than only at pen, deck, class of cattle or voyage levels. Measures on individual animals should be compared between pens with varying stocking densities, with pens with varying stocking densities located on the same ship and preferably on the same deck.

2. *It is not possible to study effects of stocking density on animal welfare without variation in stocking density.*

Variations in prescribed minimum stocking densities are not a useful basis for assessing effects of stocking density on animal welfare. Variation in stocking density due to varying definitions would also not be a useful basis for assessing effects of stocking density on animal welfare. However some natural variation in stocking density probably occurs under commercial conditions due to rounding effects and to random variation when loading pens, particularly pens loaded with smaller numbers of cattle. Before observational studies relying on natural variations in stocking density between pens are implemented, the extent of this variation should be examined using data collected prospectively before any redistribution of cattle after loading. If such observational studies are to proceed, such redistribution would need to be limited to only that required to ensure minimal animal welfare standards are maintained. Loading light may offer an additional opportunity to conduct observational studies relying on natural variations in stocking density between pens. The frequency and extent of loading light should be further investigated, along with stocking densities by pen on such voyages.

Data for potential indicators of animal welfare were available from all voyages. However, these data have important limitations for assessing welfare at animal level for purposes of research to assess effects of stocking density. Animal welfare experts should be consulted when designing any future studies assessing effects of stocking density on animal welfare.

3. *Potential confounders should be identified during the design phase of any study.*

It is likely that there is no clear threshold of stocking density above which animal welfare is affected and below which there is no effect on welfare. Potentially important interacting factors should be identified when designing any future studies assessing effects of stocking density on animal welfare.

Both case series and cohort studies could be conducted using existing data routinely collected by exporting companies. However, such studies conducted using existing data would face several major constraints that would preclude reaching scientifically sound conclusions. Prospective studies offer the possibility of addressing these limitations and potentially reaching scientifically sound conclusions. Expert advice should be sought from epidemiologists, the export industry and animal welfare experts when designing any future studies assessing effects of stocking density on animal welfare.

CONTEXT OF THIS REPORT

This report assesses the potential for using data collected by live cattle exporting companies in future observational studies and controlled trials to assess effects of varying stocking densities on various indicators of welfare. The exporting companies do not aim to collect data suitable for research purposes. Rather, this study is to assess whether such data can be used opportunistically, that is, whether the data can be used for a purpose other than the reasons for collection of that data. Accordingly, shortcomings identified in using such data for research purposes in no way reflect on the quality of management and data collection methods used by exporting companies.

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1 BACKGROUND

Stocking density on live cattle shipments may affect welfare of shipped animals during their voyage. If relationships between stocking density and various indicators of welfare were clearly defined, industry, government and community would be better able to assess current practice and to alter practice if necessary.

Relationships between stocking density (the ‘exposure’ variable) and various indicators of welfare (‘outcome’ variables) can be assessed using a series of controlled trials (most preferably randomised). Alternatively, it may be possible to study these relationships using one or more observational studies. Such studies would utilise the variation in stocking density that occurs due to decisions by exporters and shipboard managers and stockmen rather than to interventions by researchers. Because observational studies do not rely on researchers allocating cattle to pens at predetermined stocking densities, concerns about animal ethics associated with unacceptable researcher-imposed regimens do not arise. Observational studies are also often substantially cheaper than controlled trials, particularly when they can be conducted utilising data collected for other purposes. In addition, observational studies can sometimes be conducted more quickly than intervention studies. Some types of observational studies can also be very efficient, especially when either the exposures or outcomes of interest are rare.

Studies relying on data collected for other purposes are obviously only possible if available sources consist of appropriate data of adequate quality for all necessary exposure and outcome variables. Data quality is affected by the frequency of missing values and the accuracy of recorded data. Such data must also be accessible to researchers.

In addition, potential confounders must be addressed in any analytic study. In this context, confounders are factors that would bias or falsely alter the observed associations between stocking density and various indicators of welfare. Accordingly, accurate data for known or suspected confounders must be available, in order to remove effects of these sources of bias.

Observational studies assessing relationships between stocking density and various indicators of welfare rely on sufficient natural variation in stocking density (i.e. variation not determined by researchers). In addition, the frequency of outcome events of interest must be known as this affects decisions about study design and the practicality and expense of such studies.

In live cattle shipments, there is a natural hierarchy of data aggregation with individual animals grouped within pens, pens grouped within decks, decks grouped within voyages and voyages grouped within ships. To study effects of stocking density on various indicators of welfare, the individual animal is the theoretically correct unit of analysis. However, to perform such analyses, any data that varies between individual animals within pens would be required at the individual animal level (i.e. at the lowest level of aggregation available).

To help determine the most appropriate designs for possible future Australian studies to assess effects of varying stocking densities, the usefulness of routinely collected data for this purpose should first be described. This pilot project will use currently available data from a sample of recent short-haul voyages from Australia, conducted by two cattle exporting companies, to assess the potential for using this type of data in future observational studies and controlled trials to evaluate effects of varying stocking densities on various indicators of welfare.

2 PROJECT OBJECTIVES

This project will:

- Describe relevant data that is available from a sample of recent voyages conducted by either one or two cattle exporting companies.
- If adequate data is available, describe the variation in stocking densities for cattle on these voyages.
- If adequate data is available, describe the variation in selected potential indicators of welfare for cattle on these voyages.
- Assess this type of data for suitability for use in future observational studies to assess effects of varying stocking densities on various indicators of welfare.
- Make recommendations on design of future studies to assess effects of varying stocking densities on various indicators of welfare.

3 MATERIALS AND METHODS

Ten voyages conducted by Exporter 1 and nine voyages conducted by Exporter 2 were selected by company staff for inclusion in the study. Although the original proposal was to study twenty voyages from each exporter (Appendix 1), reduced voyage numbers were suggested by one exporter for practical reasons; project objectives could still be achieved despite this reduction in numbers of voyage studied. Summary details of these voyages are shown in Table 1. The voyages were from Darwin, Broome and Wyndam to Jakarta, Panjang and Manila. Voyages selected by Exporter 1 were conducted in 2004 and 2006 while voyages by Exporter 2 were conducted in 2007.

Offices of both exporters were visited and relevant records for these voyages selected from hard copy files by the author and copied. Some data were also copied from electronic files from Exporter 1. Copied records were checked by company staff before removal.

Table 1. Details of voyages used in a study assessing the potential for using existing data to assess effects of varying stocking densities on animal welfare

Exporter	Voyage ID	Ship	Embarkment date (mm/yy)	Discharge date (mm/yy)	No. loaded	Voyage duration (days)
1	1	A	07/04	07/04	2884	8
1	2	B	06/04	06/04	2815	9
1	3	C	07/04	08/04	2617	7
1	4	D	08/04	08/04	2612	5
1	5	E	08/04	08/04	2552	5
1	6	F	08/04	08/04	3195	6
1	7	F	09/04	09/04	2924	8
1	8	F	09/04	09/04	3153	7
1	9	A	04/06	05/06	1620	9
1	10	C	10/06	10/06	2998	6
2	1	A	05/07	05/07	4365	11
2	2	G	04/07	04/07	1217	6
2	3	H	05/07	05/07	2482	5
2	4	H	06/07	06/07	2452	5
2	5	H	06/07	07/07	2560	4
2	6	H	07/07	07/07	2608	5
2	7	H	07/07	07/07	2425	5
2	8	H	08/07	08/07	2431	6
2	9	H	08/07	08/07	2643	5

4 RESULTS AND DISCUSSION

4.1 AVAILABLE DATA

Key point: Data recording methods and availability of data vary between voyages.

