[Photograph: Stephen O'Connor]

Swan's Lagoon: Golden Years of Beef Research

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Foreword
As this iconic research facility passes to another role, it is time to reflect on its history as well as it's legacy for the future.

Fifty years ago "Swans Lagoon" emerged as the product of industry requirements to overcome the numerous challenges facing cattle production in the dry subtropics. Thinking producers were then, as now, aware that productivity was the key to a successful beef production enterprise. It is a tribute to the foresight and support of producers and Government that they worked cooperatively to develop research priorities that were relevant to this vast Northern region.

Research, itself, has always generated enormous debate about it's worthiness and true value. The true value of "Swans Lagoon" research lay in the practical, outcomes-driven approach adopted by the Advisory Committees and the consequent activities of so many dedicated scientific practitioners. The personal commitment and dedication, offered so unselfishly, by all who worked at "Swans Lagoon", has delivered immeasurable benefits to the North Australian cattle industry.

The fact that "Swans" commenced with *Bos taurus* cattle and concluded with *Bos indicus* cattle, demonstrated it's ability to maintain relevance in a beef cattle industry that is advancing at great speed.

"Swans Lagoon" has delivered so many sound, science-based, research solutions to issues confronting the Northern cattle industry, that it is impractical to start listing them on this page. But there is one enormous resource, often undervalued and never fully appreciated, that must not be lost to the passing of time. I refer to the great "human reservoir" of scientific knowledge and practical experience that resides with those who laboured to overcome the issues of the time. The North Australian cattle industry and Queensland Government alike, would be negligent in the extreme, if this immensely valuable mentoring resource is "turned out to pasture". These individuals possess invaluable experience that can never be purchased and must, if they wish, be given the opportunity to convey some of this knowledge to those who choose research as a career.

So, as the dust settles on the achievements of "Swans Lagoon", let's look forward with anticipation to the outcomes that I am sure "Spyglass" and a new generation of researchers can deliver to the beef cattle industry. I hope that in another fifty years from now, it to will possess the same proud record of achievement that "Swans Lagoon" now holds.

Don Heatley
"Byrne Valley"
Home Hill

Preface

I was stationed at Swan's Lagoon for 18 years, and have continued to conduct research there after shifting camp in December 1999 to Charters Towers. It has been a fabulous place to conduct applied beef production research and a core to my professional life. How it was when I arrived was a legacy of great leadership by those who set the place up and led its operations in the first 10 years, people like Rod Strachan, Max Burns, Tony Plasto, Lyle Winks, Darryl Lynch, Peter Allan and Peter Smith.

I was very lucky to arrive on 8th February 1982 to start work with mentors of extraordinary talent, especially Dick Holroyd and the Late Keith Entwistle; Keith completed supervision of my James Cook University Master of Science degree, replacing Michael Goddard who was also a fabulous mentor, and who has since gone on to achieve substantial fame.

Swan's Lagoon for much of its operation as a research station has been a small community itself, providing the fabric of life there. Their integration with the local farming community, mainly through the Millaroo social club, has been strong. I have very good memories of living within the Swan's Lagoon and Millaroo communities; indeed, my wife Linda was a product of the latter, and I was not the first to find a bride amidst the lower Burdekin cane paddocks.

Working with and husbanding cattle and managing rangelands is never simple. But with good resources, good and skilled people, and good planning, it can be made to look like that. Swan's Lagoon has had its share of these features over the years, hence the extraordinary achievements emanating from the station.

Given the strong history of Swan's Lagoon, it is with some sadness that operations will be transferred to Spyglass Beef Research Facility, north of Charters Towers. However, the move promises to offer new opportunities to the Queensland beef industry and community. Spyglass has been well cared for by the Lyons and Kirkwood families. In comparison to Swan's Lagoon, it can accommodate more cattle. It is closer to the main northern beef producing areas, so is more accessible to graziers enhancing the technology transfer process. Spyglass has a range of land types that do not exist on Swan's Lagoon. It is easily accessed all year round by scientists, advisers, producers and the community. Finally, it represents the upper Burdekin catchment which sustains a large regional cattle population.

I have enjoyed compiling this brief record of Swan's Lagoon's history and outputs with assistance from others who equally value their time stationed at Swan's Lagoon - blokes with towering reputations like Lyle Winks, Russ Tyler, Peter Smith, Reg Andison, Dave Smith and John Lindsay. Photographs from Stephen O'Connor, Mark Savage, Rod Strachan, Lyle Winks, Dick Holroyd, Alan Ernst, Rebecca Hall, David Hirst and Wayne Hall make valuable contributions. There is a fantastic trail of evidence through publications, with the most valuable being the annual reports; they were always eagerly sought by scientists, extension staff and beef producers alike. Ruth Kerr, DEEDI historian, has been able to uncover and contribute many pearls of history buried in south-east Queensland vaults.

I hope this record is of value to current and future generations of scientists and beef producers who are looking for some understanding of tropical beef cattle management that can be derived from 50 years of Swan's Lagoon research.

Geoffry Fordyce
Senior Research Fellow
Queensland Alliance for Agriculture and Food Innovation
University of Queensland
August 2011

Summary
Swan's Lagoon is a beef cattle research facility that has been owned and operated by the Queensland Government for 50 years. Initially it covered 80 km^2, but now covers 340 km^2, and can accommodate a herd of over 3,000 cattle. The areas used are generally flat with low-fertility soils. Annual steer growth on natural pastures in this dry tropical environment averages 105 kg. With approximately 150 paddocks, including many replicated trial areas, it has provided a very effective resource for a massive amount of component and systems research.

There are many achievement highlights. One of the most significant has been training of generations of advisory staff to support the adoption of more efficient beef production strategies across Queensland. Research has focussed on improving cattle growth and survival, reducing management costs, preventative cattle health care, pasture management, and improving efficiency through better reproduction and genetics. Many of the strategies studied have impact in all beef production areas. Applied research has been the main thrust of Swan's Lagoon work.

A vast majority of the research at Swan's Lagoon has been conducted on a collaborative basis with scientists from other beef industry research agencies in north Australia, a feature of research in this region. Therefore, the achievements listed below are partially attributable to their involvement.

Swan's Lagoon, August 2005
[Photograph: Stephen O'Connor]

Some of the most significant growth and nutrition research achievements include:

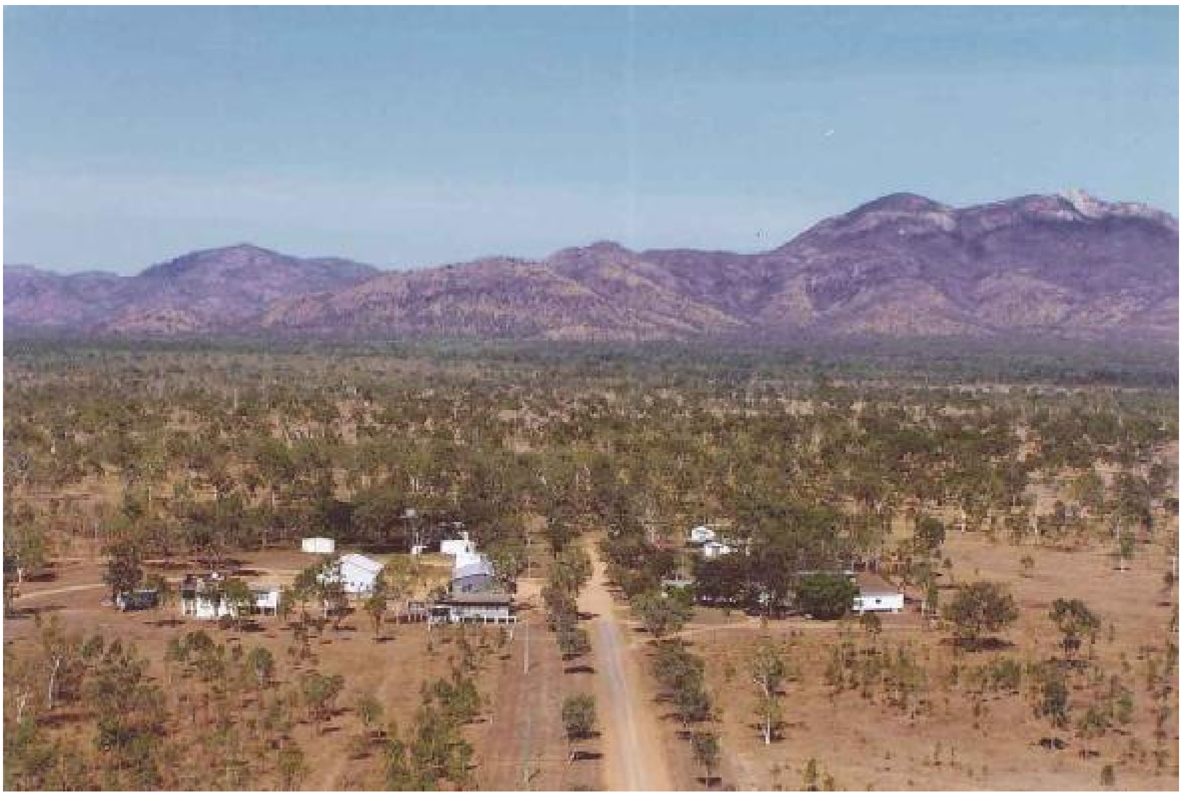
- Developing urea-based supplementation principles for protein deficiency in beef cattle.
- The principles of using fortified molasses supplements for both survival and production feeding.
- Spike feeding to improve pregnancy rates in first-lactation females.
- Quantifying the value of a large range of potential supplements, especially protein- and energy-rich meals derived from plant sources.
- Establishing production expectations from use of HGPs
- Methods to establish and utilise *Stylosanthes* spp. legumes, and the expected live weight responses to established legume pastures in the dry tropics.
- The impact of burning on pastures and beef production.
- The increase in long-term production efficiency and the reduced risk when moderate, rather than high, pasture utilisation rates are used.

