The Winston Churchill Memorial Trust of Australia

Report by Christopher J. O'Neill

2007 Churchill Fellow

The need and potential for integrating livestock behaviour and fitness into genetic improvement programs utilising data from radio telemetry.

Signed Christopher J. O'Neill Dated 24/11/08

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ACKNOWLEDGEMENTS

The fellowship provided me the opportunity to travel to Scotland, France, USA and Brazil, where I met with researchers, students, technicians and livestock producers.

Appreciation to the Churchill Trust is profound; not only for facilitating the scientific endeavour, but for the cultural experience of southern France, rural USA and tropical Brazil.

Gratefully I acknowledge Dr Alan Bell, Chief of Livestock Industries and my Project Leader, Dr Dave Swain for supporting my Churchill project and for providing me the leave for travel. A special thank you to local Seedstock producers Alf Collins Snr, Tony Hansen and Philip Quayle whose discussions helped focus the Churchill project.

To all my hosts and the students of the University of Lavras, the hospitality you showed a travelling Aussie was so much appreciated.

Finally I am indebted to John Maddux (Box 1), a Nebraskan cattle rancher who commented to me, “Beef cows today are too big and too soft”, a comment that initiated my application for the Churchill Fellowship. Indeed have livestock industries world-wide reached a crossroad in the production of food?

Box 1. John Maddux, *2S Ranch* (Sand Hills Region), Imperial, Nebraska, USA

EXECUTIVE SUMMARY

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The Churchill Fellowship travel to Scotland, France, USA and Brazil was undertaken between 16 June and 13 August 2008. The aim of the project was to explore the need for and potential of radio telemetry to generate behavioural and fitness (fitness defined as the survival and reproduction of a species in a natural environment) data for inclusion into livestock genetic improvement programs. I visited universities, research institutions and beef producers concerned with animal behaviour, fitness and production efficiency. At each location I gave a 40-minute presentation of our group's telemetry work at CSIRO, JM Rendel Laboratory, Rockhampton. A total of 20 presentations were delivered with discussion sessions varying between 30 and 90 minutes. Discussions centred on the need for livestock industries to focus on environmental adaptation and low-cost production. There was also concern for the lack of preparedness for climate change and the influence of 'Animal Rights' organisations. The Churchill project was enhanced by my attendance at the Welfare and Epidemiology Conference at Iowa State University, the Triennial Research Field Day at the Corona Range and Livestock Research Centre, New Mexico and the 45th Meeting of the Brazilian Society of Animal Science at Lavras, Brazil.

Highlights

- Insightful discussions on the future of agricultural research and development (R&D) with Dr John Huntley, Jack Maddux, John Young and Dr Cleber Soares.
- Dr Alain Boissy and his concepts and methods of studying animal behaviour.
- Researchers at New Mexico State University, USDA Jornada Experimental Range, New Mexico and the University of the Semi-Arid Region, Mossoro, Brazil for their approach to investigating desert adaptation of livestock.
- Dr Dean Anderson and progress with USDA virtual fencing technology.
- Meeting with Dr Huw Jones – elucidating the power of information dissemination.
- Dr Suzanne Millman's appreciation of animal welfare issues for livestock.
- Dr Roberto Torres – composite breeding using tropically adapted *Bos taurus.*

Recommendations

It is recommended that providers of agricultural R&D support the following:

- Compile an inventory of breeds of environmentally adapted livestock for Australia.
- Invest in genetic adaptation to environmental stressors.
- Invest in studies of the relationship between immunocompetence and production.
- Invest in the biological applications of telemetry and their miniaturisation.
- Initiate a review of models of dissemination of information.
- Initiate short term exchanges of staff and students with research institutions in tropical regions with publication as a mandatory outcome of an exchange.

Implementation and Dissemination

Outcomes of the tour will be disseminated to industry forums, ABC Rural Report, Qld Country Life newspaper, CSIRO and DPI&F seminars, and by informing stakeholders of the existence of the report on the Churchill Fellowship's website.

FELLOWSHIP PROGRAMME

19 – 24 June, Edinburgh, Scotland UK

- Roslin Institute: Drs Steve Bishop, Ozzie Matika, Pam Wiener, Jennifer Gill, Liz Glass and PhD students – physiological limits to meat and milk production, the impact of climate change on UK livestock industries, genetics of parasite and disease resistance, genetic resistance to Bovine Tuberculosis and finding genes that cause these differences.
    - Dr Georgia Hadjipavlou – sheep genetics.
- Moredun Research Institute: Dr John Huntley – sheep scab disease, parasitology.
- Centre for Tropical Medicine: Dr Ivan Morrison – gastrointestinal resistance.
- Scottish Agricultural College: Dr Mike Hutchings – parasite avoidance, climate change.
    - Drs Lutz Bunger, Maree Haskell and Simon Tursve – behaviour and beef and dairy cow production limits, dairy cow temperament.
    - David Ross – agricultural consultant, dissemination of information.
    - Dr Mike Coffey – dairy cattle genetic evaluation.
- Genesis-Faraday: Dr Huw Jones – technology translator.
- Ice Robotics Ltd: Robert Boyce, Antonia White and visiting students – dairy cow lameness, telemetry technology.

26 – 27 June, Bordeaux, France

- ENITA de Bordeaux (School of Science and Technology): Didier Chinzi – biotechnology, agricultural education and technology transfer.
    - Dr Catherine Bennetau-Pelissero – phytoestrogens, soybean isoflavones, commercial diets disrupting endocrine homeostasis.
    - Christian Germain – France's National Livestock Identification Scheme.
    - Drs Maria Urdaci, Marie Lefevre and Muriel Denayrolles – probiotics.
- Conservation of Rare d'Aquitaine Breeds of Livestock: Luclle Callede and Stephanie Audrain (student from ENITA) – programme financed by regional council, inventory of the remaining pure breeds and their traits.
- *Beraut* – a Blonde d'Aquitaine stud owned and operated by the Barberin family (one of the original farms of the breed). Selection for growth has increased birth weight without increased calving difficulties.
- Lionel Giraudeau director Blonde d'Aquitaine bull testing and evaluation centre, selection for production traits.