The types of data collected for each voyage are summarised in Tables 2 and 3. The form of recording data varied between voyages and some types of data were not available for some voyages.

4.2 STUDY TYPES TO ASSESS EFFECTS OF VARYING STOCKING DENSITIES ON WELFARE

Key points: Studies comparing cattle exposed to different stocking densities such as cohort studies and controlled trials are much preferred to case series (where no control cattle are studied) when assessing effects of stocking density on animal welfare. Controlled trials may result in greater control of bias than that afforded by cohort studies but may pose greater logistic problems.

4.2.1 Case series

Effects of stocking density on animal welfare could be assessed using a case series. For example, measures of welfare could be collected for a series of voyages and compared with standard figures or expectations. This approach involves no control groups and so has a major limitation – it is difficult to choose valid figures for comparison. Standard figures may not be valid for particular shipments due to differences between the actual shipments and the source of the standard figures. For example, differences in month of shipping, classes of stock shipped, duration of voyage, etc, may invalidate such comparisons. In addition, standard figures may not reflect potential performance as it may be possible to achieve better performance than standard performance.

4.2.2 Observational analytic studies (in particular, cohort studies)

Much better evidence about the effects of stocking density on animal welfare could be obtained from one or more observational analytic studies. These include cohort studies, a design particularly well suited to this question. This would involve collecting data for cattle loaded at a range of stocking densities as part of the usual management of export voyages, and comparing various outcome variables between these groups of cattle. Such studies could be conducted retrospectively, using existing data, provided suitable data is available. They can also be conducted prospectively.

Table 2. Summary of types of data collected from 10 voyages by Exporter 1 for a study assessing the potential for using existing data to assess effects of varying stocking densities on animal welfare

Type of data	Voyage ID									
	1	2	3	4	5	6	7	8	9	10
Notice of intention & consignment management for live-stock exports									✓	
Load plan - class/no./av weight/space/total sqm per head		✓		✓	✓	✓	✓	✓	✓	
Load plan - diagram of ship decks/numbers in pens						✓		✓		
Vessel requirements - class/no./av weight/space/total sqm per head/fodder/water								✓		
Trucking details (to ship) – registration no./origin/class/no./weight										
Trucking details (from station) - truck no/driver/station/class/no.										
Stockman daily report - food & water consumption/temp/humidity/illness/mortalities/comments		✓	✓	✓	✓	✓	✓	✓	✓	✓
Stockman report record - daily report record/mortalities										
Stockman's end-of-voyage report	✓	✓	✓	✓	✓	✓	✓		✓	✓
Condition on ship - daily temperature and humidity/water/fodder			✓	✓				✓		
Livestock treatment report - date/ID/medicine/dose rate/withholding period	✓	✓				✓	✓			
Fodder & water usage - by day	✓									
Numbers, class and total/average weight at origin cf destination feedlot	✓									
Declaration of welfare and supervision of loading livestock		✓	✓	✓	✓	✓	✓	✓		✓
Declaration of pre-export isolation of livestock for export - origin, DOA, class			✓	✓	✓	✓	✓	✓	✓	✓
Daily cargo mortality report - mortalities by deck & owner/tmp & humidity by deck									✓	
Permission to leave for loading										✓

Table 3. Summary of types of data collected from 9 voyages by Exporter 2 for a study assessing the potential for using existing data to assess effects of varying stocking densities on animal welfare

Type of data	Voyage ID								
	1	2	3	4	5	6	7	8	9
Notice of intention & consignment management for live-stock exports	✓	✓	✓	✓	✓	✓	✓	✓	
Supply Order	✓						✓		
Origin of cattle - station/numbers & sometimes class	✓				✓				
Buying sheet - vendor/class/breed/depot/no./total kg/av kg								✓	✓
Load plan - class/no./av weight/space/total sqm per head	✓	✓	✓	✓	✓				✓
Load plan - diagram of ship decks/numbers in pens	✓	✓		✓	✓	✓	✓	✓	✓
Vessel requirements - class/no./av weight/space/total sqm per head/fodder/water	✓	✓	✓			✓	✓		✓
Trucking details (to ship) - registration no./origin/class/no./weight	✓	✓	✓	✓	✓	✓		✓	✓
Trucking details (from station) - truck no/driver/station/class/no.					✓				
Stockman daily report - food & water consumption/temp/humidity/illness/mortalities/comments		✓	✓	✓	✓	✓	✓	✓	✓[1]
Stockman report record - daily report record/mortalities	✓						✓		
Stockman's end-of-voyage report	✓	✓	✓	✓		✓	✓	✓	✓
Condition on ship - daily temperature and humidity/water/fodder	✓								
Accredited stockperson voyage confirmation - ship details/cattle details/stockman declaration		✓							
Shipping summary - ship details/mortalities			✓						
Weighbridge docket				✓					
Manifest of Cargo - shipper/consignee/qty/gross weight					✓				
Permit to export animals or animal reproductive material							✓		
Shipment audit checklist - documentation checklist								✓	✓
Shipment summary - no./loaded wt/discharge wt/origin/mort on board/mort on discharge									✓

[1] *Day 1 only*

4.2.3 Controlled trials

Controlled trials would also compare groups of cattle loaded at a range of stocking densities; they differ from cohort studies in that stocking densities that particular cattle are exposed to would be determined by the researcher (preferably using a random method of allocation), rather than being determined by exporters applying export standards in the usual management of voyages. This approach may result in greater control of bias than that afforded by cohort studies. However, controlled trials may well raise greater logistic difficulties than cohort studies, particularly when loading cattle. Various stocking densities would be prescribed in advance in a controlled trial whereas in a cohort study, stocking densities would be determined in the normal process of loading ships.

4.3 COMPARING VOYAGES, CLASSES OF CATTLE, DECKS, PENS OR ANIMALS

Key points: Comparisons between stocking densities on live cattle voyages can be performed at various levels of organisation. Studies assessing effects of stocking density on animal welfare should be conducted at the animal level rather than at pen, deck, class of cattle or voyage levels. Such studies require data for each animal rather than only at pen, deck, class of cattle or voyage levels. Measures on individual animals should be compared between pens with varying stocking densities, with pens with varying stocking densities located on the same ship and preferably on the same deck.

4.3.1 Natural levels of organisation

From discussions with both exporters, it became evident that comparisons between stocking densities on live cattle voyages can be performed at various levels of organisation: voyage, class of cattle, deck, pen or animal. Other possible levels include farm and registered premises levels. To explain this concept of levels of organisation, examples of variables that inherently occur at particular levels are described in Table 4.

Table 4. Examples of inherent voyage-, class of cattle-, deck-, pen- and animal-level variables

Level of aggregation	Example variable
Voyage	Ship name
Class of cattle	Gender
Pen	Location on ship
Animal	Blood cortisol concentration

Voyage-, class-, deck- and pen-level variables can also be created by aggregation of data to higher levels (Table 5).