Research highlights for improving efficiency through better reproduction and genetics include:

- Successful use of artificial insemination in northern beef herds.
- Demonstrating the advantages of Brahman crosses over Shorthorns.

- Weaning and weaner management systems for efficient cattle production in the dry tropics.
- Efficient mating management systems.
- Nutrition and other factors that affect time of puberty in both heifers and bulls.
- Expectations of pregnancy rates in disease-free cattle and the related economics.
- Achieving and managing pregnancies in yearling cattle.
- Documenting normal levels of calf wastage, and major causes of elevated losses.
- Effective methods to identify sub-fertile bulls.
- Management to maximise calf output from bulls without compromising herd reproduction.
- Development of alternative methods of contraception in beef cattle.
- Breed effects on major production traits.
- Demonstration that both puberty and the ability to cycle during first lactation are highly heritable in Brahmans with strong genetic correlations to readily-measured traits in bulls.

Significant studies that have assessed management, health care and its costs include:
- Demonstrating efficacious use of vaccines to control botulism and vibriosis.
- Quantifying the effects of a range of parasites such as ticks and buffalo flies.
- Showing that coccidiosis, and not worms, is the usual cause of weaner diarrhoea in the dry tropics, and how to manage this disease.
- Objective measurement of temperament and demonstrating its high heritability.
- Pre-slaughter management principles for cattle to avoid loss of carcass weight and value.
- Demonstrating the short-comings of dry-curfew over wet-curfew selling.
- Development and commercialisation of Hirst short-arm spears for trapping cattle.



Swan's Lagoon office, sheds and housing complex, September 2004
[Photograph: Stephen O'Connor]

Common abbreviations:

MUP	Molasses, urea and protein meal, typically in the ratio of 100:3:10, plus DCP, salt and monensin.
M8U	Molasses and urea mix at 100:8 by weight. Various additives may be included.
HGP	Hormonal growth promotant, administered as an implant placed under the skin of the ear.
DCP	Di-calcium phosphate, a source of balanced phosphorus and calcium in cattle supplements.

1. Introduction

Swan's Lagoon is owned and operated by the Queensland Government as a beef cattle research station. It was purchased in 1961, three years after initial survey. The first advisory committee formed and met in the same year and research began in 1962.

Swan's Lagoon is situated in the sub-coastal spear grass region in the dry tropics of north Queensland and is located at Millaroo, a predominantly cane farming community 80 km south of Ayr on the left (west) bank of the Burdekin River. Originally the station was only 80 km^2 (east of Millaroo Ck). The station included two river-side blocks (Deep Creek and Riverside paddocks), each of approximately 400-500 ha. These were north and south of the Millaroo cane-farming areas. These additional areas were relinquished in the late 1970s.

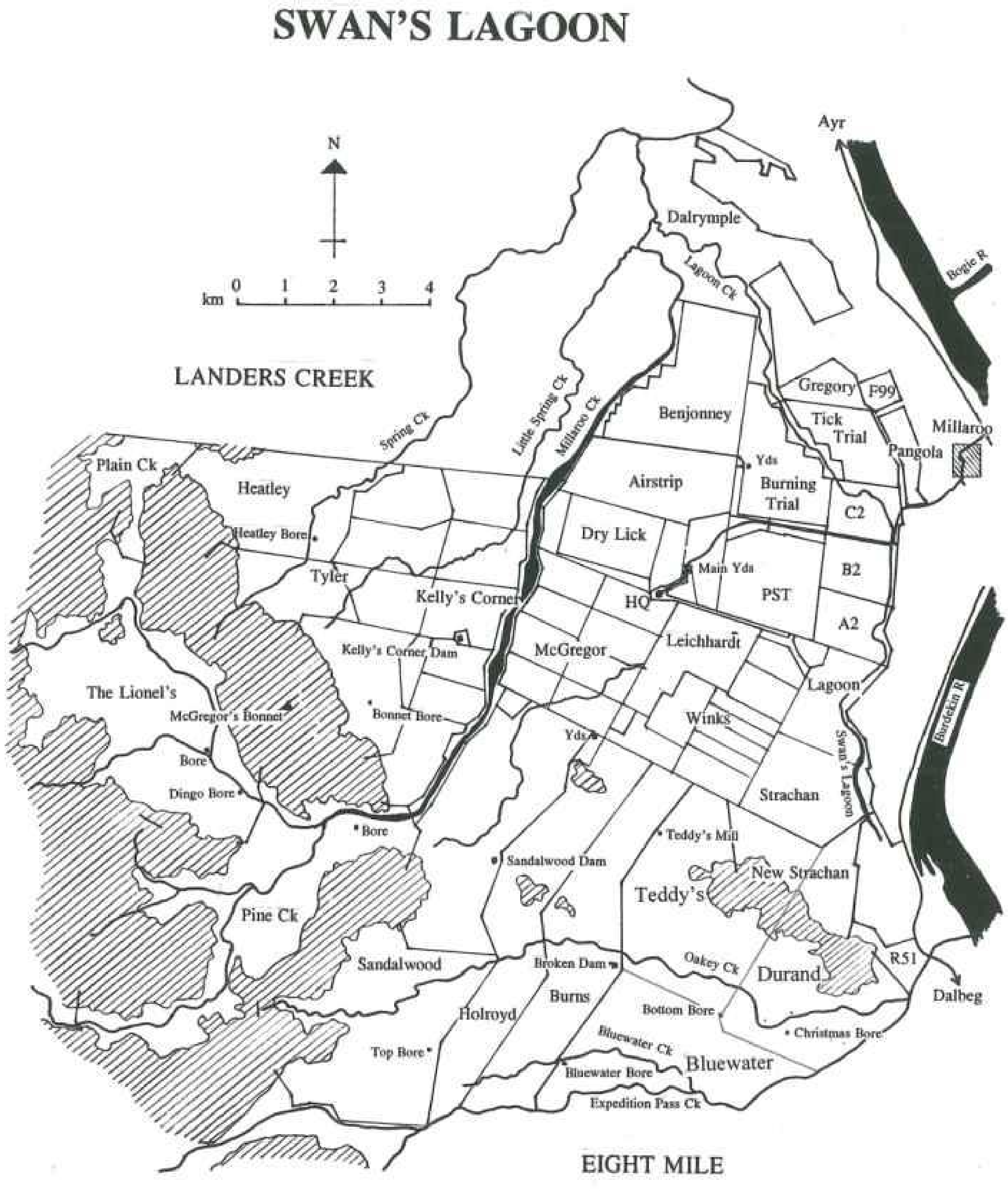
Acquisition of the adjoining Expedition block which included the Kelly's Corner area (north of Millaroo Creek) in 1978 increased the station area to 350 km^2. Subsequently, some areas on the eastern side were resumed in 1994 for cropping and the station now covers an area of 340 km^2, of which approximately half is steep mountainous country of no practical grazing value.