30 June – 1 July, Clermont-Ferrand, France

- INRA (National Institute for Agricultural Research): Dr Alain Boissy – animal behaviour and cognition, fearfulness, vulnerability to stress, stress-related diseases.
    - Stephane Andanson and Christine Ravel – measuring stress and physiological indicators of stress.
    - Eric Delval – behavioural research laboratory.
    - Dr Claudia Trelouw – animal behaviour and meat quality.
- INRA Experimental Farm: Francis Decucq – grazing behaviour and telemetry.
    - Dr Veronique Deiss – stress at slaughter.
    - Dr Marie-Madeleine Richard-Mialon – oestrus behaviour.

6 – 10 July, Imperial, North Platte, Whitman and Hastings, Nebraska, USA

- Maddux Cattle Co. *2S Ranch*: John and Jack Maddux – medium sized, easy-care maternal *Bos taurus* composite adapted to the Nebraskan Sandhills, Estimated Breeding Values (EBVs) that impact on the costs of production, using goats to systematically eradicate weeds from pastures.
- Wauneta Calisade Science Club: Ms Teresa Hayes and high school students.
- *Rex Ranch*: John Young (manager) – successful selection of *Bos taurus* composite cattle for adaptation to the Sandhills environment, winter grazing observations.
- *Gudmundsen* Sandhills Laboratory (University of Nebraska Cooperative Extension): Andy Applegarth (manager) – The Nebraska Ranch Practicum (rancher educational program), Beef Basics Home Study courses, practical experience for university students, composite cattle breeding and bull sales.
- West Central Research & Extension Centre (University of Nebraska): Dr Rick Funston – beef nutrition and heifer development.
    - Dr Aaron Stalker – beef/range system specialist, farm production economics.
    - Gastal Nicolas – visiting French student, breeder of Aubrac cattle.
- USDA Meat Animal Research Centre (Clay Centre): Dr Ed Casas – QTLs for production and adaptation, cattle eye disease (Bovine Pink-eye).
    - Dr Bob Cushman – reproduction, oestrus behaviour, photo-period genes, telemetry.
    - Dr Mark Thallman – genotype evaluation, USA's National Livestock Identification Scheme.
    - Drs Tammy Brown-Brandl, Larry Kuehn and Gary Rohrer – cattle heat stress, welfare of feedlot cattle, housing cattle in deep bedded barns.
    - Dr Shuna Jones – pig diseases and identification of genetic resistance, tour of research facility.

13 – 15 July, Ames, Iowa, USA

- Inaugural Welfare and Epidemiology Conference – Across species, across disciplines and across borders.
- Iowa State University: Dr Suzanne Millman – sickness behaviour, social behaviour and immunity, techniques to assess animal welfare.
    - Dr Annette O'Connor – sickness behaviour, modified behaviour due to onset of Bovine Pink-eye.
    - Eldon Uhlenhopp – Associate Dean of Outreach and Operations.
    - Dr Sue Fairbanks – climate change associated with pathogens and parasites in wildlife.

16 – 19 July, Las Cruses and Corona, New Mexico, USA

- New Mexico State University: Triennial Research Field Day at the Corona Range and Livestock Research Centre.
    - Neil Burcham – development of Corona Black Angus adapted to a semi-arid environment.
    - Dr Derek Bailey (Chihuahuan Desert Rangeland Research Centre) – foraging behaviour, Brangus adapted to a semi-arid environment, grazing distribution.
    - Dr Milt Thomas – genetics and physiology of adaptation, development of the desert adapted New Mexico State University Line 1 Brangus.

    - Santiago Utsumi (PhD student) – targeted grazing with small ruminants to control weed invasion.
- USDA Jornada Experimental Range: Dr Ed Fredrickson – ancient Criollo cattle from Mexico adapted to an arid environment, behavioural syndromes.
    - Dr Dean Anderson – virtual fencing technology, ancient cattle husbandry techniques.

22 – 25 July, Lavras, Minas Gerais, Brazil

- University of Lavras: 45th Meeting Brazilian Society of Animal Science. Paper presented: Applications of radio telemetry to monitor an animal's environment and its behavioural response to that environment: beef cattle in the tropics by C.J. O'Neill, R.G. da Silva, G.J. Bishop-Hurley, T. Wark and D.L. Swain.
    - Dr Agustin Blasco (University of Wisconsin, invited speaker at conference) – biodiversity, endangered breeds, conservation programs.
    - Dr Bob Cushman (USDA, Clay Centre, invited speaker at conference) – germplasm preservation, reproduction, telemetry.
    - Dr Jose Camisao de Souza – dairy cow performance, dairy composite.
    - Professor Tarciso de Moraes Goncalves and graduate students Miguel Bottino and Leonardo da Silva – development of the Tabapua (*Bos indicus* composite) a polled breed of extremely docile temperament, feedlot performance, cell grazing, tour of university and experimental farm.

27 – 29 July, Mossoro, Rio Grande do Norte, Brazil

- University of the Semi-Arid Region: Debora Andrea Morais – sheep and goat adaptation to a desert environment.
    - Dr Roberto da Silva – bioclimatology.
    - Dr Alex Maia – heat stress, shade/sun seeking behaviour.

