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Free Range Chickens – Odour Emissions and Nutrient Management

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by Grant Brown and Erin Gallagher

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Foreword

The Australian chicken meat industry grows approximately 565 million chickens producing 1 million tonnes of meat annually. The free range sector accounts for about 10-15% of this production and is growing at 15% per annum. As this sector expands, it becomes increasingly important to understand odour and nutrients emissions that come from free range farms and how they may differ from conventional meat chicken farms. Odour emissions and nutrient export are recognised as an issue for intensive animal industries worldwide, including the Australian chicken meat industry. By researching and characterising these emissions, potential impacts can be minimised.

While substantial research has been conducted on conventional style meat chicken farms, there is little information regarding free range farms. Emerging industries like the free range meat chicken sector can be subject to incorrect assumptions about potential environmental issues. By investing in this research, producers, consultants and the community will have scientifically based information regarding the free range chicken meat sector.

The objectives of this project were to investigate odour emissions from free range meat chicken farms and determine if they were different to conventional styled meat chicken farms. And secondly, to determine nutrient (nitrogen and phosphorus) content in both the runoff and soil on the free range area. The research showed that odour emission from free range farms were comparable to conventional styled meat chicken farms; the runoff from free range areas would generate less load on the environment than, for example, a commercial golf course; and that the nutrients that accumulated in the soil of the range were at concentrations comparable to areas where the birds do not access.

The information contained in this report will provide knowledge about the free range sector that could prove useful for consultants/planners concerned with environmental modelling. The report also contains useful information for producers on range area environmental management.

This project was funded from industry revenue which is matched by funds provided by the Australian Government.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Chicken Meat R&D program, which aims to stimulate and promote R&D that will deliver a productive and sustainable Australian chicken meat industry that provides quality wholesome food to the nation.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation

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Abbreviations

ou	Odour unit
Lpm	Litre per minute
OER	Odour emission rate
mg	Milligrams
kg	Kilograms
ha	Hectare (10,000 m^2)
P	Phosphorus
SRP	Soluble Reactive Phosphorus (as orthophosphorus)
N	Nitrogen
NH_3	Ammonia
NH_4	Ammonium
NO_3^-	Nitrate
NO_2^-	Nitrite
CO_2	Carbon Dioxide
CO	Carbon Monoxide

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What the report is about

This report focuses on odour emissions and nutrient management from free range meat chicken farms. Specifically – odour emissions from the sheds and free range area as well as potential nitrogen and phosphorus loss from the range areas in the soil and in runoff. There is currently a lack of information relating to free range meat chicken farms when it comes to odour emissions and nutrient loss. Improved understanding of the emissions from free range farms will support the continued growth of the free range sector in Australia.

Who is the report targeted at?

This report is targeted primarily at environmental regulators and environmental consultants to provide information and knowledge regarding the environmental impacts of free range chicken farming in terms of nutrients and odour from the range areas. Free range chicken meat producers will also benefit from the information in the report on management strategies to minimise nutrient accumulation and runoff.

Background

The free range chicken meat industry accounts for about 10 to 15% of total chicken meat production in Australia, but is a growing industry expanding at approximately 15% per annum. While substantial odour emission research has been conducted on conventional style broiler sheds, there is little information regarding free range farms. It is thought that as free range chickens are raised at lower stocking densities, compared to conventional meat chickens, this may serve to lower the odour emission rate from the sheds. In addition to lower stocking densities, free range raised meat chickens also have access to an outdoor 'range' area, which may add to the overall odour emission rate of the farm.

On free range farms, birds have access to the open outdoor range areas, which have the potential to accumulate nutrients (in the form of nitrogen and phosphorus). The nutrients deposited on the range area can potentially leach into the soil or be lost as runoff. It is important to quantify the amount of nutrient being accumulated in the range soil as this nutrient may limit the lifespan of the range area and increase the potential for nutrient loss in runoff. By characterising the runoff from the range area, accurate information will be available on the true impacts of free range chicken production.

Aims/objectives

The aims of this project can be divided into two separate goals. The first was to quantify the odour emission rates from free range meat chicken farms, being off the free range surface, as well as from the actual sheds and compare these values to conventional style broiler farms. The second goal of this project was to quantify nutrient (nitrogen and phosphorus) concentrations lost from the free range area, with respect to how much nutrient accumulates in the soil and how much nutrient is lost in the runoff from the range area.

Methods used

The methods used in this project can be split into three sections: odour emissions, nutrient runoff, and nutrient accumulation.

A case study of two Queensland free range farms was conducted to measure odour emissions from the sheds and associated free range areas. Odour measurements were taken during summer and winter at three milestones during the batch; before the birds were released from the shed, the day prior to the

first pickup and the day prior to the final pickup. Odour samples were collected from the sheds along with associated litter moisture contents to determine an odour emission rate from the sheds. The range area was measured by dividing the area into four zones; open sunlight, under trees, under shades and pop-hole exits, with an additional control grass sample taken for comparison against the range samples. All range samples were collected using flux chamber and assessed with dynamic olfactometry.

To assess nutrient concentrations in the runoff from a free range area, a case study of two Queensland farms was undertaken over a period of 16 months. Two runoff channelling and measurement devices (flumes) were installed on each farm; a control device to collect runoff from a similarly grassed area with no manure deposition, and a device to collect runoff from the ranging area of one meat chicken shed. Runoff was analysed for nitrogen and phosphorus concentrations.

The nutrient accumulation component was conducted on eight Queensland free range farms and three Victorian free range farms. Soil samples were taken on the free range areas at deep (30-90 cm) and shallow (0-30 cm) depths to determine nitrogen and phosphorus accumulation throughout the soil profile. A similar sampling strategy was applied in a control area at each farm that contained similar soil type and no manure deposition from the chickens or other livestock.

Results/key findings

Odour emissions from the two free range sheds in the case study were found to be comparable to odour emissions measured from conventional style broiler sheds. It was expected that the free range sheds would have a lower emission rate when compared to conventional style sheds, but this difference was not detected in the project. Unseasonably wet conditions during the sampling period resulted in elevated litter moisture content, which may have resulted in higher odour emission rates from the sheds. The range area was found to be almost undetectable when compared to the emissions from the sheds, contributing about 1% of the total odour emission rate.

Nutrient concentrations found in the runoff from the range areas were variable at the two farms in the study. Expectedly, the majority of the nutrients were captured during large storm events. One farm showed no statistical difference between range and control runoff concentrations, whereas the other farm showed a considerable difference between range and control concentrations. This is thought to have been caused by the larger than expected difference in soil types between range and control runoff catchment areas at that farm, resulting in the control area needing much more rain to trigger a runoff sample. Comparatively, it was seen that the overall nutrient load in the runoff from the range areas would be less than the load from a commercial golf course.

Nutrient concentrations in the range soils were, in general, found to be slightly higher than the control areas in nitrogen and ammonium concentrations, and slightly lower in phosphorus concentrations. Nutrient concentrations were observed to decline further down the soil profile. No evidence was found of a relationship between number of years of free range operation and amount of nutrient build-up in the subsurface soil, meaning the concentrations of nutrients deeper in the soil was not increased by the amount of time the farm had been operating free range.

Implications for relevant stakeholders

The information provided in this report will enable producers, consultants and regulators to improve their knowledge of odour emissions and nutrient concentrations on free range meat chicken farms. Producers will be able to use the findings in this report to more effectively manage the range areas with respect to nutrient cycling and odour management. This could help to reduce the potential for negative odour impacts and nutrient related issues associated with free range meat chicken farms.

Recommendations

While odour emission rates from the two free range sheds in this study were shown to be comparable to conventional poultry sheds, this should not be seen as an indication that all free range sheds will have the same odour emission rate as all conventional sheds. A broader range of sheds and sampling conditions needs to be explored before such conclusions can be made.

Even though odour emission rate from the range surfaces was shown to be very small in comparison to the overall emissions from the sheds, it is important for producers to manage the range areas to limit the amount of odour that may be generated. Specifically by managing the pop-hole exit areas which were observed to generate odour, particularly during wet conditions.

Introduction

Background

The free range chicken meat industry accounts for about 10 to 15% of total chicken meat production in Australia, but is a growing industry expanding at approximately 15% per annum (Australian Chicken Meat Federation Inc, 2012). At present there is little information available regarding the environmental impact of free range meat chicken farming. To support continued growth of the free range sector, improved information about odour emissions and nutrient accumulation and transport will be required.

Recent research (Dunlop *et al*., 2011) has generated substantial information regarding odour emissions from Australian conventional meat chicken farming, however, this information may not be representative of free range farms if used for planning purposes due to lower stocking density and deposition of manure in the sheds and range areas. There is potential that using data for conventional farms may disadvantage expansion of the free range industry.

There is little information in the public domain on the environmental impacts of free range poultry production, nor how to correctly manage the range areas to minimise nutrient losses and odour emissions. Numerous studies have investigated the environmental impact of the land application of poultry litter (Eldridge *et al*., 2009; Felton *et al*., 2007; Haynes and Judge, 2008; Smith *et al*., 2007), however little information is available on the environmental effects of the actual free range areas.

A recent desktop mass balance investigation on free-range egg production (Redding, 2002) indicated that without daily dropping removal the nutrient storage capacity would quickly be exceeded. This representation may not accurately reflect the realistic stocking densities and loading rates of free range meat chicken production. Nutrient accumulation may limit the life span of the range area and increase the potential for nutrient loss in leaching and runoff. By characterising runoff from the area, accurate information will be available on the true impacts of free range production.

There is one line of thought that nutrient accumulation may limit the life span of the range area and increase the potential for nutrient loss in leaching and runoff (Kratz *et al*., 2004a). By characterising runoff from the ranging area, accurate information will be available on the true impacts of free range production. Quantification of nutrient loss/accumulation may help to identify impact mitigation strategies, such as increased emphasis on planting a certain type of vegetation that heavily utilises a particular nutrient.

Free Range Chicken Meat Production

Australian free range chicken production is regulated by an independent body known as the Free Range Egg and Poultry Association (FREPA), which outlines housing and husbandry standards that are to be maintained (Free Range Egg and Poultry Australia, 2009). While there are some similarities between growing conventional meat chickens and free range meat chickens, there are also fundamental differences that need to be noted.

Similar to conventional meat chicken production, free range chickens are sourced from a hatchery and placed in a large shed as day old chicks. The birds are restricted to a portion of the shed, known as the brooding section, which is fitted with heaters to keep them warm as they are yet unable to regulate their own body temperature. The brooding period generally lasts 10-14 days, after which the birds are given access to the entire shed. At around 21 days the birds can more effectively regulate their own body temperature and it is at this point where the chickens are given access to a fixed outdoor ‘range’ area. The range area may be partly shaded using shade structures such as shade cloth, or trees. Birds are allowed access to the range area when weather conditions will not adversely affect bird

performance. Around day 35 a portion of the birds will be removed from the shed for processing (known as the first thin-out or pickup). Then between days 35 to 55 more chickens may be removed for processing until ultimately all the birds have been removed from the shed. Typical turn around times, i.e. the time between batches of chickens leaving and arriving at the farm, varies from about 5 days to 2 weeks.

The other important difference between conventional and free range broiler chickens is the decreased stocking density of birds in a free range shed. Depending on shed type, conventionally raised meat chickens are permitted to have between 28-40 kg/m² of chickens, whereas free range sheds can only contain between 16-32 kg/m² (Australian Chicken Meat Federation Inc, 2012). In terms of odour generation, it is thought that having a slightly lower stocking density in free range meat chicken sheds may lead to a decrease in odour generated from the shed.

Emissions from Free Range Meat Chicken Production

Odour emissions from meat chicken sheds is primarily released during microbial decomposition of accumulated faecal matter (Jiang and Sands, 2000) and from the birds themselves (Lacey *et al*., 2004). There are a number of dynamic aspects and complex interactions that contribute to the odour in a broiler shed including; litter composition, litter moisture, temperature, ventilation, dust, the birds (age, weight, activity, health, stocking density, and weather conditions (Dunlop *et al*., 2011). The multifaceted nature of odour generation in a broiler shed makes it difficult to identify the causes of increased odour generation.

In free range meat chicken production, odour may be emitted from a number of sources, specifically;

- the exhaust fans;
- the side openings for naturally ventilated sheds; and
- exclusive to free range production, manure accumulation on the range surface.

There is little information published about odour emissions from free range meat chicken farms. And as such, it is unknown if the range area will contribute to the whole farm odour emissions or not.

Nutrients and Manure

Optimal nutrition is required to grow crops (Havlin *et al*., 1999). There are a variety of fertiliser options available for use that are normally split into two groups: organic and inorganic fertilisers. Inorganic fertilisers are formulated with specific quantities of nutrients. Organic fertilisers, however, generally do not contain a balanced proportion of nutrients for optimal plant growth. Animal manures, and therefore poultry manure, are classed as organic fertilisers.

The feed consumed by poultry is rich in nutrients such as nitrogen and phosphorus, however, considerable amounts of the nutrients are not utilised by the birds and is excreted (Ferguson *et al*., 1998). As free range broilers have access to the outdoor range areas, naturally some of the manure and nutrients contained in it get deposited on the range. When excessive nutrient loadings are applied to land, there is the risk that the excess nutrients will become mobile in the environment (Sharpley and Rekolainen, 1997; Sims and Wolf, 1994). Specifically for nitrogen and phosphorus, nutrient mobilisation can have significant environmental implications.

Excess Nutrients in the Environment

As previously mentioned, nitrogen and phosphorus are essential nutrients for plant growth and both are abundant in poultry manure. However, if these nutrients are present in excess quantities, i.e. greater than natural uptake capacity, this can lead to negative environmental implications, specifically, eutrophication (see Figure 1).

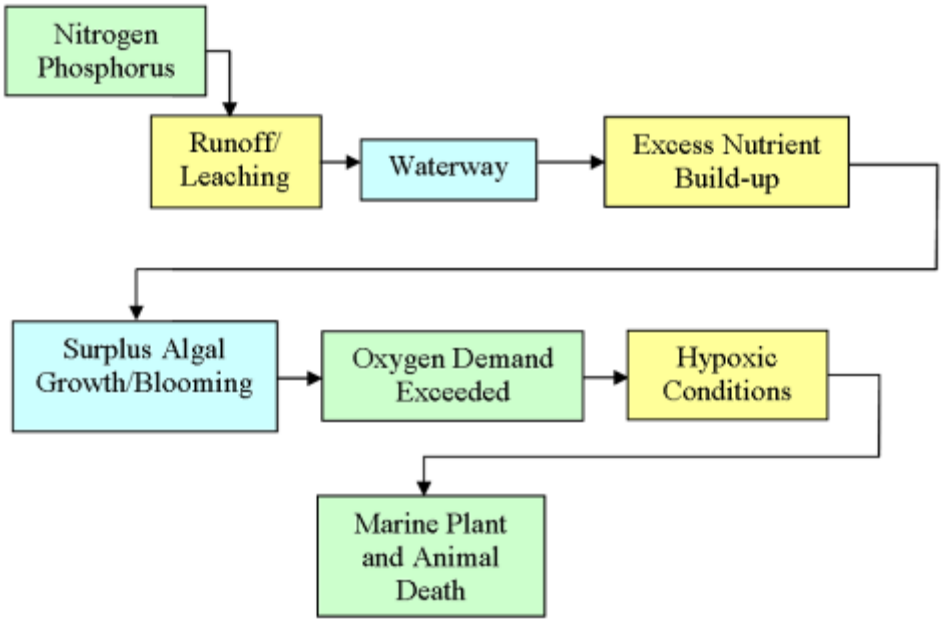


Figure 1: Nutrient interactions that lead to eutrophication (excess nutrient build-up). (Tyler Miller, 2000) (simplified).

Simply put, eutrophication occurs when excess nutrients, nitrogen and phosphorus, enter a system overloading the natural nutrient capacity. When this occurs, populations of algae are allowed to grow in larger than normal amounts as they are normally limited by the amount of available nutrients, causing an algal 'bloom'. This excess of algae can then lead to; odour problems from the affected waterway, increased turbidity (cloudiness of water), increases in unwanted fish populations and fish death due to decreased oxygen availability in the water (hypoxia) (Felton *et al.*, 2007).

Nitrogen

Nitrogen is a highly mobile and essential nutrient for plant growth. Nitrogen moves through the environment in a number of ways—denitrification; assimilation; fixation; volatilisation; and leaching (see Figure 2). The movement of nitrogen can impact on the environment in two main ways—as ammonia (NH_3) movement through the air causing odour or as nitrate (NO_3) movement through the soil or groundwater causing eutrophication (Nahm, 2003). While recent improvements in feed conversion have reduced the levels of nitrogen in poultry manure, it still has one of the higher nitrogen contents of domesticated animal species. Meaning not only is it a valuable nutrient source for plants, it can quickly exceed a system's natural usage capacity. Once this capacity is exceeded, eutrophication in water systems can occur.

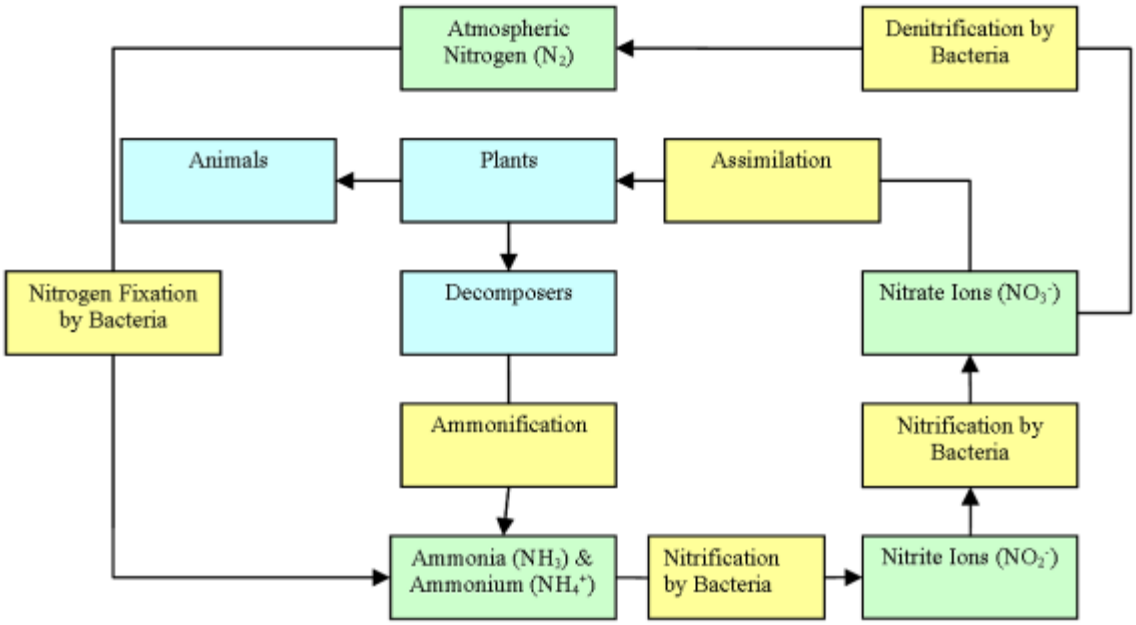


Figure 2: Nitrogen cycle in the environment. (Tyler Miller, 2000).

Phosphorus

Phosphorus is another essential plant nutrient. The main environmental effect of phosphorus is its role in the eutrophication of surface waters (Sharpley and Rekolainen, 1997). Phosphorus moves into the surface waters in three ways—erosion/weathering (i.e. sediment); runoff (i.e. soluble); or as subsurface flow in drainage and groundwater discharge (see Figure 3).

Soils have a limited holding capacity for phosphorus and once the limit is reached, phosphorus starts to become much more mobile in deep drainage and surface runoff (De Haan and Van Der Zee, 1994). Studies have shown that phosphorus runoff losses are generally highest shortly after deposition followed by a short, intense rainfall event, then significantly less after two to three events (Sharpley and Rekolainen, 1997; Smith *et al*., 2007). This indicates the greatest risk for potential phosphorus runoff from free-range chicken production may come from short, intense storm events that occur shortly after bird activity on the range.

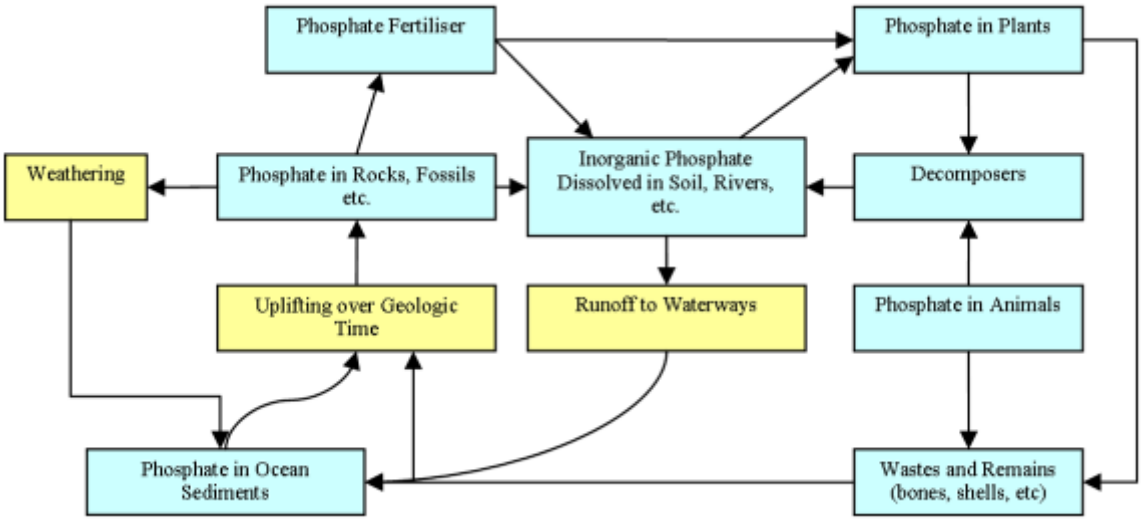


Figure 3: Phosphorus cycle in the environment. (Tyler Miller, 2000).

Objectives

The objectives of the project were to:

- Quantify range odour emission rate and determine whether range areas generate significantly more odour emissions compared to surrounding areas where chickens do not access;
- Quantify odour emission rates from tunnel ventilated free range sheds and compare with conventional tunnel ventilated sheds and previously reported odour emission rate data; and
- Quantify nutrient (Nitrogen and Phosphorus) accumulation in the soil within the range area and the potential for nutrient runoff.

Methodology

The project was split into three sections: odour, nutrient runoff, and nutrient accumulation. The odour component of the project entailed measurement of odour emissions from two Queensland farms during summer and winter. The nutrient runoff component entailed collection and analysis of runoff from two Queensland farms over 16 months. The nutrient accumulation component entailed collection and analysis of soil from the ranges of 8 Queensland farms and 3 Victorian farms.

Farm Selection

Farms were selected for each research component based on the following criteria:

Odour

- Operating under free range guidelines as detailed by Free Range Egg and Poultry Australia (FREPA) (Free Range Egg and Poultry Australia, 2009);
- Operating as a free range farm for at least 5 years;
- Housing fitted with tunnel ventilation capability.

Nutrient Runoff

- Operating under free range guidelines as detailed by FREPA (Free Range Egg and Poultry Australia, 2009);
- Operating as a free range farm for at least 5 years;
- Sufficient range drainage to assess representative nutrient loading in runoff.

Nutrient Accumulation

- Operating under free range guidelines as detailed by FREPA (Free Range Egg and Poultry Australia, 2009);
- Operating as a free range farm for at least 5 years;
- Range areas with minimal additional nutrient loading (such as litter spreading or fertiliser application);
- Presence of a control area with minimal additional nutrient loading.

Farm Descriptions

Table 1 Farms used in odour assessment trials.