The station directly represents approximately 14,000 km^2 of tropical spear grass country in Queensland, and has been suited to developing the principles for many elements of beef production across north Australia. The research conducted has aimed to provide options to deal with the primary prevailing challenges of weaning rates that have averaged less than 60%, low annual growth rates, eg, 100 kg, high mortality rates, and high management costs. All of these have some relationship to the region's low and variable rainfall. The tropical environment also offers further challenges with insect-borne viruses, ticks, buffalo fly and internal parasites widely prevalent.

Swan's Lagoon research has contributed to understanding the biology of many aspects of beef production, and tested strategies to manipulate it for maximum beef production efficiency. Through this process, not only has the station produced a vast amount of practical beef production science, it has also trained many people, including technical staff and post-graduate students, who have then been able to very effectively support beef producers throughout Queensland in increasing their business efficiency.

Swan's Lagoon research has been strongly supported by the beef industry throughout its operation. The station operates as a business and has provided revenues to match development, maintenance and operation similar to commercial businesses. The major funder of research has been the Queensland government through salaries and research infrastructure development. Meat industry levies, currently managed by Meat and Livestock Australia, have consistently provided the majority of operational research funding since the Australian Meat Research Committee's first grant for "Studies of management practices, adaption of different breeds and strains to tropical environments, and studies on tick survival and resistance" in 1962/63. A large number of other agencies and commercial companies have also provided research funding.

This document provides a brief history of Swan's Lagoon and a synopsis of the research and other achievements. The documentation to compile this has not been complete, and I apologise for any key missing information or errors.



Map of Swan's Lagoon, 2011 - Old timers will note that some trial areas have had names changed

2. The people
Swan's Lagoon has usually been staffed by 10-20 people. These have typically included a manager, administrative assistant, station hands, scientists and technicians.

The old Millaroo Club (circa 1965) that was replaced in the 1970s
[Photograph: Rod Strachan]

Working together in the one business has built strong friendships and a sense of family for many staff. In the first 25 years, commercially-available entertainment outside work hours was limited. Employment conditions were different; for example, staff worked nine to five daily, flexi-time did not exist, and leave was not allowed within the first year of employment. Together, this meant that locally-made fun was a regular feature. Beer O'Clock on Friday was eagerly anticipated by staff. Christmas was a major annual event for the Swan's Lagoon community. Many staff went on their annual leave at this time. The annual Millaroo Merry Muster (rodeo) at Tudehope's Landers Creek Station next door was strongly supported by Swan's Lagoon staff. The last rodeo was held in 1981, though campdrafts have been held there on a few occasions since. The picnic races at Gladys Lagoon in Clare were also a highlight on the Swan's Lagoon calendar. Tennis, darts and other community activities were centred around the Millaroo Club and primary school. Swan's Lagoon staff were members of the club committee for much of its operation as a research station.

A classic scene from the Gladys Lagoon picnic races in mid-1970s
[Photograph: Mark Savage]

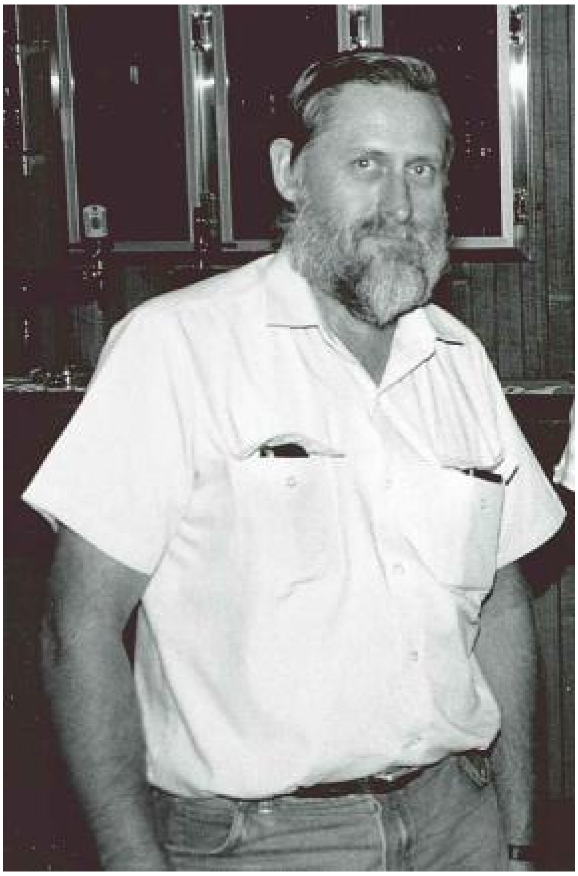
2.1 Managers

The station managers have had the role of coordinating all activities on the station. They have had to be good cattle managers, people managers, and business managers, as well as being able to understand and support research within the administrative framework of the department – quite a challenge!

Dick Holroyd and Russ Tyler leading a wet season lagoon crossing in C2, 1978
[Photograph: Mark Savage]

Till the mid-1980s, the manager and station staff were part of the same group as the science staff. These groups were then split administratively at a high level within the department. Managers from this time were appointed by the resource management (research stations) or regional management group. Those who have held this position include:

Name		*Manager*	*Other years*	*Name*		*Manager*	*Other years*
Strachan	Rod	1962-1965		Laing	Alan	1985-1988	1968-1973
Fletcher	Jock	1966-1968		Jeppesen	Keith	1989-1995	1996
Lynch	Darryl	1968-1969	1966-1967	Mims	David	1996-2001	
Smith	Peter	1969-1970		Erlich	Wayne	2002	
Sands	Bill	1970-1973		O'Connor	Stephen	2003-2007	
Holmes	Alan	1973-1975	1970-1973	Andison	Reg	2007	
Gannon	Bob	1976-1978	1966-1968	Brown	John	2007-	
Tyler	Russ	1978-1984	1968-1969				

Historical versions of former managers, Peter Smith and Alan Laing, who are now both well-known beef industry advisers

2.2 Administration support

The name of the Queensland Government department responsible for Swan's Lagoon has changed several times during its life. However, for most of its operational life Swan's Lagoon was under control of the Department of Primary Industries, or DPI for short. The structure of the department and how the station has been managed has also changed. For the first half of its operational life, it was managed by Cattle Husbandry Branch and then Beef Cattle Husbandry Branch. The resource management aspects were transferred to a research stations group, which had various names over the years, in the mid-80s. In 1997 management shifted to the newly-created Queensland Beef Industry Institute (QBII). When QBII was discontinued, control of the station was shifted to Townsville-based north Queensland regional department management. This control was transferred back to a state-based research infrastructure branch in 2010.

Administration support staff at Swan's Lagoon have included:

Family name	*Given name*	*Years*	*Family name*	*Given name*	*Years*
Crothers	Joyce	1988-2004	Miokovich	Cindy	1990-1995
Ford	Casszandra	2006	Neilson	Hayley	2010-2011
Holmes	Merilyn	1973	Pete	Margaret	1989
Kenniff	Lyal	1983	Wyburg	Rudi	1963-2010
McLachlan	Sue	1990			

Rudi Wyburg at her 65th birthday party, 18 October 2006, Swan's Lagoon
[Photograph: Geoffry Fordyce]

Rudi Wyburg was the longest-serving employee at Swan's Lagoon and a legend in her own lifetime. She was still working part-time at Swan's Lagoon when she passed away in 2010 after a very brief illness. Rod Strachan, the first station manager, explains:

"I employed Rudi sometime in 1963 - she was working in the Millaroo Post Office. I did advertise for a secretary and there was some interest from a couple of local girls who had completed their 'commercial' studies at Ayr High School. I told Rudi that if she would teach herself to type she had the job!! So that's what happened and I copped the 'flack' from the mothers of the other girls!! But what a stroke of luck!! Not only did Rudi learn to type but over the years she must have coped with all the technical advances that continue to drive me 'nuts'. More than that, somehow she had to prepare papers from the likes of Winks, Holroyd, Lindsay and Fordyce!!!