Table 5. Examples of aggregation of animal-level data (in this example, hypothetical mortality data) to pen, deck, class of cattle and voyage levels

Level of aggregation	Replicates within voyage	No. deaths
Animal	1001	Died
	1002	
	1003	
	1004	Died
	1005	
	1006	Died
	1007	
	1008	
	etc	
Pen	Deck 1	
	Pen 1-1	0
	Pen 1-2	0
	Pen 1-3	0
	Deck 2	
	Pen 2-1	0
	Pen 2-2	1
	Pen 2-3	0
	Deck 3	
	Pen 3-1	1
	Pen 3-2	1
	Pen 3-3	0
	etc	
Deck	Deck 1	0
	Deck 2	1
	Deck 3	2
	Deck 4	0
	Deck 5	0
	Deck 6	0
	Deck 7	0
	etc	
Class of cattle	Heifers	1
	Steers	2
	Bulls	0
	etc	
Voyage	None	3 deaths for voyage

4.3.2 What is the appropriate unit of analysis?

As discussed above, when studying effects of stocking density on animal welfare, one could theoretically compare voyages, i.e. identify voyages having a range of average stocking densities, calculate averages for various outcome variables across all cattle in each voyage and compare these averages across stocking densities. One previous study has used this approach (Morgan and Sykes 1995). This is an example of an ecologic study. Studies that make conclusions at the individual animal level yet are conducted at levels higher than the individual animal are called ecologic studies.

Ecologic studies would have some advantages over alternative designs when studying effects of stocking density on animal welfare. Only one measure of each variable would be required per voyage, substantially simplifying data collection and potentially allowing use of existing datasets. In addition, statistical analyses are relatively simple and transparent.

However, observed relationships at the voyage level may not be the same as those occurring at the animal level (i.e. results are biased) for reasons other than random variation. These serious difficulties in interpreting ecologic studies are well-documented (Morgenstern 1998; Dohoo et al 2003). Because effects of stocking density are of interest at the individual animal level, this is a major concern. Often ecologic studies overestimate the strength of effects. If this occurred when studying effects of stocking density on animal welfare, adverse effects of high stocking densities would be overestimated with this approach. Ecologic studies can also underestimate the strength of effects. This bias occurs for a range of reasons and some of these problems are not easily prevented. For example, while confounding by voyage-level variables can be controlled using standard methods such as multivariable modelling, confounding by pen-, deck- and class of cattle-level variables can be difficult or impossible to control. Similar concerns arise with studies at class of cattle, deck or pen levels.

The solution to this serious problem is to conduct studies assessing effects of stocking density on animal welfare at the animal level. Measures on individual animals should be compared between pens with varying stocking densities, with pens with varying stocking densities located on the same voyage and preferably on the same deck.

4.4 STOCKING DENSITY

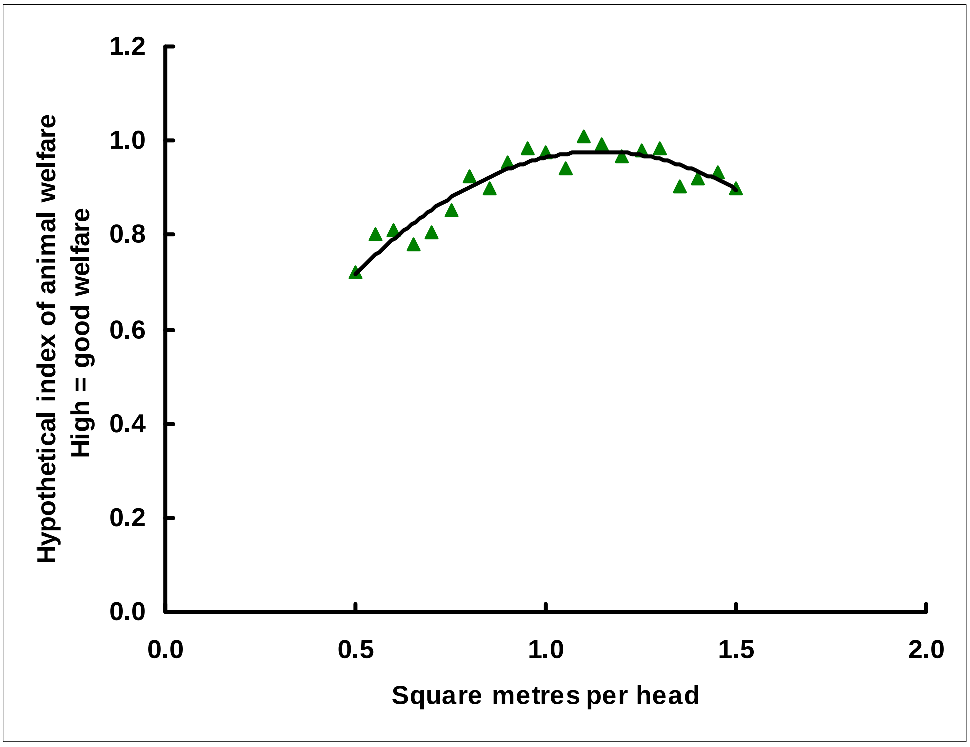
4.4.1 Why variation in stocking density is required for research

Key point: It is not possible to study effects of stocking density on animal welfare without variation in stocking density.

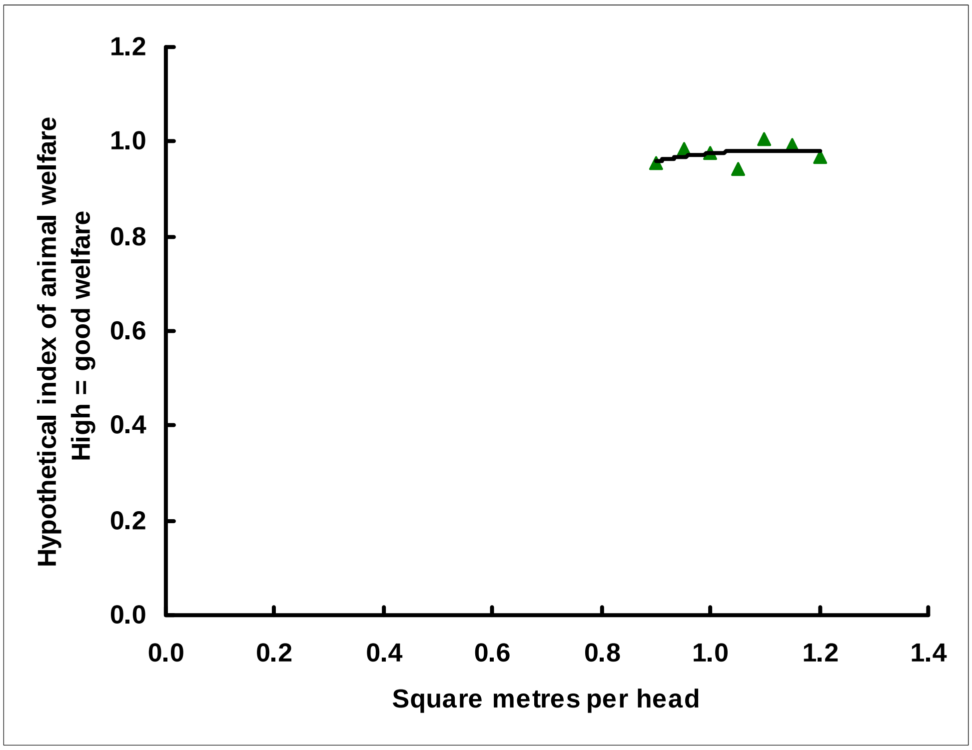
To study effects of stocking density on animal welfare using a comparative study, variation in stocking density is required. To illustrate this, consider the following hypothetical example. Suppose the relationship between stocking density for 300 kg steers and some hypothetical index of animal welfare is as shown in Figure 1a, with optimal values of the index at around 1.1 m^2/head and declining welfare with both lower and higher stocking densities. If one studied only pens with stocking densities between 0.9 and 1.2 m^2/head, the results may appear as in Figure 1b, leading to the erroneous conclusion that there is no important effect of stocking density when in fact, in this hypothetical study, welfare deteriorated with stocking densities lower than 0.9 m^2/head and above 1.2 m^2/head.