Farm	Location	Ventilation Type	Shed Age	Shed Walls	Tunnel Fans	Litter/ Management
A	QLD	Tunnel	1999	Curtain sided	8x American Coolair MNBFA54L	Wood shavings/ partial reuse
B	QLD	Tunnel/ Natural	1983	Curtain sided	7x Titan WM1200/1.1kw/6B* (*only used during summer)	Wood shavings/ partial reuse

Table 2: Farms used in nutrient runoff assessment trials.

Farm	Location	Shed Age	Years Operating Free Range	Size of Range Area (m^2)	Average Annual Rainfall (mm)
A	QLD	1999	6 Years	1200	929*
C	QLD	1980	7 Years	1800	1271.2**

* (http://www.bom.gov.au/climate/averages/tables/cw_040854.shtml)

** (http://www.bom.gov.au/climate/averages/tables/cw_040265.shtml)

Table 3: Farms used in nutrient accumulation trials.

Farm	Location	Years Operating Free Range	Size	Ventilation Type	Dominant Soil on Range Area
A	QLD	6 Years	4 Sheds	Tunnel	Silty clay
B	QLD	5 Years	5 Sheds	Tunnel/Natural	Sandy clay / Fill
C	QLD	7 Years	3 Sheds	Natural	Sand / Fill
D	QLD	8 Years	4 Sheds	Natural	Clay loam
E	QLD	6 Years	4 Sheds	Tunnel/Natural	Silty clay loam
F	QLD	9 Years	4 Sheds	Tunnel	Sandy clay
G	QLD	5 Years	3 Sheds	Natural	Sandy clay / Sand
H	QLD	9 Years	3 Sheds	Natural	Sandy clay
I	VIC	5 Years	3 Sheds	Natural	Silty clay / clay
J	VIC	6 Years	2 Sheds	Tunnel	Silty clay
K	VIC	5 Years	2 Sheds	Natural	Sandy clay

Odour

Sampling Program

A sampling program was designed to measure emissions from the sheds and range areas. Odour samples were collected from two farms—Farm A and Farm B. A summer and winter batch was monitored at each farm to assess seasonal variability. Samples were collected over one day at three milestones during each batch:

- Before birds were released from the shed, typically day 15-20;
- Day prior to first pickup, typically day 30-35; and
- Day prior to final pickup, typically day 42-46.

On the sample collection day before the birds were released onto the range, six odour samples were collected:

- Two control stainless steel samples;
- Two control grassed area samples; and
- Two range samples (open sunny area and area underneath a shade sail).

On the sample collection days before the first and final pickups, 10 odour samples were collected:

- Two control stainless steel samples;
- Two control grassed area samples;
- Four range samples (open sunny area, area underneath a shade sail, area directly in front of a shed pop hole, area under a tree used by the birds); and
- Two shed emission samples collected from the fans.

Additional information about sample collection locations is detailed in subsequent sections of the report.

Odour Sample Collection

Air samples were drawn into Melinex® bags (polyethylene terephthalate) using a vacuum pump. All components of the sampling train that were in contact with the poultry odour were manufactured from stainless steel or polytetrafluoroethylene (PTFE). The maximum volume of sample collected was 120 L.

An empty sample bag was placed into a rigid sample drum customised for odour sampling work. All bags were preconditioned by filling with odorous air then emptied prior to the sample being collected.

Where odour samples were drawn from within a flux chamber, the samples were sourced by drawing air from within the chamber through PTFE tubing. One end of the PTFE tube was connected to the stainless steel probe on the flux chamber and the other end attached to the sampling drum fitted with a Melinex® bag.

Where odour samples were collected from the downwind side of one of the tunnel ventilation fans, PTFE tubing was used to collect the samples. One end of the tubing was connected to the sampling

drum and the other end was carefully positioned within the fan housing and guard to prevent crosswind interference (see Figure 4).

Samples taken directly from the fans were collected over approximately six minutes, while samples taken from within the flux chamber were collected over approximately 40 minutes. Once filled, the drums were sealed and transported to the olfactometry laboratory for analysis. All samples were analysed within 9 hours of collection. Each bag was used once and discarded after analysis.

Figure 4: Odour sample collection from the tunnel ventilation fans.

Flux Chamber Odour Sample Collection

The flux chamber sample collection method was used for all range odour samples. To speed up the sample collection process, two chambers were used. In accordance with Australian Standard 4323.4:2009 (Standards Australia, 2009), a control blank sample was collected from each chamber at the beginning of each collection day. Air was collected from within each chamber while in place on a clean sheet of stainless steel (see Figure 5).

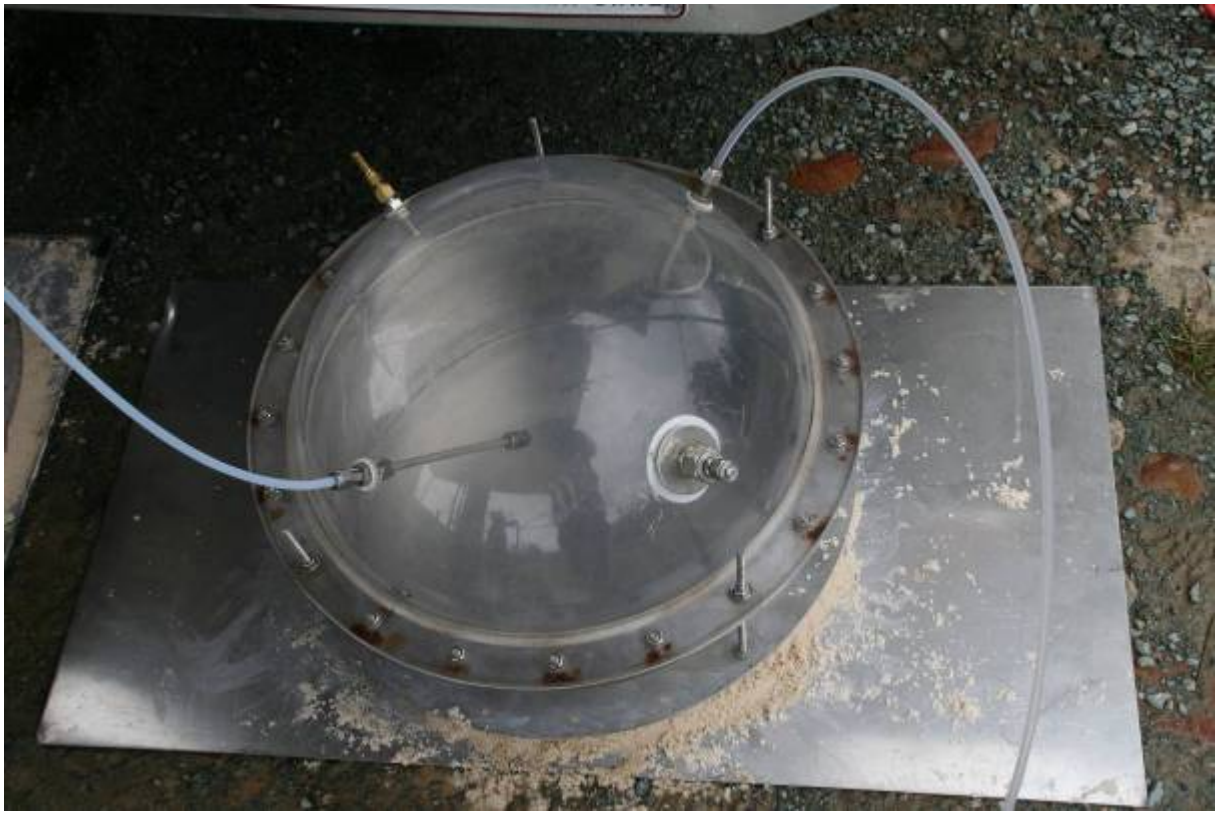


Figure 5: Control blank flux chamber sample collection.

Where possible, the flux chambers were shaded from direct sunlight. Shading ensures that chemical processes are not accelerated by concentrated sunlight or increased temperatures inside the chamber.

A suitable location was identified for sample collection, and the flux chamber was placed over the area of interest. Where necessary, clean sand was used to seal the chamber against the surface. Cylinders of 'zero grade' air provided the flushing air to the flux chamber. The flushing air flow rate was set at 5 Lpm with the aid of a TSI Series 4143 flow meter (TSI Incorporated, Tennessee) and monitored visually using an Influx Uniflux 0-13 Lpm rotameter (Influx Measurements Ltd, Hampshire).

SKC model PCXR8 Universal Pumps (SKC Inc, Pennsylvania) set at 2.3 Lpm were used to collect the odour samples. Tygon® tubing was attached to the SKC pump and sample drum in order to draw the air from between the inner surface of the drum and outer surface of the sampling bag, thereby drawing odorous air into the bag.

The chamber was allowed to stabilise for 25 minutes before sample collection commenced. During this time, the bag was preconditioned. The bags were then filled over a 40 minute time frame.

Flow rates were adjusted for standard temperature and pressure (0 °C, 101.3 kpa) as described in Australian/New Zealand Standard 4323.3: 2001 Stationary source emissions Part 3: Determination of odour concentration by dynamic olfactometry (Standards Australia, 2001) using the following Equation 1.

$$Q_{R,0} = Q_s \times \frac{(273+0)}{(273+t)} \times \frac{P_s}{101.3}$$ **Equation 1**

Where:

$Q_{R,0}$ = Volume flow rate at standard conditions

P_s = Absolute pressure, in kPa

t = Temperature, in °C

Flux chamber odour emission rate was calculated using the following Equation 2.

$$F_i = C_i Q / A_c$$ **Equation 2**

Where:

F_i = Zone atmospheric contaminant flux emission rate (ou.m³/m².s) (at 0°C and 101.3 kPa)

C_i = Zone chamber atmospheric contaminant concentration (ou)

Q = Chamber flow rate (m³/s (at 0°C and 101.3 kPa)

A_c = Area enclosed by chamber (m²)

Equation 3 was used to estimate odour emission rate from the entire range area:

$$E = \sum F_i A_i$$ **Equation 3**

Where:

E = Area source emission rate (ou.m³/s)

F_i = Zone flux emission rate (i = 1, 2, …, n)

A_i = Zone area (m²)

Odour Sample Collection Points on the Range

The range area was broken up into the following sections for individual odour emission assessment and to characterise odour emissions from the range area as a whole:

- Open sunny areas (Figure 6);
- Areas underneath shade sails (Figure 7);
- Areas under shade trees (Figure 8); and
- Areas immediately adjacent to the shed pop holes (Figure 9).

As dynamic olfactometry is an analysis method that determines an odour concentration irrespective of offensiveness, it was necessary to collect odour samples from an appropriately grassed area where chickens could not access (Figure 10). This odour concentration could then be used to assess whether the range areas were producing any significant odour emissions compared to other grassed areas without any manure added.

Figure 6: Odour collection in sunny area

Figure 7: Odour collection under shade sail

Figure 8: Odour collection under tree

Figure 9: Odour collection at pop hole

Figure 10: Odour collection at control grassed area

On the sample collection day before the birds were released onto the range, six odour samples were collected:

- Two control samples;
- Two control grassed area samples; and
- Two range samples (open sunny area and area shaded by shade sail).

On the sample collection days before the first and final pickups, ten odour samples were collected:

- Two control samples;
- Two control grassed area samples;
- Four range samples (open sunny area, area underneath a shade sail, area under tree, and area adjacent to pop hole); and
- Two shed emission samples.

The daily schedule for collection of samples remained constant throughout the project, as outlined in Table 4.

Table 4: Odour sample collection order

Order of Collection	Sample Description		
1	Stainless steel control	Stainless steel control	
2	Control grassed area	Range sunny area	Shed emission
3	Control grassed area	Range shade sail area	
4	Range shade tree area	Range pop hole area	Shed emission

Odour Concentration Analysis

Odour concentration was determined using the eight panellist, triangular, forced choice dynamic olfactometer developed by Department of Agriculture, Fisheries and Forestry (DAFF) which has been described previously (Nicholas *et al*., 1999; Zeller *et al*., 2002). This olfactometer was constructed to comply with the Australian/New Zealand Standard for Dynamic Olfactometry AS/NZS 4323.3:2001 (Standards Australia/Standards New Zealand, 2001). The conduct of the odour assessment also complied with this Standard.

During a typical odour sample assessment routine, each panellist was first screened with the reference gas (n-butanol) to ensure that his or her detection threshold was within the required concentration range of 20–80 ppb (v/v). Thereafter, the odorous sample was diluted and presented to the panellists in one of three ports, while the other two ports emitted clean, odour-free air. The panellists were required to sniff from the ports and determine whether they could detect a difference between the three ports. Each panellist was allowed a maximum of 15 s for this assessment. The panellists indicated via a keypad whether they were certain, uncertain or guessing that one of the ports was odorous, as well as from which port the odour (if detectable) was emitted.

This process was repeated, doubling the concentration of odorous air of the previous presentation each time, until each panellist had entered a "certain and correct" response for two consecutive presentations. Each panellist's individual threshold estimate ($\overline{Z}_{ITE}$) was then determined by calculating the geometric mean of the dilution at which the panellist did not respond with certainty

and correctly and the first of the two dilutions where the panellist did respond with certainty and correctly. A complete dilution series is defined as a round. Three rounds were completed for each sample provided sufficient sample was available.

At the end of the three rounds, the results of the first round were discarded in accordance with AS/NZS 4323.3. The results from rounds two and three were then geometrically averaged ($\overline{Z}_{ITE}$). The ratio between Z_{ITE} and $\overline{Z}_{ITE}$ is defined as ΔZ . The calculation of ΔZ is presented in the following equations:

$$if\ Z_{ITE} \geq \overline{Z}_{ITE}, then\ \Delta Z = \frac{Z_{ITE}}{\overline{Z}_{ITE}} \qquad \textbf{Equation 4}$$

$$if\ Z_{ITE} \leq \overline{Z}_{ITE}, then\ \Delta Z = \frac{\overline{Z}_{ITE}}{Z_{ITE}} \qquad \textbf{Equation 5}$$

If ΔZ is greater than ± 5 then all $\overline{Z}_{ITE}$ values of the panel member with the largest ΔZ were excluded from the data set. The screening procedure was then repeated, after re-calculation of $\overline{Z}_{ITE}$ for that measurement. If a panel member again did not comply, the results for this panel member (with the largest ΔZ) were omitted. This was repeated until all panel members in the dataset had an acceptable ΔZ value. The last value of $\overline{Z}_{ITE}$ was then defined as the odour concentration and expressed as odour units per cubic metre (ou/m³).

Ventilation Rate

Ventilation rate was measured or estimated during collection of each odour sample.

Shed ventilation rate can be estimated using farm performance data (Dunlop and Duperouzel, 2008; Wilhelm *et al.*, 2001). Flow rate for each active fan was estimated using performance data provided by the fan manufacturer or from an independent testing laboratory (for example the BESS Laboratory at the University of Illinois http://www.bess.uiuc.edu/). Ventilation rate was calculated by multiplying the number of active fans by the estimated flow rate through each fan.

Calculating ventilation rate with this method assumes that the fan performance data is accurate and that the fans are clean and in good condition. It is essential that the fan performance data exactly matches the fans installed at the farm. It is therefore necessary to record details including: fan manufacturer; model number; number of blades; blade pitch (if adjustable); motor size and manufacturer; and pulley size.

Fan performance data was sourced from fan manufacturers or suppliers. Figure 11 displays the fan performance data for the fans installed on Farms A and B. The fan performance curve equations (see Table 5) were calculated using Microsoft® Excel 2003 by fitting a polynomial trend line to the flow rate data at difference static pressure values.

For this method to be successful, it is essential to measure the shed static pressure at the time of ventilation measurement. Temperature and barometric pressure should also be recorded to enable the air flow to be adjusted to match the conditions under which the fans were evaluated and then, for the purposes of calculating emission rates, adjusted to match standard temperature and pressure conditions.

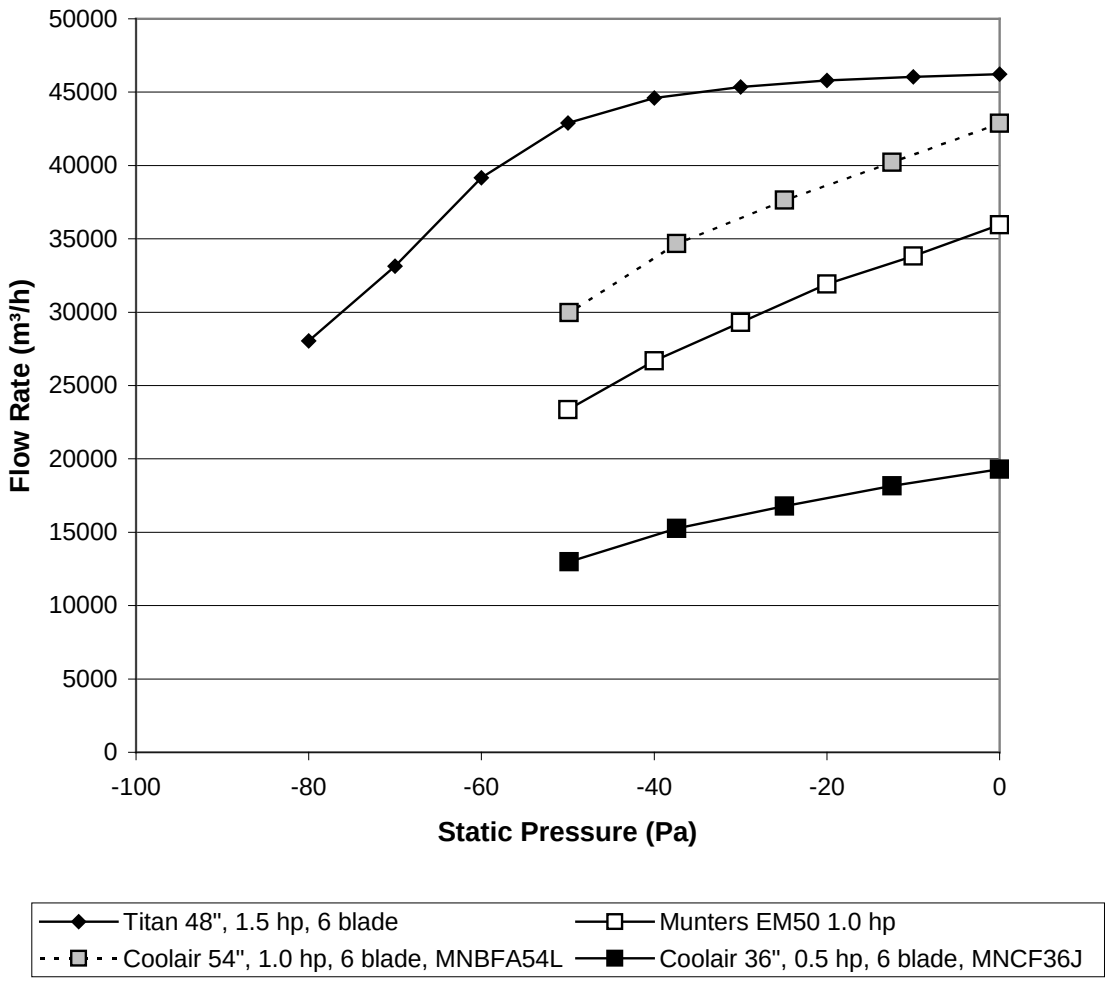


Figure 11: Fan performance curves as supplied by manufacturer

Table 5: Fan performance equations

Fan	Fan Performance Equation
Titan 48" (1219.2 mm) 1.1 kw (1.5hp), 6 blade (Titan Fan Products Australia Pty Ltd, 2006)	For pressure between 0 and (equal to) -20 Pa: $Q = -0.295p^2 + 15.65p + 46231$ For pressure between -20 and (equal to) -40 Pa: $Q = 0.1018p^3 + 7.535p^2 + 226.97p + 48410$ For pressure less than -40 Pa: $Q = -11.45p^2 - 885.5p + 27250$
American Coolair MNBFA54L (1372 mm), 1.0 hp, 6 blade (American Coolair Corporation, 2010)	$Q = -2.0474p^2 + 149.29p + 42700$
Munters EM50 (1270 mm) 1.0 hp (University of Illinois Department of Agricultural Engineering BESS Lab, 2002)	$Q = 0.0234p^3 + 0.173p^2 + 201.77p + 35937$
American Coolair MNCF36J (914 mm), 0.5 hp, 6 blade (American Coolair Corporation, 2001)	$Q = -1.116p^2 + 69.447p + 19263$

Where Q = ventilation rate, in m^3/hour, and
p = internal shed differential pressure, in Pascals (Pa).

The relevance and accuracy of the ventilation rates generated using fan curve information was checked using manual measurement of ventilation rate on-farm. Airspeed was measured inside the broiler shed at a cross section under the final baffle before the tunnel ventilation fans. Where baffles were not in place, measurements were taken between final minivent and the tunnel ventilation fans. Using AS 4323.1 (Standards Australia, 1995), a grid pattern with 32 measurement points was formulated (Figure 12). Airspeed was measured inside the shed using a hot wire anemometer (TSI Incorporated VelociCalc® Model 8386–M–GB). Each point was measured over ten seconds, with the average value recorded. An average of the 32 measurement points was used to calculate the average airspeed (m/s). Ventilation rate (Q) was calculated by multiplying the average airspeed by the shed cross-sectional area (see Equation 6).

$Q\ (m^3/s)$ = average airspeed (m/s) × internal shed cross sectional area (m^2) **Equation 6**

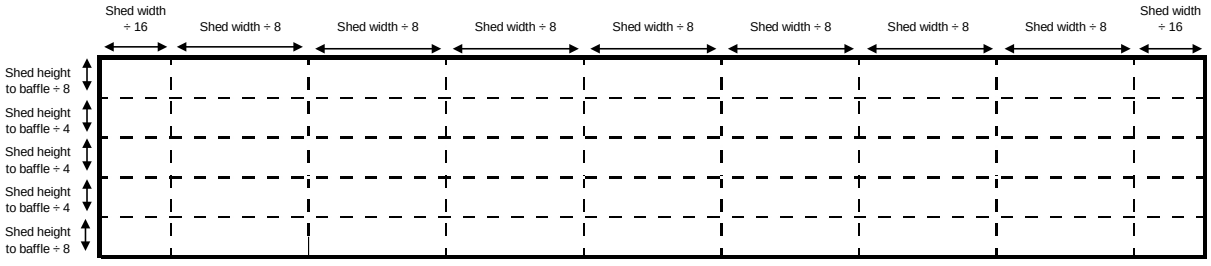


Figure 12: Internal shed airspeed measurement grid pattern

Natural Ventilation Rate

Farm B operated using natural ventilation for the batch sampled during winter, and as such the natural ventilation rate needed to be calculated to determine the correct odour emission rate. Natural ventilation refers to air entering into the shed from non-mechanical or 'natural' means i.e. wind. This is essentially accomplished through dropping down the side walls on a shed and allowing the prevailing outside winds to pass into the shed and regulate bird temperatures. This method of ventilation is common in times where temperatures are not excessively high and the outside air is sufficient enough to maintain optimal growing temperatures.

As there is a less 'controlled' environment in the sheds during natural ventilation, accurately measuring and calculating ventilation rates can be quite difficult. There are two main ways of estimating ventilation rate in a naturally ventilated shed, indirectly or directly (Li *et al*., 2004). Indirect methods generally employ the release of a tracer gas, commonly, CO_2, CO, He or SF_6 and monitoring the decay rate of the gas downwind from the source (Blanes and Pedersen, 2005; van Ouwerkerk and Pedersen, 1994). This requires calculation of the metabolic rates of the birds in the shed as well as uniform mixing of the tracer gas with the in shed air and, in addition, it is quite an instrument intensive process that can require a considerable amount of time to achieve a good result (Xin *et al*., 2009). The direct method involves measuring the actual airflow velocity and direction into the shed and multiplying this value by the cross-sectional area of the opening of the shed. While this method has been shown to have a 20-25% error (Wheeler *et al*., 2002) it is quicker and easier than indirect methods and was the most suitable for the purpose of this project.