"I was fond of Rudi and for years after I left Swans she would let me know if anything was happening that I should know about. Life can be tough - it is very sad she could not enjoy a retirement - while those left behind are blessed that she crossed their path."

Swan's Lagoon staff, 17 March 1978: Back – Dick Holroyd, Peter Dunster, Tom James, Russ Tyler, Howard Reimers, Trevor Morrison; Centre – John Lindsay, Marcus Platen, Rudi Wyburg, Jack Kirk, Peter Knights, Stu McLennan; Front – Ian Loxton, Stan Allan, Tony Merrifield, Mark Savage, Bob Gannon
[Photograph: Mark Savage]

2.3 Operational staff

The station has enjoyed the services of a large number of skilled station hands. These are the people who often do the tough work and get little credit, but they generally enjoy every moment. They and their families have provided the fabric of station life at Swan's Lagoon. People who have served in this role include:

Family name	*Given name*	*Years*	*Family name*	*Given name*	*Years*
Allan	Stan	1977-1979	Leake	Michael	2003-2005
Atkinson	Don	1999-2003	Lee	Gregory	
Balias	Kathleen	1985	Leppien	Gavin	1998
Barden	C	-1970	Litschauer	Andrew	2006-2007
Barden	E	1972-	Lyons	B	1977-1978
Bardon	Col	1972;1989	Maddern	Peter	2004-2006
Barlow	Darryl	1987	Madigan	David	1999
Barrett	A	1980	Makaravicius	Victor	1972-1973
Barton	Michael	1989	Maloney	Vanessa	1997-1998
Bastin	Vicky	1984	Markham	Rohan	2010-2011
Baxter	Arthur	1988	Martin	David	
Beckman	Gavin	2004-2007	Matthews	James	2001
Bell	Brett	1989-2004	Matthews	Tamara	1995
Bettany	Steve	1991-1992	McBride	T	1986
Bliss	Katie		McLachlan	Dennis	1989-2002
Boccolatte	Chris		McShane	Michael	1984-1986
Bonassi	V	1986	Menzies	Kevin	1985
Bradshaw	Felicity	2006-2008	Merrifield	Tony	1974-1980
Bradshaw	Ken	1984-1986	Miller	Bruce	1987-1988
Bright	Malcolm	1984	Milner	Carly	
Bronson	Shane	1984	Moore	Dave	1988-1992
Brown	Eric	1982-1988	Moran	John	1998-1999

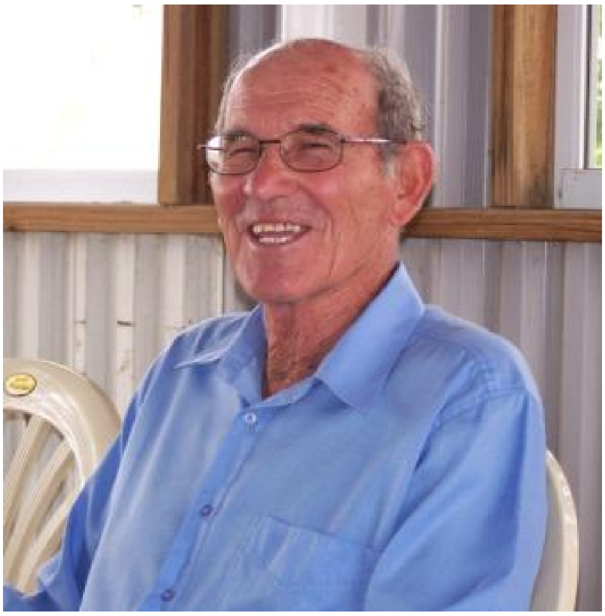
Family name	*Given name*	*Years*	*Family name*	*Given name*	*Years*
Brown	Robert	1982-1986	Morrison	Trevor	1982-1984
Burgess	Kent	1990-1996	Morrissey	Justin	2006
Burke	Bob	1992-1993	Mulvey	KJ	1971-
Butler	Dale	1996-1997	Naughton	John	
Callanan	Edmund	1996	Newman	Beverly	2005-2006
Cant	Victor		Newman	R	1984
Casalegno	Cliff	1989	Noack	Evan	1988
Cervoni	Michael	1986-1987	Oakes	Terry	1994-1996
Coops	Colin	2003	Oates	Paul	1986
Cornford	Robert	1972-1973	O'Connor	Matt	2005-2006
Cowen	Paul	1986	O'Grady	Michael	1994
Danello	Peter	1973	Olsson	Ken	2004-2005
Dodt	Lance	1976-1977	O'Malley	Jack	1964-1970
Doman	Peter	1988	Pascoe	Fred	1991
Duff	Ray	1978-1980	Peachy	Alex	
Eva	Williams	1974-1976	Phillot	D	1973-1974
Ferguson	Aaron	2007	Platen	Marcus	1977-1981
Ferguson	Betty	1994-Current	Price	A	1986
Ferguson	Jim	1994-Current	Pyott	Alexander	1986-1987
Ford	Dale	2005-2008	Pyott	Warwick	
Forster	Neil	2008-2010	Rafter	Gavin	1997-1998
Garde-Wilson	Chris	1996	Randall	Robert	1986
Gardiner	Dave	1988	Rawlinson	Alan	1985
Garland	Paul	1994-1995	Rawlinson	Lester	1986
Garner	John	1986-1987	Rawlinson	Morris	1988
Gericke	Ross	1979-1980	Reaburn	Olivia	
Godlonton	Richard	1990	Reeves	Andrew	
Gornalle	Tristan	1989	Reid	Kristy	2004-2006
Gough	Peter	1989	Reilly	Susan	1989
Grassell	A	1981	Reimers	Howard	1974-1980
Guild	James	1996-1997	Roberts	Colin	1985
Hansen	Arthur	1986	Robertson	H	1971-
Harrison	Benjamin		Robinson	Bruce	1982-1987
Harrison	Dennis	1984	Rodighiero	Marco	
Hartwell	Tara	2007;Current	Rossiter	Kirsty	1996
Hartwell	Tex	2007-Current	Rupena	A	1986
Heath	Wayne	1982-1985	Samson	Christopher	1995
Heron	Charlie	1991	Schaumburg	Michael	1987
Hetherington	Peter	1986	Schefe	Darcy	1969-1971
Hintschel	T	1970-	Scott	J	1968-1969
Hockey	Barry		Shand	Norm	1986-1989
Holmes	Keith	1972-1977	Sheahan	Danny	1982-1984
Huggers	Tony	2008-2009	Sim	Lance	1989
Hughes	John	1991-Current	Spry	Ted	1972
Huson	Tiffanie		Stokes	Edward	1984
James	David	1995	Stone	Brett	1997
Jensen	S	1985	Thomas	Janelle	1989
Jeppesen	David	1989	Thomas	Lyndon	1989-1990
Jeppesen	Jennifer	1989	Thomas	Owen	1989
Jones	Clint	1988-1989	Thompson	Michael	1985

Family name	Given name	Years	Family name	Given name	Years
Jones	Gavin	2007-Current	Thorley	Hazel	1966-1971
Jusseaume	Erin		Tomlinson	Mark	1988
Kaye	Peter	1985	Tudehope	Don	1967-1969;1974-1975;1985
Keating	PA	-1969	Veitch	Rodney	
Keller	Peter	1972	Veivers	Terry	1987-1988
Kelly	Andrew	2006-2007	Vener	Willie	2011
Kendall	Alison	1989	Vogel	Halbe	1985
Kennedy	Doug	1987	Wallace	Lyle	2003-2004
Kennedy	Pat	1967-	Watterson	S	1984
Kennedy	Ross	-1967	Watts	Stuart	1989-1996
Kennedy	Virginia	1971-1993	White	D	1970-1971
Kerriush	R	1973	Williams	Peter	1969-1970
King	Amie		Williams	W	1981
Kippen	Norm	1964	Wilson	Chris	1999
Kirk	Jack	1973-1981	Woods	Timothy	1986
Kuskie	Jayne	1995	Wyburg	Bruno	1967-1968
Lamperd	Stuart	1987;1989	Young	Billy	1990
Lane	Alwyn (Bronco)	1968-1974	Young	Darryl	1989-1992
Lawrie	Peter	1992-1993	Zanocco	Tony	1986-2001