Figure 1. Hypothetical relationship for 300 kg cattle between stocking density (measured as square metres per head) and a hypothetical index of animal welfare

a) Relationship over stocking densities from 0.5 to 1.5 square metres per head



b) Relationship over stocking densities from 0.9 to 1.2 square metres per head



4.4.2 Prescribed minimum stocking densities

Key points: Currently prescribed minimum stocking densities (area per head) vary linearly with liveweight, with additional space allowances at some liveweights for voyages longer than 10 days, for voyages from ports south of latitude 26 degrees south, time of year of voyage and for pregnant cows and pregnant *Bos taurus* heifers. However, variations in prescribed minimum stocking densities are not a useful basis for assessing effects of stocking density on animal welfare because this variation is only at some liveweights and because comparisons between animals stocked at different densities due to these variations in prescribed stocking densities would be either confounded or would be at the voyage level. For voyages to the Middle East and beyond, the Heat Stress Model ('HotStuff') is currently used to prescribe stocking densities. However, variations in stocking densities between pens based on the model's outputs would be confounded by deck and class of animal and would vary at the voyage level with ship, anticipated climate and possibly other factors. As such, this variation in stocking densities is not a useful basis for assessing effects of stocking density on animal welfare.

Since mid 2005, minimum stocking densities (minimum areas per head) have been prescribed in the Australian Standards for the Export of Livestock (Anonymous 2005; Anonymous 2006). These standards prescribe minimum areas per head for various liveweights, with additional space allowances at some liveweights for voyages longer than 10 days, for voyages from ports south of latitude 26 degrees south, time of year of voyage and for pregnant cows and pregnant Bos taurus heifers. From 1999 to 2004, stocking densities were defined by industry in the Australian Livestock Export Standards (Peter Stinson, personal comm.). These standards are described in Anonymous (2003). These stocking densities are identical to current standards except that no allowances were included for pregnant cattle as export of this class of cattle was not allowed under these standards. (For voyages to the Middle East and beyond, the Heat Stress Model ('HotStuff') is currently used. This is discussed separately, below.)

The current prescribed minimum areas per head for non-pregnant animals of various average liveweights are shown in Figures 2 and 3. Minimum areas per head increase linearly with average liveweight, with marginal increases varying as shown in Table 6.

Although the particular liveweight statistic to be used when applying these standards is not specified, practice of both exporters involved in this study is to calculate required area for each class of cattle for each voyage using the average liveweight for the class.

Thus, for a given liveweight, there is variation in minimum stocking density. However this variation is either between classes of livestock (pregnant versus non-pregnant animals) or at the voyage level, where variation occurs between voyages of 10 days or less versus longer than 10 days, for voyages from ports south of latitude 26 degrees south versus more northern ports, and by time of year.

This variation could potentially be used to study effects of stocking density on animal welfare. However, this variation is only at some liveweights. More importantly, comparison between animals stocked at different densities due to these variations in prescribed stocking densities would be either confounded by class (ie pregnant versus non-pregnant) or would vary at the voyage level. But, as discussed in section 4.3, studies assessing effects of stocking density on animal welfare should not be conducted at the voyage level. Therefore variations in prescribed minimum stocking densities are not a useful basis for assessing effects of stocking density on animal welfare.

Table 6. Prescribed minimum stocking densities for non-pregnant cattle with average liveweight up to 200 kg and marginal increases with additional average liveweight (from Anonymous 2005; Anonymous 2006)

	Prescribed minimum stocking densities for cattle with average liveweight up to 200 kg (m^2 per head)	Marginal increase with average liveweight (extra m^2 per head per extra 5 kg liveweight)
Default values		
Voyage of 10 days or more	0.77	0.017
Voyage of less than 10 days	0.77	
Up to 400 kg		0.017
405-420 kg		0.009-0.019
425 kg and above		0.013-0.014
Voyages from ports south of latitude 26 degrees south; 1 May-31 October	0.847	
Up to 390 kg		0.0187[1]
395-400 kg		0.0550-0.0552
405-500 kg		0.0195[1]
Above 500 kg		0.020
Voyages from ports south of latitude 26 degrees south; 1 Nov-30 April	0.77	
Up to 480 kg		0.017
485 kg to 520 kg		0.051-0.053
525 kg to 550 kg		0.019-0.020
Above 550 kg		0.020

[1] *Marginal increases vary from these for some liveweight increments*

Figure 2. Prescribed minimum areas per head for non-pregnant animals of various average liveweights for voyages from ports north of latitude 26 degrees south