At Farm B, natural ventilation was measured directly with a sonic anemometer (*Gill® Windsonic 1405-PK-040 Option 3*). The anemometer was placed half way down the shed on the eastern side wall, where wind velocity and direction were measured and recorded using a data-logger (*dataTaker DT500 v7*) at 10 second intervals during the sampling period. Data was then compiled to form a wind-rose (using GenStat 11.1 *VSN International Ltd*.) of the velocity and direction of the wind during the sampling period.

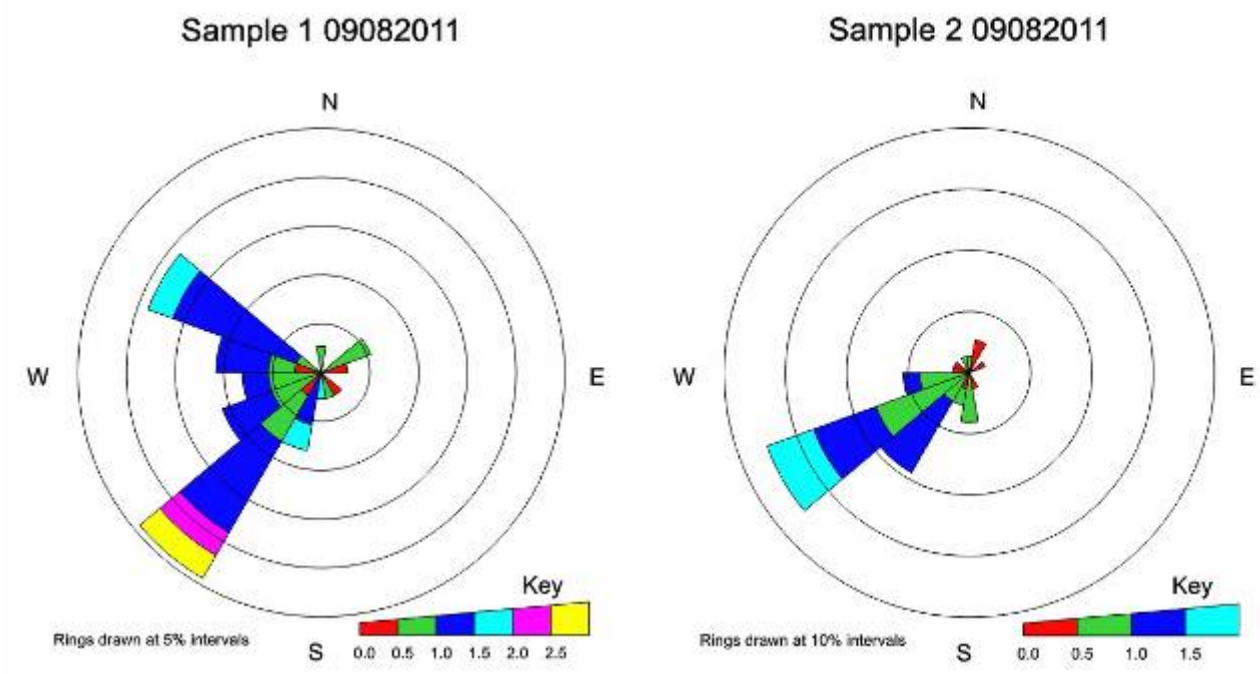


Figure 13: Wind direction and velocity over the 40 minute sampling periods on day one, taken during natural ventilation conditions.

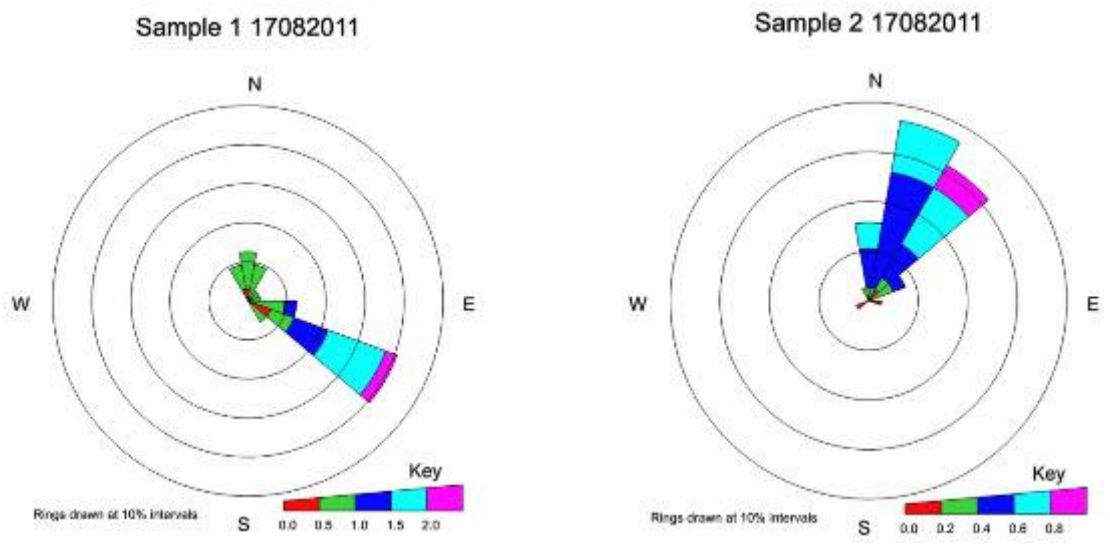


Figure 14: Wind direction and velocity over the 40 minute sampling periods on day two during natural ventilation conditions.

Calculating the actual ventilation rate from a naturally ventilated shed can also be achieved in two ways. As both methods are conceptually valid, yet produce different results, this report will present both options for calculating ventilation rate (as Option A and Option B) and two separate odour emission rates based on the different ventilation calculations will be reported in the results section.

Option A

Option A is the first method of calculating natural ventilation rates used in this report. This method calculates ventilation rate by considering the magnitude of the two velocity components that make up the air speed. This method considers the velocity of both the components of air entering the shed.

$$Ventilation\ Rate\ (Q)\ (m^3/s) = V \times A$$ **Equation 7**

Where V = velocity of air entering the shed (m/s)

A = area of the opening (m^2)

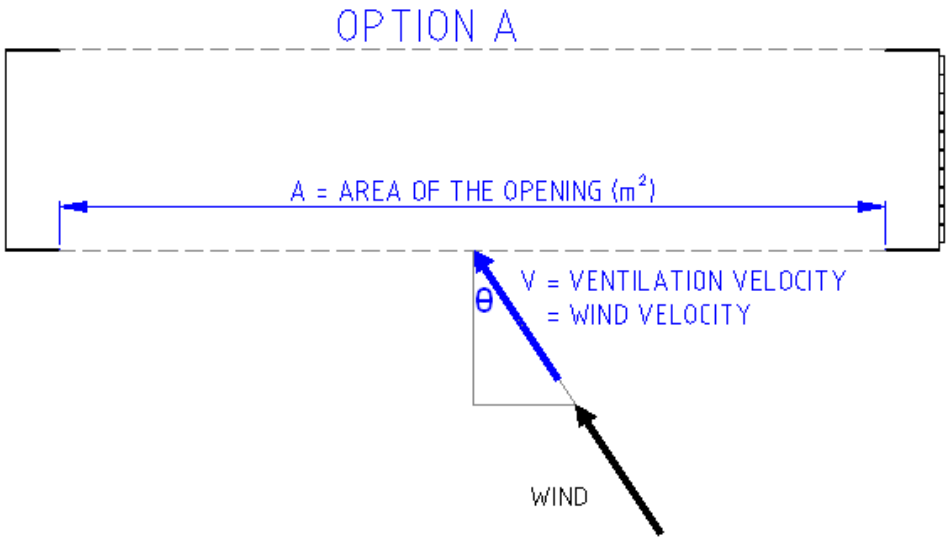


Figure 15: How 'Option A' for natural ventilation rate is calculated

Option B

The other method for calculating ventilation rate involves calculating ventilation rate by using the wind velocity through the shed at the time of sampling. This method considers the velocity of the direct air moving through the shed.

$$Ventilation\ Rate\ (Q)\ (m^3/s) = VCos\vartheta \times A$$ **Equation 8**

Where $VCos\vartheta$ = resultant wind velocity entering the shed (m/s)

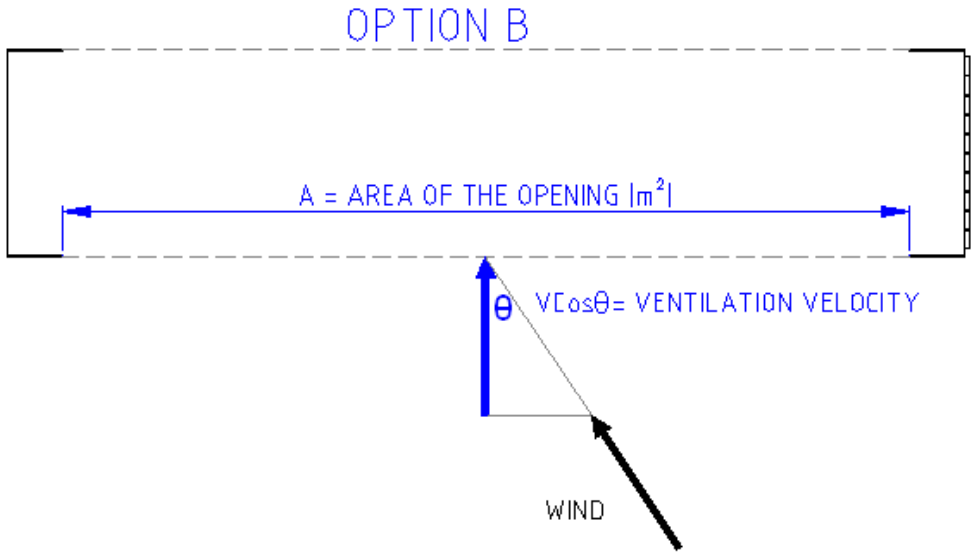


Figure 16: How 'Option B' for natural ventilation rate is calculated

Litter Moisture

Litter moisture content was monitored by collecting litter samples on the days when shed odour samples were taken, i.e. before the first and final pickups. In each shed, a grid system similar to that of Miles (2006) was used so that litter samples would be collected at equal intervals across the entire floor area. For sheds approximately 100 m in length, six transects were used; and for sheds approximately 150 m in length, nine transects were used. For each transect, five samples were collected across the width of the shed at:

- Sample A – between drinker line and wall;
- Sample B – between first feeder line and second drinker line;
- Sample C – shed centre;
- Sample D – between fourth drinker line and fourth feeder line; and
- Sample E – between fifth drinker line and wall.

Figure 17 depicts the location of litter collection points.

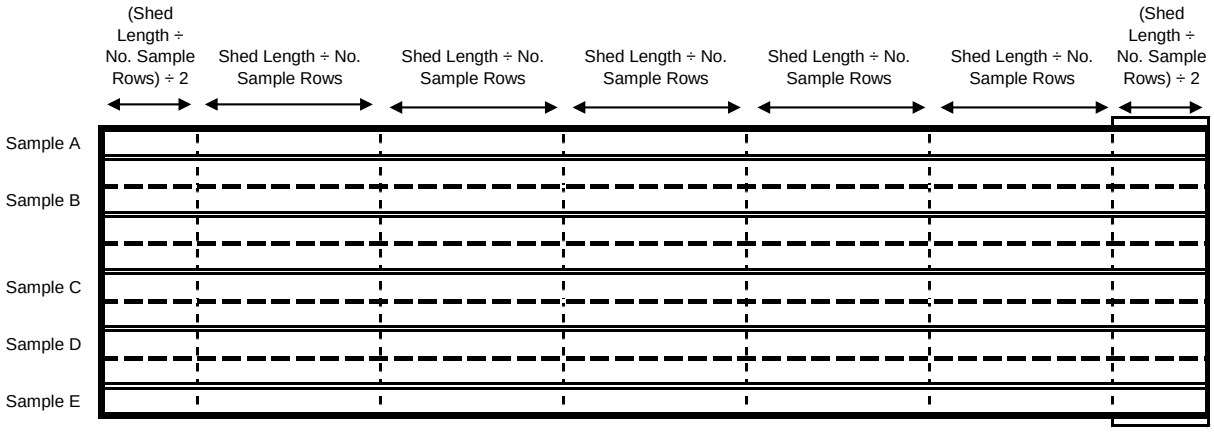


Figure 17: Litter sample collection grid pattern

Note: Double line represents a drinker line and dotted line represents a feeder line.

Samples were collected to full depth using a steel scoop, and stored in individually marked Nasco WhirlPak® bags (710 mL, 0.076 mm thickness). Samples were stored in the laboratory and analysed within 7 days in accordance with AS 4454-2003 (Standards Australia, 2003).

Litter moisture content was determined using Australian Standard 4454–2003 Composts, soil conditioners and mulches: Appendix H, Method for determination of moisture content and level of visible contamination (Standards Australia, 2003).

A proportion of each sample (approximately 50 g) was placed in an individually identifiable 100 mL ceramic evaporating dish. Each dish was dried at 105 °C and weighed before the addition of litter. The litter was immediately weighed to ascertain a wet sample weight. All samples were dried in an oven at 105 °C overnight. After cooling in a desiccator cabinet, the dry litter samples were weighed. To calculate wet basis moisture content, Equation 9 was used.

$$\%Moisture\ content = \frac{m_2 - m_3}{m_2 - m_1} \times 100\% \qquad \textbf{Equation 9}$$

Where m_1 = mass of the dish (g)

m_2 = combined mass of the dish and wet litter (g)

m_3 = combined mass of the dish and dried litter (g)

All samples collected were analysed individually in order to assess intra-shed variability of moisture content.

Contour plots were drawn using Surfer® version 7 (Golden Software Inc, 1999) to visually assess moisture content differences.

Ambient Temperature and Humidity

Ambient temperature, humidity and barometric pressure were measured using a Kestrel® Pocket Weather Tracker (Nielsen–Kellerman model 4500, see Figure 18). The Kestrel was suspended from DAFF's sample collection trailer out of direct sunlight and influence from air exiting the poultry shed. Readings were recorded every minute.

Figure 18: Kestrel® Pocket Weather Tracker

Production Parameters

Production information was provided by the farm manager and integrator. Number of birds placed, number of birds present on each sample collection day, and average daily live weight were supplied, and average live weight density was calculated accordingly. These parameters were assessed for their influence on air quality.

Bird Weight

Details of bird weight were supplied by the producers using the weekly average weight and the integrator at collection for slaughter.

Bird Numbers

The number of birds placed and number of birds removed at each pickup were supplied by the integrator. All other data regarding the number of birds present was provided by the producer. The number of birds present on each day of the batch was estimated using the number of birds placed; number of birds collected at each pickup; and estimated or measured mortality rate.

Liveweight Density

Liveweight density (LWD) was calculated by using Equation 10.

LWD (kg/m^2) = (No. birds in shed × av. bird live weight (kg)) ÷ shed floor area (m^2) **Equation 10**

Nutrient Runoff

Nutrient concentration in the runoff water from two Queensland free range farms was monitored by collecting and analysing runoff samples. Two runoff channelling and measurement devices (flumes) were installed on each farm; a control device to collect runoff from a similarly grassed area with no manure deposition, and a device to collect runoff from the range area of one meat chicken shed. Neither farm had gutters or downpipes installed on the shed roofs, so rain was able to freely flow uniformly off the shed roof onto the free range area.

Table 6: Size of runoff areas for the range and control areas.

Farm	Size of Range Area (m^2)	Size of Roof Area (m^2)	Total Size of Catchment for Range (m^2)	Total Size of Catchment for Control (m^2)
A	1800	1680	3480	1200
C	1800	1670	3470	2300

Runoff Sample Collection

Standardised flumes developed by the U.S. Department of Agriculture and described by ISCO® (2008) as 'H' style flumes, were used to channel and measure runoff. This style of runoff measurement is capable of monitoring flow over a wide range of applications with reasonably good accuracy at both large and small flows, and have been used in the past for measurement of runoff from feedlots (ISCO®, 2008). Runoff volumes were estimated by calculating catchment areas for each range area and multiplying by the estimated one hour rainfall intensity event at the one year recurrence interval (http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml).

The calculated potential runoff for the range areas at both farms and the control area at the Farm A indicated that a 0.457 m H flume was required to minimise potential for over-filling of the flume. This size flume had the ability to measure flows 0.025 – 151.6 L/s. The potential runoff for the control area at Farm B indicated that a 0.305 m H flume was required. This size flume had the ability to measure flows 0.0157 – 53.2 L/s.

The flumes were constructed of 2 mm galvanised sheeting, and were installed level by either cutting the earth away or constructing 3 mm galvanised steel tubing framework onto which the flumes rested. A stilling well installed in the side of the flumes was constructed of 40mm PVC (polyvinyl chloride) pipe and included a sediment trap in the base with a screw-cap for easy cleaning.

Flow was monitored by Tyco Environmental Systems (Greenspan Analytical) PS7000 pressure sensors suspended inside the stilling well of each flume. A dataTaker® DT500 triggered a Global Water Inc. WS700 (Gold River, California) sampler to collect runoff samples. The volume of sample collected varied depending on the magnitude of the runoff event. The sampling interval is detailed in Table 7.

Table 7: Runoff sample collection interval

Flume Size	Trigger Height Range (mm)	Sampling Frequency
0.457 m	5-55	5 minutes
	56-75	3 minutes
	76-90	90 seconds
	91-457	Constant
0.305 m	5-35	5 minutes
	36-5	3 minutes
	51-60	90 seconds
	61-305	Constant

NB. Sample was not collected when stilling well water height was below 5 mm due to inherent inaccuracy in water flow measurement during very low flow runoff events.

The length of time the pump collected a sample was calculated using either Equation 12 for the 0.457 m flume, or Equation 12 for the 0.305 m flume (derived from ISCO® Handbook (2008)).

$$t = 652.31 \times \left(\frac{H}{1000}\right)^3 + 427.53 \times \left(\frac{H}{1000}\right)^2 + 3.9796 \times \left(\frac{H}{1000}\right) \quad \textbf{Equation 11}$$

$$t = 794.3 \times \left(\frac{H}{1000}\right)^3 + 350.18 \times \left(\frac{H}{1000}\right)^2 + 2.1016 \times \left(\frac{H}{1000}\right) \quad \textbf{Equation 12}$$

Where t = pump run time, and

H = water height in flume/stilling well

The pump time intervals and pump run times were calculated in an attempt to collect time-weighted samples. This means that less water is collected during smaller runoff events, and large volumes are collected during larger runoff events.

Diversion sheeting was used to ensure that all runoff from the target area was directed through the flume. Runoff samples were collected approximately 0.5 m in front of the flume from within a galvanised steel channel. Collection at this point eliminated obstruction of water flow through the flume that would cause incorrect water volume measurements. The collected sample was held in a 60 L reservoir. Sample overflow from the collection reservoir was prevented by fitment of a sensor in the lid which stopped the sampling process once full. A visual representation of the runoff sampling equipment is shown in Figure 19.

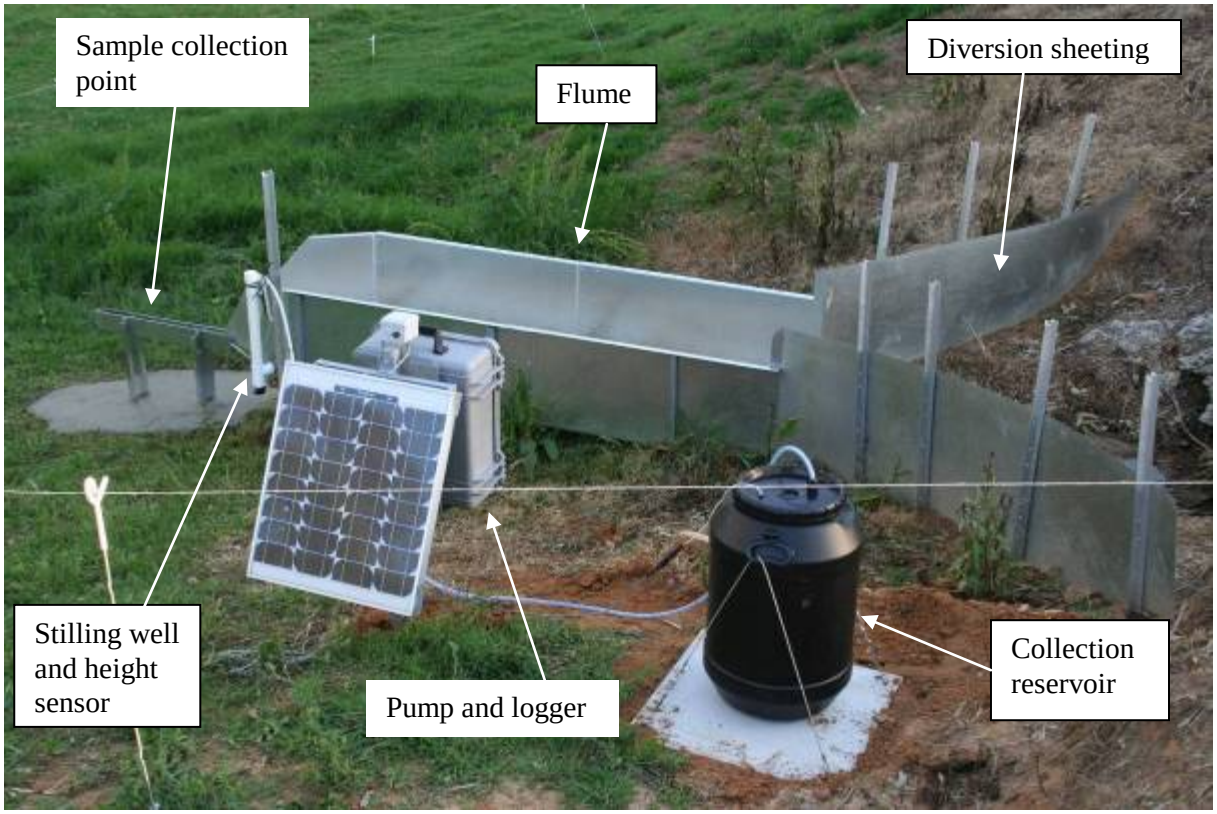


Figure 19: Runoff measurement and sampling equipment

The sampling equipment was remotely monitored using telemetry. Runoff samples were collected promptly and stored in food grade high density polyethylene (HDPE) bottles. The samples were transported either directly to the laboratory, or frozen and transported at a later date.

Ambient Weather Monitoring

A 2 m automatic weather station (AWS) was positioned on each farm to record ambient weather conditions, including;

- Temperature;
- Relative humidity;
- Wind speed;
- Wind direction;
- Rainfall;
- Barometric pressure; and
- Sunlight intensity.

Variables were recorded at 15 minute and daily intervals.

Table 8: Sensors used on the AWS

Sensor/Parameter	Brand	Model Number	Sensitivity	Range
Data Collection	dataTaker	DT500 (version7)	0.11% for Voltage 0.21% for Current	0-2500 mV 0.25-25 mA
Temperature	Vaisala	50Y Humitter	±0.6 °C at 20 °C	-10 to +60 °C
Humidity	Vaisala	50Y Humitter	±3% at 90% RH	10–90%
Wind Speed	Gill Windsonic	1405-PK-040 Option 3	±4% at 20 m/s	0 to 60 m/s
Wind Direction	Gill Windsonic	1405-PK-040 Option 3	+- 3° at 20 m/s	0 to 359°
Total Radiation	Li-Cor	LI200SZ	0.2 kW/m^2/mV	
Barometric Pressure	Vaisala	PTB101B	±0.5 hPa at 20 °C ±2 hPa at 0–40 °C	600 to 1060 hPa
Rainfall	Hydrological Services	TB3	one tip/0.2 mm rain	0 to 700 mm/hr

Analysis of Runoff

Runoff samples were analysed by Queensland Urban Utilities' (Brisbane City Council) SAS Laboratory. The runoff samples for analysed for concentrations (mg/L) of the following compounds;

- total nitrogen as N;
- total phosphorus as P;
- ammonia;
- nitrate;
- nitrite; and
- soluble reactive phosphorus (SRP) as orthophosphorus.