In addition to these staff, Swan's Lagoon has also had the privilege of a number of trainees who have usually remained for up to a year. They have included:

Family name	Given name	Years
Boylan	Shadai	
Dallachy	Kerry	1999
Gilbo	Errol	1992
LeBlowitz	Adam	2002-2003
Thomas	Clint	1998

Felicity Bradshaw, Station hand, after calving, circa 2005
[Photograph: Rebecca Hall]



Eric Brown, Head Stockman 1982-1987, October 2006
[Photograph: Geoffry Fordyce]

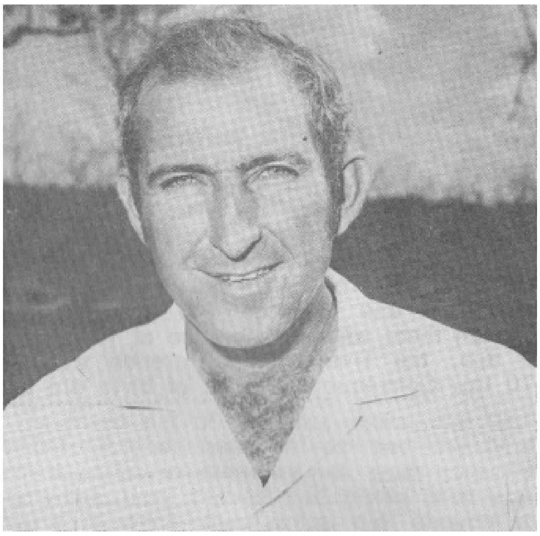
Howard Reimers saddled up, 1978
[Photograph: Mark Savage]

2.4 Science staff

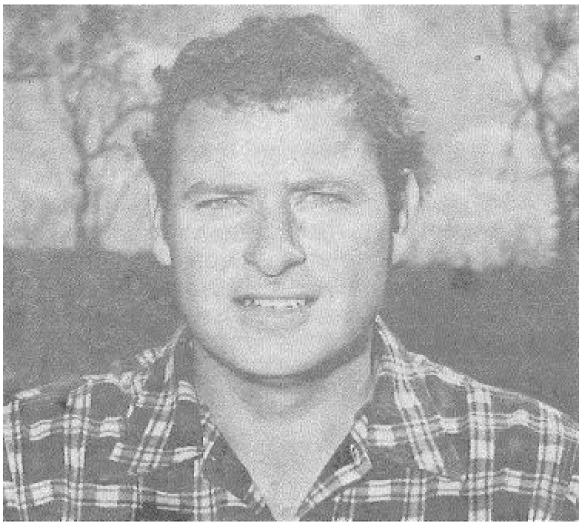
Science staff based at Swan's Lagoon have included post-graduate scientists, graduate and diplomat technical officers, cadets, scientific support officers and students posted there for half-year training. These people have included the managers plus:

Name		***Years***	***Name***		***Years***
Allan	Peter	1968-1973	Kendall	Ian	1987-1994
Auld	Michael	1979-1980	Kidd	Jim	1986-1988
Batterham	Ian	1994-1996	Knights	Peter	1978-1981
Jackson	Désirée	1986-1987;1991-1992	Leutton	Ralph	1968-1969
Beaman	Nigel	1983-1987	Limpus	John (Blue)	1969-1972
Beattie	Andrew	1987	Lindsay	John	1978-2002
Boothby	Karen	1982	Litschner	John	1969-1971
Bowen	Maree	1997	Loxton	Ian	1971-1973;1976-1982
Bradshaw	IR	1970-	Mackett	Esther	1989-1999
Burns	Brian	1987	Marshall	A	1976
Cheffins	Roger	Late 1960s	Mason	Gary	1980-1981
Cherry	Don	2008-2009	Mawn	Joe	1974-1977
Clarke	Ross	1973-1976	McCartney	Cindy	2008-2010
Coates	Ruth	2005-2006	McLennan	Stuart	1973-1987
Condon	Mick	1968-1969	Miller	Stan	1969-1971
Cooper	Alice	1997	Muller	Tracy	2006
Cooper	Neil	1986-2007	Mullins	Tom	1978-1988

Name		Years	Name		Years
Corlis	Phil	1969-1973	Murphy	T	1972
Cox	Roger	1986-1991	O'Leary	Bernadette	1989-1992
Crebert	P	1965	Olsson	Peggy	
Debney	Megan	2004	Petherick	Carol	1993-1997
Dixon	Rob	1992-2001	Platso	Tony	1964-1968
Dodt	Ross	1970-1974	Porch	Ian	1995
Doherty	Ian	1974-1975	Ramm	Sonia	1990
Dunster	Peter	1977-1980	Savage	Mark	1974-1978
Dyer	Rodd	1992-1993	Schatz	Tim	1992-1993;1999-2001
Edwards	Bill	1963-1964	Schroter	Karen	1982-1983
Emery	Tim	2007	Smith	Dave	1992-1996
Enchelmeier	Karl	2009-2010	Smith	Ellen	1980
Ernst	Alan	1973	Smith	Ross	1966-1969
Farries	John	1967	Sneath	Roger	1986-1987
Fisher	Marcus	1969-1971	Taylor	Kay	1989
Fordyce	Geoffry	1982-1999	Taylor	Wally	1966
Fry	Peter	1995-1997	Thompson	Peter	1975
Gelling	Bev	1989-1994	Tune	David	1981
Hall	John	1966-1969	Vandersee	Lyn	1966
Hall	Rebecca	2005-2008	Venamore	Peter	1968-1970
Haller	Amy		Wall	P	1963
Heater	Kathleen	1983-1985	Warne	Peter	
Hirst	David	1979-2002	Warriner	Paul	1966
Hobbs	Kieran	1987-1989	Weller	Max	1964
Holroyd	Derek	1997	White	Adrian	1992-1999
Holroyd	Dick	1974-1985	Winks	Lyle	1965-1976
Hunter	Sandra	1997	Winter	Maree	2008
Hutchinson	Lisa	2010-Current	Wright	Graham	1972-1974
James	Tom	1976-1984	Young	Rob	1997



Lyle Winks, Scientist, Swan's Lagoon 1965-1976



Dick Holroyd, Scientist, Swan's Lagoon 1974-1985

2.5 Collaborating scientists

The science conducted at Swan's Lagoon for the most part has been in collaboration with science groups from many research agencies operating in north Australia. These relationships have been very fruitful and have enabled a “critical mass” to operate science in the region; without it, Swan’s Lagoon research would have been much poorer.

Biometrics (statistical mathematics of biology) is a key element of successful research in experiment planning and statistical analyses; without it, publication is not possible and research is worthless. Swan’s Lagoon scientists have had a long association with many outstanding biometricians. At the forefront was Peter O’Rourke; Peter still works with us on the Cash Cow project. Others of note include Vivienne Doogan, Tony Swain, Pat Pepper, Bob Mayer, David Mayer, David Reid, Mark Toleman, Ross Shepherd, Honour Stephenson, Angela Reid, and in recent times, Kerri Dawson and Yutao Li.

Economic evaluation is a vital part of assessing the potential impact of research outcomes prior to embarking on a project. Taking research into commercial practice also requires an assessment of potential returns and risk. Swan’s Lagoon has enjoyed association with several noted economists, the longest-serving being Bill Holmes (25 years) whose Breedcow and Dynama model is a valuable beef industry asset.

Keith Entwistle (James Cook University) examining ovaries by endoscopy at Expedition yards, March 1986
[Photograph: Geoffry Fordyce]

Collaboration with James Cook University was very strong, especially in the period between 1970 and 1995 with a number of eminent scientists including Keith Entwistle, Phil Ladds, Bruce Copeman, Max Murray, Bob Johnson, Peter Durham and Michael Goddard. Staff from Veterinary Services Branch of the Queensland Department of Primary Industries were also regular collaborators in animal health studies; noted among these were Steve Johnston, Ian Paull and Rick Parker. Michael D’Occhio from CSIRO (now UQ) collaborated in many studies during the 1990s. In recent years, major collaborators have included David Johnston from the Animal Genetics and Breeding Unit in Armidale and Rachel Hawken, formerly of CSIRO in Brisbane.