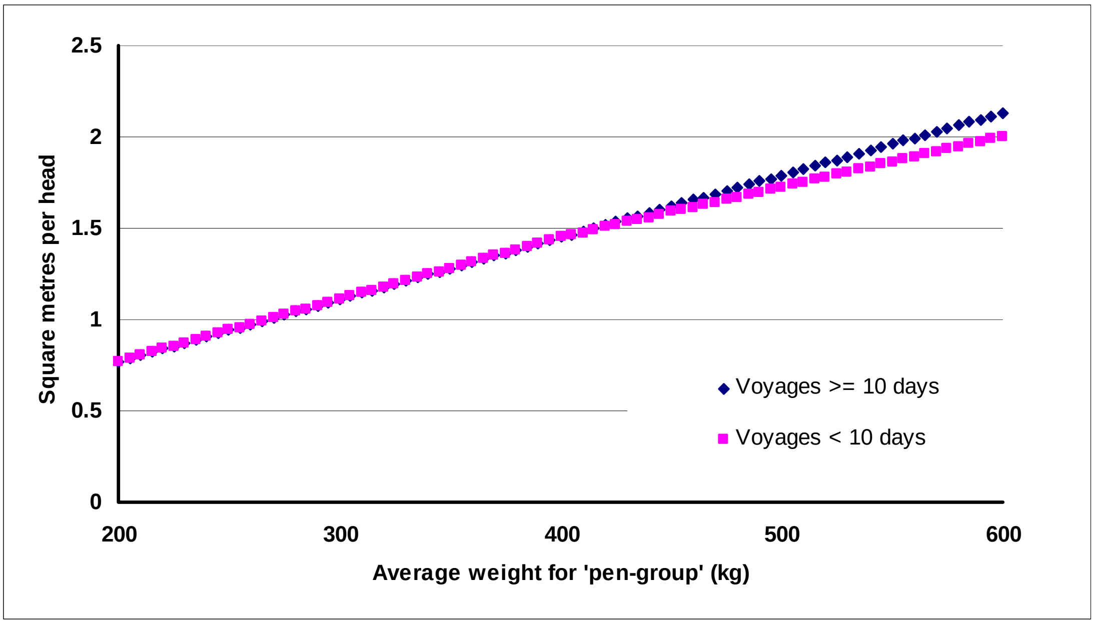
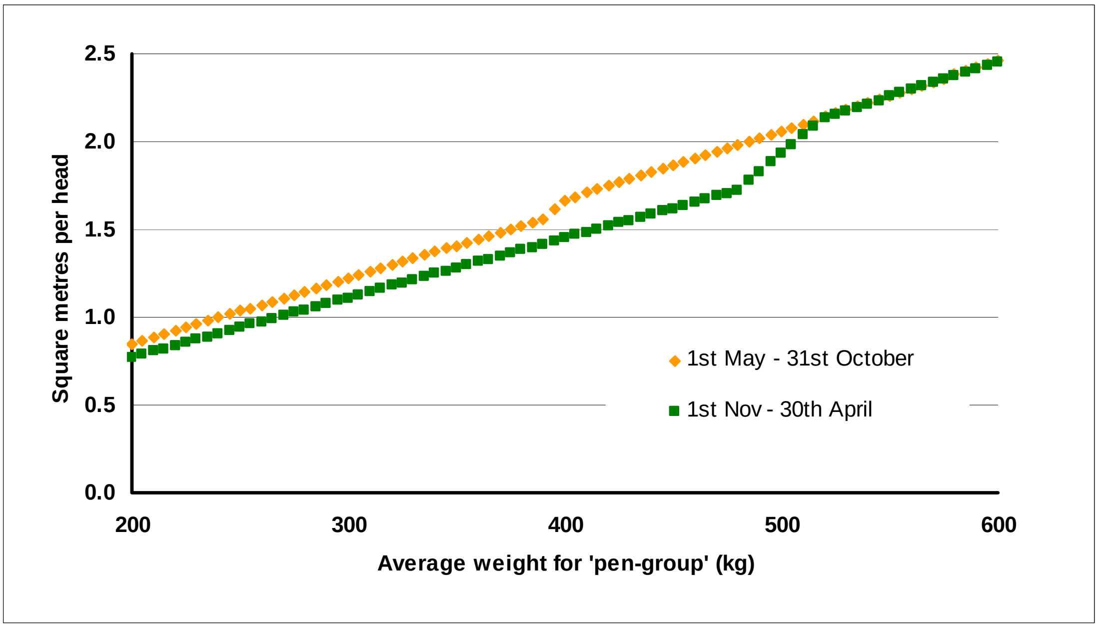


Figure 3. Prescribed minimum areas per head for non-pregnant animals of various average liveweights for voyages from ports south of latitude 26 degrees south



For voyages to the Middle East and beyond, the Heat Stress Model (‘HotStuff’) is currently used to prescribe stocking densities. As only short haul voyages were the subject of this review, this model was not investigated in detail. However, assuming that this model prescribes stocking densities by deck and class of animal for individual shipments, variations in stocking densities between pens based on the model’s outputs would be confounded by deck and class of animal and would vary at the voyage level with ship, anticipated climate and possibly other factors. As such, this variation in stocking densities is not a useful basis for assessing effects of stocking density on animal welfare. As actual climatic conditions will vary from predicted, it may be possible to compare animal-level indicators of welfare between voyage using analytical techniques to remove confounding by climate. However between voyage comparisons are highly undesirable due to potential for confounding by other voyage level factors.

4.4.3 Other causes of variation in stocking density

Key points: Variation in stocking density due to varying definitions would not be a useful basis for assessing effects of stocking density on animal welfare. However some natural variation in stocking density probably occurs under commercial conditions due to rounding effects and to random variation when loading pens, particularly pens loaded with smaller numbers of cattle. Before observational studies relying on natural variations in stocking density between pens are implemented, the extent of this variation should be examined using data collected prospectively before any redistribution of cattle after loading. If such observational studies are to proceed, such redistribution would need to be limited to only that required to ensure minimal animal welfare standards are maintained. Loading light may offer an additional opportunity to conduct observational studies relying on natural variations in stocking density between pens The frequency and extent of loading light should be further investigated, along with stocking densities by pen on such voyages.

4.4.3.1 Variation due to varying definitions of stocking density

Stocking densities above are described in terms of area per herd for given liveweights. Stocking densities can also be described in terms of area per unit weight eg m^2 per 100 kg. Figures 4 and 5 show prescribed minimum stocking densities expressed as m^2 per 100 kg for increasing liveweights. These figures show that there is also variations in prescribed minimum stocking densities when stocking densities are described in terms of area per unit weight. However, these variations are not a useful basis for assessing effects of stocking density on animal welfare because comparisons between animals stocked at different densities due to these variations in prescribed stocking densities would be either confounded by class of stock (pregnant/non-pregnant) and/or by actual liveweight, or would be at the voyage level (as discussed in section 4.4.2).

Figure 4. Prescribed minimum areas per 100 kg liveweight for non-pregnant animals of various average liveweights for voyages from ports north of latitude 26 degrees south