Soil Nutrient Accumulation

Nutrient accumulation in the soil profile on the range areas was monitored on eight Queensland free range farms and three Victorian free range farms. Soil samples were taken on the free range areas at deep, 30–90 cm, and shallow, 0–30 cm, depths to determine nutrient (nitrogen and phosphorus) accumulation and movement throughout the soil profile. A control area was identified at each farm that contained similar soil type and no manure deposition from chickens or other livestock, with soil samples also being taken from 0–30 cm and 30–90 cm in these areas.

Sampling Program

The sampling program at each farm consisted of taking 45 soil cores on the range area and an additional 45 control samples off the range area, at the aforementioned depths. As each farm had a different range area layout; with some farms having more or larger trees, low shade sails, sloping range areas and inaccessible areas for vehicles, it was difficult to apply the same sampling strategy at each farm i.e. concentrate on specific areas of interest on the range and combine the result of these

areas for a whole of range nutrient concentration (as was applied on the odour sampling section). It was decided that the best way to characterise nutrient accumulation on the range area was to perform 3 repetitions of 15 samples, for a total of 45 samples, taken randomly from all over the range area (see Figure 20). These samples were then combined to give a representative indication of the nutrient concentrations on the range area as a whole.

As with the range areas, the control area had 45 soil cores taken and which were split into the same depths (0–30 cm and 30–90 cm). Control areas on each farm were identified based on the following criteria—similar soil type to the range, not predisposed to runoff from the range area and not influenced by any other livestock that may be present on the property. However, selecting control areas with similar soil types at some farms was challenging, as some sheds and range areas were originally built on fill and a variety of amalgamated soil types. In these cases control samples were taken as close to the sheds/range areas as possible, without potentially being influenced by runoff from these areas i.e. higher ground. Soils samples were collected between batches at each farm, meaning that no chickens were on the ranging areas at the time of sampling or potentially up to a week prior to sampling. Additionally, each farm has individual management practices when it comes to range access for the birds; mostly dictated by local weather conditions. This meant that it was impossible to guarantee that each farm that was assessed, had allowed the birds to access the range for equal time periods throughout the batch.

Figure 20: Soil sample collection over all of the different areas of the range, including; pop-holes, open areas, near shade and near trees.

It should also be noted that due to the size and mobility of the sampling equipment, it was not possible to sample directly under the shade sails at any farm. Attempts were made to use a smaller manual foot-sampler in these areas, but only depths of <10cm could be reached. As this depth runs a strong risk of surface contamination in the sample, this method was not employed.

Soil Sample Collection

Soil samples were taken on each farm using a custom made vehicle-mounted hydraulic soil rig (Figure 21). The hydraulic rig was used to drive a 2300 mm x 23 mm chrome-moly (CrMo) steel tube approximately 1 m deep into the sampling area. The tube was then removed bringing up a soil sample, which was then measured and cut into the two sample depths; 0–30 cm and 30–90 cm (Figure 22). Silicon oil was used to lubricate the sampling tube to prevent sticky soils from becoming lodged inside the sample tube.

Figure 21: Fully extended soil sampling assembly.

Figure 22: Soil core before being cut into sections.

Each 15 sample replicate from the range area was bulked together to give one representative sample for that replicate. After samples were bulked in the field, they were transported back and stored, on the day of collection, in a freezer at 0 °C before being processed. Before being sent to the laboratory for analysis, the bulked samples were broken up by hand and mixed thoroughly. Samples were then ‘coned and quartered’(Carter and Gregorich, 2006) down to a minimum of 500 g per sample then sent for nutrient content analysis by the laboratory.

Analysis of soil samples

Soil samples where analysed for nutrient concentrations by Incitec Pivot Ltd’s *Nutrient Advantage Laboratory*. All samples analysed after being dried at 40 °C and ground to less than 2 mm.

The soil samples were analysed for concentrations of the following compounds;

- nitrate (mg/kg);
- ammonium (mg/kg);
- colwell phosphorus (mg/kg) — 0-30 cm only;

- total nitrogen (%) — 0-30 cm only; and
- total phosphorus (%) — 0-30 cm only

Nitrogen compounds were analysed for both depths; 0–30 and 30–90 cm, whereas phosphorus compounds were only tested for at the shallow depth. This was done as nitrogen is a more ‘mobile’ nutrient in the soil profile (Rayment and Lyons, 2011) and has the ability to move down through the soil profile, with the potential to accumulate or leach into water. Whereas phosphorus is almost exclusively found at the surface and shallow depths and is unlikely to move through the soil profile.

Results

Odour

Odour measurements were taken at two free range farms in South East Queensland, Farm A and Farm B (see Table 1). Odour samples were collected during the summer of 2010/2011 and winter 2011 to assess seasonal variability. Detailed data for each of the samples is provided in Appendix A-D. Samples were collected over one day at three milestones during each batch:

- Before birds were released from the shed; typically day 15-20;
- Day prior to first pickup; typically day 30-35; and
- Day prior to final pickup; typically day 42-46.

Odour emissions from the free range farms have been divided into the two main areas of importance; the emissions from the shed itself i.e. those emissions exhausted through the sheds tunnel ventilation fans; and the emissions from the actual range.

It should be noted that as there is a limited number of sites examined in this report, the results should not be taken as a cross section of free range broiler farms in Queensland, rather, a case study of the odour emission rates (OER) from two sample farms over two seasons.

Shed Emissions

Figure 23 displays the emission rate data for both farms in both seasons in odour units per second (ou/s), which represents the total emission rate from the sheds. Emission rates varied from 2972 - 164968 ou/s. Odour emission rates varied on each sampling day, seasonally and with bird age.

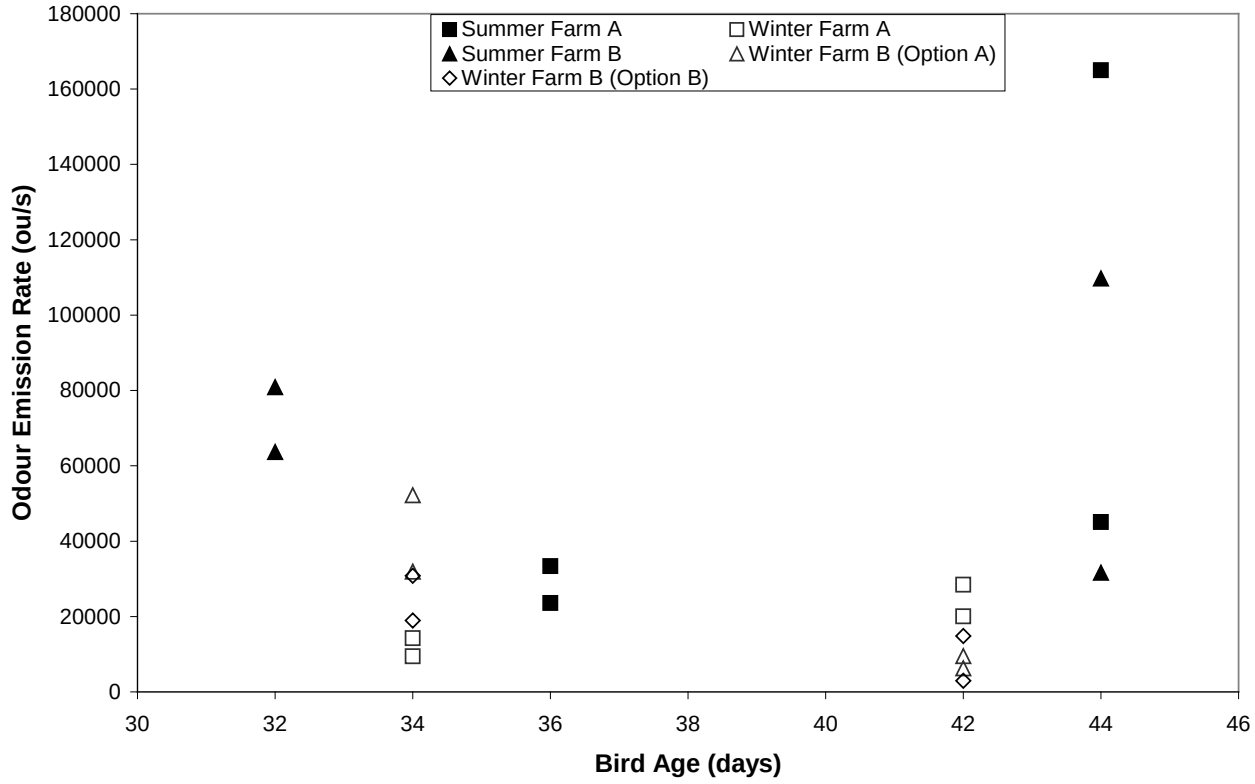


Figure 23: Odour emission rate for the two free range farms. Noting the two options for natural ventilation rate calculation for Farm B.

Figure 24 presents the emission rate data in the units of odour units per second per 1000 birds placed at the start of the batch (ou/s/1000 birds placed). These units are particularly useful for comparing odour emission rates for different sized sheds, which can be valuable when comparing free range sheds to conventional sheds as there is a lower stocking density. Odour emission rates ranged from 270 – 6101 ou/s/1000 birds placed, averaging 2676 ou/s per 1000 birds placed in summer and 801 ou/s per 1000 birds placed in winter.

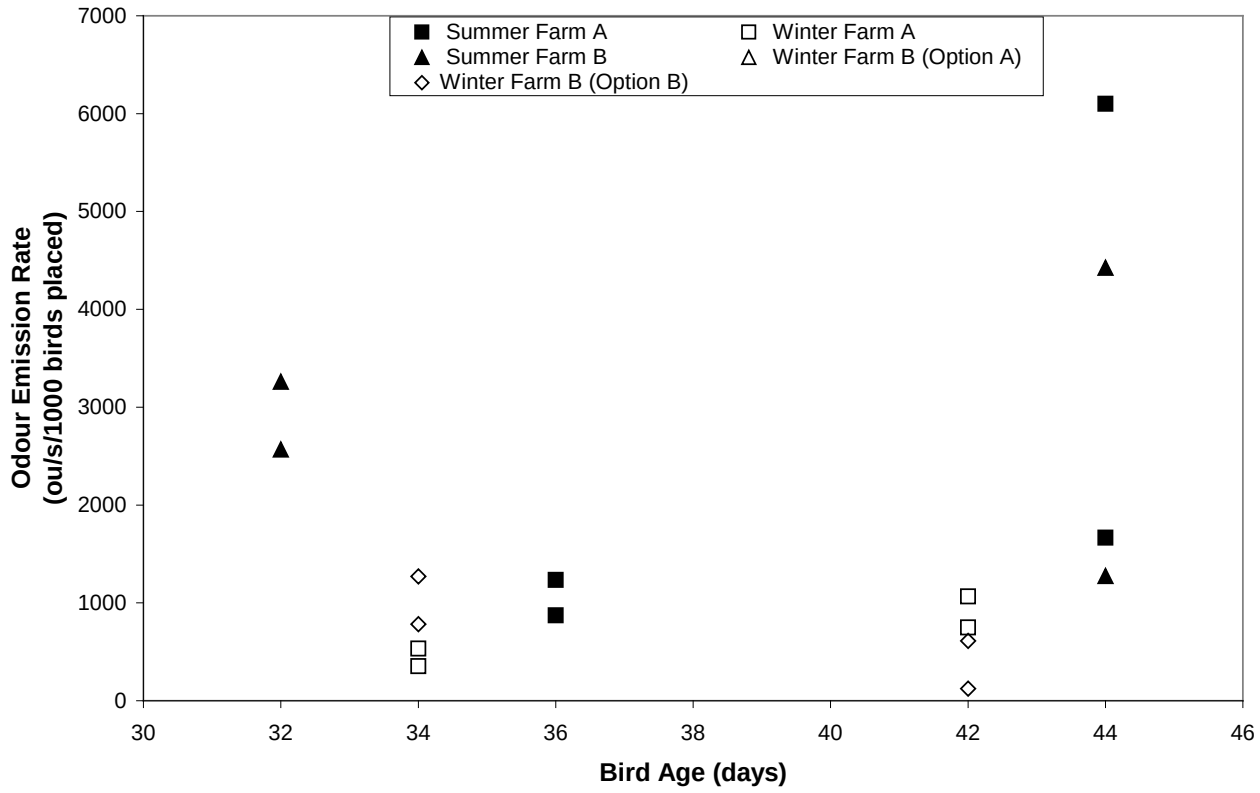


Figure 24: Odour emission rates per 1000 birds placed.

Figure 25 presents the shed emissions in terms of odour units per second per kilograms of live bird weight in the shed at the time of sampling per square metre of floor space (ou/s/kg/m²). These units represent the emission rate with respect to the stocking densities at the time of sampling. Odour emission rates varied from 344 – 9048 ou/s/kg/m².

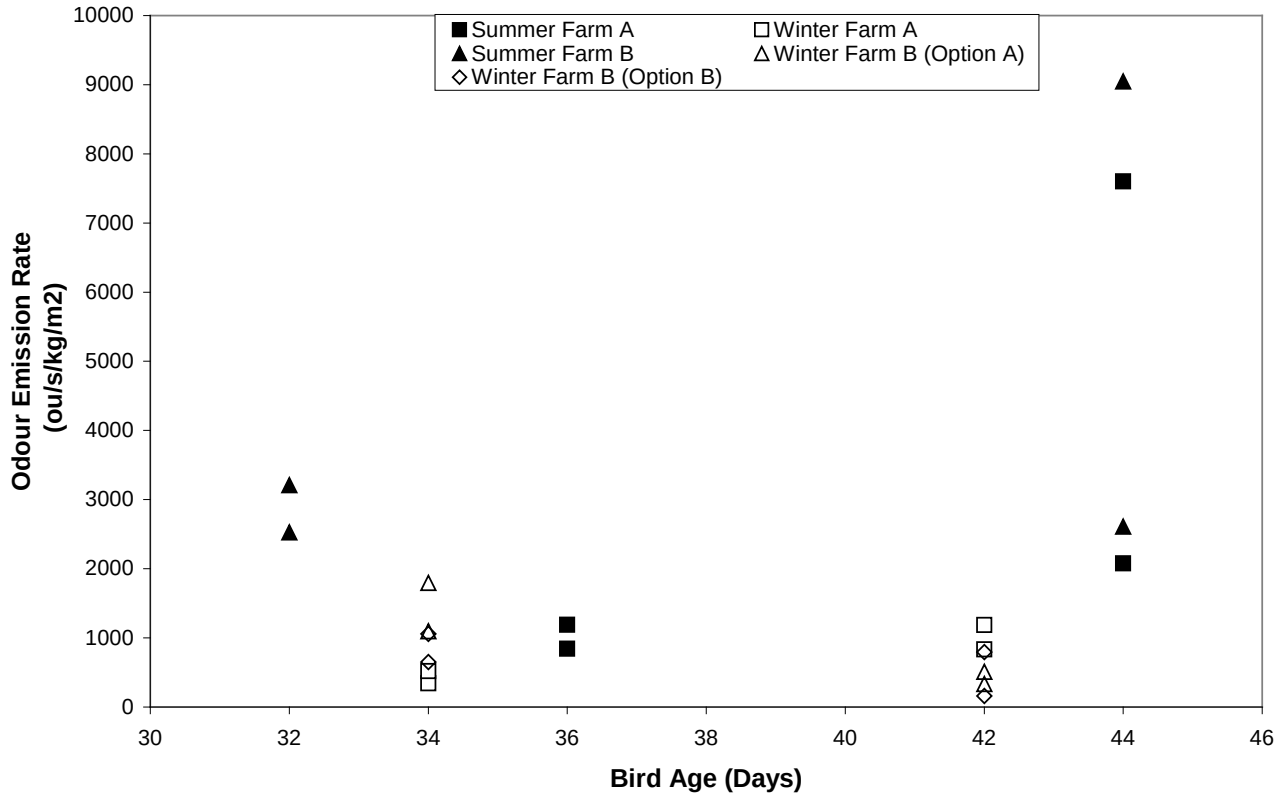


Figure 25: Odour emission rates per kilogram per square metre.

Overall, the lowest OERs from the free range sheds were experienced during the winter season at 34 and 42 days into the batch. The higher OERs were observed towards the end of the batch (44 days) during the summer season. Irrespective of the units used to present the odour emission rates, both of these trends reflect OERs measured from conventional style broiler sheds in other research (Dunlop *et al*., 2011). Suggesting that, in terms of odour variability and emission patterns, the free range farms in this study behave in a similar way to conventional style broiler systems.

One point of interest in the above OER figures is the considerably higher OER for the summer measurements at both farms on day 44 of the batch. One explanation for the increased odour emission rate at both of the farms is the year they were collected; December 2010 an unseasonably wet period for Queensland. In the summer of 2010/2011 South East Queensland experienced excessively wet conditions with December of 2010 being the wettest on record (http://www.bom.gov.au/climate/current/month/qld/archive/201012.summary.shtml). These exceptionally wet conditions may have contributed to increased litter moisture (see Table 9) and subsequently raised the odour emission rates for the summer results.

Table 9: Average litter moisture content at each farm during the sampling seasons. Note the elevated moisture content in summer 2010.

	Average Litter Moisture Content			
Farm	**Summer 2010**	**Summer 2011**	**Winter 2011**	**Winter 2011**
A	44.83%	37.02%	31.33%	30.84%
B	37.07%	29.84%	29.74%	28.37%

Shed odour emission rates were also observed to vary with time of day and ventilation rate. Samples taken on the same day from the same shed a few hours apart sometimes varied considerably. For example; on day 44 of the batch in summer at Farm B the OER varied from 1667 ou/s/1000 birds placed at 9:00am to 6101 ou/s/1000 birds placed at 11:56am. This can most likely be explained by ventilation rate increases (see Appendix A–D for full list of odour samples and corresponding conditions), with the first sample taken at 80% ventilation and the second sample taken at 100% ventilation. While only a slight increase in ventilation rate, this does serve to highlight the variability in odour emission rates from the sheds, particularly when bird density is towards the higher end of the scale.

There is one line of thought that the decreased stocking densities of free range sheds will result in a distinctly reduced odour emission rate. Based on the two farms in this case study, this notion was not reflected in the odour emission rates (ou/s) from the sheds. The free range farms were shown to have comparable OER to conventional tunnel ventilated broiler sheds reported in previous studies (Dunlop *et al*., 2011).

Range Area Contribution

The range area was initially divided into four different areas for individual odour assessment; the results from these areas were then combined to give a whole of range odour emission rate. The individual areas were; the open sunlight grass areas, under the shade sails, under trees used by chickens and the pop-hole exit areas. Additional samples were also taken at each farm on an open grass area that the birds could not access to act as a comparison between range area grass and regular grass.

When considering odour emission from the individual areas that make up the range, from a pure odour emission rate perspective, the highest OER was produced by the pop-hole exit areas with an average emissions rate of 0.25 ou/m²/s for Farm A and 0.71 ou/m²/s for Farm B (Figure 26). Note that Figure 26, Figure 28 and Figure 29 present the data in the form of a ‘box and whisker plot’. In these plots, the extent of the ‘whiskers’ represent the maximum and minimum values, the upper and lower ends of the box show the 25th and 75th quartile values and the line inside the box represents the median value.

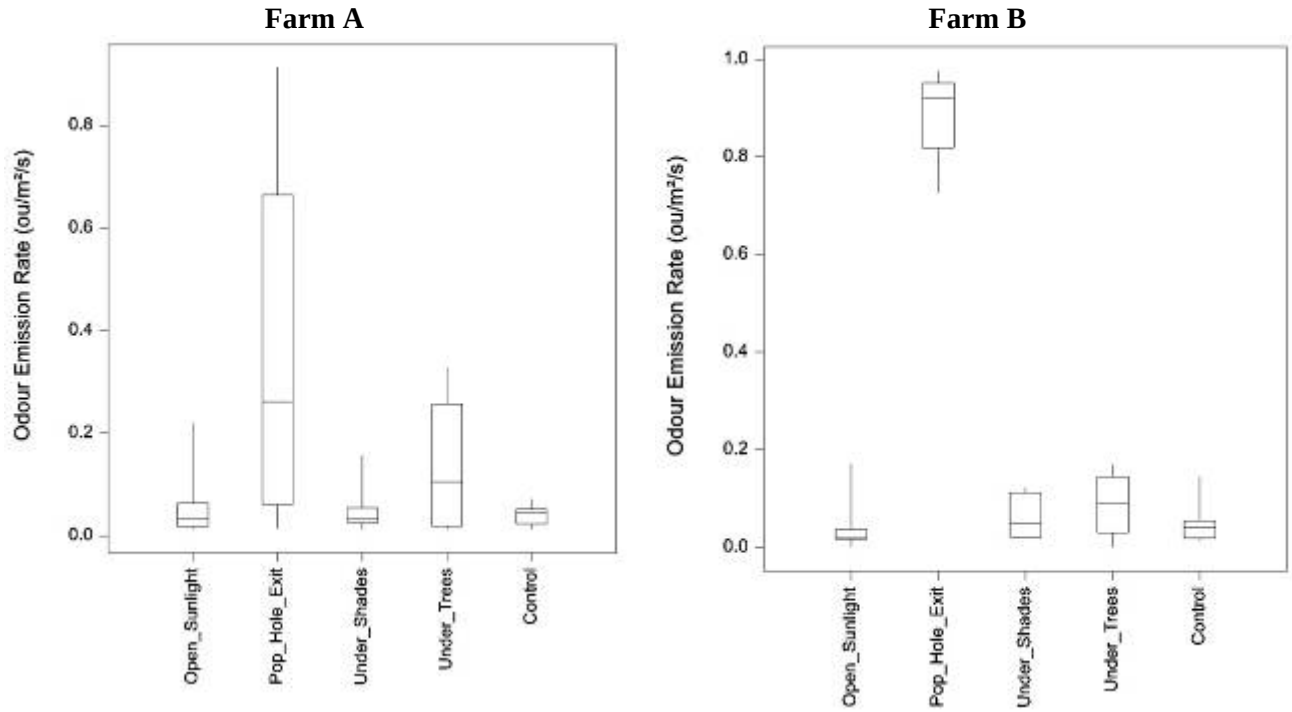


Figure 26: Breakdown of range odour contribution, per metre square. Combined summer and winter results.

There are several reasons why the pop-hole exit areas produce the highest odour emission rate per unit of area. Firstly, these areas are the most trafficked areas on the range and are a common spot for the birds to rest for extended periods of time leading to increased manure deposition and decreased grass cover. The second cause is the lack of sunlight these areas receive due to shading from the shed eaves or shade sails (note that the pop-holes were on the southern side of the shed), and consequently the inability to dry out (see Figure 27). The combination of these two factors in some cases can cause anaerobic conditions, leading to increased odour emissions.

Figure 27: Wet conditions and lack of sunlight at the pop-hole exit, likely causing increased odour generation from these areas.

While the pop-hole exits may have the highest odour emission rate per unit of area, these areas take up such a small percentage (about 1%) of the whole range, that the contribution of the pop-hole exits to a whole-of-range odour emission rate is minimal. Figure 28 shows the contribution of each of the individual range areas to an overall emission rate by multiplying individual emission rates (ou/s) with the area (m^2) it takes up on the range. These figures indicate that the single highest contributor to a whole-of-range odour emission rate is the open-sunlight areas. The reason for this appears to be entirely due to these areas being the most dominant feature on the range (about 80% of total area), essentially overpowering the odour emissions from the other areas.