31 July – 2 August, Compo Grande, Mato Grosso do Sul, Brazil

- Embrapa (Brazilian Agricultural Research Organisation): Dr Cleber Oliveira Soares (Head of Research Development) – future for tropical research and development.
    - Segio de Medeiros – nutrition.
    - Dr Roberto Torres and graduate student Lucas Silva – tropical composites, genetic evaluation, Caracu development.
    - Quintino Izidio dos Santos Neto (Destron Fearing) – radio frequency identification and software, remote observation, miniaturised microchip technology.
- Sete Estrelas Embrioes (Nellore Artificial Breeding Centre): David Antunes.

4 – 8 August, Belo Horizonte, Minas Gerais, Brazil

- University of Minas Gerais: Dr Ferando Madalena – tropical dairy cattle.
    - Dr Jose Bergmann – EBVs for cattle temperament, industry engagement.
    - Walsiara Maffei (PhD student) – reactivity in a mobile cage, temperament evaluation.
    - Professor Romario Leite – parasitology, declining effectiveness of acaricide in Brazil.
    - Andre Naves – tropical beef composite, agro-forestry.

Introduction

Domestication of cattle commenced about 10,000 years ago when Neolithic hunter-gatherers began to tame aurochs (*Bos taurus primigenius*) – ancestors of our current cattle breeds. By 6,000 years ago the domesticated *Bos* genus had separated into 'humped' cattle (e.g. Nellore) of tropical Asia and 'hump-less' cattle (e.g. Hereford) of temperate Europe (cattle historically referred to as *Bos indicus* and *Bos taurus,* respectively). About sixty years ago cattle farmers began to intensify systems of agriculture and concentrate on producing quantity (bulk meat or milk). There was also increased production through modified nutrition, chemicals to control parasites and infrastructure to mediate the negative effects of climate, as well as through genetic improvement programs. Genetic improvement was achieved firstly by favouring breeds of high production potential (e.g. Angus or Charolais for beef and Holstein for milk) and secondly by focusing on both quantitative and molecular genetic technologies to improve the product. The genetic improvement in product traits was achieved but at the expense of behavioural and fitness traits – where fitness is defined as the survival and reproduction of a species in a natural environment. Hence, over the past sixty years there have been dramatic improvements in product quantity and quality from a small number of current popular cattle breeds, but there has been a loss of fitness in these breeds (Kraublich, 2000). Moreover, breeds of low production potential have declined in number and some are extinct or near extinction.

The loss of cattle breeds adapted to their environment and the focus on production traits in an artificial production environment has made the global cattle industries vulnerable to climate change and the rising economic and carbon costs of maintaining that artificial environment. To address the sustainability of beef and dairy industries, future research and development must include fitness and adaptative behavioural traits as well as revisiting those breeds that could contribute genetically to maintaining acceptable levels of production and product quality, but from cattle resistant to environmental stress, i.e. functional adaptation.

This report of the Churchill travel summarises the knowledge and impressions gained in animal behaviour and fitness in the fields of maternal ability, reproduction and resistance to environmental stress. The report also draws parallels with the animal behaviour work at CSIRO Rendel Laboratory where Proximity Loggers (UHF transmitter-receivers) are used to measure contacts and Global Positioning System (GPS) collars are used to track animal movement over a landscape. Special mention is also made of animal welfare and programs of information dissemination. Implications for genetic selection are discussed.

Environmentally Adapted '*taurine*' Cattle

Bos indicus cattle originated in tropical regions and possess inheritantly high levels of resistance to the stresses of heat and parasites, but compared to the European evolved *Bos taurus* cattle, the former possess relatively low levels of growth potential (appetite, metabolic rate), fertility and meat quality. Nevertheless, due to historical movement of *taurine* cattle into the wet and dry tropics there are small genetic sources of cattle adapted to these environments. An example of this is the Criollo (Spanish cattle taken to the Americas 400 years ago). Moreover, in temperate regions that experience harsh environmental conditions, small genetic pools of adapted cattle also exist. The Churchill Fellowship project was able to identify some of these adapted *taurine* beef breeds and a brief description of the breeds is given below (Boxes 2 – 6). Also included is a description of the Adaptaur - a breed that was developed in northern Australia by CSIRO (Box 7).

Box 2. Aubrac: an old French mountain breed renowned for its calving ease, mothering ability and high resistance to disease (Photo courtesy of Gastal Nicolas).

Box 3. Nebraskan Sandhills Composite: based on Red Angus selected for medium size, productivity and adaptation to the Sandhills environment

Box 4. Corona Angus: From 1979 Black Angus selected by the New Mexico State University for reproductive efficiency, low cost production (cow energy value $EN) and adaptation to the desert environment of New Mexico.

Box 5. Jornada Criollo: based on Chinipas and Chinampo Criollo – heat resistance and mobility over the landscape and now being developed by researchers at the USDA Jornada Experimental Range of New Mexico.

Box 6. Caracu: a large Criollo from Brazil. Embrapa is proposing to select the breed for medium size, productivity and adaptation to a tropical environment.

Box 7. Adaptaur: A composite developed from Herefords and Shorthorns brought on to CSIRO *Belmont*, northern Australia in 1952 and selected for growth and tick resistance, focusing on a single family since 1980.

In each example of an adapted *taurine* beef breed both fitness and adaptation were major considerations in the genetic make-up of the breed. The list of breeds is not exhaustive as other adapted *taurine* breeds are known to exist in other regions as evidenced by the French government sponsored Conservation of Rare d'Aquitaine Breeds of Livestock. More importantly, there is a need to identify the environmentally adapted genetic sources for dairy cattle, sheep, goats and pigs, as these livestock industries have undergone a comparable production focus since domestication. Dr Dean Anderson of the Jornada Experimental Range noted that whilst this is being undertaken, ancient husbandry techniques should also be documented before they are lost for ever. The return to the days of cheap energy and supplementary feed is most unlikely to occur in the foreseeable future. Moreover, the negative effects of climate change and accumulating chemical residues from acaricide use will place pressure on livestock industries to utilise those genotypes with relative high levels of resistance to environmental stress.