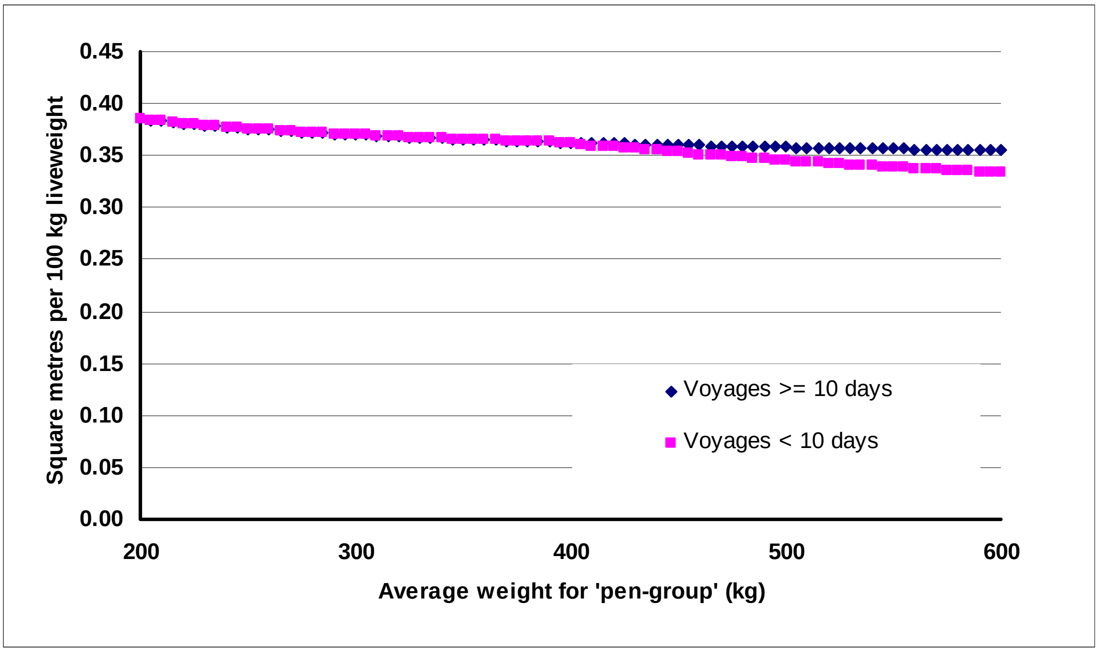
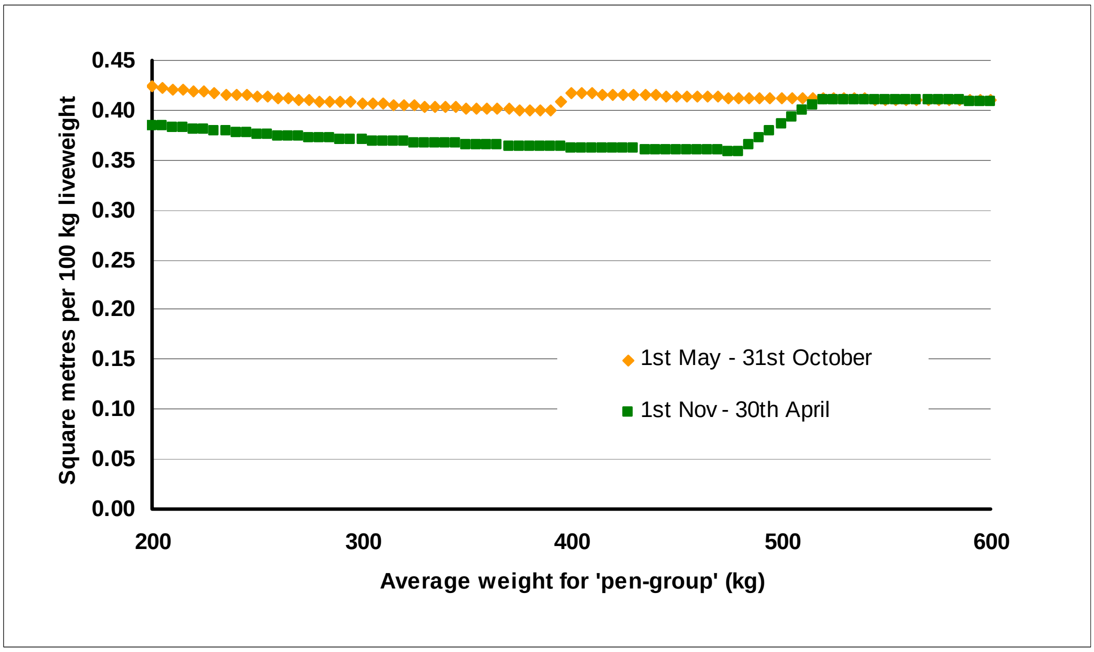


Figure 5. Prescribed minimum areas per 100 kg liveweight for non-pregnant animals of various average liveweights for voyages from ports south of latitude 26 degrees south



Alternative approaches may be more appropriate when describing stocking density; for example area per unit weight raised to the power of 0.66 has been proposed (Petherick and Phillips, personal communication). Stocking densities under this proposal would vary from those prescribed under the Australian Standards for the Export of Livestock. However, this approach for comparing animal welfare at varying stocking densities has the same limitations as previously discussed, i.e. such comparisons would be either confounded by class of stock (pregnant/non-pregnant) and/or by actual liveweight, or would be at the voyage level (as discussed in section 4.4.2).

4.4.3.2 Natural variation in stocking density under commercial conditions

For a number of reasons, stocking densities for a voyage may vary in the usual management of voyages. This can occur due to rounding effects, random variation when loading pens and loading voyages light. These are each discussed below.

a) Rounding effects

Rounding effects occur when the number of cattle to be allocated to a particular pen at the prescribed minimum stocking density for their liveweight is not a whole number. From the data collected from exporters, numbers of animals allocated to pens in loading plans appeared to be rounded (rather than rounded down). Rounding would mean, for example, that in a pen that can hold 11.9 head (ie pen area divided prescribed minimum area per head =11.9), 12 head are loaded whereas under rounding down, 11 would be loaded.

With rounding, in pens that receive between 6 and 18 cattle from a class whose average liveweight is 300 kg, deviations between pens from the prescribed minimum areas per head would be up to 3 to 8% both above and below prescribed minimum areas per head (estimation methods available on request). Thus rounding effects are probably causing small to modest variation in stocking densities.

b) Random variation when loading pens

When pens are loaded based on average liveweight for the class, average liveweights by pen will vary. Some pens will, by chance, receive a disproportionate number of light cattle and by chance others will receive a disproportionate number of heavy cattle. The extent of this random variation between pens will depend on the variation in liveweights within the class, the number of animals loaded into each pen and the extent of non-random loading of cattle from the same class (see below for a description of non-random loading).

To further explore the effect of random variation when loading on variation in pen stocking density, a model was designed using the following two step procedure within individual classes of cattle originating from the same property.

Step 1: Estimate the standard deviation of liveweights for the class

Although no individual animal liveweights were available for this study, average liveweights by truck at loading were available for some voyages.

Three groups of trucks with at least 4 trucks per group with cattle from the same voyage, class and property were selected and the standard deviation of the truck averages (SD_t) calculated. Given the same number of cattle were on each truck (the 'sample' in statistical terms), the standard deviation of the truck averages estimates the standard error of the mean for the cattle (SEM_a) from that class and property shipped in that voyage (the 'population' in statistical terms). The 95% confidence intervals for those estimates were also calculated (Wildman and Freudenthal 2002).

The estimated standard deviation for the class from the property was calculated as follows:

$$SDt = SEMa = SDa / \sqrt{n}$$

where:
SD_a = Standard deviation of individual animal liveweights
n = the number of animals in the sample (i.e. the number in each truck)

Therefore:

$$SDa = SDt * \sqrt{n}$$

Associated 95% confidence intervals for the estimated standard deviation for the class from the property were also calculated using the limits of the confidence interval for the estimated standard error of the mean for the class.

Estimates of the standard deviation of liveweights for 3 classes from the same property are shown in Table 7.

Table 7. Estimated standard deviations of liveweights shipped by Exporter 2 for 3 classes of cattle from the same property and associated 95% confidence intervals

Voyage, class and property ID	Average liveweight[1]	Estimated standard deviation for class (95% confidence interval)
Voyage 1, steers from property 1 (7 trucks)	338.9 kg	26.7 kg (17.2, 58.8)
Voyage 5, steers from property 2 (4 trucks)	314.7 kg	25.2 kg (14.2, 93.8)
Voyage 5, heifers from property 2 (4 trucks)	320.1 kg	60.1 kg (34.0, 223.9)

1 Average of truck averages

Step 2: Estimate the expected variation in average liveweights for pens

Using these estimated standard deviations, the expected distribution of average liveweights for varying numbers of head per pen of cattle from that class and property was then calculated using the t-distribution with n-1 degrees of freedom where n = number of head loaded per pen.

Estimates of the expected variation in average liveweights for pens with varying numbers of cattle loaded from a class with average and standard deviation of 300 kg and 26 kg, respectively are shown in Table 8. For example, from that table, for pens loaded with 12 head, we can expect 6.9% of pens to have average liveweights between 285 and 290 kg ie 3.3 to 5% less than the average for class).

Results of this modelling show that modest variations in average liveweights for pens would be expected due to random variation, with greatest variation in pens with small numbers of cattle loaded.