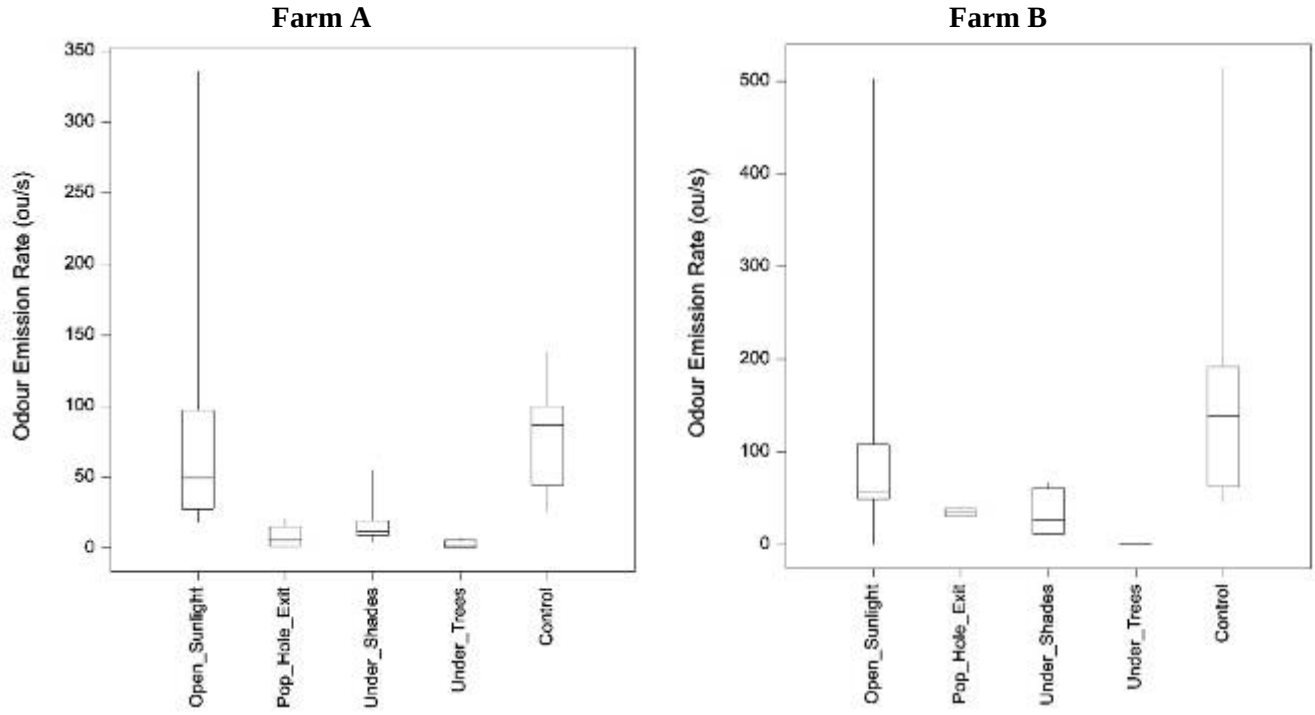


Figure 28: Breakdown of average whole of range emission rates per farm. Combined summer and winter results.

This result indicates that when considering whole of range odour emission rates, on average the odour emitted from the range area comes essentially from the grass and the impact of the birds is negligible. Figure 29 reinforces this statement as it shows how the range area, as a whole, compares to regular lawn grass. For the most part there was no difference detected between the odour emission rates from the range area and the control grass, with the one exception coming in the summer of 2010/2011 on day 44 i.e. the wettest period after maximum bird usage.

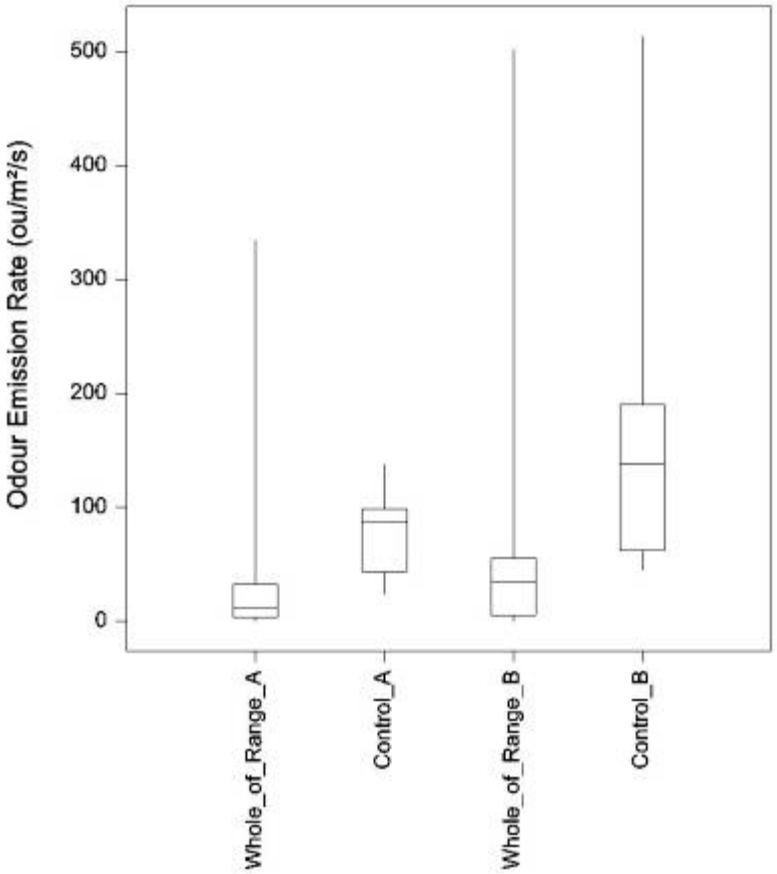


Figure 29: OER comparison of the entire range surface, compared to regular 'control' grass. Combined summer and winter results.

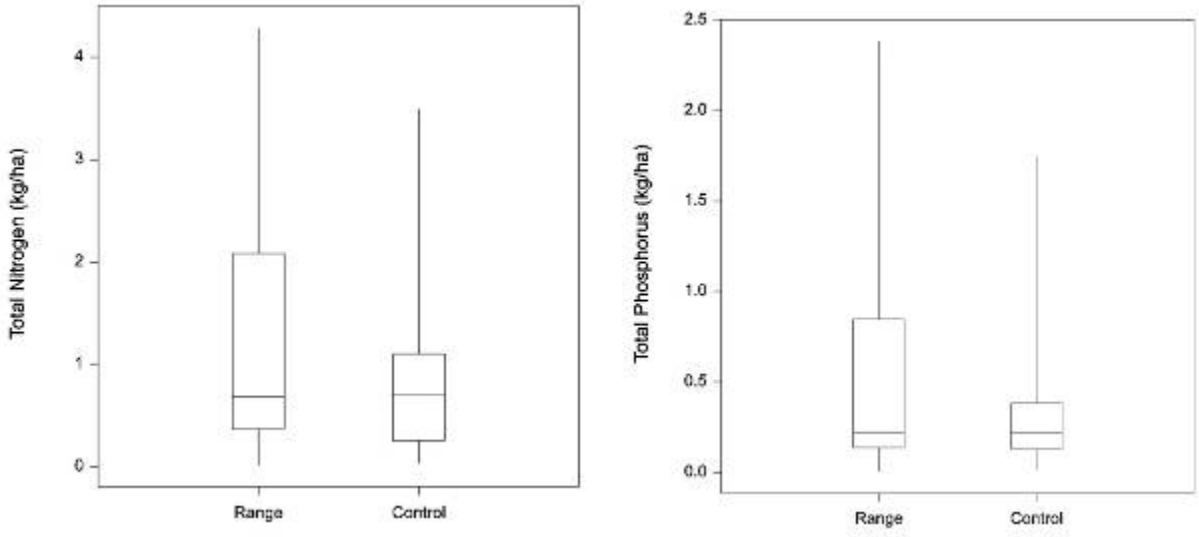
Finally, when the whole-of-range odour emission rates are compared against the shed odour emissions, it becomes clear that emissions from the range area are virtually of no consequence. The whole-of-range OERs averaged 124 ou/s for Farm A and 218 ou/s for Farm B and even the day of highest range emissions, the range only produced values that were 0.85% of the average odour emission rate from the sheds.

Nutrient Runoff

Nutrient concentrations present in the water running off the free range surface were also monitored in this project. A case study of two farms; A and C (see Table 2 for details), was conducted from December 2011 to April 2013. Detailed data for each runoff sample can be found in Appendix G and H. Monthly rainfall data can be found in Appendix I; this contains recorded rainfall values over the length of the runoff trial as well as historical monthly averages for the area. Farm A experienced about average annual rainfall during the trial, whereas Farm C experienced slightly above average annual rainfall for the trial period. Several large storm events (10-20 year events) were experience during the trial period and the majority of the nutrient loss occurred during these large events. This result is in line with previous research done on nutrient export on agricultural lands, (Felton *et al.*, 2007; Pionke *et al.*, 1996; Sharpley and Rekolainen, 1997).

It should also be noted that both range and control flumes did not always trigger during the same rainfall event. The control flume at Farm A tended to need less intense rainfall to trigger the sampler compared to the range. As a result, the range flume collected 20 samples and the control flume collected 26 samples. This was also the case at Farm C, at which the range flume more readily received enough runoff to trigger the sampler, resulting in the range flume collecting 26 samples and the control flume collected 17 samples.

Figure 30 presents the runoff results from the range flumes (n=20) and control flume (n=26) at Farm A. Over the course of the runoff trial the average total nitrogen measured from the range flume was 1.382 kg/ha and the average from the control flume was 0.968 kg/ha. Total phosphorus levels for the range flume averaged 0.549 kg/ha and for the control flume averaged 0.397 kg/ha over the course of the trial. Average ammonia level for the range area was 0.306 kg/ha and 0.111 kg/ha for the control. Average combined nitrate and nitrite levels for the range were 0.536 kg/ha and 0.273 kg/ha for the control area. Average ortho-phosphorus levels from the range were 0.427 kg/ha and 0.360 kg/ha for the control. Overall, the results for the range and control at Farm A were observed to be comparable. An ANOVA was performed on each of the analysed nutrients comparing the levels measured in the range to the levels measured in the control. The test did not detect any significant difference for any analysed nutrient ($P<0.05$).



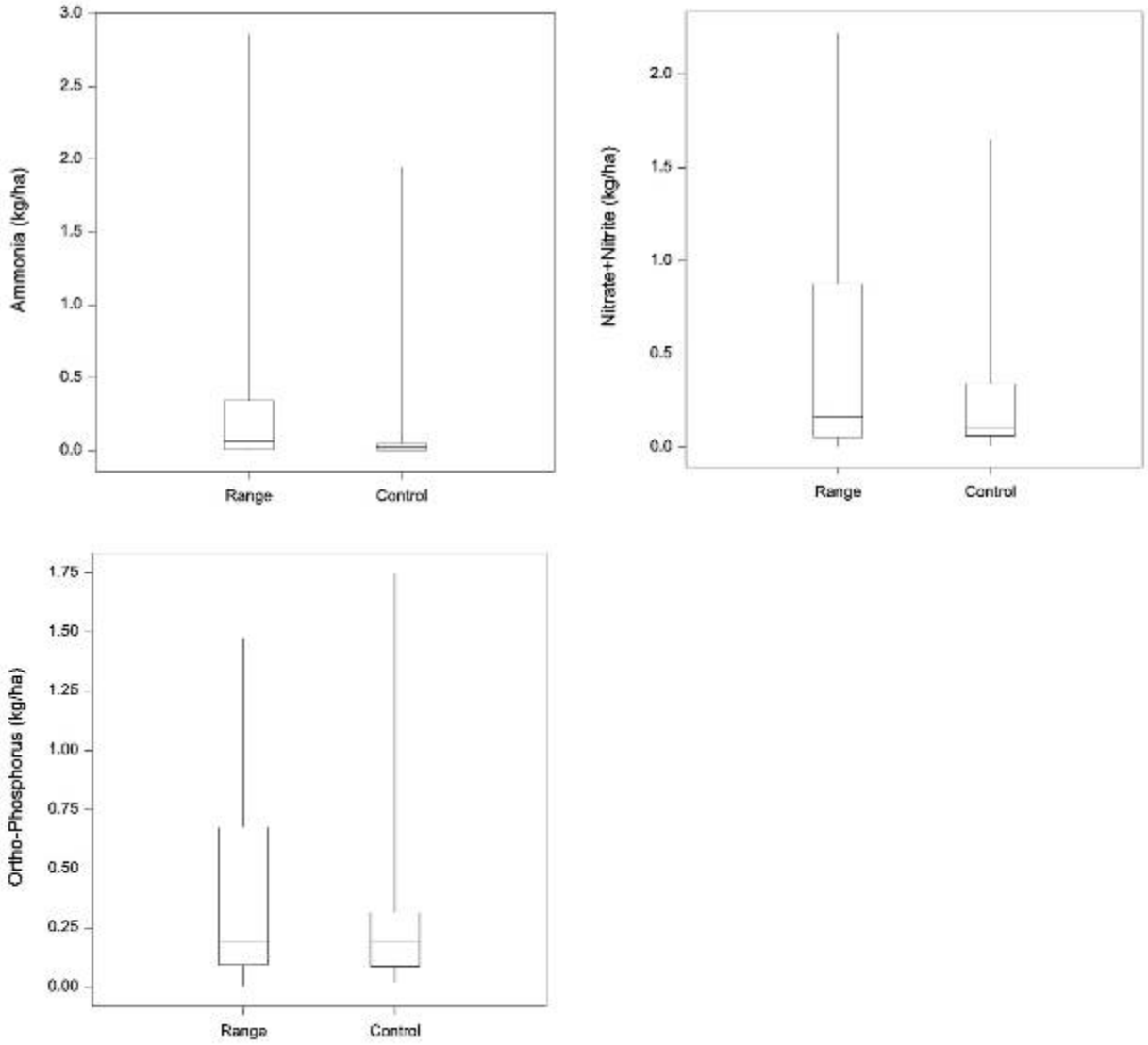


Figure 30: Nutrient levels in runoff measured from the range area and control area at Farm A

Figure 31 shows the nutrient levels in the runoff from the range flume (*n*=26) and control flume (*n*=17) at Farm C. Over the course of the runoff trial the average total nitrogen measured from the range flume was 2.373 kg/ha and the control flume averaged 0.035 kg/ha. Total phosphorus for the range flume had an average of 1.050 kg/ha and the control flume had an average of 0.020 kg/ha. The average ammonia level for the range flume was 0.535 kg/ha and 0.014 kg/ha for the control area. The combined nitrate and nitrite average measured for the range flume was 0.919 kg/ha and 0.011 kg/ha for the control. Finally, the average ortho-phosphorus level measured from the range flume was 0.997 kg/ha and 0.066 kg/ha for the control flume. Overall, the nutrient levels measured from the control area runoff were much lower than the levels measured in the runoff from the range. As with the data from Farm A, an ANOVA was performed on each of the analysed nutrients at Farm B, comparing the levels measured in the range to the levels measured in the control. The test showed that there was a statistically significant difference for all analysed nutrients ($P<0.05$).

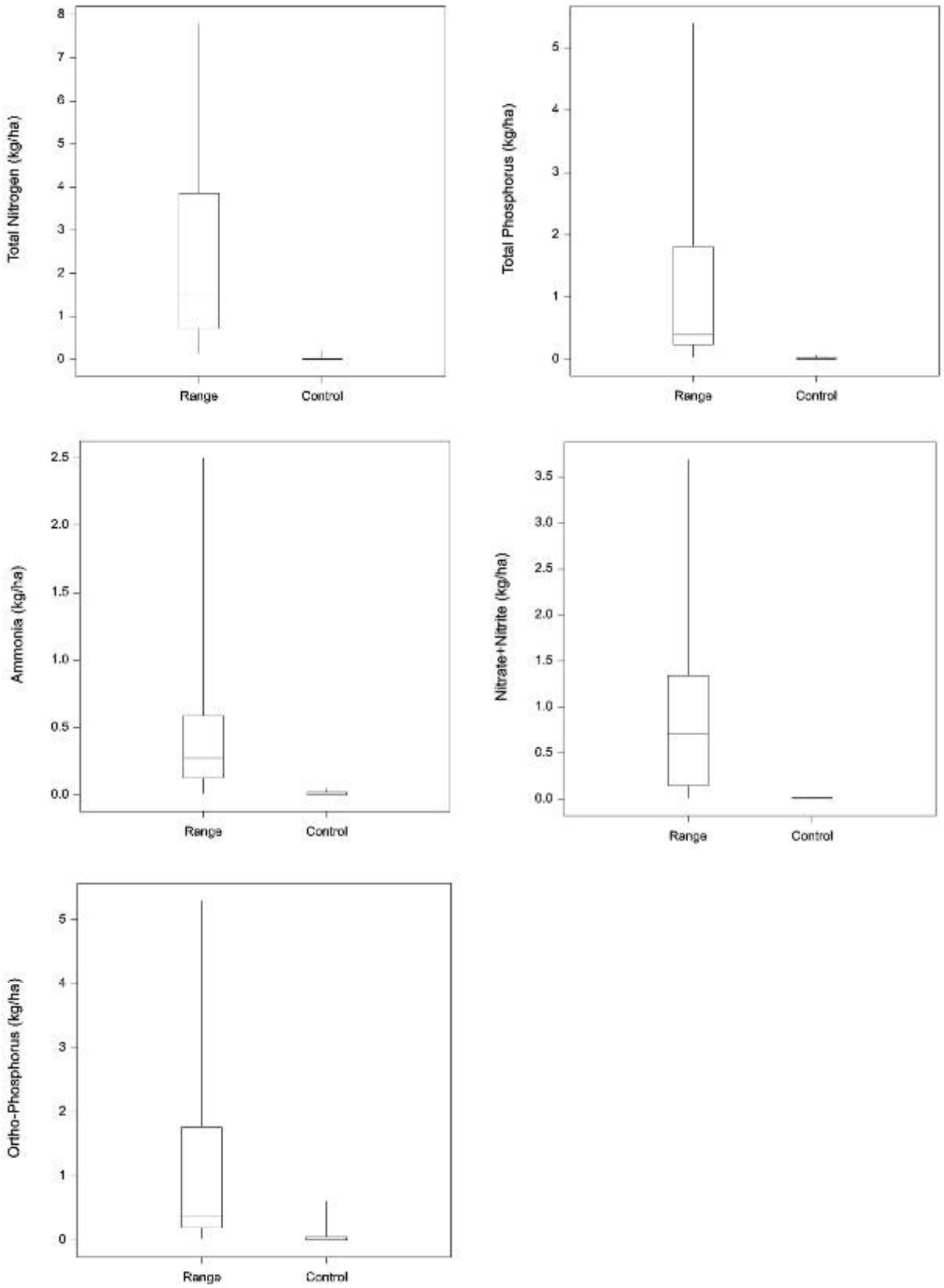


Figure 31: Nutrient levels in runoff measured from the range area and control area at Farm C

The findings at Farm C are obviously quite different to the results seen at Farm A. While the range nutrient levels between farms remain comparable; the control results from Farm C are much lower

than those from the control at Farm A. Several factors could explain this difference. On first inspection of the range and control sites, they both appeared to have roughly the same soil type and drainage properties, and as they were located quite close to each other any differences were thought to be minor. However, the runoff catchment area for the control site contained a considerably different soil type than initial inspections showed, which influenced the hydrological properties of the catchment area. The soil ended up being much drier than the range, resulting in the control area having a greater field capacity and tending to absorb rainfall more readily than the range catchment. The absorption meant that the control flume collected much smaller samples than the range and only tended to begin collecting runoff in intense rainfall periods. The lower runoff volumes have lower energy than that of the higher volumes, and thus the ability of the runoff to pick up and carry the nutrient containing particulates was lower on the control catchment. This may explain why such low nutrient levels were seen in the runoff from the control at Farm C.

Runoff Load Comparisons

As there is little available research on nutrient runoff concentrations from free range farms it is difficult to determine if the numbers seen in this case study are high or low for this particular type of land use. However, extensive research has been conducted on nutrient levels in runoff from commercial golf courses. Table 10 presents findings on nutrient loads from previous studies on golf courses compared with the findings in this project.

Table 10: Nutrient level comparisons measured from managed golf courses in other studies

Reference	**Load (kg/ha-yr)**		
	TN	**TP**	**NO_3**
(Winter and Dillon, 2006)	3.00 - 9.00	0.20 - 0.60	1.00 - 4.00
(Yang *et al*., 2013)	0.31 - 3.71	0.13 - 0.76	-
(Kunimatsu *et al*., 1999)	5.42 - 13.4	0.13 - 3.0	-
(Line *et al*., 2002) (mean)	31.20	5.50	4.80
This Study (mean)	(kg/ha)	(kg/ha)	(kg/ha)
Farm A	1.38	0.54	0.58
Farm B	2.37	1.06	0.89

The above comparisons between nutrient levels in runoff from golf courses compared with the two free range farms in this study indicate that the overall nutrient load from the farms is less than a commercial golf course. Additionally, the size of the range areas from the two farms studied was 0.12 ha for Farm A and 0.18 ha for Farm C, whereas the average size of a commercial 18-hole golf course is about 30 ha (https://en.wikipedia.org/wiki/Golf_course, 2013), suggesting the overall nutrient load on the surrounding area would be much greater for a golf course.

Bird Age and Nutrient Load

The age of the current batch was recorded during each sampling event to determine if bird age (i.e. the amount of time the birds have accessed the range area) had an immediate effect on the amount of nutrients in the runoff from the free range area.

Figure 32 presents the total amount of nutrient exported during a runoff event (kg/ha) with the age of the birds for Farm A. The highest recorded nutrient levels for the range area were experienced when the birds were 36 days old, 6 days old and then 2 days after the birds were removed. Conversely, the lowest nutrient levels were recorded when the birds were 24 days old, 22 days old and 37 days old.

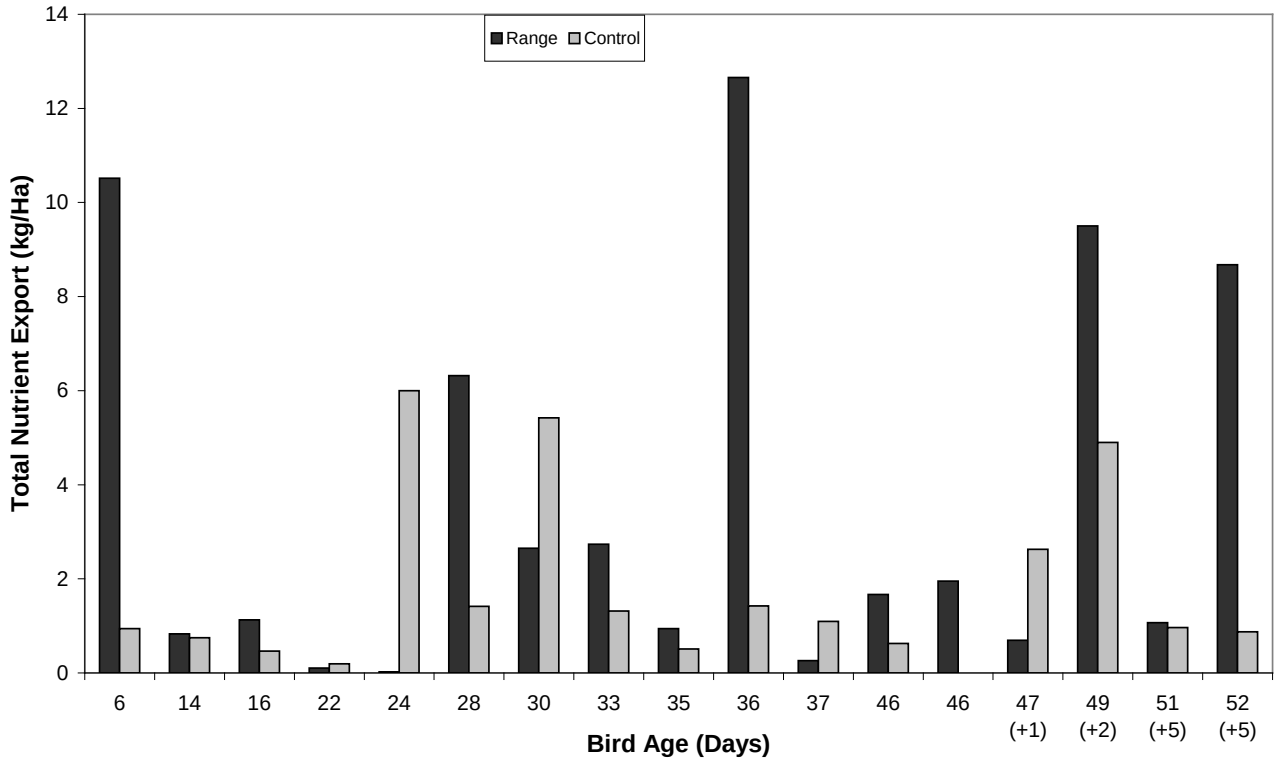


Figure 32: Bird age and amount of nutrient (combined N and P) exported from the range on Farm A. Noting that the number in brackets is days after the birds have been removed

Figure 33 shows the total amount of nutrient exported during a runoff event (kg/ha) with the age of the birds for Farm C. The highest nutrient levels for the range area were seen when the birds were aged 15, 20 and 47 days old. The lowest overall nutrient concentrations from the range were experienced when the birds were 46, 48 and 32 days old.

