Linking Production and Financial Metrics in Agriculture

A report for

By James L. Walker

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Executive Summary

Production performance monitoring (that is, the periodic monitoring of an animal's production performance through objective data feeds) is on the verge of revolutionising animal management. When this occurs it will transform agriculture and animal management.

At the time of writing this report, advancements in such monitoring are compounding rapidly which will generate opportunities to address reproductive wastage in sheep production.

The key findings of the report are:

- With frequent accurate production performance monitoring there is increased control of the breeding ewe's performance throughout the breeding schedule.
- With frequent, accurate, production performance monitoring there is increased opportunity for intensive breeding systems in rangeland Merino sheep breeding.
- There are technologies currently available which can be adapted for rangeland sheep enterprises.

Additional findings: The consequences of establishing performance optics

- The greatest component of successful enterprise management is not production performance but understanding the financial impact of varying the production performance, which will contribute to more profitable decision-making.
- Once production performance and financial potential are linked in an enterprise; new and compelling opportunities for improved profitability can be understood by the owner/manager.

The implications include:

- The ability to accurately decide how to monitor and control animal health to optimise animal performance.
- Monitoring and improving management decisions by stakeholders in animal husbandry disciplines.
- Opportunity for regional, state, national and international species-specific benchmarking of animals, and physical traits.
- Increases in investment in grazing enterprises, and animal management industries with the development of a link between production and financial metrics.

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Foreword

Growing up, my first living memory of the relationship between the human race and the land was when I was a young boy visiting my grandfather; I could remember a compelling photograph on my Grandfather's office wall. It was a captivating photo of the world with all its blues, browns, greens and greys. I would always be drawn to it and look at it in wonder. It was a photo given to my grandfather by US astronaut, Colonel David Scott, thanking him for hospitality while he visited Longreach. It stated "The World... what an Amazing Place". Looking upon that photo with all the complexities of the clouds, the sea and the land, it truly is an amazing place and one that we should value, and cherish greatly.

This Nuffield Scholarship is the result of managing the animal husbandry of approximately 20,000 sheep per annum in a semi-arid environment throughout the past 15 years. During this time I developed systems to improve the sheep enterprise productivity within variable seasonal conditions. The intentions of developing this system were to raise the ability for the individual sheep to perform to biological potential in harmony with the available resources and financial requirements. During this time provisions were made with production infrastructure including over 42 new watering points, with a two kilometre maximum distance between watering points for the sheep to walk. The size of the property developed was 28,000 hectares and I found, due to the reduction in distance between watering points and the delivery of clean filtered water, the health and condition of the sheep dramatically improved, and productivity was lifted.

Figure 1Water Infrastructure at Wakefield Station, Isisford

Source: Walker Photo Archives

In 2009, with the Australian National Flock at an all-time low and our infrastructure at its best, we attempted a rapid breeding programme by lambing three times in two years. This strategy had varying success and was limited by the condition of the breeding ewe at critical times during pregnancy and lambing.

From 2010 the focus for our business, given that the water infrastructure was now in place, turned to the sheep's biological potential and the effects of external influences on our breeding ewe.

This Nuffield scholarship was bought about by the desire to obtain production performance data on Merino ewes for semi-arid pastoral zones, so management intervention could be activated immediately ahead of a biological impact from declining nutrition. Although biological processes involving living organisms have always been considered too complex to be monitored and controlled automatically, new technologies offer possibilities to develop full automatic on-line monitoring and control of many of these processes. From a production performance perspective, there needs to be an understanding, not only of the critical points where nutrition supply and nutrition requirements deviate, but trigger points and trends that can anticipate these events.

Once this understanding of nutritional fluctuations can be established; management of performance to allow the natural productive potential of sheep can be realised.

Countries and states visited during my scholarship travel include:

- Netherlands
- Brussels
- France
- United Kingdom
- Ireland
- Philippines
- China
- Hong Kong
- USA
- Canada

Acknowledgments

Agriculture is an inspiring industry and, I believe, the most honourable profession in the world. It is with great pleasure that I would like to thank everyone who has contributed to this project. In particular, I would like to thank all my colleagues, mentors and teachers who have helped build my capacity and knowledge. I consider my network one of the most valuable parts of my business and social life, and within my year group and the Nuffield network of scholars I now have colleagues, teachers and mentors who, like me, aspire to greater things for global agriculture and world sustainability.

To Manny, my wife, you are truly magnificent and I look forward to propelling our goals and achievements together, based on the sacrifices made to fulfil this scholarship.

I also acknowledge my family and the efforts they made while I was on my scholarship. To my father and mother, David and Lyn; brother, Daniel, and sister-in-law, Brook; thank you for having the confidence to allow me to pursue this award.

To Jim Geltch, I am in awe and value greatly the mentorship provided over the years. I would like to take this opportunity to honour the role of Tim Harslett, and the Honourable Bruce Scott MP, for giving me the conviction to step into the arena.

Most importantly, I would also like to thank, from Australian Wool Industry, Emily King, Dr Paul Swan and CEO, Stuart McCullough for their professionalism, guidance and friendship while supporting me throughout the Nuffield journey. Thank you for allowing me to capture this body of work.

My sponsor, Australian Wool Innovation (AWI), aims to aid and assist wool producers in achieving improved outcomes for their animals, and their stakeholders. In modern society the consumer demands that corporations and industries address the 'Triple Bottom Line' in practice and innovation, and I am honoured AWI has sponsored my interest in researching this topic to implement new opportunities for the sheep and wool industry.

Abbreviations

These include:

Artificial insemination (AI)

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

Australian Wool Innovation (AWI)

Condition Score (CS)

Crude protein (CP)

Dry matter digestibility (DMD)

Global Positioning Systems (GPS)

Individual Animal Management (IAM)

Inertial Movement Analysis (IMA)

International Species Information System (ISIS)

National Livestock Identification Scheme (NLIS)

Near Infrared Scanning (NIRS)

Nitrogen (N)

Radio Frequency Identification Data (RFID)

Triboelectric Nanogenerator (TENG)

Walk Over Weighing (WOW)

Zoological Information Management System (ZIMS)

Objectives

The reason for this research is to link production performance metrics in agricultural production systems with financial metrics.

The objectives of this project are to:

- Determine the factors affecting rangeland sheep production in Australia’s pastoral industry.

- Research alternative sheep breeding practices globally.

- Research the application of performance monitoring technologies around the world.

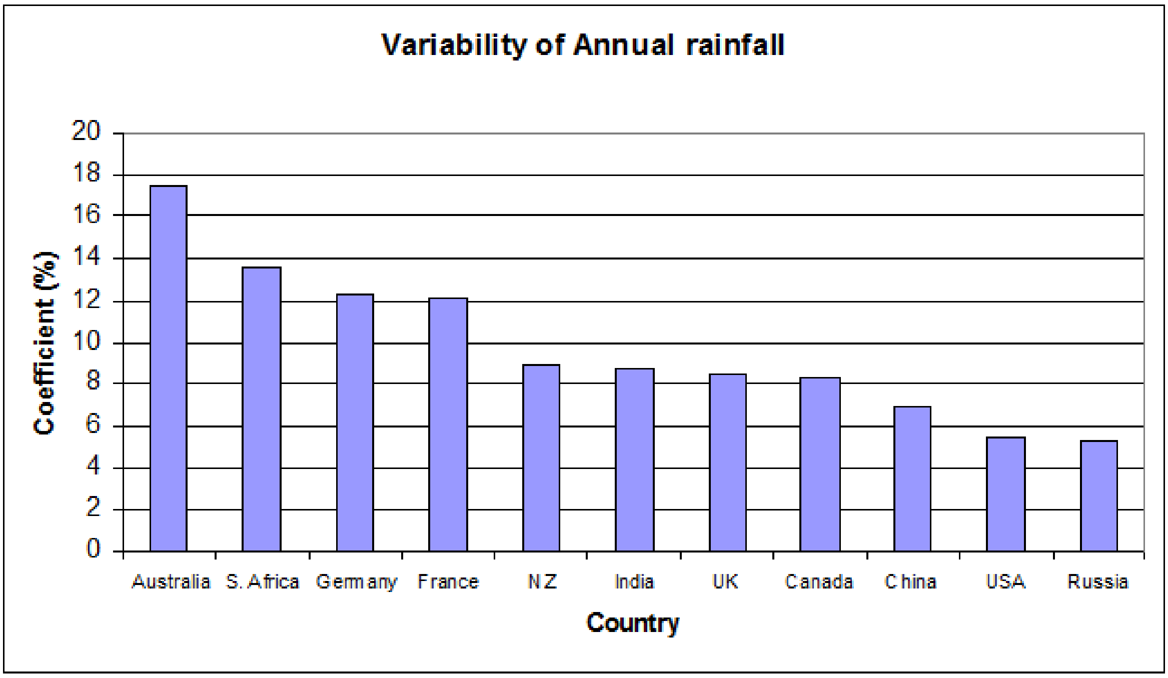
Introduction

Background

Australia has the highest rainfall variability of any continent in the World. Longreach, in Western Queensland, is one of the most highly variable rainfall regions within Australia. The implications of this high rainfall variability are significant in agriculture; planning for both cropping and livestock enterprises is improved with greater consistency of rainfall and weather conditions.

Table 1 International Rainfall Variability

Source: Professor Roger Stone, 2014



Western Queensland is classed as arid to semi-arid. Longreach, has an average of 452mm annually and a variation between 106.8mm in 2002, and 886.2mm in 2010 (Observations were drawn from Longreach Aero - station 036031).

The following map helps to illustrate the variability of rainfall within Australia.

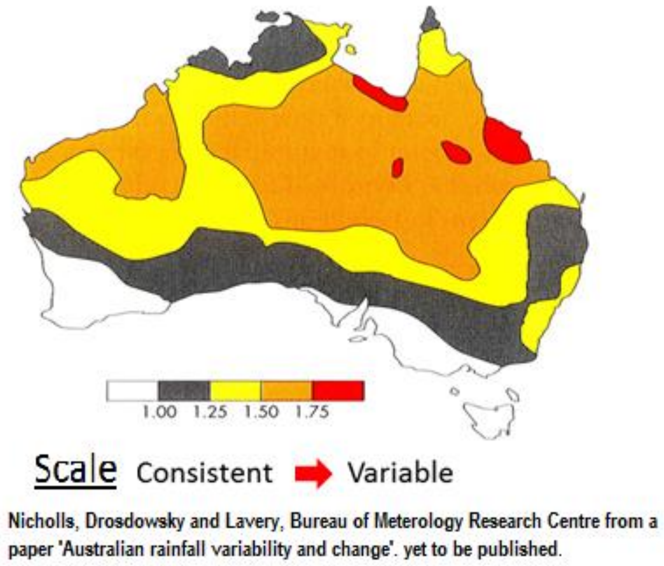


Figure 2 Rainfall variability in Australia

Source: Nicholls, Drosdowsky and Lavery, 2012

Due to rainfall variability in the arid to semi-arid regions, agricultural production systems are impossible to replicate year-on-year, impacting on financial repeatability. As illustrated below, in Western Queensland the availability of nutrition can be highly variable as a result of inconsistent rainfall; this has implications for stocking rates, and the economic opportunities available during any given season.