Maternal Behaviour

The Churchill project clearly identified maternal ability as a critical consideration for future genetic improvement programs due to the behaviours associated with predators, stress and fitness. Both John Maddux and John Young of Nebraska were concerned that the emphasis on maternal 'milk' has been at the expense of all other maternal traits. For Debora Morais of the semi-arid region of Rio Grand do Norte, both social and maternal ability of ewes and nannies are fundamental to survival of offspring in a harsh environment. Indeed, the profound importance of maternal traits, other than supplying adequate milk to the offspring, has only recently been realised.

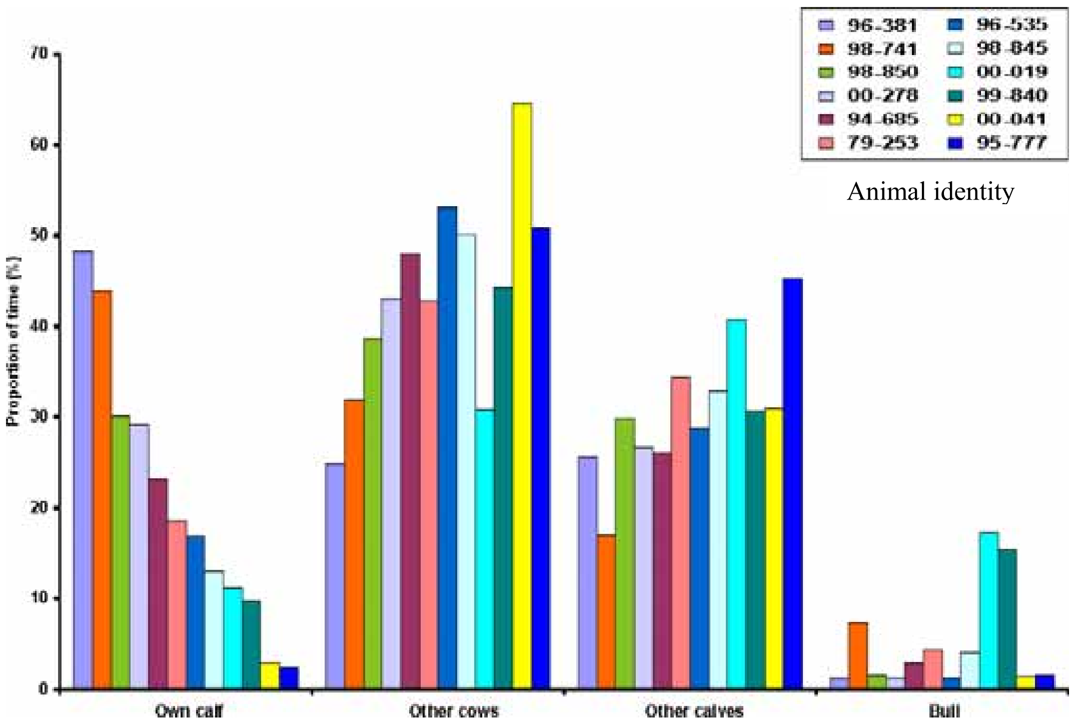

Figure 1. A 10-day deployment of contact loggers of 12 cows and calves and mating bull during the 2005-06 breeding season on *Belmont*, Australia showing for each cow the proportion of time spent with own calf, other cows, other calves and mating bull. (O'Neill *et al*, 2006)

That mothering ability should also be considered in a social context is illustrated from telemetry data from Belmont Research Station, Australia. Figure 1 shows contact data from a 10-day deployment of Proximity Loggers (SirTrack Ltd, Havelock North, NZ) on 12 Belmont Red cows and calves and a mating bull from 23 to 30 December 2005. The reading range of each logger was set at 6m. Clearly some cows (e.g. cow 96-381) spent almost half of their contact time with their own calf, whilst other cows (e.g. cow 95-777) spent less than 10% of their time with their own calf, preferring instead other cows and calves. It could be concluded that cow 96-381 was a better mother than cow 95-777. This would be so if not for the social behaviour of the group. The majority of these cows synchronise their foraging whilst deploying crèches for their calves with one to three cows acting as sentinels. There was anecdotal evidence from the Churchill study tour that crèche formation is utilised by other livestock species in extensive production systems and is crucial for the survival of young against predators. The degree to which this behaviour is under genetic control or is mimic behaviour is yet to be evaluated.

A component of maternal behaviour, that of mother-offspring grooming, has only recently been identified as having a profound consequence for offspring behaviour. Through rodent cross-fostering studies Ian Weaver and Michael Meaney (Zhang *et al*, 2004) found that maternal licking/grooming of offspring during early development can have a long-term effect on the offspring's response to stress and this response is epigenetic. Here epigenetic is defined as a change in gene expression, gene(s) being switched on or off, via environmental or developmental factors. In the case of rodent maternal behaviour, high rates of maternal grooming and licking reduced the offspring's responsiveness to stress when they reached adulthood compared with those that received relatively low rates of maternal care and these differences were passed on to the next generation. It is not unreasonable to extrapolate these findings to a cow's grooming/licking of her calf. However it may not be the act of grooming that elicits the above responses, but rather the act of touching or very close contact between mother and offspring.