This approach is simplistic as it assumes complete mixing of cattle within the same class from a particular property before loading onto trucks. This would not occur if cattle from different mobs/paddocks within properties with differing mob average liveweights were yarded and trucked to the ship as separate subsets. With the statistical methodology used above, this handling would result in overestimation of the population standard deviation (resulting in overestimation of variation in pen averages) but would also cause increased variation in pen averages over that expected if the standard deviation were estimated without error. This approach is also simplistic as it assumes that cattle from the same class from different properties have the same average liveweight. Where average liveweights differ between properties, this method would underestimate the variation in average liveweights for pens.

Table 8. Expected variation in average liveweights for pens with varying numbers of cattle loaded from a class with average and standard deviation of 300 kg and 26 kg, respectively

Mean liveweight for pen	% difference from 300 kg (ie from class average liveweight)	Expected percentage of pens		
		6 head loaded per pen	12 head loaded per pen	18 head loaded per pen
<280	More than 6.7% less	5.9%	1.1%	0.2%
280-285	5.0-6.7% less	4.9%	2.4%	1.0%
285-290	3.3-5.0% less	8.6%	6.9%	4.8%
290-295	1.7-3.3% less	13.4%	15.5%	15.2%
295-300	0.0-1.7% less	17.1%	24.0%	28.7%
300-305	0.0-1.7% higher	17.1%	24.0%	28.7%
305-310	1.7-3.3% higher	13.4%	15.5%	15.2%
310-315	3.3-5.0% higher	8.6%	6.9%	4.8%
315-320	5.0-6.7% higher	4.9%	2.4%	1.0%
> 320	More than 6.7% higher	5.9%	1.1%	0.2%

c) Redistribution of cattle after loading

In response to these natural variations in stocking density between pens, under commercial conditions, after cattle are loaded, the stockmen may move small numbers of cattle from ‘tight’ pens to pens with a disproportionate number of lighter cattle. While this is probably completely appropriate management, from a research perspective, it will reduce the natural variation in stocking density between pens, limiting the usefulness of such studies. Thus, if observational studies relying on natural variations in stocking density between pens are to be implemented, redistribution of cattle after loading would need to be limited to only those required to ensure minimal animal welfare standards are maintained. Clearly such studies would require careful animal ethics appraisal before being implemented.

d) Loading voyages light

Both exporters indicated that loading voyages ‘light’ (ie loading less cattle than permitted for the available deck space under the Australian Standards for the Export of Livestock), is highly undesirable from a commercial perspective and does not occur frequently. However for a range of reasons, loading light occasionally occurs. One exporter indicated that, in this situation, under some circumstances, less pens are loaded and the cattle are spread across the excess pens resulting in higher than prescribed minimum areas per head than on voyage loaded to capacity. This management may result in further variation in stocking densities. If observational studies relying on natural variations in stocking density between pens are to be implemented, the frequency and extent of loading light should be investigated, along with stocking densities by pen on such voyages.

e) Conclusion - natural variation in stocking density under commercial conditions

Before observational studies relying on natural variations in stocking density between pens are implemented, the extent of this variation should be examined using data collected prospectively before any redistribution of cattle after loading.

4.5 INDICATORS OF ANIMAL WELFARE

Key points: Data for potential indicators of animal welfare were available from all voyages. However, these data have important limitations for assessing welfare at animal level for purposes of research to assess effects of stocking density because the data are either collected only at voyage- or class-level, individual animal level data is not linked to pen identity, clinical disease and post mortem data do not appear to be collected using standard case definitions. The sensitivity of monitoring systems for detecting and reporting clinical disease is uncertain. All indicators for which data is available have limitations as sole indicators of animal welfare. Animal welfare experts should be consulted when designing any future studies assessing effects of stocking density on animal welfare.

4.5.1 Indicators of animal welfare from existing data

Data for potential indicators of animal welfare were available for all of the voyages (Table 9). No data for any indicator were available at the pen-level and although some data are collected at the individual animal level, individual animal ID number is not linked to pen identity. All indicators for which data are available have limitations as sole indicators of animal welfare.

4.5.2 Suggested additional indicators of animal welfare

Shipboard measures of animal welfare have been the subject of a survey of stakeholders (Pines et al 2007). The survey identified mortality incidence, clinical disease incidence, respiration rate, space allowance, ammonia levels, weight change and wet bulb temperature as the most preferred indicators. Of these, the effect of space allowance is the research question so this is not a welfare indicator in this context, and ammonia levels and wet bulb temperature can be viewed as exposure variables rather than outcomes. The difficulties with using existing data to assess mortality incidence, clinical disease incidence and weight change are noted in Table 9 and no quantitative data were available on respiration rate for the 19 voyages studied. Animal welfare experts should be consulted to explore additional indicators of animal welfare when designing any future studies assessing effects of stocking density on animal welfare.

Table 9. Data for potential indicators of animal welfare available for some or all of 19 voyages studied to assess the potential for using existing data to assess effects of varying stocking densities on animal welfare

Indicator of welfare	Available at which level of organisation	Comments
Mortality	Voyage and class	Mortality is considered to be a relatively insensitive and blunt measure of animal welfare. For the 19 voyages studied, the incidence risk of mortality was low (minimum 0.00%, median 0.03%, maximum 0.16%). Accordingly, any effects of stocking density on the incidence risk of mortality are likely to be small and very large studies would be required to identify such small effects. However, mortality incidence risk would be a suitable indicator of welfare in voyages with higher mortality incidence if used in combination with other indicators. It was not always clear whether deaths occurring during loading or unloading were included in recorded mortalities.
Clinical disease occurrence	Voyage and class	Case definitions for common syndromes do not appear to have been defined. The sensitivity of monitoring systems for detecting and reporting clinical disease is uncertain. Veterinarians are not present on all voyages
Post mortem findings	Voyage and class	Veterinarians are not present on all voyages
Liveweight data	Voyage and class[1]	These liveweight data would be subject to important measurement error due to fluctuations in water and feed intake and variation in intervals from weighing to loading and from unloading to weighing, resulting in misclassification bias. If management differences between pens of different stocking density affect liveweight, confounding would also occur.

Table 9. Continued

Indicator of welfare	Available at which level of organisation	Comments
Feed and water intake	Voyage	These data were available on a daily basis during the voyage for some voyages. These feed estimates may be stockmen's estimates or, for ships with silos based on the number of toughs filled times the average feed weight to fill troughs or, where feed is handled in bags, the number of bags fed times weight per bag. Total voyage feed usage is calculated as total feed loaded minus remaining feed at end of voyage. Daily water consumption may be estimated by stockmen, or based on total fresh water volume on hand if monitored by ship staff and volume of fresh water produced is also recorded. Water for domestic use can not be accounted for separately from that used by livestock but would constitute only a relatively small proportion of total water use on a fully loaded ship.
Animal demeanour	Voyage	No case definition or criteria for assessment appear to have been developed for this indicator. This is a potentially interesting variable that may prove useful at the pen- or individual animal-level if the criteria for assessment can be described objectively and a scale developed.

1 Preloading liveweights by truck and/or class were available for this study. Liveweights by groups of 12-30 cattle before loading (for some voyages) and on unloading are also collected but were not available for purposes of this study. These group weights may also be available by sale category within voyages. Liveweight data is not linked to pen identity.