Photo 1a) and 1b) Wakefield Station

Source: Walker Archives 2003, 2010

Longreach Rainfall Variability

Comparing rainfall data in the years 2002 and 2010 demonstrates why establishing a consistent management system in these environments is a great challenge. In 2002 Wakefield Station recorded 106.8mm rainfall and then in 2010, 886.2mm. (Observations were drawn from Longreach Aero - station 036031). Pastoral sheep production in Western Queensland presents contrasts in available nutrition and requires a responsive management approach.

Western Queensland has four combined environmental influencing factors that affect consistent production. All these factors contribute to a very harsh environment for effective sheep production. They are

1. Nutritional deficits
2. Rainfall deficiencies,
3. Grazing competition and
4. Predation

In a pastoral semi-arid environment it is critical for reproduction performance, to objectively monitor the breeding ewes' health, particularly their correlating condition score (CS) as their biological performance is a direct consequence of available nutrition.

Photo 2 Wakefield Station

Source: Walker Archives, 2013

At the time of writing this report, the national sheep flock is recovering from an all-time low, of 68.1 million head in 2009 – 2010. (Australian Wool Production Forecast Report, 2015). In *Merinos, Money & Management* by Fred Morley (1994), contributor, Allan Wilson, after substantial research into the rangelands environment and reproductive wastage in Merinos notes:

"The marking percentage of Merinos in the rangelands is woeful. The average for the pastoral zone as a whole is about 65%, while in some regions in Qld and WA it runs at an average of 45%. When coupled with a substantial mortality, this is hardly sufficient for replacement. Sheep may or must be kept until they die of old age" (Morley, 1994).

To alter reproductive wastage the most direct management activity is to manage the health of the breeding ewe, monitor her condition and adapt practices to realise her biological potential.

"Monitoring is the continual critical assessment of the flock or property status. Monitoring of production systems is essential if standards are to be reached, maintained, and improved. "(Morley, 1994).

Sheep and wool husbandry operates with limited timely and objective data on physiology in the rangelands. This requires the animal husband to have highly acute observation skills, which can still be subjective and inaccurate.

Rangeland management efficiencies are being eroded by not being able to detect fluctuations in weights and condition scores in sheep. Adverse incidents, particularly those due to nutrition, develop progressively and the effect often is extremely difficult to identify without comparing individuals continually. Lack of proximity to the animals over vast areas contributes to the current difficulty of obtaining production performance data. Observable indicators can be delayed or lagged, and therefore management responses can lack timeliness and effectiveness, making it difficult to address nutritional deficiencies.

Current strategies used to observe the animal's health include visually identifying the moving trends and imbalances of the health and condition of the animals. The trend direction can be caused by factors such as nutritional changes, seasonal conditions, and animal behaviour, resulting from predation, or feed reserve depletion due competitive grazing by native animals. Other factors affecting individual sheep can include parasites and diseases.

Current commonly used observations of sheep health include;

- Gait and mobility
- Supplement feed consumption
- Flock behaviour
- Individual demeanour and posture
- Near Infra-Red Scanning (NIRS) for nutrition and egg faecal counts in dung
- Presence of grazing competition
- Pasture budgeting
- Lambing rates
- Moisture profiles
- Skin pigmentation
- Predictive management based on historical data
- Seasonal forecasting

Chapter 1 Condition Scoring

Body condition score (CS) is a valuable indicator for managing reproductive potential in sheep. Condition Score is calculated by a subjective, manual palpation of fat coverage on an individual sheep (refer Condition Scoring Table, Appendix 1), and is generally conducted when the sheep can be manually restrained in stockyards. It is difficult to calculate the condition scores accurately in a pastoral grazing system across an entire flock. Gathering CS regularly enables graziers to monitor patterns in sheep growth. In the semi-arid, where this data is harder to collect, patterns are therefore much harder to analyse.

Billionaire Investor Warren Buffet (2013) says, *"If you can't read the scoreboard, you don't know the score. If you don't know the score, you can't tell the winners from the losers".* In pastoral sheep production this equates to not understanding the factors contributing to the performance of livestock; moreover, it is difficult to know the financial trajectory of the enterprise.

Condition scoring of sheep has been a widely endorsed management tool by sheep industry bodies and sheep extension officers. Jefferies (1961) describes it as "*a six point scale, 0 being near death, with scores 1 to 5 being the scale used to describe 5 levels of health and condition; 5 being the maximum biological condition possible*", (Jefferies, 1961). Condition scoring is commonly used as the standard base for reference and comparison.

Condition scoring is used as a link to the nutrition a ewe is experiencing. It is also a guide to the reproductive potential of individual sheep. The link between condition score and reproductive performance is shown below, in a table used by Jonathan England, in the 2009 publication '*Visual aids to increase the awareness of condition scoring of sheep - a model approach*'.

Table 2 Condition Scoring and Conception in Sheep Flocks

Source: http://www.csu.edu.au/__data/assets/pdf_file/0011/109586/EFS_Journal_v05_n01_25_England.pdf

Condition Score	Color	Primary Message	Message
CS <2	Red	DO NOT JOIN!	20% will be dry and those that conceive twins will be in big trouble at lambing IF PREGNANT AT SCANNING FIND EXTRA FEED
CS 2.5	Orange	OK at Joining	Conception volunteers for a potential of 110% lambing. 10% higher survival of twins compared to score 2
CS 3	Green	Best at Joining	120% conception <10% are dry, 30% conceive twins Best lambing: Good lamb survival, good early lactation, good lamb growth rates, good buffer for poor weather at lambing.
CS 4	Orange	Good at Joining	140% conception. < 5% are dry, > 40% twins Careful at lambing: Increased survival of twins, decreased survival of singles? Good lamb growth rates, but stocking rate reduced?

The above table shows that condition scoring is a phenotypic ranking system. To assess the sheep, the animals must be contained and be available for manual access, which has a cost attached, making it difficult in the pastoral zones. It is, however, a relatively inexpensive monitoring tool if the assessment occurs in conjunction with other necessary management practices.

Condition Scoring can be used:

- For assessing the requirement for more or less supplementary feeding.
- Where there is a requirement to obtain a target condition score.
- To create a guide for management parameters.

The condition scores individual ewes hold in a sheep breeding enterprise can directly affect profitability. The key opportunities for collecting data on CS are at times of shearing, lamb marking, crutching, pregnancy scanning, or parasitic treatment. At these times the sheep are contained and available at close proximity for manual inspection. Knowing, monitoring and maintaining the breeding ewe's appropriate condition score through pre-conception, pregnancy and during lactation is critical.

Current obstacles preventing accurate condition scoring from individual sheep in a pastoral zone include:

- The paddock size can average 1600 hectares with low visibility, due to vegetation, terrain and grass, which limits accessibility.
- Sheep must be mustered and put into processing yards.
- Paddock distance from yards can average five kilometres.
- Mustering may require the cost of a plane or helicopter to assist.
- Mustering and processing involves at least two people, for a minimum of 8-10 hours.
- The process to obtain comparative data for decision making should be repeated weekly.
- Sheep can get heat stress in summer which can have an adverse effect on handling, increase exposure to diseases and parasites, will consume energy and may cause increased stress during the process.
- The process must be replicated, and for an enterprise with 20,000 sheep, 10 to 15 days are required to obtain one set of comparative data and would average approximately $1,000 per labour day plus opportunity costs. The cost associated with this method of data collection is exorbitant.

It is believed that the aforementioned challenges contribute to reproductive wastage in the rangeland areas because information is more difficult to collect and act-on in a timely manner. This report will identify techniques to gather and monitor information relating to the condition of the ewes during pregnancy and lactation for improved performance of sheep flocks in the rangelands.

Chapter 2 Monitoring

"Monitoring attempts to replace guesswork with knowledge and understanding."(Morley, 1998).

Due to extensive research, the requirements of grazing ruminant animals are well known. These requirements allow the precise preparation and combination of feed to support the animal. J.B. Rowe concluded in his work on "Nutritional Management of the Australian sheep flock" (2003), *"Firstly, that most nutritional management targets are met when animals are gaining weight (over 100g/d) and/or are in moderate condition score (above 2.5)"* and *"The challenge for nutritionists is to accurately determine the most cost effective options and appropriate times for nutritional intervention in order to achieve appropriate production targets."*

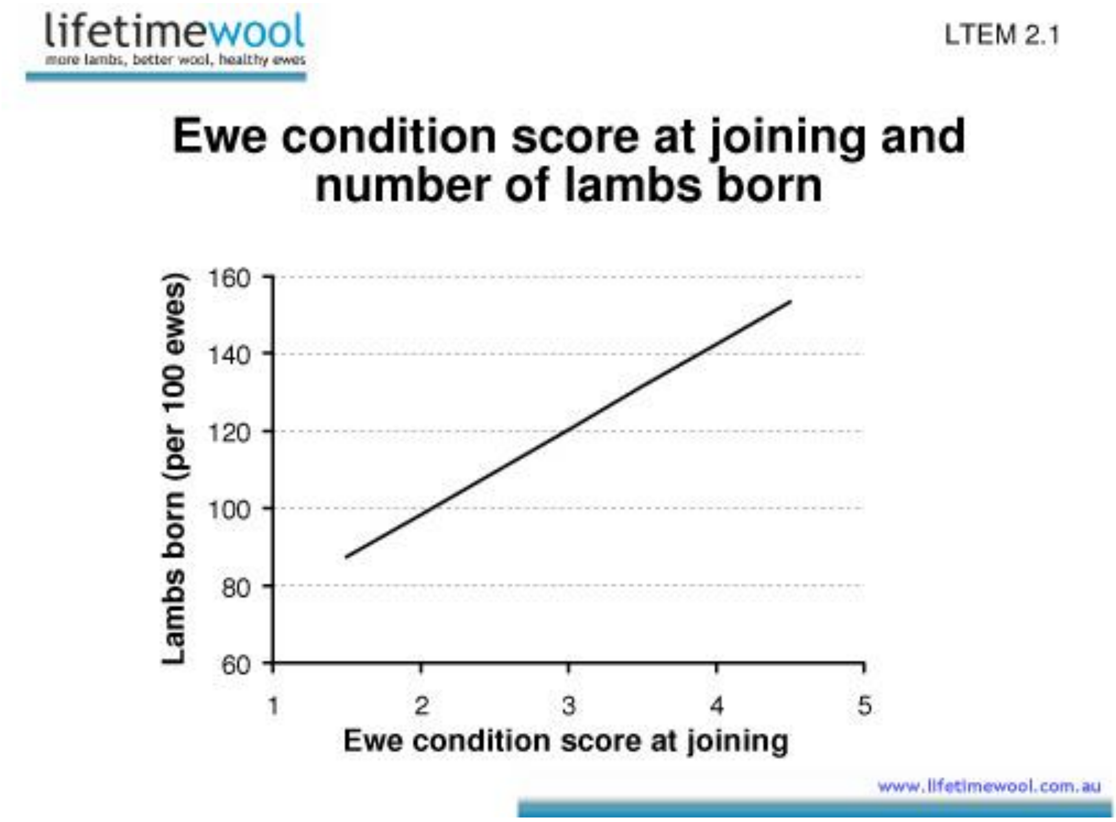
Providing more nutrition than required makes no economic sense, but providing fewer nutrients can be detrimental to the health of the animal. The aim of financial and physiological management is to monitor the sheep and provide nutrition that satisfies the animal's biological requirements at the lowest possible cost.