At every location visited on the Churchill trip where cows and their calves were present, numerous incidents of calf grooming were observed. *IceRobotics* of the UK, stated technology is available that could be incorporated in a Proximity Logger device to record both close contact and head movements associated with grooming. Thus, there is now the opportunity for telemetry devices to generate objective data on maternal grooming and investigate other traits associated with maternal behaviour.

Box 8. Brahman cow grooming her calf – *Chihuahuan Desert Rangeland Research Centre*, New Mexico, USA.

Oestrus Behaviour

Complementary to recording maternal behaviour, contacts associated with oestrus behaviour of lactating cows can also be recorded from the same deployment of Proximity

Loggers. Figure 1 also shows that unlike most of the cows of the group there were two cows (99-840 and 00-019) with almost 20% of their contact time being reserved for the bull. Figure 2 shows the hourly contacts during 26 December 2005 (date of conception as determined by ultra-sound) of cow 99-840 with the bull (00-094) and the remaining 11 cows of the group. The bull's contact duration with cow 99-840 totalled 547.8 minutes on the day of conception, whereas daily contact with the bull on other days averaged 24.7 minutes. The Proximity Logger not only identified bull contact behaviour that resulted in a conception but also the contact activity of the other females associated with the oestrus event for cow 99-840. The data of Figure 2 shows that by 6:00 PM the bull had lost contact interest in the cow on 'heat', but the duration of contacts of the other cows, particularly cow 98-850, would suggest that the oestrus event had lasted a further four hours.

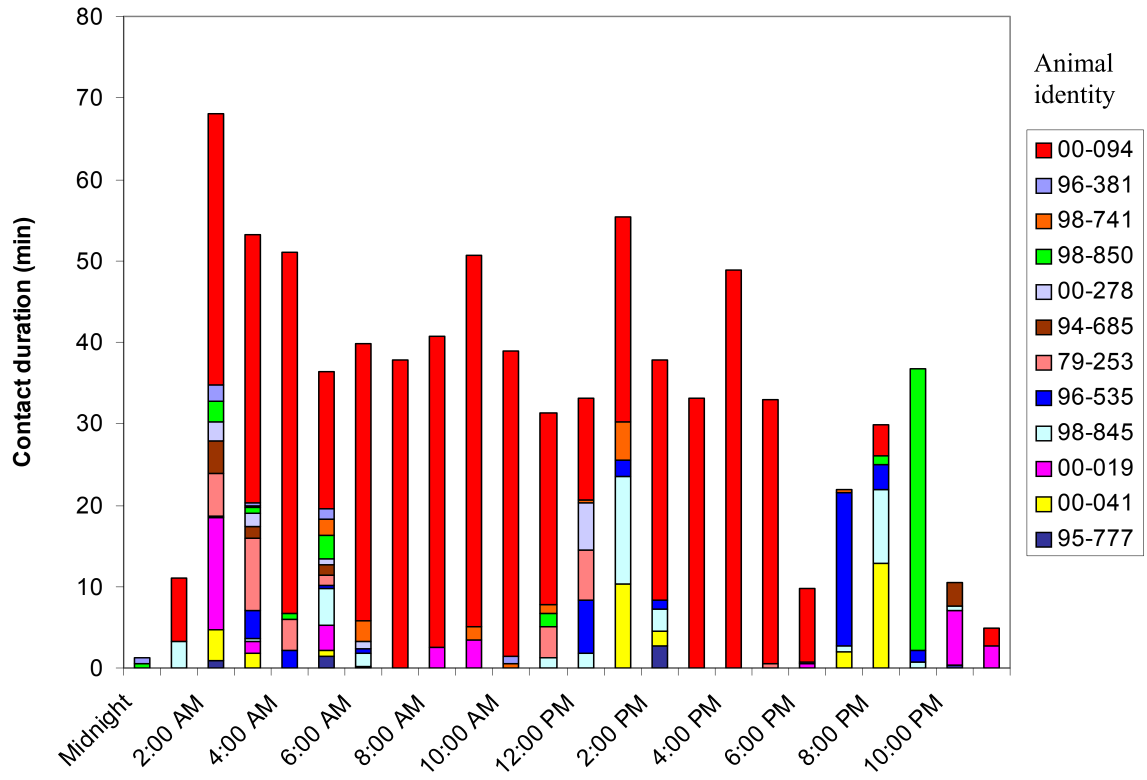

Figure 2. Hourly contact duration (min) of cow 99-840 with the bull 00-094 and other cows on the day of conception, 26 December 2005, *Belmont* Australia. (O'Neill *et al*, 2006)

Dr Bob Cushman of the USDA Clay Centre believes that the data of Figure 2 would also provide an insight into the relationship between oestrus behaviour and the physiology of oestrus. However, in the first instance the information of Figures 1 and 2, identifying females in oestrus, has the potential to assist artificial insemination and embryo transfer programs. Secondly, the data have ramifications for research into bull libido, onset of puberty, anoestrus during lactation and the social aspects of reproduction. Indeed all these contact traits have a profound contribution to fitness and warrant further investigation.

Anti-parasite Behaviour

Maternal ability has additional significance for cows raising their calves in tropical regions because the act of grooming also removes cattle tick from the calf. Although the removal of tick by grooming was documented in the 1950s (Riek, 1956) the other anti-tick strategies of acaricide chemicals, vaccines and the inheritantly resistant *Bos indicus* genotype gained favour with tropical cattle industries worldwide. Given the yearly global costs of cattle tick and tick-borne diseases is around US$16 billion (de Castro, 1997), and all these strategies have limited efficacy (e.g. Sonenshine *et al*, 2006), it is timely to reconsider the animal's own anti-parasite behaviour. The science communities of Roslin and The Scottish Agricultural College are concerned that climate change could manifest itself as tropical parasite infestations of *taurine* genotypes in temperate regions bordering the sub-tropics, genotypes naive to such parasites.