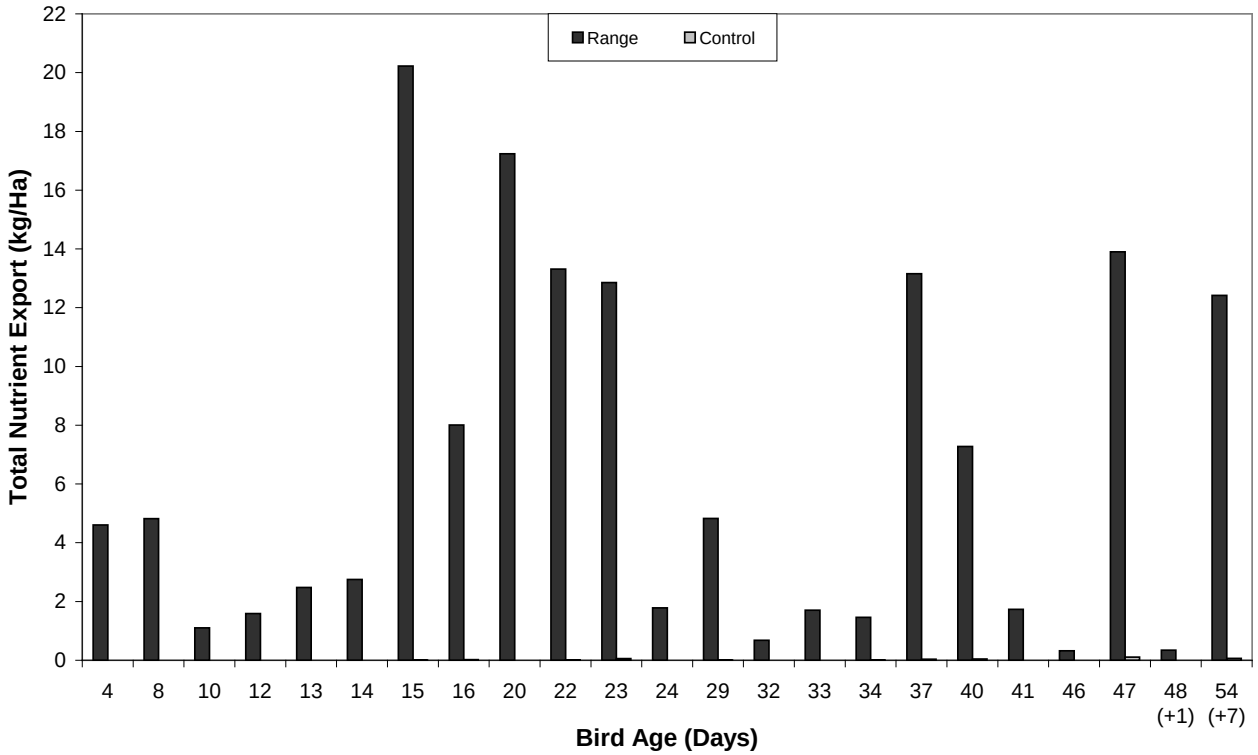


Figure 33: Bird age and amount of nutrient (combined N and P) exported from the range on Farm C. Noting that the number in brackets is days after the birds have been removed

Overall, total nutrient export in the runoff from the range area appears to vary throughout the course of the batch. The results also show that there are nutrients being lost from the range area prior to bird access (before day 21) and continue being lost after the birds were removed (after day 46). This may indicate that the primary influence on nutrient levels in the runoff is not the amount of bird activity but, as previously suggested, the main influence on the amount of nutrient in the runoff appears to be the size and intensity of the rainfall event.

Soil Nutrient Accumulation

In addition to looking at what nutrient levels are seen in the runoff from the free range surface, nutrient levels on and in the range area were measured through soil samples from the range area. Range area soils were analysed for Nitrogen and Phosphorus content in 11 free range farms in Queensland and Victoria at two depths: 0-30 cm and 30-90 cm. Detailed data for each of the samples is contained in Appendix E and F. Samples were taken between batches, meaning there were no chickens on the range area for up to week prior to sampling. Also, each farm has its own management practices concerning chicken access to the free ranging area; this means that at some farms the birds may have had a longer time to access the range area than others.

Nutrient Concentration Comparisons

As previously mentioned, soil samples were taken on the range area (in 3 replicates) as well as a control area for each farm. Presented below are the nutrient concentrations from the range and control areas at each farm. The range results are the average values from the three replicates. It should be noted that as there was such varied soil types between farms, it is difficult to compare one farm to another and as such each range area can only be compared to the corresponding control area. Even comparing the range to the corresponding control can be difficult, as often the range areas are built

with a variety of soils and not necessarily identical to the control area. This is further discussed in the next section but should be kept in mind when examining these results.

It should also be noted that the size of the sampling equipment made it impossible to take soil samples from under the shade sails on the free range areas. As such, the overall range nutrient concentrations given below do not include these areas.

Figure 34 shows the concentration (mg/kg) of nitrate (NO_3) present in the range and control areas from 0-30 cm. Results from the range area varied from 2.53 mg/kg at Farm G to 17.10 mg/kg at Farm E, whereas control results varied from 0.50 mg/kg at Farm D to 17.67 mg/kg at Farm G. Overall, the average of the range areas was 9.85 mg/kg and the control areas averaged 7.25 mg/kg. Out of the 11 farms assessed, 5 farms showed a higher concentration of nitrate in the range compared to the control.

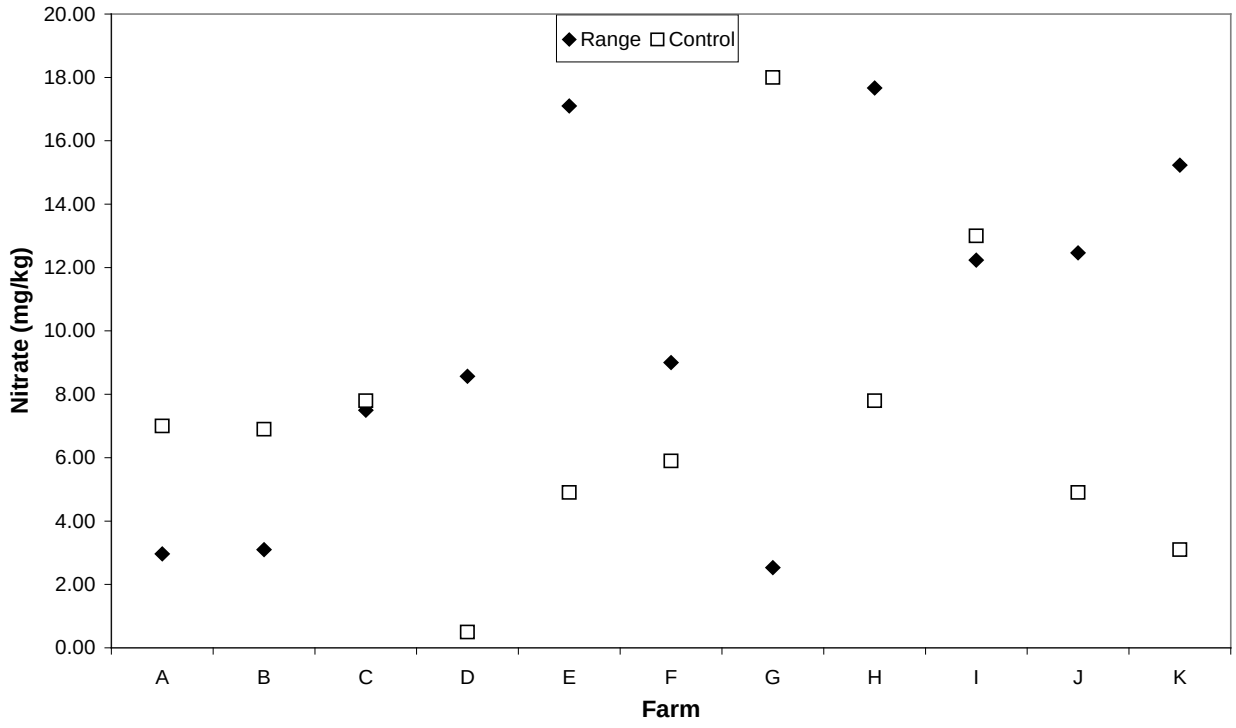


Figure 34: Nitrate concentrations at 0-30 cm for each farm.

Figure 35 presents the concentration of nitrate below the surface of the range and control areas from the 30-90 cm depths. Range concentrations varied from 0.50 mg/kg at Farm F and 19.67 mg/kg for Farm G. Control concentrations varied from 0.55 mg/kg at Farm D to 34.00 mg/kg at Farm I. Out of the 9 farms that this depth was reached, 6 showed an increase in nitrate concentration in the range compared to the control, with an average increase of 5.09 mg/kg.

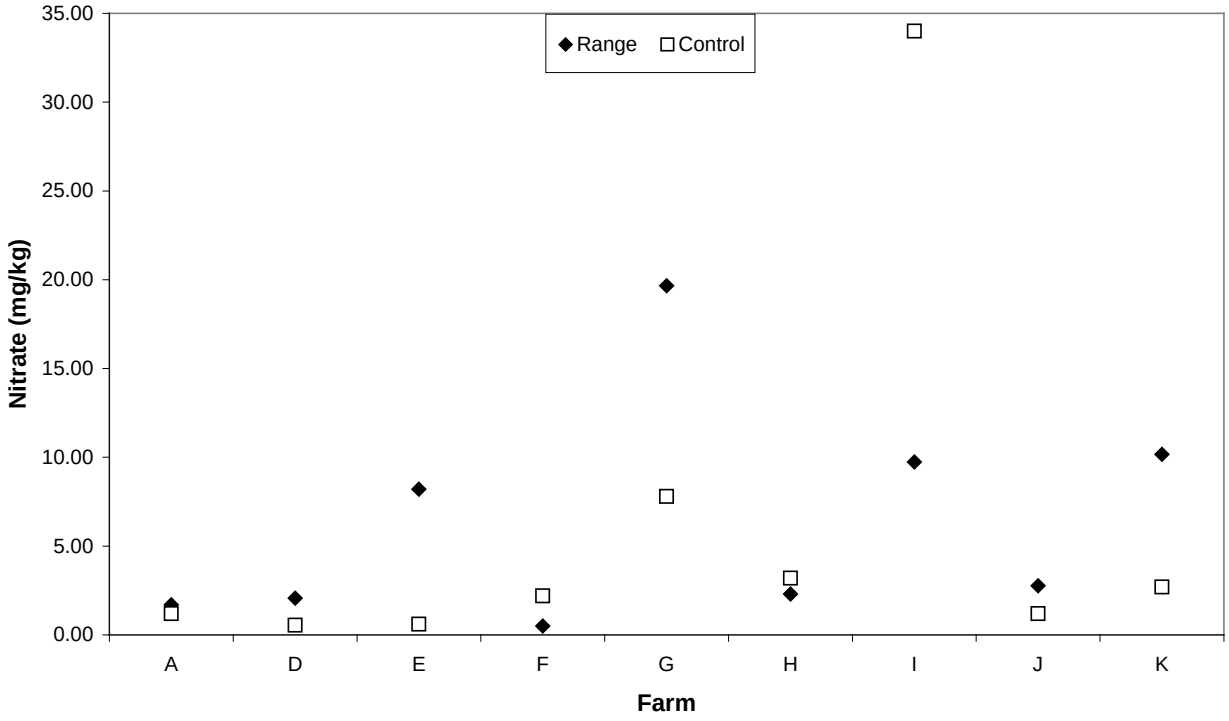


Figure 35: Nitrate concentrations at 30-90 cm for each farm. Noting that there are no results for Farms B and C.

When comparing surface (0-30 cm) nitrate to subsurface (30-90 cm) nitrate, all but one farm (G) showed reduced levels of nitrate at depth compared to surface levels. This reduction in average concentration between the range surface and below the range surface could be an indication there is minimal movement of nitrate through the soil profile on the range areas. Contextually, the Australian National Water Quality Management Strategy (NWQMS) recommends a maximum value of 50 mg-NO_3/L of nitrate in water for safe human consumption (NWQMS, 2011).

Figure 36 shows the concentrations of ammonium (NH_4) in the range and control surfaces from 0-30 cm. Results for the range areas varied from 2.70 mg/kg for Farm B and 15.23 mg/kg for Farm E. Control results varied from 2.00 mg/kg at Farm J to 7.6 mg/kg at Farm C. The biggest difference in concentrations was seen at Farm E, which showed a higher result for the range (15.23 mg/kg) than the control area (3.00 mg/kg). The range areas averaged 7.11 mg/kg of ammonium and the control areas averaged 3.84 mg/kg concentrations. Overall, again a slightly elevated nutrient concentration was seen on the surface of the range areas compared to the control areas, with all of the 11 farms tested showing an increase in ammonium from range to control, at an average of 3.27 mg/kg higher.

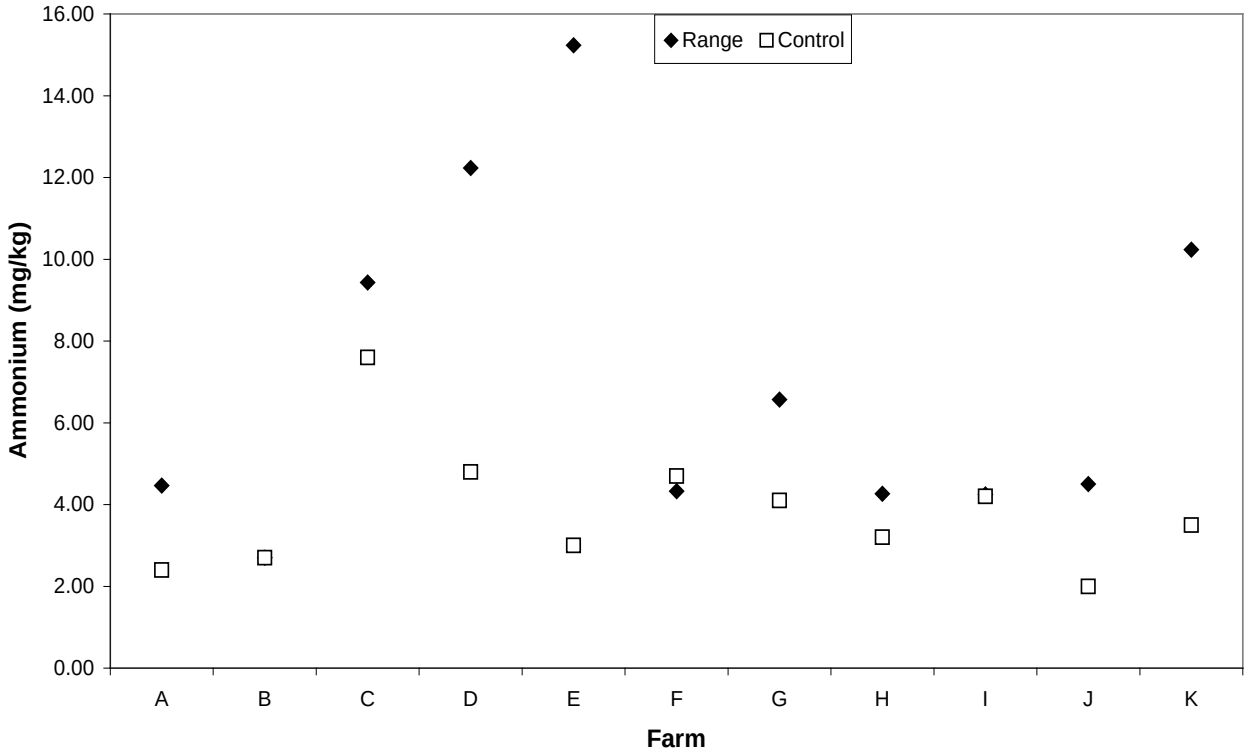


Figure 36: Ammonium concentrations at 0-30 cm for each farm.

The NH_4 concentration levels for the range and control areas from 30-90 cm are shown in Figure 37. The results in the range areas varied from 1.30 mg/kg at Farm F to 4.80 mg/kg at Farm K and the control areas varied from 0.60 mg/kg at Farm G to 2.10 mg/kg at Farm A. The range areas averaged 2.37 mg/kg and the control areas averaged 1.44 mg/kg. Out of the 9 farms that this depth was reached, six had higher NH_4 levels on the range area than the control, with an average increase of 1.54mg/kg.

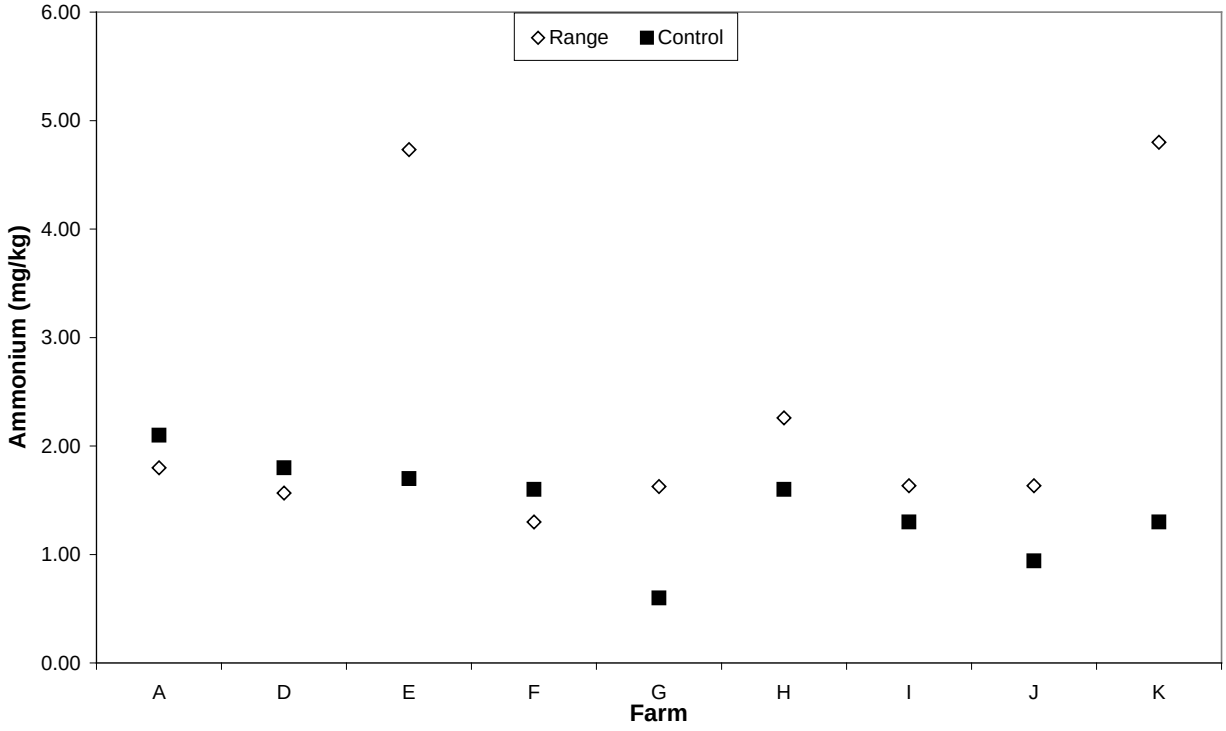


Figure 37: Ammonium concentrations at 30-90 cm for each farm. Noting that there was no result for Farms B and C.

Comparing surface ammonium levels to subsurface levels, a decrease in overall concentration from the surface results to the levels recorded at depth can be seen. This could be an indication of limited movement of deposited ammonium through the range soil profile than there is from the deposited nitrate on the range surface.

Figure 38 shows the Colwell Phosphorus (Colwell P is a measure of phosphorus available for plant uptake) concentrations for the range and control areas from 0-30 cm. Concentrations for the range area varied from 16.0 mg/kg at Farm A to 246.7 mg/kg at Farm K, whereas the concentration for the control area varied from 7.6 mg/kg at Farm C to 330.0 mg/kg at Farm G. Overall, the control areas had a higher average concentration (114.7 mg/kg) of Colwell P than the range areas (70.5 mg/kg). As such, only 4 of the 11 farms had a higher reading for Colwell P on the range compared to the corresponding control area.

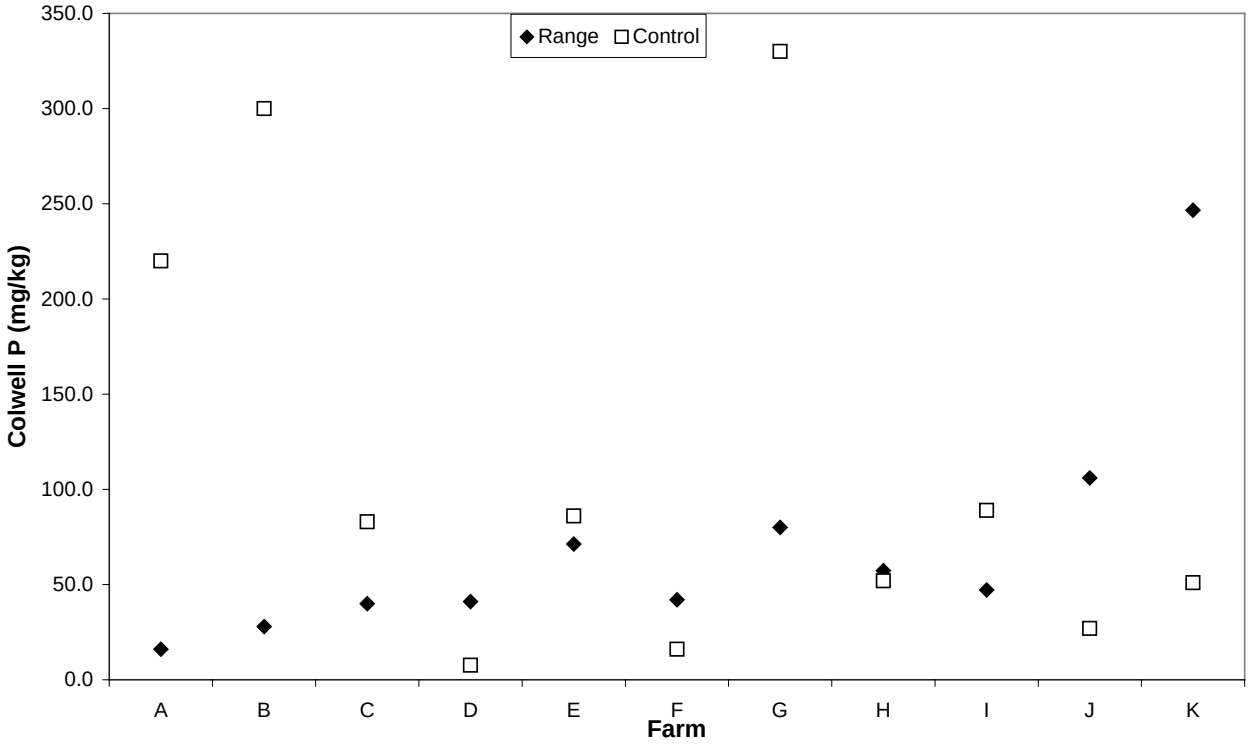


Figure 38: Colwell Phosphorus concentrations at 0-30 cm for each farm

Overall, the nutrient levels in the soils of the range areas appear to vary from farm to farm, with some having comparatively high results for some surface nutrient and low results for deeper nutrients, where as others showed the opposite. This is not an unexpected result, as soil type is the primary factor that influences nutrient concentrations and the range areas had different soil types from farm to farm.