In the Ewe Management documents from Sheep CRC it was noted "*Ewes in better condition at joining have more lambs and the response is linear between a CS 1.5 and 4.5.* [Refer Condition Scoring Table, Appendix 1]. *The average response is about 20 extra lambs born per 100 ewes for every additional unit CS at joining*".

(http://www.lifetimewool.com.au/Ewe%20Management/conception.aspx)

Table 3 Ewe condition scoring at joining and number of lambs born

Source: http//www.lifetimewool.com.au/Ewe%20Management/conception.aspx



In 1989 a reproduction wastage survey was carried out by Jordon et al (1989), titled "*The magnitude of reproductive wastage to lamb marking in 30 Merino flocks in south-west Queensland*". The study monitored and compared 30 flocks in south-west Queensland between 1976 and 1985. They found that there was a lamb marking range of 10% to 115% and a mean of 78%. Yet this arose from a conception rate mean of 93% with a range of 77-100%. There was a very low failure to mate rate of 1.6%, and a failure to lamb rate of 3.4%. The conclusion drawn was that the major cause of reproductive wastage was lambs lost between birth and marking. The number of pregnant ewes losing all lambs was a mean of 33%, with a high of 90%.

The major conclusion drawn was that lamb losses were caused by "*poor nutrition during and after lambing*" (Jordon, et al, 1989). The marking percentage dropped from 89% when lambing in a good season, to 53% when lambing in a poor season.

A significant deficiency in reproductive management in pastoral zones is the ability to recognise the critical balance between nutrition availability and nutrition requirements of the breeding ewe; hence the management requirement to define and diagnose the needs of the ewe to maintain energy, protein and trace elements.

Timely decision-making in response to monitoring physiology has the ability to pre-emptively adjust the enterprise to prevent production losses from nutritional and metabolic deficiencies. With improved monitoring, management can keep production levels closer to the biological potential of the ewe, sustaining financially viable production.

The critical association between lamb survival and profit, based upon the gross income is shown in the following table created by the author. This draws attention to the rangeland industry average and the production potential available with increased condition scores in the 5,000 ewes. This is an example of the intangible costs associated with reproductive wastage.

Table 4 Revenue scenario potential for rangeland sheep flocks

Source: Walker, 2014

		Increase in dollars per head									
Increase in weaning numbers		$30	$40	$50	$60	$70	$80	$90	$100	$110	$120
	500	15000	20000	25000	30000	35000	40000	45000	50000	55000	60000
	1000	30000	40000	50000	60000	70000	80000	90000	100000	110000	120000
	1500	45000	60000	75000	90000	105000	120000	135000	150000	165000	180000
	2000	60000	80000	100000	120000	140000	160000	180000	200000	220000	240000
	2500	75000	100000	125000	150000	175000	200000	225000	250000	275000	300000
	3000	90000	120000	150000	180000	210000	240000	270000	300000	330000	360000
	3500	105000	140000	175000	210000	245000	280000	315000	350000	385000	420000
	4000	120000	160000	200000	240000	280000	320000	360000	400000	440000	480000
	4500	135000	180000	225000	270000	315000	360000	405000	450000	495000	540000
	5000	150000	200000	250000	300000	350000	400000	450000	500000	550000	600000
	5500	165000	220000	275000	330000	385000	440000	495000	550000	605000	660000
	6000	180000	240000	300000	360000	420000	480000	540000	600000	660000	720000

40% reared   60% reared   80% reared   100% reared

Chapter 3 Precision Sheep Management, Financial Modelling and Production Metrics

Although there are many innovations and technologies becoming available for tracking and monitoring sheep in a range land environment, it is pertinent from a business owner's perspective to give financial rationale for any alterations to any agricultural production system. Precision Sheep Production uses technology to collect livestock data to monitor flocks, providing data relating to animal health and nutrition, which in turn provide information for financial analysis.

In a paper by J.B. Rowe and K.D. Atkins 2006, "Precision Sheep Production – Pipedream or Reality?" they explain the current technologies available for sheep production and suggest there is nothing to prevent rapid uptake of the technology in response to a well-managed plan of commercialisation and adoption. They make the following observations:

1. "*It is essential to know which sheep in the flock contribute to enterprise profit. This involves measurement of the basic characteristics that determine value such as fleece-weight, fibre diameter and body weight. These parameters are easy and cheap to measure…*
2. *Electronic tags make collection of data easier, cheaper and more accurate. [and]…are therefore regarded as a fundamental component of precision sheep production.*
3. *Automated data entry, data management and decision support systems are available for practically all aspects of precision sheep production and are becoming more powerful and easier to use.*
4. *Automatic drafting based on electronic tags and decisions based on an index or single parameter allow precise management of culling, joining and marketing." (Rowe and Atkins, 2006)"*

A significant opportunity for sheep production exists with precision management. The timely data collected from this technology-based approach, means animal performance can be linked more accurately to financial performance of livestock enterprises, with room for improved financial modelling and forecasting. Having this sort of information contributes to more effective enterprise decision-making.

The author believes an inhibiting factor in sheep enterprises, and agricultural businesses, is the level of financial modelling associated with decisions. In order to develop accurate and useful financial models and forecasts, production and financial data needs to be up-to-date. This, coupled with a deep understanding of cost structures, allows for full cost-benefit analysis to help determine the financial viability of technology uptake.

Chapter 4 Individual Animal Management

When referring to the profitability potential in sheep production (Table 4, page 26); technologies, including the combination of Radio Frequency Identification Data (RFID) and Individual Animal Management (IAM), can assist with maximising the biological potential of the most productive sheep, and reduce the costs incurred by the least productive in the flock. RFID links all data compiled for the individual animal, and simplifies the recording process, making management of the data more accurate, more labour efficient, and the comparisons for the data more accessible.

The limit to IAM in the rangelands of Australia is that seasonal conditions, and therefore animal management are not static year-on-year. The variability in climatic conditions may require the enterprise to sell all stock one year and buy a completely new inventory the next year, with new data sets to be collated. The priority can shift dramatically from IAM during a run of good seasons, to accumulating and breeding new animals to appropriately re-stock the enterprise following poor seasons.

The profitability of the enterprise is determined by utilising feed when available while the lowest performing individual animals can still have high value when replacements are scarce.

Table 5 Production variability within a merino flock of sheep

Source: Atkins, Richards and Semple, 2006

Trait	***Production level of flock:***		
	Average	***Top 25%***	***Bottom 25%***
Wool traits:			
Fleece weight (kg)	4.6	5.3	3.9
Fibre diameter (µm)	20.4	18.9	21.9
Staple strength (N/ktex)	35	42	28
Meat traits (crossbred lambs)			
Growth rate (g/day)	284	357	200
Fat depth (mm)	10.6	8.9	12.5
Reproduction			
Lambs weaned per ewe joined	0.86	1.43	0.28
Profitability traits			
Fleece value per ewe ($)	$54	$82	$37
Carcass value per ewe ($)	$33	$56	$12

As seen in the table above the genetic and phenotypic variation can represent as much as $89 difference between individual sheep in a Merino flock, by adding the fleece and carcass value, between the top and bottom 25% and finding the difference.

Due to the National Livestock Identification Scheme (NLIS) accepting varying standards across Australia for the specifications for electronic identification tags for recording in sheep, the uptake of RFID in the sheep industry has been limited to state or territory legislation. Therefore IAM relies on phenotypic selection based on limited subjective observations. RFID is the first step in ranking animals using a number of indicators of production targets. Once RFID is taken up by pastoral enterprises the opportunity exists to employ elevated levels of IAM. This will assist with identification of superior animals and natural variations across the sheep flock, which will lead to a rapid improvement of productivity and profitability.

In semi- arid environments, consistent nutrition availability is a dominant variable for performance; the nutritional status of the flock needs constant monitoring. With increased monitoring the potential for increased agricultural production per hectare is greater.

Chapter 5 Sheep Reproduction Support Tools

Sheep production systems are located across a wide range of diverse geographical zones in Australia. As such, there is significant variation in seasonal conditions between regions and management of livestock breeding enterprises need to reflect this. In semi-arid regions therefore, the challenge is to match the ewe’s nutritional needs with feed availability.

Lambing Planner Virtual Shepherd Version 3 - Annual Lambing

For reproduction management, the Lambing Planner tool has been produced for varying climatic regions to create standardised assistance for Australian sheep producers. The Lambing Planner Virtual Shepherd Version 3 can be adjusted and manipulated so that "*production per hectare is maximised when lactation (peak nutritional demand) matches the time of the peak supply of cheap green feed*.” (Lambing Planner Virtual Shepherd Version 3, 2014)

A specific consideration to be factored into the Lambing Planner Virtual Shepherd V.3 also includes having the ewes in good condition at joining as lambing percentages increase with increased condition scores.

The Lambing Planner is a vital support tool and effectively displays the requirements of nutrition and management throughout a breeding cycle. It is based on an annual breeding schedule with one lambing event per year, as detailed below.

Table 6 Lambing Planner Virtual Shepherd Version 3

Source: http://www.makingmorefromsheep.com.au/wean-more-lambs/tool_10.2.htm, **2015**

Climatic variables in the rangeland areas of Australia present difficulties in replicating this system effectively year-on-year. A good understanding of the Lamb Planner is important for livestock managers and it's applicaton in more intensive breeding schedules, alongside increased levels of monitoring, will highlight opportunities for adaptive management and improved production. The greatest benefit for semi-arid zones will come from adaptatoin to, and demonstration of, the tool within regions.

Chapter 6 Accelerated Lambing

This report researched two accelerated lambing schedules. Accelerated lambing is the term that best describes sheep production systems where ewes are joined more than once a year to increase reproductive performance. The principle motivation for accelerated lambing is to spread business overhead costs over more lambs and decrease expenses per lamb raised.