Australia will also be vulnerable to climate change. It is anticipated that changes to the climate will spread parasites and diseases from northern Australia into southern Australia (White *et al*, 2003). However, the historical movement of *taurine* genotypes into the tropics (e.g. Criollo) have provided a model of a susceptible genotype acquiring resistance to tropical stresses. In northern Australia, a closed herd of Hereford-Shorthorns was established on *Belmont* in the 1950s and the highly susceptible population was selected for growth and tick resistance. Since 1980, this selection has focused on a single family that contained animals of extreme resistance and the two-breed composite was named Adaptaur (Frisch *et al*, 2000). In an experiment recently conducted at *Belmont*, Brahman and Adaptaur heifers were each infested with 10,000 tick larvae, *Rhipicephalus microplus* (formerly *Boophilus microplus*). The heifers were collared with a Proximity Logger to record contact behaviour and the tube of tick larvae was attached to the collar, and the heifers were observed for anti-parasite behaviour. A preliminary analysis of the data shows that compared to the Brahmans the Adaptaur displayed twice as much skin licking, similar scratching and very little allogrooming (allogrooming defined as one animal grooming another animal). Moreover almost half of the Adaptaur heifers yielded zero counts of mature ticks from the infestation. The total removal of tick larvae on day-1 of infestation of the extremely resistant Adaptaur (O'Neill *et al*, unpublished data) has further implications for transmission of tick-borne diseases.

Box 9. An allogrooming event in young Blond d'Aquitaine bulls at the Blond d'Aquitaine bull testing station Bordeaux, France.

The grooming activity described above was observed in many herds I visited on the study tour. In the brief time I visited the two locations of Blonde d'Aquitaine I saw numerous allogrooming events (Box 9) – but is this programmed grooming, grooming to enhance social bonding, social grooming to relieve stress from confinement or a response to skin irritation? Alternatively is allogrooming simply a continuation of communal grooming from an evolutionary past when there was a communal effort to remove external parasites?

Foraging Behaviour

Where Proximity Loggers are being used to document contact behaviour and potentially to record grooming events, GPS technology is being used to record movement of animals over the landscape. Again, modifications to this technology allowing the study of foraging behaviour and estimates of intake were demonstrated by Francis Decucq at the INRA experimental farm, Clermont-Ferrand, France.

This technology has the potential to quantify observations made by John Young of the winter foraging behaviour of his breeder herd at *Rex Ranch*, Nebraska. For the past 15 years John has been applying selection pressure on the adaptation qualities of his herd – medium sized cows given minimal winter supplementation despite wind chill temperatures approaching -10^{0}C. The herd divides itself into those that routinely forage the hills and those that forage the valleys (Boxes 10 and 11). The hill/valley foraging behaviour was also documented by Dr Derek Bailey of New Mexico State University. John Young observed that by the end of the Sand Hills' winter, the hill-foragers were consistently in better condition than the valley-foragers. An explanation of this may be that the better adapted cows prefer hill-foraging over valley-foraging. In terms of foraging environment the two groups of cattle do face differences in topography, species of plant foraged and micro-climate and any, or all of these factors may contribute to the improved performance of the hill-foragers over the valley-foragers. However, the hill-foragers have also modified their foraging behaviour by turning over and eating the roots of a small soapweed called 'Yucca' (*Yucca glauca*), a plant normally regarded as a pest and routinely poisoned with herbicide. I was also shown a summer pasture where Yucca plant was in abundance and needed controlling. Cows placed under the pressure of adaptation modified their winter foraging behaviour and enhanced their fitness.

Boxes 10 and 11. Cows of *Rex Ranch*, Nebraska foraging the hills and valleys respectively.

Heat Stress

Heat stress in cattle is not only a concern for tropical locations. In the south of France, Blonde d'Aquitaine animals are tethered in barns during the day to avoid heat stress. Whilst travelling through the Nebraskan Sand Hills, a region relatively devoid of tree cover, the gregarious behaviour of young cattle (Box 12) was observed on numerous occasions. Ranchers have varying views as to the motivation of the tight head-to-tail group formation. It is generally believed that the herding behaviour is a response to biting horn flies (*Haematobia irritans*) and the animals standing together exploiting an encounter-dilution affect (Mooring and Hart, 1992). Alternate suggestions include reducing the effects of wind or a perceived response to the fear of predation. Dr Tammy Brown-Brandl of USDA Clay Centre has observed a similar behaviour of feedlot cattle and believes it is a response to heat stress. It is plausible that the accumulated body heat of the group is negated from the combined effect of ground shading – heat radiated from the ground would be substantially reduced from shading. Tammy has also observed that on days of heat stress cattle ignore the mound in the middle of the feedlot pen, preferring instead to stand in wet areas thereby utilizing the cooling effect of evaporation. Radio telemetry devices on feedlot animals as well as probes to record weather data has the prospect to generate objective data that could improve the design and functioning of feedlots.

An insight into the capability of radio telemetry generating objective data associated with weather events was obtained from the sickness behaviour experiment described earlier. Incidental to the tick infestation experiment at *Belmont*, data from Proximity Loggers also suggested variation within *Bos taurus* to climatic adaptation. The experiment was conducted in the summer of 2007-08 and data from the *Belmont* weather station showed that ambient day-time temperatures reached 35^{o}C with animal visits to the water trough being recorded via a Proximity Logger placed on the water trough. Of the 15 *taurine* heifers, the two Murray Grey and one Adaptaur heifer not only displayed heat stress behaviour (panting), but frequented the water trough almost twice (significant $P<0.05$) as much as the remaining heifers (O'Neill *et al*, 2008). Thus the telemetry technology could have the potential to not only identify severe weather events, but also generate data for the estimation of genetic parameters for resistance/susceptibility to heat and humidity stress.