Similar to the runoff results, the range areas, on average, showed slightly elevated nutrient levels compared to the corresponding control areas. The surface (0-30 cm) results showed a larger difference between range and control, compared to the levels seen under the surface (30-90 cm). This would indicate that bird activity on the range area does have some influence on the amount of nutrient that accumulates in the soil; however, at the concentrations seen in this study, the influence would appear to be minimal.

Nutrient Accumulation over Time

Nutrient levels in free range areas of different ages were also considered to quantify any relationship between length of time operating as free range and levels of nutrient accumulation. Out of the 11 farms in this study, ages ranged from 5 years operating as free range to 9 years of free range operation (see Table 3 for full list). As previously mentioned only NO_3 (nitrate) and NH_4 (ammonium) concentrations were analysed at the 30-90 cm level. Nutrient build up over many years should be most evident deeper in the soil profile rather than at the surface.

Figure 39 shows the nitrate concentrations in the range and control areas from 30-90 cm compared to years of free range operation. Three farms that had been operating for 5 years free range had samples taken from 30-90 cm and averaged 13.19 mg/kg on the range area and 14.83 mg/kg for the control area, while two farms operating for 9 years free range averaged 1.40 mg/kg of nitrate on the range and 2.7 mg/kg on the control area.

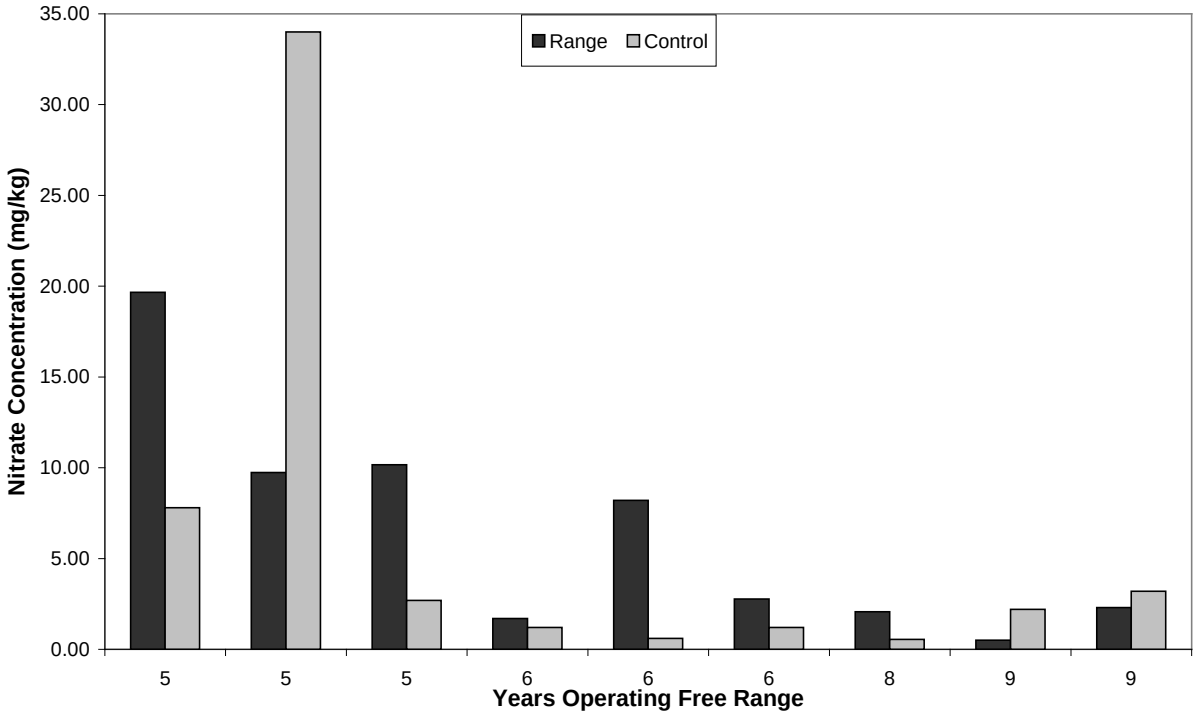


Figure 39: Nitrate concentrations from 30-90 cm for the range and control areas, farm age increases from left to right.

Figure 40 shows the ammonium concentrations in the range and control areas from 30-90 cm compared to years of free range operation. Of the three farms that had been operating for 5 years free range the average ammonium concentration on the range was 2.69 mg/kg and 1.06 mg/kg for the control. The two farms that had been operating for 9 years free range had an average ammonium concentration of 1.78 mg/kg for the range and 1.60 for the control area.

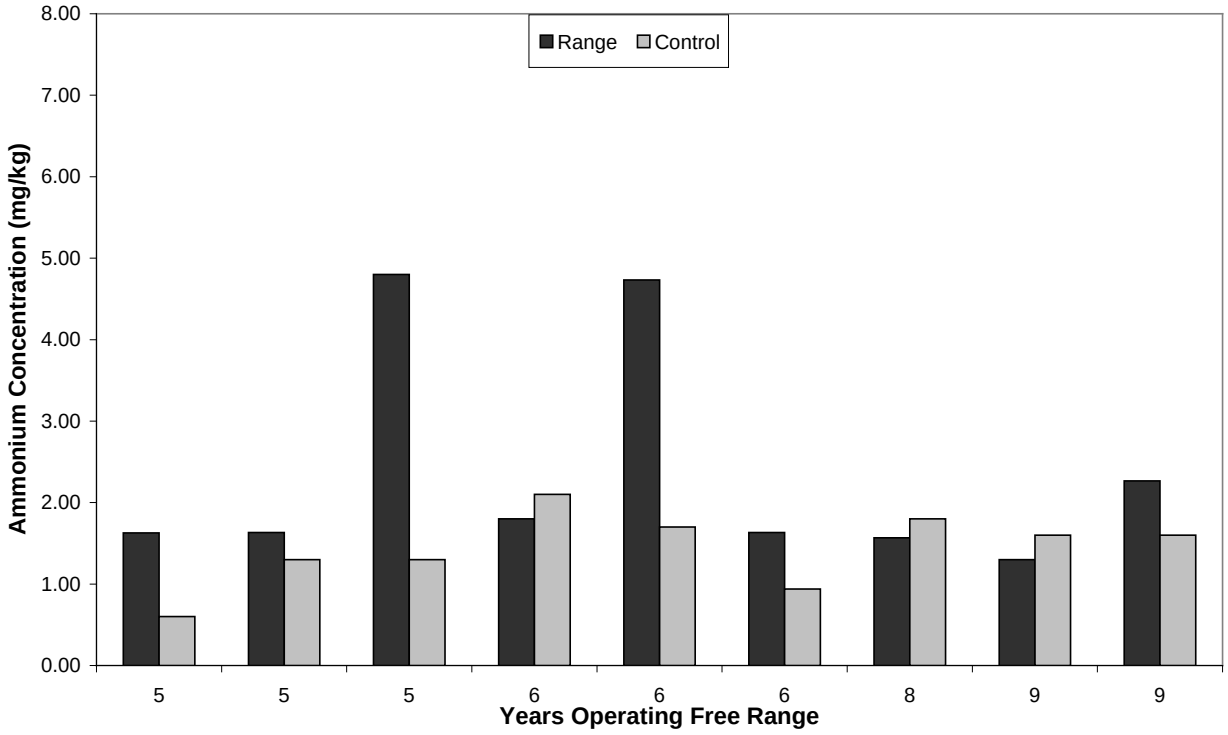


Figure 40: Ammonium concentrations from 30-90 cm for the range and control areas, years operating free range increases from left to right.

If there was nutrient being built up over time, the results would be expected to show higher nutrient levels compared to control levels, with the difference between the two increasing with years of free range operation. This trend was not observed in the results from this study, indicating that there is no correlation between number of years of free range operation and amount of nutrient build up.

The main reason for there being little correlation between number of years operating free range and the amount of nutrient accumulation in the soil, is the ability of nitrogen to quickly volatilise to the atmosphere (i.e. removed from the surface of the range). With generally only small amounts being deposited on the range at any one time the volatilisation would limit the amount of nitrogen absorbed into the soil. However, it is also possible that the nitrogen has moved further down the profile beyond that of the maximum sampling depth of 90 cm in this study. Although this would be heavily soil type dependent, with each soil type having a different capacity for nitrogen to pass through the profile.

Conclusions

Odour emissions from the two free range sheds in this case study were found to be comparable to odour emissions measured from conventional style broiler sheds. Odour emissions from the range surface were seen to be negligible when compared to emissions from the sheds, contributing about 1% of total odour emission rate.

Nitrogen and phosphorus concentrations in the runoff from the range areas were variable at the two farms in the study. Farm A showed no statistical difference between range and control runoff concentrations, the range area at Farm C had statistically higher nutrient levels than the control area. This is thought to have been caused by the differences in soil types between range and control runoff catchment areas at Farm C, resulting in the control area needing much more rain to trigger a runoff sample. Comparatively, the overall nutrient concentration in the runoff from the range areas was less

than would be expected from a commercial golf course. The majority of the nutrients were captured during short, intense, infrequent storm events (i.e. 1 in 5, 10 and 20 year events).

Nitrogen and ammonium concentrations in the range soils were slightly higher than the control areas. Conversely, phosphorus concentrations in the range areas were lower than the control area. Nutrient concentrations were observed to decline at lower depths in the soil profile. No evidence was found of a relationship between number of years of free range operation and amount of nutrient build-up in the subsurface soil

Implications

Little data is currently available on the odour emissions and nutrient export from free range meat chicken farms. The information provided in this report will hopefully shed some light on the environmental aspects of growing commercial free range meat chickens. This increased understanding will lead to more accurate modelling of free range odour emissions and provide increased information into the nutrient cycling associated with the free range area. Producers in particular will be able to use the findings in this report to more effectively manage the range areas with respect to nutrient cycling and odour emissions to reduce the potential for negative impacts.

Naturally, comparisons between free range and conventional style meat chicken production are going to be made. The findings about free range farms in this study, at least in terms of odour, would indicate that free range farms and conventional styled farms have a similar odour emission rate. However, it should be kept in mind that the results presented here are from a case study of two Queensland farms over a short period of time. It should not be assumed that the findings about odour from the sheds would be representative of all free range farms; they are simply an indication of the odour emissions at the time and conditions of sampling.

As previously mentioned, soil samples from some of the bird congregation areas (i.e. shade sails) were not able to be taken due to the size of the soil sampling equipment. Although the nutrient concentrations measured on the range indicated little difference compared to the control, by not being able to directly test these areas for nutrient accumulation, a potentially important part of the range was not considered. While other research suggests bird congregation areas may lead to a significant increase in nutrient accumulation and therefore be exported off the range area (Kratz *et al*., 2004b), the runoff results in this trial did not show a dramatic increase in nutrients coming off the range. If these bird congregation areas were contributing significantly to the nutrient levels on the range area, the nutrient concentration in the runoff would likely have indicated an increase. As this was not seen in this case study, the influence of these shaded areas on overall soil nutrient content may not be significant.

Recommendations

Free range broiler farming on a commercial scale is relatively new. The majority of free range farms currently in existence have been 'converted' to free range, rather than purpose built and as a result each free range farm can differ in setup from one to another. This makes it difficult to draw conclusions and make recommendations about potential environmental impacts of free range farms. The findings in this report are not necessarily indicative of free range farms industry wide, rather a case study of 11 free range broiler farms. As the industry expands more purpose built free range farms will emerge, which may lead to more representative range areas. A future trial of purpose built free range farms may be able to shed more light on the potential impacts of free range broiler farms, and allow development of an industry standard design free range farms.

Free Range Odour Emissions

A larger number of free range farms should be included in future odour studies to more conclusively characterise the odour emission rate from free range farms. Confidence in the results could be increased by sampling a larger number of farms to help minimise effects such as the exceptional rain experienced during this study.

From the measurements recorded in this report it could be argued that odour modellers do not need to include the range area as an additional source of odour when modelling odour emissions from a free range shed.

Range Area Contribution to Odour

It is worthwhile identifying areas of the range that may cause elevated odour generation, even though these results indicate that range odour emissions are minimal compared to those expected from the sheds. In particular, the areas in close proximity to the shed pop-holes were identified as a location of increased odour production as manure may accumulate and not dry out during wetter periods. Discouraging birds from residing under the eaves would reduce manure accumulation in these damp areas, thereby minimising odour generation potential. On the other hand, compared to the overall size of the range, the areas near the pop-holes represent such a small portion of the whole area that odour generation may not be an issue. It would still be worthwhile for producers to keep an eye on the size and condition of these damp areas and take action if required.

Nutrient Accumulation Sampling

The soil samples from the range areas did not include the area directly under the shade sails. While reasons listed above explain why these areas may not have a large influence on the overall range areas nutrient concentrations, it is recommended that these areas be included in subsequent studies to confirm this outcome.

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Appendix A—Farm A, Shed Odour Emission Results

Sample Number	Odour Source	Litter Reuse	Season	Date (ddmmyy)	Batch Age (Days)	Collection Time (hh:mm)	Ventilation Status (% of max fan activity)	Ventilation Rate (m^3/s)	Ambient Temperature (°C)	Ambient Relative Humidity (%)	Bird weight Distribution (kg/m^2)	Average Litter Moisture Content % (Wet Basis)	Total Live weight	Number of Birds
013	Shed	Partial	Summer	07/12/10	36	10:51	50	46.1	25.5	85	28.0	44.8	51318	26590
016	Shed	Partial	Summer	07/12/10	36	13:28	50	46.1	24.0	84	28.0	44.8	51318	26590
021	Shed	Partial	Summer	15/12/10	44	9:00	80	75.9	28.4	61	21.7	37.0	39715	14655
026	Shed	Partial	Summer	15/12/10	44	11:56	100	95.8	31.9	51	21.7	37.0	39715	14655
063	Shed	Partial	Winter	19/07/11	34	10:27	82	78.8	18.6	45	27.4	31.3	50286	25921
068	Shed	Partial	Winter	19/07/11	34	14:05	82	78.8	21.6	29	27.4	31.3	50286	25921
079	Shed	Partial	Winter	27/07/11	42	10:24	44	42.7	20.7	39	24.0	30.8	43935	16333
084	Shed	Partial	Winter	27/07/11	42	13:38	73	70.1	25.7	26	24.0	30.8	43935	16333

Sample Number	Odour Concentration (ou/m^2)	Odour Emission Rate OER† (ou/s)	OER† (ou/s/bird)	OER† (ou/s/1000 birds)	OER† (ou/s/1000 birds placed)	OER† (ou/s/kg)	OER† ($ou/s/kg/m^2$)
013	724	33376	1.26	1255.22	1234	0.65	1190
016	512	23603	0.89	887.67	873	0.46	842
021	594	45085	3.08	3076.40	1667	1.14	2077
026	1722	164968	11.26	11256.75	6101	4.15	7601
063	120	9456	0.36	364.80	354	0.19	344
068	181	14263	0.55	550.24	534	0.28	519
079	469	20026	1.23	1226.13	749	0.46	834
084	406	28461	1.74	1742.52	1065	0.65	1185

† Geometric mean of duplicate olfactometry measurements

Appendix B—Farm B, Shed Odour Emission Results

Sample Number	Farm	Odour Source	Litter Reuse	Season	Date (ddmmyy)	Batch Age (Days)	Collection Time (hh:mm)	Ventilation Status (% of max fan activity)	Ventilation Rate (m^3/s)	Ambient Temperature (°C)	Ambient Relative Humidity (%)	Bird weight Distribution (kg/m^2)	Average Litter Moisture Content % (Wet Basis)	Total Live weight	Number of Birds
039	B	Shed	Partial	Summer	18/02/11	32	10:20	100	83.70	29.7	60.4	25.2	37.0	39312	23826
042	B	Shed	Partial	Summer	18/02/11	32	13:00	100	83.70	31.6	49.3	25.2	37.0	39312	23826
047	B	Shed	Partial	Summer	02/03/11	44	10:22	100	83.70	30.2	64.9	12.13	30.0	18919	6855
052	B	Shed	Partial	Summer	02/03/11	44	13:31	100	83.70	31.6	62.1	12.13	30.0	18919	6855
089*	B	Shed	Partial	Winter	09/08/11	34	11:14	-	98.78	21.2	32.5	29.09	29.7	45384	23394
089**	B	Shed	Partial	Winter	09/08/11	34	11:14	-	58.68	21.2	32.5	29.09	29.7	45384	23394
094*	B	Shed	Partial	Winter	09/08/11	34	15:08	-	77.24	20.1	28.0	29.09	29.7	45384	23394
094**	B	Shed	Partial	Winter	09/08/11	34	15:08	-	45.59	20.1	28.0	29.09	29.7	45384	23394
099*	B	Shed	Partial	Winter	17/08/11	42	10:35	-	55.66	20.5	58.8	18.65	28.4	29098	11456
099**	B	Shed	Partial	Winter	17/08/11	42	10:35	-	86.80	20.5	58.8	18.65	28.4	29098	11456
104*	B	Shed	Partial	Winter	17/08/11	42	13:37	-	45.47	19.1	60.7	18.64	28.4	29098	11456
104**	B	Shed	Partial	Winter	17/08/11	42	13:37	-	21.69	19.1	60.7	18.64	28.4	29098	11456

*Calculated using “Option A” for natural ventilation (see Natural Ventilation Rate—Option A)

** Calculated using “Option B” for natural ventilation (see Natural Ventilation Rate— Option B)

Sample Number	Farm	Odour Concentration (ou)	Odour Emission Rate OER† (ou/s)	OER† (ou/s/bird)	OER† (ou/s/1000 birds)	OER† (ou/s/1000 birds placed)	OER† (ou/s/kg)	OER† (ou/s/kg/m²)
039	B	761	63696	2.67	2673.37	2568	1.62	2528
042	B	966	80854	3.39	3393.53	3260	2.06	3208
047	B	378	31639	4.26	4615.40	1276	1.67	2609
052	B	1311	109731	16.01	16007.40	4425	5.80	9048
089*	B	323	31906	1.36	1363.85	1316	0.70	1097
089**	B	323	18954	0.81	810.19	782	0.42	651
094*	B	676	52214	2.23	2231.95	2154	1.15	1795
094**	B	676	30819	1.32	1317.38	1271	0.68	1059
099*	B	171	9518	0.83	830.82	393	0.33	510
099**	B	171	14843	1.30	1295.64	612	0.51	796
104*	B	137	6229	0.54	543.77	257	0.21	334
104**	B	137	2972	0.26	259.39	123	0.10	159

†Geometric mean of duplicate olfactometry measurements

*Calculated using “Option A” for natural ventilation (see Natural Ventilation Rate— Option A)

**Calculated using “Option B” for natural ventilation (see Natural Ventilation Rate—Option B)

Appendix C—Farm A, Range Odour Emission Results

Sample Number	Odour Source	Season	Date (ddmmyy)	Batch Age (Days)	Barometric Pressure (kPa)	Ambient Temperature (°C)	Area (m^2)	Odour Concentration (ou)	OER ($ou.m^3./ m^2.s$)†	OER for Each Area ($ou.m^3/s$)††
003	Control Grass	Summer	22/11/10	20	100.1	26.6	1920	121	0.072	138.45
004	Control Grass	Summer	22/11/10	20	100.1	25.3	1920	78	0.046	89.25
005	Under Shades	Summer	22/11/10	20	100.2	25.3	354	64	0.038	13.53
006	Open Sunlight	Summer	22/11/10	20	100.2	26.8	1520	107	0.064	96.94
009	Control Grass	Summer	07/12/10	37	101.1	25	1920	128	0.070	133.93
010	Open Sunlight	Summer	07/12/10	37	101.1	25	1520	73	0.040	60.48
011	Control Grass	Summer	07/12/10	37	101.0	26.5	1920	98	0.053	101.93
012	Under Trees	Summer	07/12/10	37	101.0	26.3	22.5	342	0.185	4.17
014	Under Shades	Summer	07/12/10	37	101.0	25.5	354	287	0.156	55.34
015	Pop-Hole Exit	Summer	07/12/10	37	101.0	25.3	22	767	0.417	9.39
019	Control Grass	Summer	15/12/10	44	100.8	27.8	1920	45	0.024	46.51
020	Open Sunlight	Summer	15/12/10	44	100.7	31.7	1520	416	0.221	335.98
022	Control Grass	Summer	15/12/10	44	100.8	29.6	1920	85	0.045	87.33
023	Under Shades	Summer	15/12/10	44	100.8	29.6	354	103	0.055	19.55
024	Under Trees	Summer	15/12/10	44	100.8	28	22	609	0.328	7.37
025	Pop-Hole Exit	Summer	15/12/10	44	100.6	31.8	22	1722	0.913	20.54
055	Control Grass	Winter	05/07/11	20	101.4	21.2	1920	24	0.014	26.88
056	Open Sunlight	Winter	05/07/11	20	101.3	21.5	22	20	0.012	18.24

Appendix C cont'd—Farm A, Range Odour Emission Results

Sample Number	Odour Source	Season	Date (ddmmyy)	Batch Age (Days)	Barometric Pressure (kPa)	Ambient Temperature (°C)	Area (m^2)	Odour Concentration (ou)	OER ($ou.m^3./ m^2.s$)†	OER for Each Area ($ou.m^3/s$)††
057	Control Grass	Winter	05/07/11	20	101.2	23.1	1920	37	0.022	42.24
058	Under Shades	Winter	05/07/11	20	101.2	23.1	354	22	0.013	4.62
061	Control Grass	Winter	19/07/11	34	101.3	18.2	1920	84	0.051	97.92
062	Open Sunlight	Winter	19/07/11	34	101.3	18.4	1520	41	0.025	38.01
064	Control Grass	Winter	19/07/11	34	101.2	20.1	1920	73	0.044	84.48
065	Under Shades	Winter	19/07/11	34	101.1	20.4	354	47	0.028	9.93
066	Under Trees	Winter	19/07/11	34	101.1	21.1	22	42	0.025	0.56
067	Pop-Hole Exit	Winter	19/07/11	34	101.1	21.3	22	24	0.014	0.32
077	Control Grass	Winter	27/07/11	42	102.2	19.9	1920	22	0.013	24.96
078	Open Sunlight	Winter	27/07/11	42	102.2	20.6	1520	30	0.018	27.36
080	Control Grass	Winter	27/07/11	42	102.1	22.8	1920	76	0.045	86.4
081	Under Shades	Winter	27/07/11	42	102.1	23.5	354	42	0.025	8.87
082	Under Trees	Winter	27/07/11	42	101.2	25.7	22	22	0.013	0.29
083	Pop-Hole Exit	Winter	27/07/11	42	101.1	25.6	22	181	0.107	2.41