To implement this intense reproductive strategy a knowledge of reproductive physiology is required. This is highlighted through the inability to avoid seasonal extremes with increasing lambing frequency; in a semi-arid production system the management of resources, inputs and adequate nutrition is paramount to this system’s success. Two forms of accelerated lambing schedules that are commonly used are three lambings every two years, or five lambings every three years.

Case Study: Kyle Farms - three lambing’s in two years

David and Jeanne Kyle founded Kyle Farms in the 1970’s. Kyle Farms is a family-based business that leases land for sheep production in Ithaca, New York State, in America. It produces fat lambs for marketing through local saleyards and through direct marketing. Matt Kyle, the Managing Director of Kyle Farms attended Cornell University and studied sheep production after spending time shearing in New Zealand. He began to grow the flock, trialling breed types and seeking out varied marketing and breeding opportunities. Kyle Farms currently uses three lambings in two years as its preferred breeding schedule.

Figure 3a) and 3b) Kyle Farms facility for housing sheep during winter.

Source: Walker Photo Archives

Three lamb drops per ewe every two years is an attempt to have 1.5 lambings per ewe per year, or an average lambing interval of eight months. It can also be modified to a monthly pattern of 7-7-10 or 7-8-9 month intervals to accommodate climatic, management and nutritional resources. The flock is divided into four groups. When a ewe fails to conceive with her group, she has a second chance to mate two months later on the next eight month cycle. Producers using this staggered two-month interval schedule have reported up to 40 percent increase in lamb production over conventional systems. Increased management attention can be given to critical lambing and early lactation periods since all ewes are not lambing at the same time.

The ewe lambs are joined and pregnancy-tested at 219 days from the end of lambing. If the ewe lamb is empty, she can either be sold as a lamb or alternatively, she can be re-joined in 146 days' time. The ewe lambs have 30 days exposure to the ram, and the main breeding mob, for ease of management, has exposure to the rams for six months until the rams are taken out. The majority of the ewes conceive within the first cycle. The system at Kyle Farms is based on fertility with a composite breed of half Dorset, quarter Finn, and quarter Suffolk over a Cheviot ram. The ewes reach 11 to 12 years of age and Matt reports a 150% to 175% lambing rate per eight-month cycle (Kyle, 2013).

This schedule of sheep breeding has application for Longreach and associated rangelands if nutritional requirements for the breeding ewe can be achieved and maintained.

Case Study: Cornell Star – Five Lambings in Three Years

Cornell University is located in Ithaca, New York State and was founded in 1865. Cornell continually conducts a wide range of research and extension projects, primarily focused on agricultural and veterinary programmes.

Figure 4 Cornell Star Sheep Breeding Planning

Source: http://www.sheep.cornell.edu/management/breeding/star/descritpion.html

The Cornell Star was developed in the 1980s; it leverages conventional breeding techniques and nutrition to reduce lamb-to-lamb intervals. In this schedule the year is divided into five equal segments that represent one fifth or 73 days of the year. The star can be rotated to establish the optimal dates throughout the year and create five lambing periods with two fifths of the system representing 146 days, which is approximately the gestation length of a ewe.

There are always five groups of ewes managed separately in this system;

- Breeding and pregnant ewes and the rams,
- Lambing and/or lactating ewes and their lambs and,
- Growing lambs (for market and replacement).

Lambing occurs at five different times throughout the year, the beginning of one lambing period is 73 days after the start of the previous. Using this strict schedule, on any of the given dates, one third of the ewes will be lambing, a third halfway through gestation and a third will be breeding. Professor Michael L. Thonney (2013) said; "*The key management activity is putting the rams in and taking them out*…*If a ewe doesn't get pregnant during a 30-day breeding session, instead of a year, its only 43 days until she has another opportunity*".

Figure 5, on the following page, highlights the reproduction potential of a breeding ewe involved in the Cornell Star program coupled with genetic selection for enhanced breeding.

Ewe Reproduction Quad Ewe CXB8604

Ewe Breed: Finn x Dorset

Ewe Information Eartags AnSc3800-11-06, AS38001310, CXB8604, L10471, L121140, L12420

Finn x Dorset **Permanent ID:** CXB8604 **Birth Date:** 6/8/2009

First lambing date:	8/24/2010
Years to first lambing:	1.2
Possible cycles:	5.1
Lambing's per cycle:	0.98
Number of lambing's:	5
Lambs delivered:	13
Lambs born alive:	13
Lambs alive at 40 Days:	12
Lamb Survival Rate to 40 days:	0.92

Progeny Table: Ewe CXB8604

Birth Date	Lamb ID	Sex	Litter Size	Raised As
24/8/2010	CXB9846	Ewe	2	2
24/8/2010	CXB9847	Ewe	2	2
1/4/2011	CXB10276	Ewe	2	1
1/4/2011	MANOLO112	Ram	2	1
23/1/2012	CXB11014	Ram	2	2
23/1/2012	CXB11015	Ram	2	2
30/8/2012	CXB11572	Ram	3	3
30/8/2012	CXB11573	Ram	3	3 Died
30/8/2012	CXB11574	Ewe	3	3
6/4/2013	CXB12105	Ram	4	4
6/4/2013	CXB12106	Ram	4	4
6/4/2013	CXB12107	Ram	4	4
6/4/2013	CXB12108	Ewe	4	4

Figure 5 The Cornell Star and Ewe CXB8604

Source: Mike Thoney, 2013

The benefit of an intensive breeding schedule, such as the Cornell Star, is the increased number of lambs per ewe. The high reproductive potential of ewe CXB8604 is seen in the above table; she has produced twelve lambs over four years.

Management considerations for this system included the ewe's elevated levels of exposure to parasites and diseases resulting from increased lambing and human interaction. The lamb production of the Cornell Star is compelling; breeding more lambs means potential income is raised considerably.

Accelerated Lambing Summary

Under such highly intensive production systems such as Cornell University and Kyle Farms, there is a strong imperative to closely follow animals to ensure they are on-track with production targets. Given the performance levels of these animals, close attention was paid to the ewe's biological state and condition score through physical palpation and close proximity assessment. The reproductive wastage in these systems is minimal.

Both Cornell, and Kyle Farms use management of physiology and condition scoring as their main monitoring techniques. Cornell was also trialling RFID tags for data management and analysis for individual ewe management purposes. The high quality nutritive resources available to the ewes in these systems were notable. Although there were increased opportunities for the ewe biologically in the Cornell Star, the Kyle Farms method of intensive breeding is a subtly more logical schedule in terms of pastoral management.

The abundance of nutrition in the fields was incomparable to the Australian pastoral zones, as evidenced in the following photo. However in winter the animals are shedded and nutritional requirements are calculated and administered by staff. The nutritional standards for this pasture negates supplementary feeding requirements and when the fields turn to snow the ration of the breeding ewe is controlled in confined yards to ensure nutritional requirements are met. Therefore the quality and quantity of nutrition is managed throughout the preconception, conception, pregnancy, lambing and lactation stages.

Figure 6 Pasture Profile Kyle Farms, Ithaca, New York State.

Source: Walker Photo Archives

The economics of accelerated lambing must be carefully examined. The increased income from the sale of lambs needs to compensate for the added nutritive costs and labour inputs. In addition, accelerated lambing requires a much higher level of skilled technical management.

Chapter 7 Production Performance Monitoring

Case Study Sheep Industry - Walk over Weighing

At the time of writing this report the only remote real-time individual monitoring technology commercially available to the rangeland sheep industry is Walk Over Weighing (WOW). WOW is paddock-based with a set of yards and a race so the sheep's weight can be recorded as part of natural movement to feed or water.

WOW negates the need to muster or bring the sheep to the yards for weighing; it is an incentive system for sheep where a particular attractant (generally water) is used to encourage sheep to walk over a weighing platform, one at a time. As each sheep with a RFID tag crosses the platform, its weight and identity is recorded. By using a number of repeated weights over a specified time period, an accurate weight for each animal can be determined. WOW is useful for monitoring the condition of the sheep as the system can identify relatively small changes in weight well before a discernible change in condition score is evident. This information can allow the manager to adjust nutrition and manage parasites before they have an adverse effect on productivity and sheep performance.

*"It is well suited to pastoral settings where labour is scarce and the stress and cost of mustering sheep are important factors. It can also be used in feedlot or rotational grazing systems where regular monitoring of a sheep's weight applies." (*Atkins KD, Richards J, 2007).

The advantages of Walk over Weighing are in;

- minimising sheep stress.
- reducing labour costs.
- gathering real-time sheep weight data.
- recording growth rates.
- monitoring ewe health and condition.
- allowing a sample of the flock to be fitted if only trends are required.

- roll calling sheep if all are fitted with electronic ear tags.
- being used to aid management and accumulate sheep for mustering, drafting and processing.

Considerations

The use of WOW has the potential to allow producers to obtain simple weight measurements of their flock and improve their flock management without the high labour costs normally associated with mustering and weighing. It will reduce the stress on animals as well as improve the options for management. Weight can be directly correlated to condition scores of individual sheep once a standard weight is determined, as referenced in the Making More from Sheep resource below. Once the standard weight has been ascertained, the following table can apply.

The Weight of One Condition Score for different sized sheep				
Standard Weight	40 kg	50kg	60kg	70kg
One Condition Score	7.5kg	9.5kg	11.4kg	13.3kg

Figure 7 The Weight of One Condition Score* for different sized sheep

Source: Making More From Sheep, Module 10: Wean More Lambs

Note: One condition score is equivalent to 19% of the standard reference weight for a sheep. The table above summarises the weight of one condition score for different sized sheep.

One issue in collecting WOW RFID data is that individual weights can vary dramatically according to the animal's length of time and position on the weighing platform and therefore, a single weight measurement using this method could be inaccurate. Continual refinement of the technology will enable this to be overcome.

WOW could be useful for collecting data that would assist a pastoral decision-maker determine potential sheep fertility and reproductive projections, but increased accuracy of data-collection is needed, along with direct flock correlations between weight and condition score.

A paper published by Brown et al (2013) on "*The Repeatability and frequency of in-paddock sheep walk-over weights: implications for individual animal management*" discussed the results on accuracy with walk over weighing. They investigated whether RFID-linked WOW data is sufficiently reliable and repeatable to generate individual live weight estimates. They concluded that in isolation "*RFID-linked WOW data had low repeatability and was unable to generate live weight estimates with a 95% CI of less than 2 kg within a suitable timeframe. Therefore, at this stage, RFID-linked WOW is not recommended for on-farm decision making of individual sheep."* However it was also suggested that with appropriate data handling; "*WOW may provide information suitable for sheep management decision making in a commercial context"*

Recommendations

This form of data retrieval on individual live-weight and condition is appealing due to the automation and value of the data. Once consistent and accurate data gathering can be achieved and collected frequently, it can then be used to inform management decisions, and forecast financial implications. The provision of real-time data supports production-based decision management.