Box 12. Gregarious behaviour of young animals in the Sand Hills of Nebraska, USA

That coat colour and hair density is related to stress from heat and solar radiation is well known. As noted above Blonde d'Aquitaine can be heat stressed in the south of France during summer and their breed society may soon have to consider selecting for traits of environmental adaptation. Blond d'Aquitaine animals vary from white to a dark golden colour. Initially, the white was the preferred colour at Seedstock sales in the d'Aquitaine region, but recently the bias has shifted to the golden colour – a change of colour preference simply based on personal choice. However, in the USA about 10% of Seedstock breeders of composite cattle, including *2S* and *Rex Ranches*, are selecting for adaptation and fitness and showing little bias to coat colour. A particular colour will become dominant if productivity is correlated with that colour. Dr Roberto da Silva, in my visit to Mossoro, told me that animals best adapted to a tropical environment had a short slick coat of white hair on a dark pigment. In the last 20 years, for both the Caracu from Brazil and Adaptaur from Australia, the frequency of animals with pigmented facial skin and black facial hair has increased. It is reasonable to assume that for the Adaptaur at least, the change in facial pigment and hair has been correlated with the significant reduction in the incidence of bovine pink-eye and cancer eye in this breed (Frisch and O'Neill, unpublished data). Caracu with black facial hair are automatically culled by the Caracu breed society. Dr Roberto Torres of Embrapa is concerned that this may be an adaptation trait (a correlated response to resistance to eye disease or to solar radiation) and should be allowed to increase in frequency in the Caracu breed and indeed be considered in genetic improvement programs for tropical cattle.

Selecting for Environmental Adaptation

As with livestock industries of Europe, USA and Brazil, Australian livestock producers will need to prepare for changes to their production systems. The overwhelming view of researchers and producers was that the cost of energy and of stock feed, coupled with carbon pollution, will force future producers to reduce their reliance on high cost infrastructure, supplementary feed and chemicals to counter the current levels of environmental stress. The strong evidence that increasing atmospheric concentrations of greenhouse gases will add to climate variability will increase the difficulty for producers to maintain long term productivity. Because livestock globally will be faced with an increasing array of parasites and pathogens, Dr Steve Bishop of Roslin proposed the need to investigate the relationships between high production potential and immunocompetence, and to ascertain whether improved immunocompetence results in improved animal health. Moreover, if reliance is solely on developing new vaccines that include anti-parasite vaccines, then an animal's health could still be compromised if the animal is vulnerable to climate stress.

For the Nebraskan *2S* and *Rex Ranches,* the answer is a low-cost production system and using appropriate genetics to complement the system. For these cattlemen, the key genetic drivers must include medium mature size, high fertility and environmental adaptation. Breeders of Brahman cattle in northern Australia, such as *Belah Valley* and *Pondicherry,* target similar genetic drivers – functional adaptation and fitness. An important difference for *Belah Valley* is not to select for a particular mature size, but rather to monitor trends in mature size whilst selecting for functional adaptation and fitness. Indeed the same principles are being applied to the development of the desert adapted Corona Angus and Jornada Criollo and the parasite resistant Adaptaur from Australia and Caracu from Brazil. Establishment of the adapted *Bos taurus* then gives the desert and tropical beef producers the opportunity to maximise the heterosis (hybrid vigour), and therefore productivity, from the crossing of *Bos indicus* with *Bos taurus* (Frisch and O'Neill, 1998). John Maddux believes that where the *Bos indicus* is not an option for the Sand Hills winter environment, the Adaptaur, a European *Bos taurus* of medium size, selected for adaptation, could give *2S Ranch* an additional opportunity for inclusion in the Sand Hills' composite.

The need to develop a robust genotype is not confined to cattle. The University of the Semi-Arid Region, Mossoro, will be embarking on a research and development program with local breeds of sheep (Moroda Nova and Cariri) and goats (Caninde and Moxoto) (Box 13), utilising both GPS and Proximity Loggers to study reproduction, maternal ability, and importantly for their region, foraging behaviour and water consumption.

Box 13. Local goats of the semi-arid region of Mossoro, Brazil

However, selecting for adaptation may involve the acceptance of trade-offs (see Jensen, 2006). On *Rex Ranch* the successful selection of cattle adapted to the Sand Hill environment of Nebraska appears to have had an unfortunate consequence for one aspect of meat quality. A recent evaluation trial of *Rex Ranch* carcasses compared with carcasses from the *Gudmundsen Ranch* has shown that marbling (US Choice) of *Rex Ranch* steers are significantly lower than those of *Gudmundsen Ranch*, but no difference for subcutaneous fat. Both herds are a Red Angus based composite. Could the selection for adaptation traits on *Rex Ranch* have had an epigenetic consequence with environmental stress switching off genes that instigate marbling in the *Rex Ranch* herd?

The many applications of telemetry technology in identifying genetic variation in such traits as maternal ability, libido, grooming and foraging behaviour can now provide comprehensive tools for selecting livestock for functional adaptation and fitness. Selecting for adaptation in any breed/region initially involves identifying those stressors that impact on productivity, estimating genetic parameters for the resistance/susceptibility to the stressor, generating an EBV for the trait, and finally combining these EBVs into an Adaptation Index for inclusion into genetic improvement programs.