†Specific odour emission rate from source

††Odour emission rate with respect to area of source

‡ Below detection limit. Or result not to standard

Control Blank Odour Results

Sample Number	Odour Source	Season	Date (ddmmyy)	Batch Age (Days)	Barometric Pressure (kPa)	Ambient Temperature (°C)	Area (m^2)	Odour Concentration (ou)	OER ($ou.m^3./ m^2.s$) [†]	Total OER for Each Area ($ou.m^3/s$) [††]
001	Stainless Steel	Summer	22/11/10	n/a	100.1	25.0	n/a	29[‡]	0.017	n/a
002	Stainless Steel	Summer	22/11/10	n/a	100.1	25.0	n/a	22	0.013	n/a
007	Stainless Steel	Summer	07/12/10	n/a	101.1	24.0	n/a	45[‡]	0.025	n/a
008	Stainless Steel	Summer	07/12/10	n/a	101.1	24.0	n/a	36	0.020	n/a
017	Stainless Steel	Summer	15/12/10	n/a	101.0	20.0	n/a	55	0.030	n/a
018	Stainless Steel	Summer	15/12/10	n/a	101.0	20.0	n/a	39	0.022	n/a
053	Stainless Steel	Winter	05/07/11	n/a	94.3	14.1	n/a	63[‡]	0.036	n/a
054	Stainless Steel	Winter	05/07/11	n/a	94.3	14.1	n/a	39[‡]	0.022	n/a
059	Stainless Steel	Winter	19/07/11	n/a	94.1	7.6	n/a	13[‡]	0.076	n/a
060	Stainless Steel	Winter	19/07/11	n/a	94.1	7.6	n/a	11[‡]	0.006	n/a
075	Stainless Steel	Winter	27/07/11	n/a	94.8	9.6	n/a	14[‡]	0.008	n/a
076	Stainless Steel	Winter	27/07/11	n/a	94.8	9.6	n/a	0[‡]	0.006	n/a

[†]Specific odour emission rate from source

[††]Odour emission rate with respect to area of source

[‡]Below detection limit. Or result not to standard

Appendix D—Farm B, Range Odour Results

Sample Number	Odour Source	Season	Date (ddmmyy)	Batch Age (Days)	Barometric Pressure (kPa)	Ambient Temperature (°C)	Area (m^2)	Odour Concentration (ou)	OER ($ou.m^3./ m^2.s$)†	Total OER for Each Area ($ou.m^3/s$)††
029	Control Grass	Summer	02/02/11	16	100.8	32.0	3525	63	0.036	127.05
030	Open Sunlight	Summer	02/02/11	16	100.8	32.1	2937	34	0.019	57.11
031	Control Grass	Summer	02/02/11	16	100.7	33.2	3525.3	31	0.018	62.21
032	Under Shades	Summer	02/02/11	16	100.7	33.0	540	34	0.019	10.46
035	Control Grass	Summer	18/02/11	32	100.4	28.7	3525	86	0.050	174.64
036	Open Sunlight	Summer	18/02/11	32	100.4	29.1	2937	64	0.037	108.14
037	Control Grass	Summer	18/02/11	32	100.4	30.0	3525	78	0.045	157.71
038	Under Shades	Summer	18/02/11	32	100.3	30.6	540	215	0.123	66.42
040	Under Trees	Summer	18/02/11	32	100.3	31.7	7	107	0.061	0.43
041	Pop-Hole Exit	Summer	18/02/11	32	100.3	30.9	41	1625	0.928	31.09
045	Control Grass	Summer	02/03/11	44	100.3	27.9	3525	103	0.059	207.99
046	Open Sunlight	Summer	02/03/11	44	100.3	28.6	2937	297	0.171	502.38
048	Control Grass	Summer	02/03/11	44	100.2	30.2	3525	256	0.146	514.38
049	Under Shades	Summer	02/03/11	44	100.2	31.3	540	199	0.113	61.02
050	Under Trees	Summer	02/03/11	44	100.2	31.6	7	297	0.169	1.18
051	Pop-Hole Exit	Summer	02/03/11	44	100.2	31.6	41	1599	0.910	37.34
071	Control Grass	Winter	26/07/11	20	101.3	18.5	3525	30	0.018	63.45

Appendix D cont'd— Farm B, Range Odour Results

Sample Number	Odour Source	Season	Date (ddmmyy)	Batch Age (Days)	Barometric Pressure (kPa)	Ambient Temperature (°C)	Area (m^2)	Odour Concentration (ou)	OER ($ou.m^3./ m^2.s$)†	Total OER for Each Area ($ou.m^3/s$)††
072	Open Sunlight	Winter	26/07/11	20	101.3	18.6	2937.26	0‡	0.000	0.00
073	Control Grass	Winter	26/07/11	20	101.2	20.8	3525	22	0.013	45.82
074	Under Shades	Winter	26/07/11	20	101.1	21.1	540	35	0.021	11.34
087	Control Grass	Winter	09/08/11	34	100.1	19.2	3525	26	0.015	54.37
088	Open Sunlight	Winter	09/08/11	34	100.1	19.2	2937	28	0.017	48.78
090	Control Grass	Winter	09/08/11	34	100.1	20.8	3525	107	0.063	222.23
091	Under Shades	Winter	09/08/11	34	100.0	21.5	540	40	0.023	12.68
092	Under Trees	Winter	09/08/11	34	99.9	22.2	7	0‡	0.000	0.00
093	Pop-Hole Exit	Winter	09/08/11	34	99.8	21.3	41	1663	0.976	40.06
097	Control Grass	Winter	17/08/11	42	101.1	21.2	3525	59	0.035	123.38
098	Open Sunlight	Winter	17/08/11	42	101.0	20.6	2937	59	0.018	54.27
100	Control Grass	Winter	17/08/11	42	101.0	20.6	3525	72	0.043	151.58
101	Under Shades	Winter	17/08/11	42	101.0	19.9	540	128	0.076	41.22
102	Under Trees	Winter	17/08/11	42	101.0	19.2	7	203	0.121	0.59
103	Pop-Hole Exit	Winter	17/08/11	42	101.0	19.1	41	1218	0.727	29.86

†Specific odour emission rate from source

††Odour emission rate with respect to area of source

‡ Below detection limit. Or result not to standard.

Control Blank Odour Results

Sample Number	Odour Source	Season	Date (ddmmyy)	Batch Age (Days)	Barometric Pressure (kPa)	Ambient Temperature (°C)	Area (m^2)	Concentration (ou)	OER ($ou.m^3./ m^2.s$) †	Total OER for Each Area ($ou.m^3/s$) ††
027	Stainless Steel	Summer	02/02/11	n/a	94.5	24.2	n/a	128‡	0.070	n/a
028	Stainless Steel	Summer	02/02/11	n/a	94.5	24.2	n/a	64‡	0.035	n/a
033	Stainless Steel	Summer	18/02/11	n/a	94.1	21.9	n/a	18‡	0.010	n/a
034	Stainless Steel	Summer	18/02/11	n/a	94.1	21.9	n/a	18‡	0.010	n/a
043	Stainless Steel	Summer	02/03/11	n/a	94.1	22.6	n/a	31‡	0.017	n/a
044	Stainless Steel	Summer	02/03/11	n/a	94.1	22.6	n/a	22‡	0.012	n/a
069	Stainless Steel	Winter	26/07/11	n/a	94.7	10.2	n/a	14‡	0.008	n/a
070	Stainless Steel	Winter	26/07/11	n/a	94.7	10.2	n/a	11‡	0.006	n/a
085	Stainless Steel	Winter	09/08/11	n/a	98.8	11.8	n/a	45‡	0.000	n/a
086	Stainless Steel	Winter	09/08/11	n/a	98.8	11.8	n/a	45‡	0.000	n/a
095	Stainless Steel	Winter	17/08/11	n/a	94.4	13.2	n/a	22‡	0.000	n/a
096	Stainless Steel	Winter	17/08/11	n/a	94.4	13.2	n/a	22‡	0.000	n/a

†Specific odour emission rate from source

††Odour emission rate with respect to area of source

‡ Below detection limit. Or result not to standard.

Appendix E—Soil Nutrient Accumulation Results, 0-30 cm

Farm	Replicate	Nitrate (mg/kg)	Ammonium (mg/kg)	Total N (%)	Total P (%)	Colwell P (mg/kg)
A	1	<0.50	4.3	0.052	0.019	15
A	2	2.3	3.6	0.050	0.006	16
A	3	6.1	5.5	0.051	0.027	17
B	1	1.5	2.3	0.044	0.140	24
B	2	4.8	3.9	0.100	0.180	54
B	3	3.0	1.9	0.051	0.034	5.9
C	1	5.4	7.3	0.110	0.076	48
C	2	6.1	11.0	0.110	0.032	34
C	3	11.0	10.0	0.099	0.031	38
D	1	12.0	9.7	0.110	0.032	53
D	2	8.1	13.0	0.084	0.031	48
D	3	5.6	14.0	0.076	0.017	22
E	1	7.3	6.7	0.071	0.060	67
E	2	26.0	25	0.063	0.032	37
E	3	18.0	14	0.180	0.051	110
F	1	2.7	5.5	0.086	0.036	110
F	2	2.2	7.0	0.082	0.024	50
F	3	2.7	7.2	0.120	0.027	80
G	1	16.0	3.3	0.190	0.039	85
G	2	22.0	2.6	0.140	0.021	41
G	3	15.0	6.9	0.120	0.009	46

Appendix E cont'd— Soil Nutrient Accumulation Results, 0-30 cm

Farm	Replicate	Nitrate (mg/kg)	Ammonium (mg/kg)	Total N (%)	Total P (%)	Colwell P (mg/kg)
H	1	10.6	5.5	0.012	0.051	45
H	2	9.8	4.3	0.210	0.021	33
H	3	6.6	3.2	0.150	0.043	48
I	1	9.4	4.6	0.280	0.092	89
I	2	7.3	6.8	0.160	0.053	9.6
I	3	20.0	5.0	0.240	0.074	83
J	1	9.4	4.6	0.230	0.036	96
J	2	11.0	3.5	0.230	0.038	82
J	3	17.0	5.4	0.260	0.036	140
K	1	24.0	5.7	0.200	0.063	360
K	2	18.0	10.0	0.190	0.066	280
K	3	3.7	15.0	0.200	0.030	100

Control Results

Farm	Nitrate (mg/kg)	Ammonium (mg/kg)	Total N (%)	Total P (%)	Colwell P (mg/kg)
A	7.0	2.4	0.088	0.075	220
B	6.9	2.7	0.140	0.100	300
C	7.8	7.6	0.200	0.059	83
D	0.5	4.8	0.120	0.014	7.6
E	4.9	3.0	0.110	0.087	86
F	5.9	4.7	0.091	0.024	16
G	18.0	4.1	0.160	0.130	330
H	7.8	3.2	0.140	0.013	52
I	13.0	4.2	0.280	0.092	89
J	4.9	2.0	0.200	0.014	27
K	3.1	3.5	0.14	0.019	51

Appendix F—Soil Nutrient Accumulation Results, 30-90 cm

Farm	Replicate	Nitrate (mg/kg)	Ammonium (mg/kg)
A	1	0.5	2.0
A	2	0.6	1.8
A	3	3.9	1.6
B	1	-	-
B	2	-	-
B	3	-	-
C	1	-	-
C	2	-	-
C	3	-	-
D	1	3.8	1.3
D	2	1.9	1.5
D	3	0.5	1.9
E	1	23.0	2.6
E	2	0.8	5.8
E	3	0.8	5.8
F	1	0.5	1.4
F	2	0.5	1.2
F	3	0.5	1.3
G	1	18.0	1.9
G	2	21.0	0.9
G	3	20.0	2.0

Farm	Replicate	Nitrate (mg/kg)	Ammonium (mg/kg)
H	1	1.8	2.2
H	2	2.3	3.0
H	3	2.8	1.6
I	1	4.2	1.6
I	2	6.0	1.6
I	3	19.0	1.7
J	1	3.7	1.5
J	2	0.5	1.9
J	3	4.1	1.5
K	1	19.0	1.8
K	2	8.2	1.6
K	3	3.3	11.0

Control Results

Farm	Nitrate (mg/kg)	Ammonium (mg/kg)
A	1.2	2.1
B	-	-
C	-	-
D	0.5	4.8
E	0.6	1.7
F	2.2	1.6
G	7.8	0.6
H	3.2	1.6
I	34.0	1.3
J	1.2	0.9
K	2.7	1.3

Note: At farms ‘B’ and ‘C’ depths >30cm were not able to be reached.

Appendix G—Farm A, Range Runoff Concentration Results

Date	Runoff Volume (L)	Rainfall Event Intensity	Bird Age (days)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Soluble Reactive Phosphorus (mg/L)
13/12/12	N/A	< 1 Year Event	43	5.50	1.10	0.120	0.039	3.400	0.800
24/01/12	N/A	2-5 Year Event	54 (+7)	4.40	1.80	0.027	0.015	0.820	1.500
27/01/12	444930	2-5 Year Event	1	3.60	1.30	0.370	0.051	1.800	1.300
31/01/12	91899	< 1 Year Event	6	3.70	2.00	0.140	0.098	0.480	1.900
13/02/12	22518	< 1 Year Event	14	6.90	2.70	1.600	0.077	0.750	2.400
15/02/12	34242	< 1 Year Event	16	5.80	1.80	1.300	0.054	2.400	1.600
21/02/12	2490	< 1 Year Event	22	9.00	2.10	0.340	0.180	3.000	1.800
23/02/12	660	< 1 Year Event	24	8.00	2..70	0.130	0.090	1.200	2.200
27/02/12	299796	< 1 Year Event	28	3.80	1.60	0.360	0.091	1.100	1.300
06/03/12	35202	< 1 Year Event	30	4.90	2.40	0.140	0.034	0.630	2.400
08/03/12	13383	< 1 Year Event	33	4.40	1.60	0.093	0.100	0.330	1.200
19/03/12	29973	< 1 Year Event	35	6.60	2.10	0.650	0.220	2.300	2.100
23/03/12	22059	< 1 Year Event	36	6.10	2.10	0.110	0.410	2.100	1.500
30/04/12	92988	< 1 Year Event	37	4.90	1.40	0.340	0.038	3.400	1.400
12/11/12	41744	< 1 Year Event	46	11.00	3.10	5.000	0.260	2.600	3.00
01/02/13	622554	5-10 Year Event	46	2.70	1.50	1.800	0.020	1.400	0.570
18/02/13	45000	< 1 Year Event	47(+1)	11.00	2.00	0.060	0.037	0.520	0.900
21/02/13	337423	< 1 Year Event	49(+2)	4.60	1.70	0.480	0.062	1.600	1.700
28/02/13	488955	2-5 Year Event	51(+5)	3.90	2.20	1.40	0.660	2.000	3.100
05/03/13	512682	2-5 Year Event	52(+5)	3.20	1.90	0.140	0.190	1.200	1.500

Control Runoff Results

Date	Runoff Volume (L)	Rainfall Event Intensity	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Soluble Reactive Phosphorus (mg/L)
08/12/11	56760	< 1 Year Event	15.00	2.30	0.16	0.160	9.70	1.90
13/12/11	3900	< 1 Year Event	11.00	2.40	0.15	0.150	5.10	2.00
18/01/12	22044	< 1 Year Event	11.00	3.20	0.02	0.120	4.50	2.90
24/01/12	52464	2-5 Year Event	6.20	2.30	0.08	0.014	2.30	2.00
27/01/12	313113	2-5 Year Event	3.80	1.90	0.11	0.048	1.10	1.90
31/01/12	116514	< 1 Year Event	5.10	4.40	0.11	0.089	0.23	4.40
13/02/12	30855	< 1 Year Event	8.20	4.20	0.67	0.220	2.40	3.80
15/02/12	26043	< 1 Year Event	4.70	2.10	0.23	0.034	0.80	1.90
21/02/12	9912	< 1 Year Event	7.00	3.00	0.09	0.046	2.90	2.90
23/02/12	6840	< 1 Year Event	4.50	2.20	0.02	0.026	1.10	1.90
27/02/12	246168	< 1 Year Event	3.50	2.20	0.11	0.020	0.37	2.10
06/03/12	75450	< 1 Year Event	4.10	1.10	0.12	0.037	0.17	0.87
08/03/12	12264	< 1 Year Event	5.80	4.10	0.04	0.047	0.27	3.90
15/03/12	13122	< 1 Year Event	6.40	2.20	0.51	0.072	2.40	2.00
19/03/12	37722	< 1 Year Event	4.50	2.20	0.43	0.075	0.67	2.00
23/03/12	32523	< 1 Year Event	4.90	2.30	0.11	0.089	0.40	2.30
16/04/12	4560	< 1 Year Event	2.20	1.40	0.10	0.015	0.24	1.20
30/04/12	117195	< 1 Year Event	3.20	1.40	0.14	0.027	1.60	1.30
29/06/12	77439	< 1 Year Event	4.80	1.50	0.16	0.002	0.44	1.20
12/11/12	22871	< 1 Year Event	9.70	1.90	0.10	0.012	6.40	1.40
01/02/13	389805	5-10 Year Event	2.30	0.34	1.70	0.022	0.31	0.07
18/02/13	25000	< 1 Year Event	9.50	2.90	0.39	0.100	3.70	2.80
21/02/13	15636	< 1 Year Event	5.80	2.90	0.86	0.100	1.80	2.20
28/02/13	36045	2-5 Year Event	3.40	2.00	0.13	0.084	0.74	1.90
05/03/13	45980	2-5 Year Event	1.90	2.30	0.12	0.038	0.53	2.10

Appendix H—Farm C, Range Runoff Concentration Results

Date	Runoff Volume (L)	Rainfall Event Intensity	Bird Age (days)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Soluble Reactive Phosphorus (mg/L)
8/12/11	57315	< 1 Year Event	48	10.00	2.50	1.90	0.500	4.40	2.20
13/12/11	9978	< 1 Year Event	48 (+1)	7.80	1.20	0.53	0.260	3.00	0.91
26/12/11	138072	< 1 Year Event	8	7.80	2.10	0.67	0.130	3.60	1.90
18/01/12	59676	< 1 Year Event	14	10.00	2.40	1.60	0.130	2.00	2.00
24/01/12	428406	10-20 Year Event	20	7.20	2.40	2.30	0.130	1.80	2.10
27/01/12	548703	10-20 Year Event	23	3.50	1.70	1.80	0.058	0.50	1.70
31/01/12	10500	< 1 Year Event	46	4.90	3.00	0.65	0.160	0.37	3.00
15/02/12	63618	< 1 Year Event	4	13.0	3.00	3.30	0.076	6.30	2.90
23/02/12	32736	< 1 Year Event	12	9.00	2.00	0.58	0.060	5.70	1.90
27/02/12	306333	5-10 Year Event	16	4.60	1.50	0.53	0.047	2.10	1.50
06/03/12	73464	< 1 Year Event	24	5.30	1.50	0.40	0.045	0.99	1.40
15/03/12	41580	< 1 Year Event	33	9.80	2.20	1.90	0.110	0.57	1.60
19/03/12	20964	< 1 Year Event	37	17.00	4.30	8.20	0.460	2.20	3.80
23/03/12	26376	< 1 Year Event	41	11.00	3.70	7.30	0.230	0.18	3.60
16/04/12	90525	< 1 Year Event	8	10.00	1.80	0.63	0.086	6.90	1.60
18/04/12	39291	< 1 Year Event	10	4.80	1.80	0.57	2.200	0.07	1.70
30/04/12	373935	5-10 Year Event	22	5.10	2.20	0.67	0.025	3.90	2.20
29/06/12	103719	< 1 Year Event	29	9.80	1.50	0.88	0.007	4.70	1.50
27/09/12	42222	< 1 Year Event	13	5.90	3.70	4.10	0.530	5.40	3.60
12/11/12	16584	< 1 Year Event	32	7.00	3.00	0.87	0.110	2.60	2.60
28/12/12	22385	< 1 Year Event	34	8.80	5.90	3.30	0.210	2.40	5.50
30/01/13	395073	5-10 Year Event	15	5.40	5.40	0.93	0.190	3.00	5.30
18/02/13	400125	5-10 Year Event	37	6.2	2.50	1.10	0.064	0.98	2.20

Date	Runoff Volume (L)	Rainfall Event Intensity	Bird Age (days)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Soluble Reactive Phosphorus (mg/L)
21/02/13	205461	1- 5 Year Event	40	5.0	3.30	1.10	0.150	1.30	3.20
28/02/13	455910	5-10 Year Event	47	4.1	2.90	0.95	0.150	1.20	2.80
05/03/13	412650	5-10 Year Event	54 (+7)	4.1	2.60	0.89	0.200	1.50	2.60

Control Runoff Results

Date	Runoff Volume (L)	Rainfall Event Intensity	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Soluble Reactive Phosphorus (mg/L)
24/01/12	N/A	10-20 Year Event	0.75	0.57	0.008	0.005	0.000	0.450
27/01/12	174819	10-20 Year Event	0.70	0.51	0.014	0.006	0.000	0.450
31/01/12	N/A	< 1 Year Event	0.64	0.44	0.008	0.004	0.000	0.450
23/02/12	1126	< 1 Year Event	1.30	0.24	0.012	0.005	0.000	0.410
27/02/12	62379	5-10 Year Event	1.10	0.53	0.026	0.027	0.000	0.086
06/03/12	390	< 1 Year Event	1.40	0.23	0.160	0.011	0.110	0.390
23/03/12	1635	< 1 Year Event	0.38	0.11	0.015	0.004	0.000	0.100
16/04/12	553	< 1 Year Event	0.61	0.16	0.022	0.028	0.000	0.760
18/04/12	1687	< 1 Year Event	0.49	0.14	0.006	0.005	0.000	0.083
30/04/12	50480	< 1 Year Event	0.94	0.45	0.015	0.005	0.000	0.051
29/06/12	17896	< 1 Year Event	1.10	0.13	0.190	0.002	0.150	0.036
28/12/12	15000	< 1 Year Event	2.20	0.60	0.120	0.010	0.020	0.480
30/01/13	24001	5-10 Year Event	0.57	0.29	0.025	0.007	0.020	0.280
18/02/13	27060	5-10 Year Event	5.60	0.55	0.120	0.020	0.170	0.100
21/02/13	83694	2- 5 Year Event	1.50	0.58	0.027	0.010	0.020	0.580
28/02/13	370358	5-10 Year Event	0.99	0.99	0.060	0.020	0.073	0.500
05/03/13	201530	5-10 Year Event	0.97	0.46	0.060	0.020	0.020	0.310

Appendix I—Rainfall Data for the Runoff Trial, Historical and Recorded

Recorded rainfall during runoff trial period for Farm A (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2011	-	-	-	-	-	-	-	-	-	-	28.4	77	
2012	306	165	78.8	76.4	12.8	107	46	0.6	18.2	24	73.6	48	975.4
2013	250	172	95.8	-	-	-	-	-	-	-	-	-	
Mean	278	168.8	96.8	76.4	12.8	107	46	0.6	18.2	24	51	62.5	942.1

Historical average monthly rainfall for BOM weather station near Farm A 1983 – 2013 (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	118.5	111.9	89	83.1	84.9	51.7	38.1	32	35.1	64.8	93.9	137.2	929.3

Recorded rainfall during runoff trial period for Farm C (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2011	-	-	-	-	-	-	-	-	-	-	-	186.8	
2012	483	189	112	213	21.4	170	52.6	0.0	37.2	25.4	70.2	59.2	1435.8
2013	174	357	158	-	-	-	-	-	-	-	-	-	
Mean	328.9	273.6	135.5	213.4	21.4	170.6	52.6	0.0	37.2	25.4	70.2	123	1451.9

Historical average monthly rainfall for BOM weather station near Farm C 1953 – 2013 (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	160.9	164.1	162.1	106.6	112.1	88.1	61.3	52.2	38.3	83.8	102.7	142.2	1271.2

Free Range Chicken – Odour Emissions and Nutrient Management

By Grant Brown and Erin Gallagher

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There is currently a lack of information relating to odour emissions and nutrient loss on free range meat chicken farms.
This report focuses on odour emissions from sheds and the free range area, as well as potential nitrogen and phosphorus loss in the soil and in runoff from the range areas.
Improved understanding of the emissions from free range farms will support the continued growth of the free range sector in Australia.

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