Unfortunately, the design limits of WOW and the reliability of some of the individual sheep data renders the modelling incomplete at this stage. Advancements in design and functionality would see this technology becoming particularly useful in aiding pastoral sheep management and decreasing reproductive wastage in rangeland sheep production. Once a correlation can be achieved between an automatic remote weight measurement and condition scores, a deeper understanding can be gained about the reproductive condition of the ewes and a likely lambing percentage may be forecast. This would allow the economic outcomes to be ranked against the costs to maintain the level of biological performance. Further research will be required to determine the algorithms for this relationship outside of the scope of this project.

Case Study - the dairy industry – Silent Herdsman, Scotland, UK.

To ascertain the potential for the sheep industry to pursue production performance monitoring, exploration of what is being undertaken in other industries and disciplines was examined.

Silent Herdsman is a revolutionary digital program for dairy heifers that continuously monitors a cow's activity and automatically detects changes in normal behaviour to identify patterns relating to fertility. Through a neck mounted collar, transmissions can be sent electronically anywhere in the world when the collared cow comes within proximity to a base station. When a particular pattern of movement is logged an alert then informs the manager that a particular cow is in oestrus and should be scheduled for treatment.

This technology is based on similar technology to that in a smart phone. The 3D accelerometer a phone uses to adjust its screen orientation is placed inside the transponder on the cow collar. The accelerometer catches every movement a cow makes. The combinations of movements produce a 3D graph, showing movements backwards, forward, up, down, left and right.

Initially, the Silent Herdsman engineers trialled a prototype dairy herd with the technology. With this herd they took progesterone samples from each cow on a daily basis over a few months. When the progesterone levels peaked, they knew oestrus was present, and the cow was ready to be served via Artificial Insemination (AI). By comparing the 3D collar data for that day, they were able to isolate 3D movements, which indicated oestrus through increased movement and activity common to cycling cows.

By repeating that process many times, a 3D graph was constructed incorporating every style of movement associated with a cow on-heat. This graph was then incorporated into the collars, which allowed the engineers to predict oestrus relatively accurately.

All analysis is carried out on board the collar, and the data is transferred every couple of hours to an antenna on the farm. Collars can hold data for up to 18 months, and when they arrive within 800 metres of an antenna they can transfer data that has been recorded. The data passes to an on farm computer. This alerts the farmer, advising which cows are on-heat and therefore which cow to draft out after milking.

According to Andy Paine (2013) of the National Milk Records "*The farmer will normally use the system to reduce the time between calvings. The average calving interval in the UK is 422 days. Our top 25% of herds are achieving a figure of 388 days and less, so there is real value in reducing a herd's calving interval. We normally work on a figure of £5 per cow/per day in lost milk yield for calving intervals over 365 days".*

Costs vary depending on the specifics of the kit that farmers buy. Some farmers take Internet connectivity, extra antennae for young stock sheds, high gain antennas and so on. This has a bearing on price; an average 100-cow dairy will normally 'kit' themselves out for approximately £10,000. This is based on £75 per collar, plus £2,500 for the PC, antenna, installation, software and support/training. A block calving herd will normally require a collar for each cow, because they have their entire herd calve at once. An all year round calving herd would normally look at one collar for every two or three cows, with the collar being swapped between cows, once the initial cow is confirmed in calf.

"*An average herd with a calving interval of 422 days can make, on average, around £20,000 of additional revenue through using the system. This does vary depending on how high yielding the herd is, but it is a reasonable estimate. Most customers say the system pays for itself in 12 to 18 months*." (Andy Paine, 2013).

Figure 8 Andy Paine Silent Herdsmen, England.

Source: Walker Photo Archive

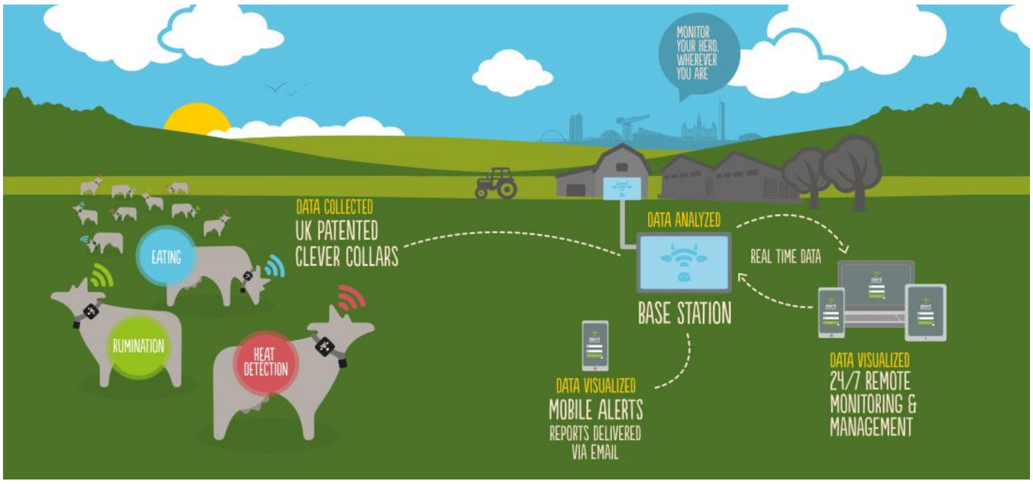


Figure 9 Silent Herdsmen Sensory Flowchart Diagram

Source http://silentherdsman.com/en-us/technology/deployment/ , 2014

This technology, although currently unavailable to the sheep industry, has great potential conceptually for pastoral grazing enterprises. Using the design intelligence of the Silent Herdsman, possibilities exist to monitor variations in sheep physiology resulting from factors such as:

- reducing levels of nutrition,
- increased predation,
- Ovulation,
- lambing and lambing difficulty,
- if the ewe has successfully reared a lamb,
- changes in water quality,
- Lameness,

- illness,
- heat stresses,
- and diseases and parasites.

Using technology such as accelerometers can give valuable information that can create algorithms specific to sheep physiology.

Case Study - The sporting fraternity - Catapult Sports

Commercial sporting teams and their sports scientists have great interests in leveraging the performance of their athletes to remain competitive. This research determines the current technologies for monitoring physiological performance of elite athletes and the potential synergies that exist for livestock industries.

Catapult Sports specialises in athlete analytics; they believe "*if you can measure it, you can manage it*" *(http://www.catapultsports.com/, 2014)*. The business works with over 300 teams and institutes worldwide quantifying elite athlete performance. Catapult is a wearable tracking technology that is a scientifically-validated performance monitoring tool. The wireless module attached to the athlete uploads every performance parameter in real-time to a smart phone, tablet, laptop and cloud-based software.

Catapult Sports' accelerometer technology, like the Silent Herdsman, collects biological information relevant to peak performance decision-making. As with the Silent Herdsman collar, it is further evidence of the potential to develop technology for the collection and interpretation of physiological data in the sheep industry.

Inertial Movement Analysis (IMA)

IMA is a term used to explain the intricate mechanics of an athlete's individual physiology and the interrelationships contributing to performance enhancement. IMA measures and monitors athlete's micro-movements in real-time and is the first complex algorithm to quantify acceleration, deceleration, directional changes and jumps with three-dimensional accurately. It can also use heart rate measurements, steps taken and external factors for the construction of the algorithms. It captures on-field data from monitors worn by the athletes, transfers the data to receivers, then uploads it in real-time to a computer for conversion by an algorithm into simple information that can be diagnosed by the user.

Figure 10a) and b) Catapult Technologies Interfaces and Athlete Harness

Source http://www.catapultsports.com/au/ , 2014.

IMA can determine the total load on athletes' bodies through accelerometers and gyroscopes, which measure orientation and tilt of the body. The monitoring units (Global Positioning Systems (GPS)/ Accelerometer Modules) are worn during training and competition, and charge at night. Analytic data is then uploaded to analyse the athlete's performance, workload and, rehabilitation and sleep patterns.

Through tracking all movements coaches and trainers can intervene to optimise individual and team performance. Due to the remote monitoring capacity, coaches can compare athletes' reports around the world in real-time, and for national teams there is the ability to monitor players' performances prior to international competition.

Sports science is enjoying the results of real-time monitoring and there are significant synergies that must be explored between the potential of current technologies in this field and real-time animal monitoring. The opportunity to improve animal production by harnessing the biological potential of an individual animal is immense.

Case Study – The zoological fraternity

In gaining an understanding of opportunities that are currently available to assess physiology through observations, this research explored the zoological fraternity and its capacity to monitor animals to identify if there were any synergies available for rangeland animal management.

Due to zoos and aquariums of today effectively being gene banks for endangered species, the management of individual animals is critical. In some cases, species that have become extinct in the wild and have been bred and nurtured successfully in zoos and have then been successfully returned to the wild.

This research explored physiological management at two zoos, the Taronga Park Zoo in Sydney and the world's largest zoo, the Henry Doorly Zoo. Although both zoos are characterised by the high standards of intensive observation and documenting, there was no evidence found of real-time data streaming of animal physiology for management decision-making. There are, however, software programs used that could be transferred into agriculture to assist benchmarking individual sheep.

Taronga Zoo

The Taronga Zoo was founded in 1879 and officially opened in 1884; it is now home to approximately 2,600 animals of 340 species over 21 hectares, and monitors the physiology and performance of its animals daily. Animal's physiology is monitored through intensive observation, it relies on the staff to identify physiological variances. At Taronga Zoo the author met with Sara Brice, the Registrar for Collections, and the Curator, Nick Boyle.

Data collection is manually entered each day. The zookeeper observes the animal in close proximity and records any changes between viewings. At the time of the report, Taronga did not have remote individual physiological monitoring technology, such as daily automatic weighing or real-time heart rate monitors, pedometers, or accelerometers for objective management. It was compelling to witness the skill and intensity with which individual animals were monitored; with observations guided by a comprehensive and detailed checklist. The limiting factor is the subjectivity of the observations, which can potentially vary between the skill sets of the observers.

Significantly, when the physiological data of the animals was collated and then logged manually onto an electronic database, it could then be analysed internally or compared to external populations in other Zoos.

This electronic system is called the Zoological Information Management System (ZIMS). Under this system the animals are inspected and assessed periodically throughout the year, critical physiology is then measured and entered into the Taronga registry, and subsequently shared with a global network of zoo databases. At the time of the visit the database was being used to compare the monthly weights of an individual gorilla within the zoo's population. The data was then being used to establish annual trends. With over 820 global subscribing zoos in the database, the individual gorillas are comparatively analysed against the logged global gorilla population.

The following table shows the male gorilla at Taronga compared to global data (global data includes 13043 weights taken from 379 animals). Note the blue line in the graph is the Taronga male.