Animal Health and Welfare

Successful use of telemetry to address maternal ability, fertility and adaptation of livestock will have positive impact on the overall health of livestock and therefore ramifications for the general public's increasing focus on animal welfare. The infestation of cattle by the cattle tick provides an example of additional applications of telemetry. In northern

Australia, as in other tropical regions, the cattle tick is endemic and the future use of acaricide may need to change from routine applications to strategic applications because of the parasite's resistance to the chemical and the accumulation of chemical residues both in meat and the environment. Beef producers may have to tolerate infestations and monitor the level of infestation and radio telemetry could play a crucial role in monitoring the effects of an infestation. Once tick larvae attaches to the skin of an animal, a range of immunological processes are activated, which in turn leads to varying changes in the behaviour of the host. These behaviours can range from grooming (as discussed earlier) to displays of 'sickness'. Sickness behaviour can be manifested as fever, lethargy, depression, appetite reduction, dehydration and reduced social exploration (Millman, 2007). Thus within any group of cattle some animals invoke anti-tick strategies whilst others succumb to the infestation and display sickness behaviour.

The displays of sickness then invoke the public's concern for animal welfare. Attendance at the Iowa State University inaugural Welfare and Epidemiology Conference gave me an insight into USA and European welfare issues for livestock, issues that Australian industries will face in the near future. Most measures of deteriorating welfare are used retrospectively and considerably fewer measures are available for the prediction of animal welfare outcomes. Currently there is reliance on those with routine access to stock to be vigilant for signs of sickness (Box 14). However, emerging real-time telemetry technology could provide the power of prediction. Once an animal's normal healthy behaviour (social contacts, visits to feed and water, body temperature, rumen pH) is known, then telemetry data could also indicate behavioural or physiological aberrations that are characteristic of 'sickness' invoking early veterinary intervention. Dr Suzanne Millman summed up the animal health - welfare situation with "if animals are healthy then their welfare will follow"

Box 14. Brazilian stockmen or Vagueiros, Compo Grande, Brazil. Embrapa has a high regard for the way their Vagueiros take care of cattle.

Dissemination of Information

If the livestock industries of Europe, USA or Brazil were faced with issues of climate change, carbon footprint ("food miles") or animal welfare, then the research institutions of those countries would call upon their group of scientific communicators to act as a conduit between the researcher and livestock producer. Moreover, because the scientific language is converted into a language that can be understood and appreciated by the industry, the general public can also be informed. Scientific communicators can take the form of extension officers, outreach scientists or technology translators with their primary role to effectively disseminate scientific information. Most impressive was the New Mexico State University field day at Corona where almost 100 beef producers were in attendance and each attendee received a Proceedings of the presentations and posters. Indeed, research institutions such as Roslin, INRA, Iowa State University, USDA Clay Centre and Embrapa regard the uptake of research by the industry, not simply as an obligation, but as a science.

In Australia, CSIRO has historically relied on the Extension Services within State Agricultural Departments to disseminate CSIRO information. Over the past decade in Queensland at least, there has been reduced interaction between the State and Federal research institutions to such an extent that the CSIRO Rendel Laboratory is reconsidering industry engagement options to facilitate communication. An effective engagement option will have added benefit of an information flow back to CSIRO from producers who deploy current technologies and willing to take on emerging technologies to maintain profitable businesses. These producers are aware of the power of information, but also the power of misinformation that can occur in the general media and internet. Leaders of Australian producer groups should have access to CSIRO scientific communicators, so that the group's position in public debates on issues such as an emission trading scheme or animal welfare, is based on independent factual information or, just as crucially, aware of the gaps in scientific knowledge. These communicators should also be utilized to effectively inform the industry of breeding and management options and the emerging biotechnology revolution. A case in point is the biotelemetry technologies of Proximity Loggers and GPS. Moreover, Wireless Sensor Networks, capable of real-time streaming information from cattle in the paddock to a computer, and utilising telemetry in the automated control of animals (Wark *et al*, 2007) will require an effective and realistic account of their prospective applications in agriculture.

For livestock industries, radio telemetry has the potential to initiate a paradigm shift from purely 'productionism' to integration of production, fitness, adaptation and welfare. So when a Nebraskan rancher observes that beef cows today have grown past their optimal mature size and lack resistance to environmental stress, the livestock industries worldwide have reached a turning point in their development.

Recommendations

Climate change, the increasing cost of energy and the expected tax on greenhouse gases will ensure that Australia's agriculture will have to move to a post-productionism era. If our livestock industries are to sustain profitability levels of quality and quantity, simultaneous with improving environmental and animal welfare outcomes, then this shift must be supported by Governments and providers of agricultural R&D. Post-productionism, characterised by breed diversity, low-cost production, concerns for animal welfare and the environment, and genetics of fitness and environmental adaptation, will be facilitated by adopting the following recommendations:

- Compile an inventory of breeds of environmentally adapted livestock for Australia.
- Research investment for genetics of resistance to heat stress and to parasites and pathogens, and the feasibility of an Adaptation Index.
- Invest in studies of the relationship between immunocompetence and production.

- Invest in the biological applications of telemetry and the miniaturisation of such devices as a contact logger to the size of a cattle ear tag.
- Initiate a review of models used to disseminate agricultural information and emulate or customise effective models such as the University of Nebraska *Gudmundsen* Sandhills Laboratory 2008 Nebraska Ranch Practicum (www.panhandle.unl.edu/ranchpracticum).
- Research institutions of Australia engage cooperatively with research institutions of tropical regions and initiate formal short-term exchanges of staff and students between institutions. A publication must be a mandatory outcome of any exchange.

Outcomes of this Churchill study tour will be disseminated to industry forums, ABC Rural Report, Qld Country Life newspaper, CSIRO and DPI&F seminars, and informing stakeholders of existence of the report on the Churchill Fellowship's website.

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