Some of those known to have collaborated at Swan’s Lagoon include:

Name		***Agency***	***Years***	***Name***		***Agency***	***Years***
Bond	John	DPI	1979-1980	Lehrbach	Phil	Fort Dodge	
Boothby	Dennis	DPI	1996-2009	Li	Yutao	CSIRO	
Burns	Max	DPI	1961-	Martin	Peter	DPI	
Bushell	John	DPI					
Chaplin	Paul	DPI	1982-1984	Matthews	Rebecca	UQ	2007
Clem	Bob	DPI	1979-1983	Mayer	Bob	DPI	
Coates	David	CSIRO	1999-2000	McCowan	Bob	CSIRO	

Name		Agency	Years	Name		Agency	Years
Coleman	Chris	JCU	1986-1994	McCullough	Marnie	DPI	
Connelly	Peter	DPI	1989-1991	McGowan	Michael	UQ	1992-2011
Copeman	Bruce	JCU	1979-1981	McGuigan	Keith	DPI	
Corbet	Nick	CSIRO	2001-2011	Murray	Max	JCU	
Dawson	Kerri	DPI		Mutch	Bruce	DPI	1966-1970
de Faveri	Joanne	DPI		Ndama	Pius	JCU	1982
Delaney	Robyn	JCU	1984-1985	O'Rourke	Peter	DPI	
D'Occhio	Michael	CSIRO	1990-1998	Parker	Rick	DPI	
Doogan	Vivienne	DPI	1983-2009	Paull	Ian	DPI	
Durham	Peter	JCU	1981-1982	Pepper	Pat	DPI	
Entwistle	Keith	JCU	1974-1994	Pressland	Tony	DPI	1984-1989
Fitzpatrick	Lee	JCU	1990-1994	Reid	Angela	DPI	
Friere	Luis	JCU	1981	Reid	David	DPI	
Gardiner	Chris	CSIRO	1978-1983	Saithanoo	Somkiat	JCU	1982
Goddard	Michael	JCU	1977-1983	Shaw	Kev	DPI	
Grant	Tim	DPI	2008-2011	Shepherd	Ross	DPI	
Hawken	Rachel	CSIRO	2006-2010	Spies	Peter	DPI	
Healing	Alison	JCU	1986-1994	Stephenson	Honour	DPI	
Holmes	Bill	DPI	1986-2011	Sullivan	Mick	DPI	2001-2008
Johnson	Steve	DPI		Swain	Tony	DPI	
Johnston	David	AGBU	2001-2011	Toleman	Mark	DPI	
Jones	Gareth	DPI	1982-1983	Wicksteed	Les	DPI	
Kellerman	Tony	Elanco		Wildeus	Stephan	JCU	1981-1983
Ladds	Phil	JCU		Williams	Paul	CSIRO	2001-2011
Laetsch	Joerg	DPI		Wythes	Jennifer	DPI	
Lambert	George	DPI					
Lamberth	Frank	DPI	1964				

2.6 Beef industry associates

A feature of Swan's Lagoon operations from its inception until 2001 was the Advisory Committee, which in the late 1990s was referred to as the Committee of Management. This committee comprised beef producers who in most cases represented grazier organisations, and senior management within the DPI as the government department responsible for the station was known during that period. The station manager acted as secretary. The functions of the advisory committee included:

- Raise beef industry issues that may be addressed by research at Swan's Lagoon.
- Assess the priority of research proposed by on- and off-station scientists.
- Assess proposed station development.
- Review on-going research.
- Review maintenance and development of the station's resources.

Dr Jock Allingham, Cattleman, Swan's Committee 1961-1979

Humphrey Heatley, Cattleman, Swan's Committee 1961-1976

The Advisory Committee usually met annually, with meetings normally held in the second half of the year. Occasionally, extra meetings were convened to deal with major agenda items such as in June 1978 when the development and role of the newly-acquired Expedition block were determined. This committee was a very effective conduit with the beef industry and provided a very high profile for Swan's Lagoon throughout the life of the committee.

Two Advisory Committee legends were Dr Jock Allingham of Fletcher Vale Station, Charters Towers, and Humphrey Heatley of Byrne Valley Station, Home Hill, both of whom were at the inaugural meeting in August 1961 and continued to serve as members for 19 and 16 years, respectively. They had originally been appointed to work with Rod Strachan in development of the station. A more complete list of committee members includes:

Beef producer members

Name		*Years*
Acton	Evan	1985-1989
Alford	Tony	1996-1997
Allingham	Chris	1996-1998
Allingham	Dr Jock	1961-1979
Barrett	Ian	1985-1989
Berryman	James	1997-1999
Brabon	Graham	1990-1992
Carter	Bill	1977-1984
Collins	Gerry	1975-1979
Condon	Neville	1996-1999
Cox	Robert	1975-1979
Fletcher	Jock	1983-1984
Heath	Jacquie	1999-2001
Heatley	Don	1983-1984
Heatley	Humphrey	1961-1976
Heelan	John	1985-1989
James	David	1990-1992
Lyons	Chris	1983-1987
Matthews	Eugene	1999-2001
McClymont	Ian	1983-1986
Rea	Andrew	1990-1992
Rea	Don	1977-1984
Rea	Robert	1999-2001

Other members

Name		*Years*
Alexander	Graham	1962-1969
Burns	Max	1961-1962
Byrnes	Ray	1988-1991
Carrigan	Dave	
Childs	John	1989-1991
Clay	Arthur	1961-1968
Durand	Marcus	1976-1984
Entwistle	Keith	1978-1979
Fletcher	Jock	1966-1967
Gannon	Bob	1976-1977
Gardiner	Chris	1979
Gilbert	Eddie	1996-1997
Hazard	Bill	1990-1992
Hodge	Brian	1977-1985
Holmes	Alan	1973-1975
Holroyd	Dick	1974-1985
Hopkins	Peter	1985-1987
Jeppesen	Keith	1989-1995
Jones	Raymond	1978
Laing	Alan	1985-1988
Laws	Lionel	1978-1985
Lindsay	Dr John	1978-1999
Lynch	Darryl	1968

Beef producer members			***Other members***		
Name		*Years*	*Name*		*Years*
Rebgetz	Ian	1990-1992	Mims	David	1996-2001
Ryan	Greg	1990-1993	Round	John	1970-1976
Smith	Dale	1990-1994	Ryley	John	1969-1978
Steele	David	1985-1989	Sands	Bill	1970-1973
Stewart	John	1983-1986	Smith	Peter	1969-1970
Tincknell	Paul	1996-1999	Stapleton	Don	1963-
Tudehope	Bill	1977-1979	Stonard	Peter	1985-1987
			Strachan	Rod	1962-1965
			Sutherland	Don	1961-
			Tyler	Russ	1978-1984
			Walker	Barry	1986-1987
			Wicksteed	Les	1984-1997
			Winks	Lyle	1974-1992
			Woolcock	Brian	1970-1979

Brian Woolcock, Director, Beef Cattle Husbandry Branch, Swan's Committee chair 1970

Graham Alexander, Director, Cattle Husbandry Branch, Swan's Committee 1962-1969

2.7 Visitors
Records of the huge number of people who have visited Swan's Lagoon annually have been published in the Annual Reports. Visitors have included beef producers and scientists from across Australia and internationally. Many students from schools and tertiary training centres visited each year. City-based departmental managers were also regular visitors.

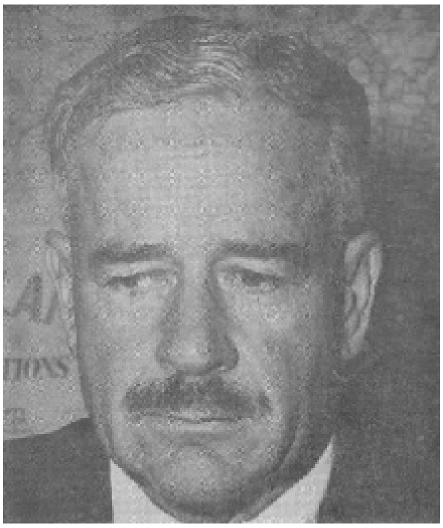
3. Resource development and maintenance

3.1 The resource

3.1.1 Selection and development of Swan's Lagoon
Arthur Clay was the Director of the Division of Animal Industry within the Department of Primary Industries when Swan's Lagoon was purchased, and was the Chair of the Swan's Lagoon Committee for the first 8 years. In a 1970 publication, "Swan's Lagoon: Beef cattle research for north Queensland cattlemen", he wrote the following, which is quoted verbatim.