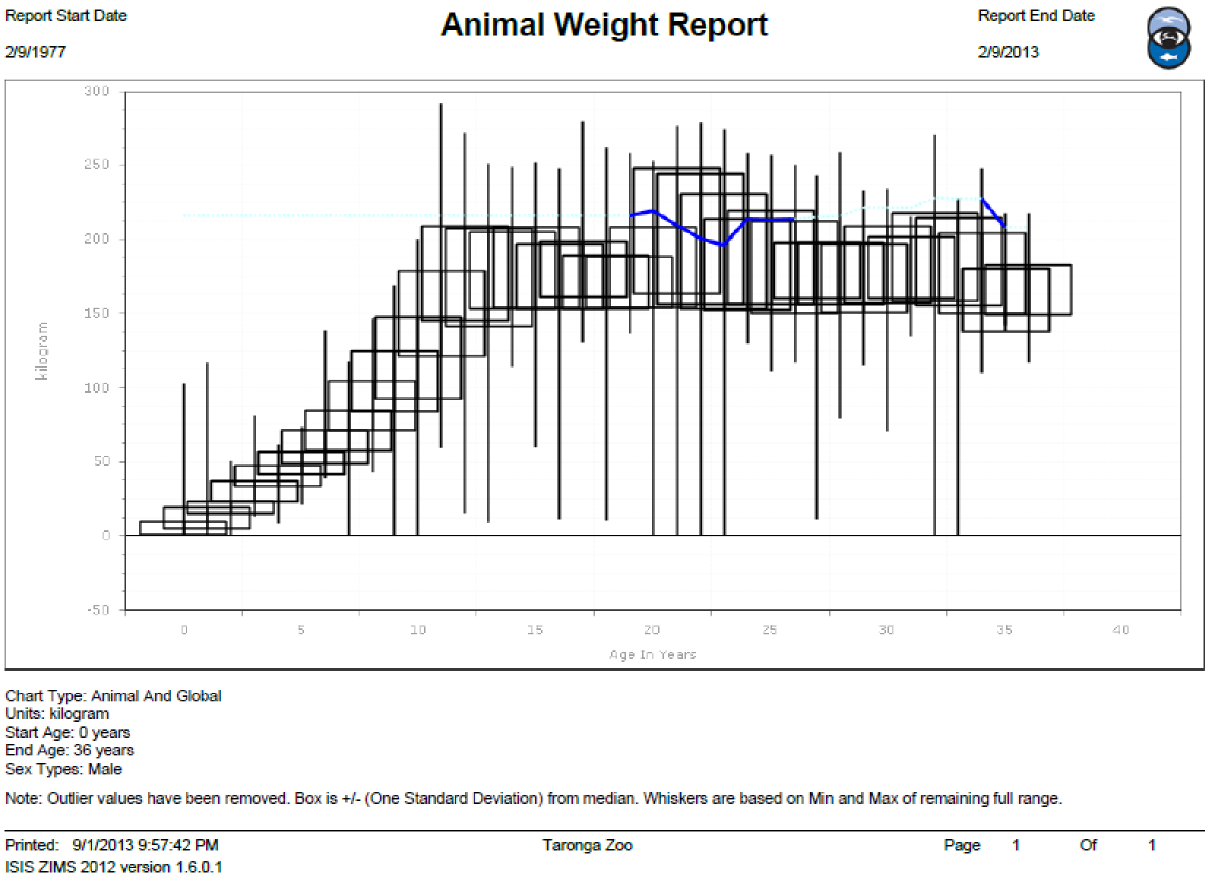


Figure 11 Individual Male Gorilla Weight, Taronga Zoo Benchmarked Globally.

Source: Sara Brice, 2013

This form of comparative data analysis provides essential benchmarking which can be used to rank the weight and other parameters, of one animal against another, as well as against a wider population. Recorded observations outside the established or expected pattern can alert to possible health or physiological issues. In the same way, benchmarking in the livestock industry has potential to establish norms and therefore identify performance outside those norms.

Henry Doorly Zoo, Omaha

The Henry Doorly Zoo in Omaha, Nebraska is the world's largest Zoo in terms of area, and species number. Established in 1864 it has over 17,000 animals, 962 species and is contained over 53 hectares. While visiting the Henry Doorly it appeared similar to the Taronga Zoo, characterised by the high standard of care given by the staff to their animals. Henry Doorly

Zoo had no evidence of remote real-time individual physiological monitoring technology. Similar to the Taronga Zoo, this zoo had access to the ZIMS Database and was uploading data continually.

International Species Information System and Zoological Information Management System

Dr Ulysses Seal and Dr Dale Makey, who proposed an international database to help zoos and aquariums accomplish long-term conservation goals, founded the International Species Information System (ISIS) in 1974. A goal of the ISIS organisation is to obtain the broadest possible participation in data collection and sharing for zoos, aquariums and related organisations worldwide.

Although the ZIMS programme from ISIS is specifically designed for Zoological Institutions it is a ready example of database management for living organisms. To-date, ZIMS has not embraced real-time management of living organisms. However, with the rate of evolving technology, once automation can be established in physiological monitoring, there could be a realistic opportunity to integrate into the available software.

Zoologically there is no evidence of real-time data streaming of animal physiology for management decision-making. To obtain physiological information economically, in a manageable form, it may be beneficial to analyse available technologies, and apply them strategically.

The sporting and zoological recording and management fields have great similarities with agricultural performance; the collective task is to monitor and improve biological performance.

Chapter 8 Technology: Production Performance Monitoring

Data Collection Options

In agriculture, often adoption of new and innovative technologies is characteristic of successful operators who employ innitiatives to complement their profitability. Strategic assessment of the productive and economic benefits of new technologies underpins their implementation decisions. Due to narrow margins, without this strategic assessment new technologies should not be pursued in haste. The uptake of new ideas and processes should add to an already successful system.

"The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency." (Bill Gates, 2008).

Manual Weighing, Condition Scoring and Containment Yards

Permanent yards constructed around water points can be used to accumulate sheep automatically. Sheep become accustomed to walking through an entry and exit gate and ,when the exit gate is blocked the sheep remain in the yard for total flock examination.

Good fencing and design is critical as this style of water infrastructure can provide security for controlling grazing pressure by kangaroos if the fence is robust and the entry and exit gates are species specific.

This infrastructure would allow weighing of the sheep manually with portable scales. To monitor physiology a percentage of the flock must be weighed which will create data sets to provide comparable information between weighing events. This would be a low-tech approach to collecting data and would not be automatically or remotely operated. This form of monitoring would not require RFID tags but would identify changes and trends in weight patterns of the sheep, sufficient for management at a low cost. This management system would be flock-based and would, without the RFID tags, allow for limited analysis of individual sheep data. Condition scoring can also be completed in this system. If, however, as discussed earlier, a correlation between condition score and flock-specific body weight ranges can be made, gaining the live-weight alone could minimise the physical handling of the livestock, and make the process far more time efficient.

At vulnerable stages of production such as lambing, it may be advisable to avoid processing the flock of sheep through this system to avoid unnecessary stress; by the lambing stage it would be advantageous to have the ewes on a stabilised ration that would maintain growth and health throughout the course of reproduction and lamb rearing.

A system such as this would reduce mustering costs considerably in the rangeland grazing system during shearing, crutching, lamb marking and weaning. This would contribute to cost recovery of developing the infrastructure associated with this system.

A test that would fit with this form of sheep handling and provide key nutritional and health information for management is the Faecal Near Infrared Reflectance Spectroscopy (F.NIRS) test (which tests faecal samples). Used in conjunction with weighing, this will give the manager a reading of the protein and nutrition being consumed. The calibration equations of F.NIRS are used to predict:

- dietary crude protein (CP)
- dry matter digestibility (DMD)
- faecal nitrogen (N) concentration
- non-grass proportion of diet
- growth rate.

Testing is currently not available on-site and there is a delay with the results of up to one week. However if there are sample sheep that can be individually weighed and faecal samples taken every week, the data collected could be correlated and information derived which may not have been oblivious to the producer. If the F.NIRS testing could be achieved on-farm this would provide valuable data for real-time monitoring.

While automated collection of live weight (as in the WOW system) would be ideal, the benefits of using containment yards as described above to manually gather data (and to complete testing as required) can be realised as an affordable entry level into real-time physiological monitoring. The full benefits of intensive monitoring can be captured by building calculations that relate sample weights and condition scores to lambing percentages and financial outcomes. This will guide management's decision-making processes around maintaining a condition score and weight range, and oversight of economic outcomes for the business. A cost benefit analysis of maintaining the nutrition levels and associated condition scores in an intensive data gathering system is necessary.

RFID and Production Performance Monitoring

As described in the WOW model, the use of RFIDs can be an efficient means of data collection. Where using a containment yard, fitting an electronic scanner to the narrow access point around a watering site allows for remote data collection by logging the individual animals as they pass. The scanner can then upload the individual identification numbers to a central database and distribute the individual attendance to water in real-time. This system can account for the presence of all animals on a daily basis and alert the manager if there are sheep missing due to predation, lambing difficulty, straying or theft; providing a daily role call, as such.

Accelerometers, Pedometers and Production Performance Monitoring

In addition to the technologies available, there is great potential to combine technologies to collate data for sheep breeding and manegment purposes. Another form of monitoring requires the use of an accelerometer module; which can be fitted, in conjunction with the RFID tags, to associate physical activity with individual animals.

Combined, the technology can potentially be used to log patterns of movement and inactivity. As the sheep graze, the steps taken can be logged in the tag, as the highly desirable grass and herbage types become scarce, the sheep may start walking further to search for more of the desirable feed. Once a day, as the individual sheep walks past the scanner, the number of steps are logged and a trend can start appearing from day to day relating to total steps taken, energy consumed and nutritional availability. If this system is incorporated with the weekly weighing and dung sampling, it can provide information relating to the possible need for supplemnetary feed.

Adrian Faccioni (2014), a GPS Sports representative, explained the opportunity for this technology;

"An accelerometer in the right place on the body would detect each stride taken. If you want to capture data and then review post 3-months then this is easy – battery life for accelerometers is nothing. The devices with accelerometers attached would do this job for you if you wanted to combine all technologies and uses"

Accelerometers and Predation

Another potential use for the accelerometer is the ability to measure rates of acceleration on the individual sheep. The application could be used to detect predators if they arrive to a paddock and pursue animals. If sheep fitted with accelerometers are pursued, they will accelerate at a faster than normal speed, a sensor will be activated and data stored in the device’s memory. As the pursued sheep passes the scanner the excessive rate of accelerations could be logged, and an alert will be automatically sent to the manager.

The cost associated with this technology it is currently from $150 to $200 per head. Whilst total flock affordability is challenged with this price structure, enough accurate data could be received from a sample group to establish comparable trends from individual sheep.

GPS and Monitoring

Whilst recording real-time movement of livestock, the GPS component of monitoring animals requires high levels of battery power, rendering the frequency of charging very time consuming, inconvenient, expensive, and at this stage unsuitable for sheep physiological monitoring in a rangeland environment. This form of monitoring is suited to sectors with large budgets, such as the armed forces.