4.6 CONTROL OF CONFOUNDING

Key point: Potential confounders should be identified during the design phase of any study.

For any study type, there would need to be comprehensive consideration of potential confounders. Confounders are variables that affect the observed relationship so that it no longer reflects the true situation. For example, in a study assessing effects of stocking density on mortality incidence, consider property of origin as a potential confounder. If cattle from some properties are at higher risk of dying than from other properties, and these cattle tend to predominate in higher stocking density pens, then higher stocking densities may appear to be associated with higher mortality incidence, when in fact, this is partly or entirely due to confounding by property of origin. Effects of potential confounders can be minimised in study design and/or during data analyses. However, they must first be identified and appropriate data recorded. So potential confounders should be identified during the design phase of any study.

4.7 STOCKING DENSITY THRESHOLDS AND/OR INTERACTIONS?

Key points: It is likely that there is no clear threshold of stocking density above which animal welfare is affected and below which there is no effect on welfare. Potentially important interacting factors should be identified when designing any future studies assessing effects of stocking density on animal welfare.

When the relationship between stocking density and animal welfare is described with appropriate studies, it is possible that a clear threshold will be evident above which animal welfare is affected and below which there is no effect. However, it seems much more likely that any relationship between stocking density and animal welfare will be more graded. If so, the appropriate stocking densities would be less evident and choices of acceptable stocking densities would require more judgement and discussion.

It is also possible that effects of stocking density on animal welfare may vary depending on other factors. For example, greater stocking densities may be required at higher environmental temperature and humidity. Potentially important interacting factors should be identified when designing any future studies assessing effects of stocking density on animal welfare. It may be desirable to conduct any such studies under a range of situations to allow identification of any important interactions.

5 SUCCESS IN ACHIEVING OBJECTIVES

All project objectives have been achieved. These objectives and the sections of this report that address each objective are listed in Table 10. In addition, substantial material has been prepared explaining key epidemiological concepts (eg sections 4.2, 4.3, 4.4.1, 4.6) and prescribed minimum stocking densities (section 4.4.2).

Table 10. Project objectives and the sections of report that address each objective

Project objective		Associated report section(s)
1.	Describe relevant data that is available from a sample of recent voyages conducted by either one or two cattle exporting companies.	4.1
2.	If adequate data is available, describe the variation in stocking densities for cattle on these voyages.	4.4
3.	If adequate data is available, describe the variation in selected potential indicators of welfare for cattle on these voyages.	4.5
4.	Assess this type of data for suitability for use in future observational studies to assess effects of varying stocking densities on various indicators of welfare.	4.2, 4.3, 4.6, 4.7, 7
5.	Make recommendations on design of future studies to assess effects of varying stocking densities on various indicators of welfare.	4.2, 4.3, 4.6, 4.7, 7

6 IMPACT ON MEAT AND LIVESTOCK INDUSTRY – NOW AND IN FIVE YEARS TIME

The live cattle export trade has a substantial economic impact on Australia's meat and livestock industry, and maintaining this trade is important economically both now and for years to come. Stocking density on live cattle shipments may affect welfare of shipped animals during their voyage. If relationships between stocking density and various indicators of welfare were clearly defined, industry, government and community would be better able to assess current practice and to alter practice if necessary. If management practices of live cattle exports are defined based on scientifically sound evidence, the meat and livestock industry would be in a good position to modify practices if necessary, and to explain the basis for practices to industry, government and community. Such knowledge is essential to ensure that the welfare of exported cattle is not compromised.

If relationships between stocking density and various indicators of welfare could be defined using existing data that has been collected for other purposes, the research cost would probably be much lower than if additional measures and/or interventions are required. However, this is obviously only possible if available sources consist of appropriate data of adequate quality for all necessary exposure and outcome variables. Data quality is affected by the frequency of missing values and the accuracy of recorded data. Such data must also be accessible to researchers. This review has identified that studies conducted using existing data would face several major constraints that would preclude reaching scientifically sound conclusions. Given this finding, the industry can now consider the various options for prospective studies and plan what research is required to evaluate relationships between stocking density and various indicators of welfare using studies that will deliver scientifically sound conclusions.

7 RECOMMENDATIONS ON DESIGN OF FUTURE STUDIES TO ASSESS EFFECTS OF VARYING STOCKING DENSITIES ON VARIOUS INDICATORS OF WELFARE

Key points: Both case series and cohort studies could be conducted using existing data routinely collected by exporting companies. However, such studies conducted using existing data would face several major constraints that would preclude reaching scientifically sound conclusions. Prospective studies offer the possibility of addressing these limitations and potentially reaching scientifically sound conclusions. Expert advice should be sought from epidemiologists, the export industry and animal welfare experts when designing any future studies assessing effects of stocking density on animal welfare.

7.1 Studies using existing data

Both case series and cohort studies could be conducted using existing data routinely collected by exporting companies. However based on the data collected from these 19 voyages, such studies conducted using existing data would face several major constraints that would preclude reaching scientifically sound conclusions. These are as follows:

- The existing data would provide some measures of animal welfare but the available data has serious limitations for this purpose (section 4.5.1).
- Even if data without such limitations were available at animal level (section 4.3), evidence from case series would be weak (section 4.2.1).
- Additional major constraints to cohort studies would be the inability to conduct these studies at the animal level due to unavailability of necessary animal-level data (section 4.3) and uncertainty about natural variations in stocking density between pens (section 4.4.3.2).
- In addition, results may be biased due to inability to control confounders (see section 4.6 for a description of confounding).
- Variation in both data recording methods and availability of data between voyages would also cause some difficulties when conducting such studies (section 4.1).

7.2 Prospective studies

Prospective studies offer the possibility of addressing these limitations and potentially reaching scientifically sound conclusions. Expert advice should be sought from epidemiologists, the export industry and animal welfare experts when designing any future studies assessing effect so stocking density on animal welfare.

7.2.1 Prospective cohort studies

Prospective cohort studies could be conducted using pens where stocking density was expected to or did vary substantially. Appropriate animal-level measures of welfare would be taken during voyages and data analysed at the individual animal level using statistical methods that account for clustering of animal-level outcomes within pens (and also possibly within decks, classes of cattle and voyages).

7.2.2 Controlled trials

As described in section 4.2.3, stocking densities for a voyage can also be varied between pens within a class of cattle by design. One approach for assessing effects of would be to design one or more cluster randomised controlled trials, whereby some pens are randomly allocated to industry-standard stocking densities and other similar pens on the same voyage are randomly allocated to receive alternative stocking densities. Similar cattle could then be randomly allocated to all study pens and a range of animal-level outcomes assessed during and after the voyage. This approach may result in greater control of bias than that afforded by cohort studies (including confounding - see section 4.6) but logistic difficulties in applying stocking densities to cattle as determined by predetermined research protocols would need to be overcome.

7.2.3 Land-based research

Land-based research may provide additional information about effects of stocking density on animal behaviour. Using sheep as a model, such research could identify the responses of sheep to simulated ship motion at varying stocking densities. This would allow predictions to be made of the extent to which high stocking density allows animals to support each other and the likelihood of shock to the body that would result in bruising. This work would best be conducted in a small chamber with a moving floor, and cameras to record sheep behaviour. Blood samples could be taken for estimation of physiological response to determine bruising etc. It may also be possible to expand this work to include cattle.

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