'It was early in the 1950's that the Department started thinking about the need for a cattle breeding station in north Queensland. The first formal proposal was put up in 1956. In 1958, Messrs Shelton and Crack surveyed land at Millaroo. At that time, the main reason for acquiring such a station was the need to breed experimental cattle for research at Millaroo, Ayr and South Johnstone, where regional experimental stations had been established for a number of years. However, even at that early stage, it was recognised that the Department needed facilities for beef cattle research, particularly for long term trials on various aspects of breeding and reproduction. Nevertheless, the station's proposed servicing role for the other research stations, plus convenience of administration, must have influenced the choice of land to that which was available in the vicinity of the Millaroo Research Station. Fortunately, this choice did not conflict with a need for a property on which conditions would be reasonably representative of north Queensland. To find any one place that would encompass the wide variety of pastures and climatic conditions encountered in the north would obviously be quite impossible, but "Swans Lagoon" does experience those conditions that have the greatest influence on beef production in the dry tropics, namely – poor soils, very dry winters, droughts, occasional flooding, and variety of native pasture species that are found over a wide area of the north.

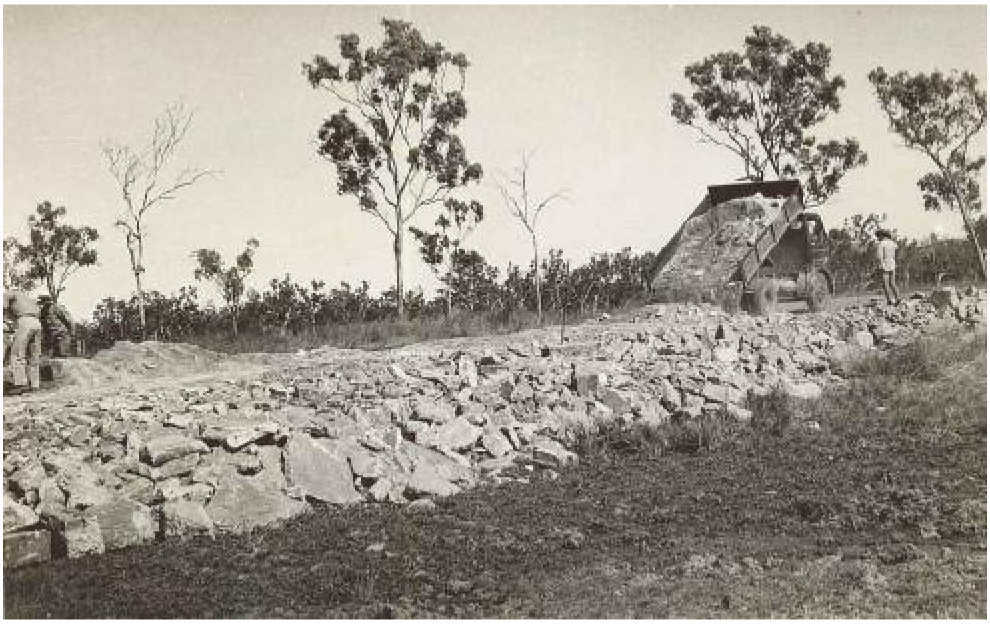
'In particular, the research station represents some 14 million hectares of spear grass country in the 600 – 1000 mm rainfall area. While conditions in the tall grass, high rainfall, regions of the Peninsula or the arid areas of the north-west would appear at first sight to be a far cry from those on "Swans Lagoon", nevertheless many of the factors limiting beef production in these regions are also encountered here. Whether or not this is the best place that could have been chosen may be debatable, but it has certainly proved eminently suitable for its present research role.



Arthur Clay, Director, Division of Animal Industry, Swan's Committee chair 1961-1968

John Ryley, Deputy Director, Division of Animal Industry, Swan's Committee chair 1969-1978

'In 1958 the three holdings that now make up the research station were held on short term leases by Messrs. E. Cunningham and E.A.S. Watt and were grazed as part of 'Woodhouse' station. At that time the shire rates were based on a carrying capacity of 30 head to the square mile, though this type of land was generally grazed at only 20 to the mile. It was considered by those who surveyed the holding that with water and pasture development the capacity of the proposed station could "probably" be raised above the immediate capacity of 750 head. However, if the present rate of stocking, in excess of 2000 cattle, had been suggested at that time, it would no doubt have been dismissed as most unrealistic.



Building the lagoon causeway on the road into Swan's Lagoon circa 1964. The causeway was concreted in 1972.
[Photograph: Rod Strachan]

'Only the southern and eastern boundaries were fenced with two strands of barbed wire. There was a set of yards and a dip at the southern-most corner. But these were in need of extensive repairs and were in any case badly situated. There were no developed water supplies and cattle had relied solely on permanent water holes in the Lagoon Creek and semi-permanent water in Millaroo Creek. Consequently, the holdings were virtually completely undeveloped when the Department finally took over the land in 1961.

'At that time the only other beef cattle research stations in Queensland were 'Belmont', near Rockhampton and 'Brian Pastures' at Gayndah. The former was devoted to a very specialised field of research while the latter concentrated on pasture work. Thus, it was recognised even then, that the research role of 'Swan's Lagoon' would soon take precedence over its originally intended role of providing experimental animals for regional research stations.

The foundations for the main yards

Some main yards posts up

[Photographs: Rod Strachan]

'A technical committee was formed and met for the first time on the 7th August, 1961. As well as myself, as Chairman, there were Dr J. Allingham and Mr H. Heatley who represented the Central and Northern Graziers Association, Mr D. N. Sutherland, then Director of the Cattle Husbandry Branch, and Mr Max Burns who was Cattle Husbandry Adviser in Townsville.

'The first meeting was concerned with a discussion of priorities for development. A tender for boundary fencing had already been accepted and work was due to start. Other development priorities were listed and comprised a central set of yards and dip, with a bore to be sunk nearby, essential roadwork, housing for staff, and a set of scales.


Shorthorn cattle on Swan's Lagoon in the 1960s

'Mr Sutherland outlined his proposed research programme – which was to be concerned mainly with factors affecting reproduction. However, at that first meeting both Dr Allingham and Mr Heatley emphasised the need to also work on improved pastures and supplementation, and both these have subsequently formed a major part of the research programme.


Main yards, September 2004
[Photograph: Stephen O'Connor]

'It was not until March 12th, 1962, however, that the first Departmental officer, Mr R. Strachan, started work on 'Swan's', and he was responsible for most of the pioneering stage of the development. With the boundary fence nearly completed, the foundation stock of 300 Shorthorn breeders were purchased that year. Thirty Brahman cross-breds were also obtained, from 'Belmont', the following July and formed the nucleus of the Brahman herd. At that time it was recognised that the Brahman had particular attributes that could be of value under tropical conditions and that the breed was likely to become established in north

Queensland. However, good quality Brahmans were scarce and therefore it was felt that a breeding herd at ‘Swans Lagoon’ would be necessary to provide animals for experimental purposes and would also contribute to the building up of what was then a scarce resource.

Calving cows, October 2005
[Photograph: Stephen O’Connor]

‘Satisfactory underground water could not be found and a plan to pump and reticulate water from the Lagoon was drawn up and completed in November, 1963. The main pipeline runs almost the length of the property and provides stock water for most of the paddocks. By this time, much of the internal fencing, to provide 12 paddocks of varying size, had been erected and so it was possible to get on with the research programme by starting the time of mating trial. However, it was not until the end of 1965 that a small laboratory and office, hay shed and further staff quarters were completed, at which stage ‘Swan’s Lagoon’ had the basic necessities for field research, although at that time the station was no better developed than many of the more intensively run properties in the north. It certainly had, and still has for that matter, far less staff, equipment or facilities than many other field research stations with a comparable research programme.