Oestrus Cycle Detection in Sheep Flocks

As a result of the dairy industry (in the case of the Silent Herdsman) developing algorithms that detect estrus cycles, there exists the possibility to develop this opportunity also for sheep breeding enterprises, once the technology becomes more widely available. This would give the producer of the sheep flock greater capacity to manage the fertility potential of the flock.

Affordability of Production Performance Monitoring and Technology

Aggressive pursuit of production performance monitoring for ewes in sheep production systems is recommended. Within the industry, graziers should re-assess condition scoring frequency and increase nutritional, seasonal and physiological awareness. The more data available to the decision maker, the greater the likelihood management decisions will be timely and profitable.

The additional expense of adding technology, such as accelerometers, pedometers and data storage software to sheep management may inhibit the uptake and adoption of useful, relevant systems relating to animal physiology when they become available. Given that GPSs and accelerometers are currently only available to the mobile phone industry, sporting fraternity, the fleet vehicle industry and military for tracking and monitoring, considerable work needs to be undertaken before pastoralists will be able to adopt this technology suitable in the livestock industry.

Nanotechnology, Nanogenerators, Biosensors

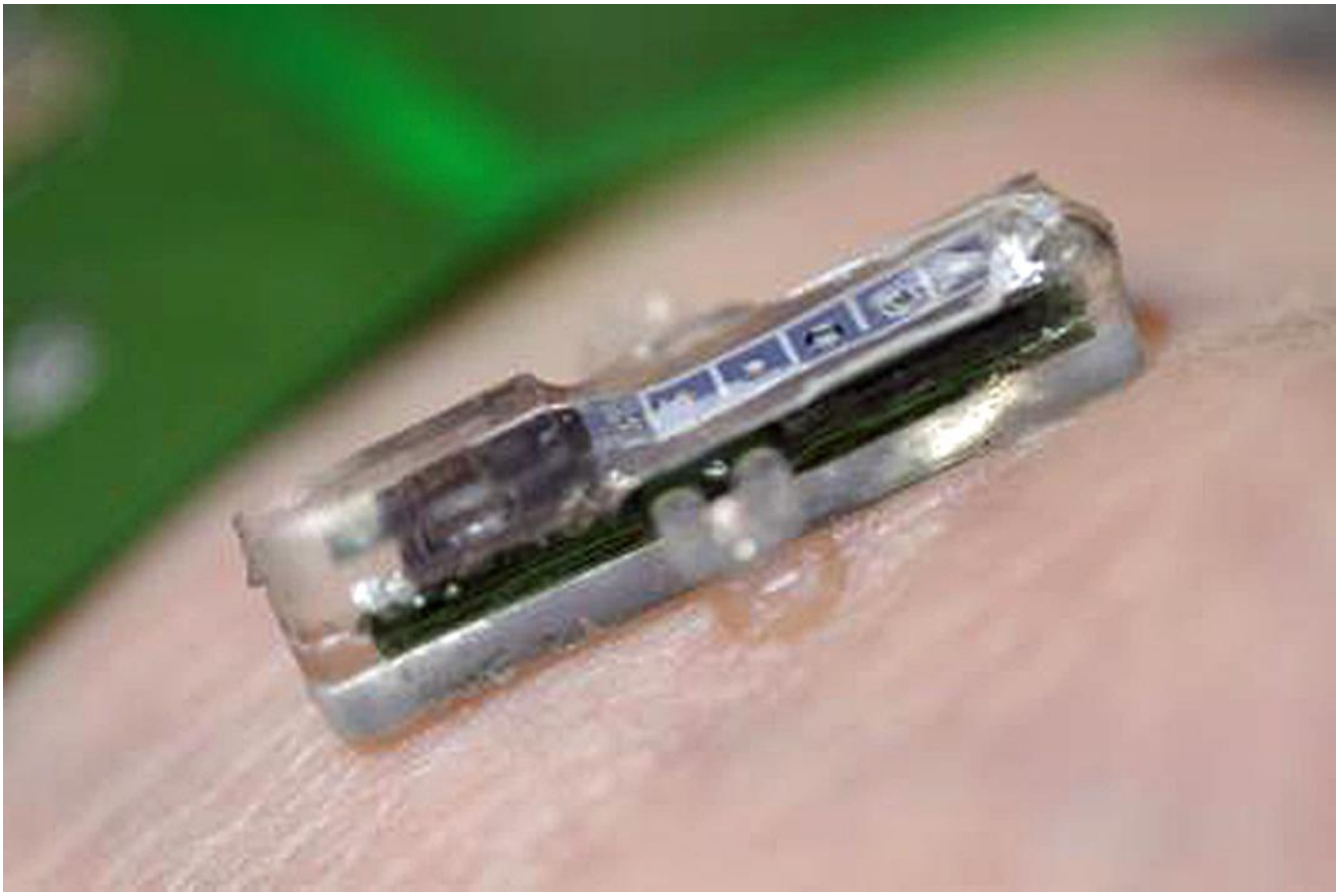


Figure 12 Subcutaneous Human Biosensor

Source: https://www.microengineeringsolutions.com/blog/micro-lab-under-the-skin/

Nanotechnology is the science and technology of devices and materials constructed on extremely small scales, as small as individual atoms and molecules. A Nanogenerator is a technology that converts mechanical/thermal energy as produced by small-scale physical change into electricity.

Moore's Law, which was coined by Gordon Moore, 1965, co-founder of Intel stated; *"The number of transistors on a chip doubles every 24 months*" and predicted rapid technological progress. He explained why the computer industry has been able to consistently come out with products that are smaller, more powerful and less expensive than their predecessors; this creates increased opportunity to combine nanogenerators with sensors for real-time physiological monitoring of individual animals in the near future.

Due to the limitations of power support for external monitoring devices in the animal industries, it is necessary to research the availability of alternative energy generating systems. Nanogenerator technology, particularly a "Triboelectric Nanogenerator (TENG), can be applied to harvest all kinds of mechanical energy that is available but wasted in our daily life, such as human motion, walking, vibration, mechanical triggering, rotating tire, wind, flowing water, and more" Wang Z L, (2013).

Furthermore, research into the technology of Nano systems is advancing rapidly with a publication published in May 2015; "Wireless, power-free and implantable nanosystems for resistance-based biodetection". This paper states that:

"*In-vivo devices and systems are extensively used in the medical field to real-time detect and adjust the physiological status of human beings, but supplying energy in-vivo for these devices and systems is still a great challenge. In this work, we first developed a new kind of wireless nanogenerator (WLNG) based on biocompatible BZT-BCT nanowires (NWs)"* (*Cheng, Yuan, Gu, Wang, et al, 2015).*

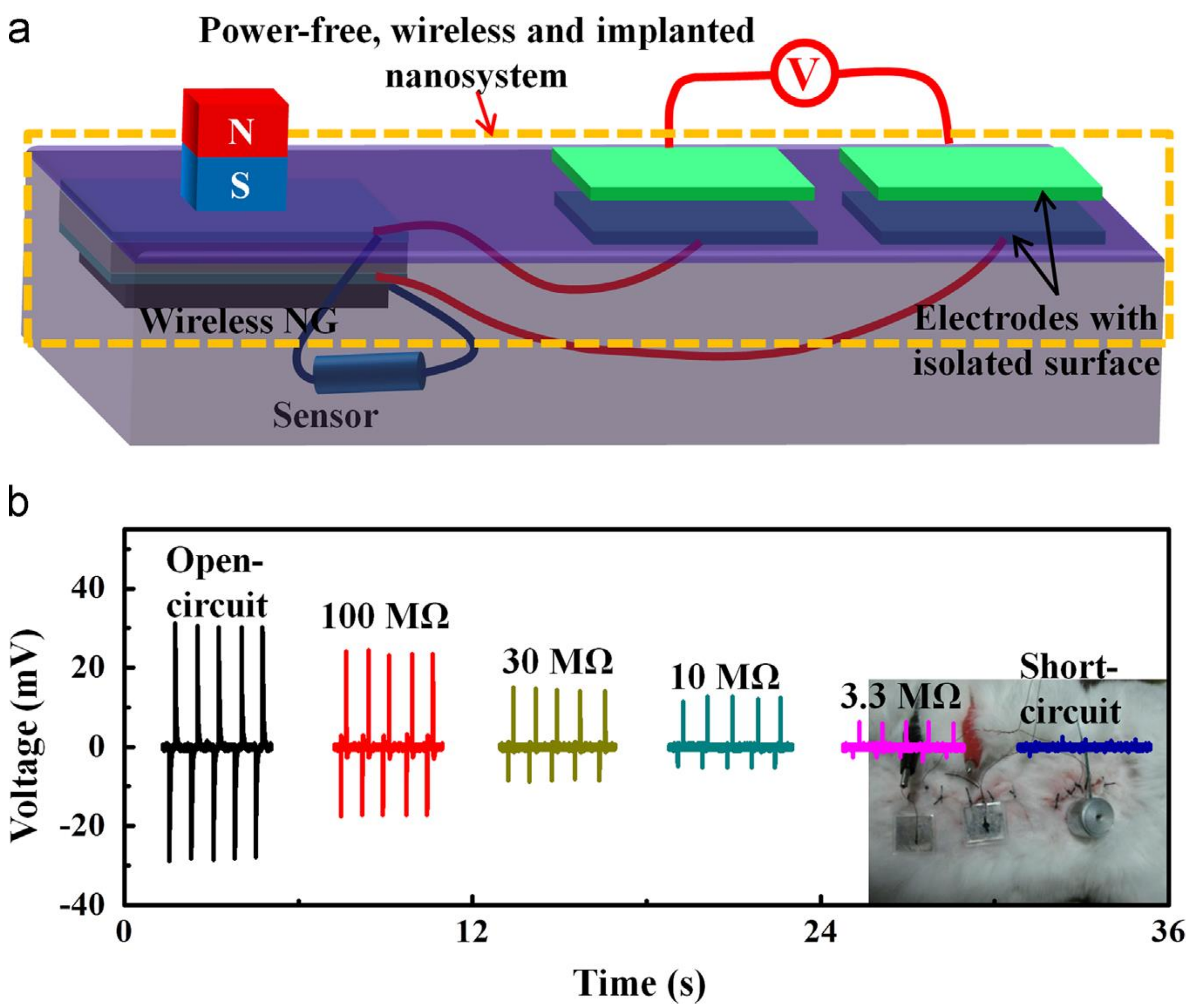


Figure 13 **The wireless power-free and impantable nanosystem**

Source: www.researchgate.net/publication/277089603_Wireless_powerfree_and_implantable_nanosystem_for_resistance-based_biodetection

Currently, nanotechnology is not used in the physiological monitoring of individual animals. It is, however, frequently used to complement human monitoring with biosensors. Opportunity exists for the sheep industry to utilise nanotechnology in the future to remotely monitor the real-time individual physiology and thus the animal's health in general. This form of monitoring would be self-generating and powered continually by the individual animal. While the cost associated with this form of monitoring technology would deem the technology unaffordable at first, the data gained from the individual animals would be valuable and comprehensive.

Nanogenerators and Biosensors in Animals

The opportunity to detect the health condition of animals is extremely important, not only through enhancing the management decisions contributing to improved production potential, but to also manage biosecurity risks which ultimately protects food production systems. In the future, if animals were fitted with biosensors, this would provide information that would support better management practices.

With future development of this technology it may be applied to detect changes in the biological state of an organism. One example of this application would include detecting leptin levels relating to feed, nutritional availability and appetite, which would give good metrics for management intervention as levels change. Leptin is the hormone product of the obese gene synthesised and secreted predominantly by white adipocytes, according to Zhang, Proenca, Maffei , et al (1994).

"*The role of leptin as a lipostatic signal regulating whole-body energy metabolism makes it one of the best physiological markers of BW, food intake, energy expenditure* (Houseknecht et al., 1998; Woods et al., 1998), *reproduction* (Cunningham et al., 1999; Garcia et al., 2002), *and certain immune system functions* (Lord et al., 1998). *Circulating leptin and adipose tissue leptin mRNA levels are correlated with BW, food intake, nutritional status, and adipose tissue mass in humans and animals (*Larsson et al., 1998; Delavaud et al., 2002*)."* Nkrumah, Li, Yu, Hansen, Keisler, and Moore (2004).

Chapter 9 Economics: Production Performance Monitoring

Whilst researching technology used to monitor animal physiology, the need to understand the financial benefits of real-time monitoring and management became apparent. Further, it was evident that improved financial modelling was required in order to link production metrics with financial metrics in a real-time context. This, coupled with disciplined cost-beneift analyses of new technologies would provide a comprehensive understanding of the financial benefits of production system changes resulting from increased data feeds.

This would help determine if there is a correlation between the use of the technology and improved cash flow. Currently the losses in cash flow from reproductive wastage remain relatvely unaccounted for. If financial literacy is low in a sheep production busines, any new technologies or innovations have the potential to complicate the practice and confuse the financial result.

Chapter 10 Unintended benefits: Production Performance Monitoring

Using innovative technologies for physiological monitoring may have unintended benefits. In innovative technology creation, design progresses in such a way that problems and solutions co-evolve. Once data sets from remotely monitored sheep are retrieved a wealth of innovations will become possible that have not hitherto been explored.

Unintended benefits will be:

- the ability to measure accurately the response to treatments applied to animals and hold service companies to account regarding product claims. .

- the potential to value the livestock inventory without yarding and inspecting; simplifing financial decision-making as planning becomes evidence-based.

- traceability and biosecurity advantages. This benefits trade protection and disease detection and is a further example of the importance of developments such as this to the entire value chain.

Conclusion

Pastoral production in Australia is becoming more challenging with the effects of drought impacting heavily on business operating conditions, particularly in rangeland grazing areas. With declining terms of trade, it has become increasingly important for producers to understand how to monitor and manage animal health and performance to optimise profit. In times of high available nutrition the opportunity to increase production must be captured.

Collecting timely livestock data is imperative in informing management decisions. Opportunity exists for the expansion and development of remote data collection systems in livestock industries, and has significant implications in rangeland grazing where the logistics of regular manual assessments are impractical. Models such as the walk-over-weighing system are currently being used in Australia. Whilst further refinement is still necessary, the opportunity to remotely collate flock data is substantially increased, with the potential to provide important data for animal health and husbandry.

Improved reproductive success of the breeding ewe is an important factor to the ongoing financial success of many sheep enterprises. There is a place for gathering flock as well as individual animal data. The use of technology streamlines this process. Whilst RFIDs allow graziers to gather a range of data about weight gain trends (and when collated with other flock information, potentially about health and condition), sheep condition scoring is still useful in determining ideal joining, gestation and lactation condition of ewes. Initial findings place importance on further work finding the correlations between flock-specific weight ranges and condition score.

Accelerated lambing has the potential to significantly increase production in sheep enterprises but lack of continuity of nutritional availability in the semi-arid region makes this approach reliant on extensive supplementary feeding. Once a range of performance metrics are used to monitor the biological performance of reproductive ewes in a rangeland environment, the poly-oestrus capacity of the breeding ewe may be leveraged to intensify sheep breeding schedules resulting in significant financial benefits for producers that have the data and can manage it.

Remote monitoring technology is rapidly evolving. The Silent Herdsman uses accelerometers in the United Kingdom dairy industry, where it is used to monitor livestock, and accurately indicate oestrus cycles for breeding purposes. Further research into its application in the sheep industry could provide opportunities for improved animal husbandry in pastoral grazing.

Technologies that are not currently available for the livestock industry, such as Nano generators and biosensors, will become available. Adoption of these innovations may create production efficiencies and streamline management.

Australian agriculture is already exceptional at leveraging biophysical opportunity within the geographical context in which it operates. Timely management of livestock enterprises will be enhanced with improved flock data collection, and many of the technologies explored throughout this study have the potential to assist graziers with this. Effective decision-making will be enhanced by improved on-hand data but must go hand-in-hand with financial modelling and forecasting. Applying financial analysis to potential technological solutions in agriculture will help improve the financial rigour of strategic and management decisions.

Recommendations

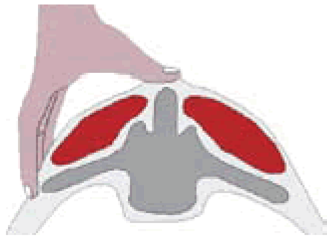
To maximize the outcomes of this report and facilitate linking financial and production modelling, further research is recommended in the areas outlined below.

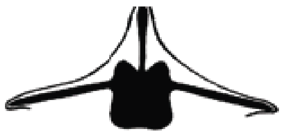
- Research to be conducted into use of subcutaneous Nano-generating biosensors to transmit sheep health and biological wellbeing.
- Further research self-powered devices to monitor leptin levels as a factor influencing management in sheep health and biological wellbeing.
- Develop standards and management protocols for monitoring individual animal's physiology in real-time for enhanced health and performance.
- Develop algorithms for accelerometers to interpret data collected.
- Further investigation is required to determine the correlation between live weight and condition score across breeds, allowing for accurate forecasting of condition score based on remotely gathered weight data.
- Conduct further research into Intensive breeding systems (such as the accelerated lambing models discussed) for potential adoption in a pastoral environment.
- Cost-benefit analysis of technology application and resultant change of management practices is needed.
- Further collaboration between livestock industry Research and Development Corporations and investments supporting investigation into emerging technologies.

Appendix 1 How to Condition Score

Condition Scoring

The animal should be standing in a relaxed position. It should not be tense, crushed by other animals or held in a crush. If the animal is tense it is not possible to feel the short ribs and get an accurate condition score





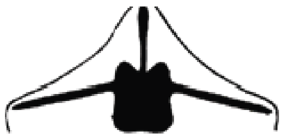
Condition Score 1

Score 1-Backbone

The bones form an elevated narrow ridge. Each vertebral process can be felt easily as a bone under the skin. There is only a very small eye muscle. The sheep is strong but quite thin (virtually unsaleable)

Score 1-Short Ribs

The ends of the short ribs are very obvious. It is easy to feel the squarish shape of the ends. Using fingers spread 1cm apart, it feels like the fingernail under the skin with practically no covering



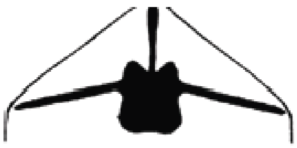
Condition Score 2

Score 2-Backbone

The vertebral processes are elevated but the points are rounded with muscle. It is easy to press between each bone. There is a reasonable eye muscle (store condition ideal for wethers and lean meat).

Score 2-Short Ribs

The ends of the short ribs are rounded but it is easy to press between them. Using fingers spread 0.5cm apart, the ends feel rounded like finger ends. They are covered with flesh but it is easy to press under and between them.



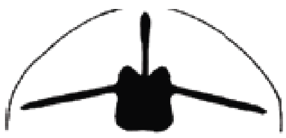
Condition Score 3

Score 3-Backbone

The spinal processes are only slightly elevated above a full eye muscle. It is possible to feel each rounded bone but not to press between them. (Forward store condition ideal for most lamb markets now. No excess fat).

Score 3-Short Ribs

The ends of short ribs are well rounded and filled in with muscle. Using 4 fingers pressed tightly together, it is possible to feel the rounded ends but not between them. They are well covered and filled in with muscle.



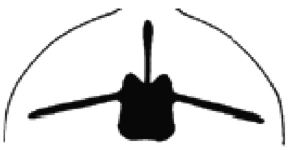
Condition Score 4

Score 4-Backbone

It is possible to feel most spinal processes with pressure. The backbone is a smooth slightly raised ridge above full eye muscles and the skin floats over it.

Score 4-Short Ribs

It is only possible to feel or sense one or two short ribs and only possible to press under them with difficulty. It feels like the side of the palm, where maybe one end can just be sensed.



Condition Score 5

Score 5-Backbone

The spine may only be felt (if at all) by pressing down firmly between the fat covered eye muscles. A bustle of fat may appear over the tail (wastefuland uneconomic)

Score 5-Short Ribs

It is virtually impossible to feel under the ends as the triangle formed by the long ribs and hip bone is filled with meat and fat. The short rib ends cannot be felt.

Source: the Lifetime Wool project (www.lifetimewool.com.au)

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Plain English Compendium Summary

Project Title:	Linking production and financial metrics in agriculture
Nuffield Australia Project No.:	1214
Scholar:	James L Walker
Organisation:	Paragon Equity Developments
Phone:	0746582141
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Email:	James.jumbuck@bigpond.com
Objectives	The objectives of this study were to: • Determine the factors affecting rangeland sheep production in Australia's pastoral industry. • Research alternative sheep breeding practices globally. • Research the application of performance monitoring technologies around the world.
Background	Poor reproductive efficiency in sheep flocks contribute to significant losses in a pastoral sheep enterprise. Research into remote, real-time monitoring of key health factors for ewes was identified as key to improving timely management decisions. The use of technologies in the livestock industries was deemed to provide the greatest opportunity to manage the full potential of livestock production systems.
Research	Research was conducted over a three-year period through research conducted in Canada, the USA, Europe, Asia, the UK and within Australia. Meetings were conducted with researchers, consultants and leading farmers.
Outcomes	Further research needs to be undertaken into the potential to monitor leptin levels as a factor to influence management in animal health and biological wellbeing. Further research is required to combine bio sensory technology with accelerometers and nanogenerators to monitor health and production performance of individual animals. Using data collected, the development of specialised algorithms and models to inform financial and production systems decisions will be necessary.
Implications	This report provides industry with scope for developing real-time biophysical monitoring devices and systems, and meshing this technology with financial impact to deliver enhanced decision-making tools for the sheep producer.