‘Development has continued steadily with many miles of sub-divisional fencing erected for trial purposes, further water reticulation from the one pipeline, two additional sets of yards constructed, thinning of timber and establishment of Townsville stylo and the construction of additional staff quarters, roads and firebreaks. This development is reflected in the rise in cattle numbers. By 1965 they had surpassed the originally estimated full carrying capacity of 750 head. By 1967 there were 1350 cattle on ‘Swans’ and the numbers have topped 2000 – and of these only a comparatively small proportion are calves. This has been helped to a small extent by the acquisition of an extra 960 ha of land.

‘At present we do not envisage much further subdivision or development of water supplies, as the environment for our research should not depart too radically from that on a commercial property. Pasture improvement will continue as new species and practical techniques are evolved, but only when these appear to be suitable for general adoption or require investigation prior to implementing on commercial stations.

The foundations for the first station building ***Fuel shed: The first station building erected***
[Photographs: Rod Strachan]

‘However, what might be regarded as a new phase of development was started in 1973. This is the provision of facilities for pen feeding and digestibility trials which were completed only a few months ago. The research conducted with these facilities will be very closely related to the paddock trials.

‘So far little mention has been made of the cattle and breeds other than to cite the steady increase in numbers. Initially all trials were carried out with Shorthorns as these formed the bases of most commercial herds. Later, Brahman crossbreds were introduced for purposes of comparison and also because they rapidly became established as the basic breed in the north-east. Shorthorns have now been phased out of all trials. The Dasbrahman stud was dispersed in 1973 because it was no longer necessary. The breed has become so well established that animals can be readily obtained from industry sources. On the other hand, two other Zebu breeds which also have a potential in the North, but which are still very scarce, are being bred at ‘Swan’s’. These are the Sahiwal and the Africander. Sahiwal crossbreds are now being used in trails along-side Brahman crosses. The Africander is regarded as being better suited to the arid tropics and while a small number are being bred on ‘Swan’s’ they are not being used for experimental work on the station. However, breeding stock is being supplied for breed comparison trials in other herds, including those of co-operators.

Some of the first half Brahmans that came from Belmont in 1962 on Swan’s Lagoon, circa 1965
[Photograph: Rod Strachan]

‘Finally a brief word about staff. At present, there are on the station 3 Husbandry Officers, including the Officer-in-Charge, Mr Winks, whose primary role is research, 3 Advisers who are there to assist them in this role, a Farm Manager, 3 Cadets who assist with both station and trial work, 5 station hands and a

Stenographer. While obviously this would be excessive for a commercial herd of this size, those conversant with research will recognise the frugal level of staffing. There is also a rapid turn over in technical officers since most of the cadets and advisers are on 'Swan's Lagoon' only for a limited period of training.

'Most of these will, after 2 or 3 years here, go to a district office where they start their career as advisers. This has some disadvantages, but at least it is one way of ensuring communication and harmony between research and extension officers serving the beef cattle industry.'

3.1.2 Acquisition of Expedition

The 1977 Advisory Committee minutes report that Mr Ted Cunningham, who owned the neighbouring Expedition block, which included the Kelly's Corner area, had made it available for sale. Under the leadership of Marcus Durand, the then Director of Beef Cattle Husbandry Branch, and Dick Holroyd the Officer-in-Charge, and with the support of the Advisory Committee chaired by John Ryley, the area was finally acquired in May 1978. The area was seen to provide the opportunity to implement systems studies with breeding herds, in contrast to component research which was mostly what had been conducted on Swan's Lagoon to that time. A driving influence was also the possibility that much of the original Swan's Lagoon block could be annexed for irrigation farms, though eventually this was the fate for only a small proportion along the eastern side of the station.

3.1.3 Soils and vegetation

About 40% of Swan's Lagoon is very mountainous with no permanent water and has limited use for stock. The remainder is quite flat with duplex soils predominating. These typically have 15-30 cm of high sand content soils overlaying a poorly-permeable clay base. These soils have low fertility and poor water-holding capacity, and are extremely boggy when wet. Key features of a 1992 analysis of duplex soils in the McGregor trial area showed they are slightly acid with very low to low contents of nitrogen, carbon, copper, and chloride (no salinity). Variable (low-high) levels of manganese and zinc are present.

A creek bank up from Kelly's Corner dam where cattle eating soil were seeking salt, January 1991
[Photograph: Geoffry Fordyce]

Soil phosphorus distribution was analysed using data collected from the 1992 soils study in McGregor, and published data for soil types and soil analyses. It revealed that in the Expedition breeder paddocks, approximately:

- 50% is acutely deficient (0-3.5 ppm).
- 20% is deficient (3.6-6.5 ppm).
- 10% is marginal (6.6-8.5 ppm).
- 20% is adequate (>8.5 ppm). Soils adequate in P are almost exclusively alluvial or frontage.

A 1995-1999 study in the Expedition breeder paddocks revealed the following:

- When not overstocked, the proportion of paddocks with standing pasture yields of <1000, 1000-2000, and >2000 kg/ha were 30%, 30% and 40% in April and 50%, 30% and 20% in August, respectively.
- Species contributions to yields were typically 20-30% Indian couch (*Bothriochloa pertusa*), 10-20% Black spear grass (*Heteropogon contortus*), 10-20% Golden beard grass (*Chrysopogon fallax*), 10-15% undesirable grass species, 15-20% other grasses, 5-15% forbs and sedges, and 1-5% legume.

A deliberate policy on Swan's Lagoon since its inception as a research station has been maintenance of native pastures in most areas to represent industry conditions. Townsville stylo (*Stylosanthes humilis*) was planted in a trial area in the mid-1960s. This species was devastated by anthracnose during the 1970s. Verano (*Stylosanthes hamata* cv Verano) and Seca (*Stylosanthes scabra* cv Seca), which have some resistance to anthracnose, were planted in a trial area (the old tick trial area which was renamed the perennial stylo trial area) in the 1980s. Verano was also planted in Strachan (200 ha) in 1977 and in the Back of Leichhardt (160 ha; now IJ of Winks) in 1978. A range of *Stylosanthes* spp. accessions were planted in what is now A of Winks in the 1970s and some of these persisted. A wide range of exotic grass species were planted in the same area, as well as in the north-west sector of Strachan paddock and almost all failed to persist. Seca has slowly spread to many parts of the station. Townsville stylo still persists across the station, but plant frequency is low.

Tordon treatment of trees was conducted in the 1960s. Treatment of approximately 3,000 ha occurred in the 1970s in laneways, and what is now the Winks area, Lagoon A2, B2, Gregory, McGregor, Benjonney and PST. Though good kills were achieved at the time, it resulted in considerable regrowth. In comparison, un-touched areas remain relatively-stable open forest areas. Fertilising of pastures other than the *Stylosanthes*-based trial areas was conducted in the back of Leichhardt (now I-K of Winks), and in the front and back of Chester A. Considerable timber thickening has also occurred in Chester A.

Darcy Schefe spraying noogoora burr, January 1971
[Photograph: Lyle Winks]

Rubber vine was for many years increasing at an alarming rate, until the introduced rust severely retarded its spread. In 1995 it was thought to have caused approximately 1.5% cow mortality. A similar outcome occurred for Noogoora burr in the late 1970s. There is a steady increase in the prevalence of *Parkinsonia* and Chinee apple in isolated areas across the station.

3.1.4 Climate

The median rainfall at Swan's Lagoon over the past 122 years (interpolated data from Bureau of Meteorology) has been 708 mm (27.9 inches; median means that half the recorded values are above and half below this figure). The variation between years is large. The average break in the season in the past

50 years has been mid-November. The break is when there is sufficient rainfall to achieve sustained growth of green grass and protein supplementation is no longer needed; it usually occurs after at least 40-50 mm of rainfall within several days. The average annual evaporation is 2.03 metres (6.6 feet). There are three main seasons at Swan's Lagoon: a warm moist period (the wet season), a cool dry season (early dry season) and a hot dry season (late dry season). These periods typically extend from December to April, May to August, and September to November, respectively.

Struggling with Blind Gully on the main road in during the 1978 wet season
[Photograph: Mark Savage]

Main road looking towards the lagoon showing the extremes of weather, 1972-73
[Photograph: Alan Ernst]

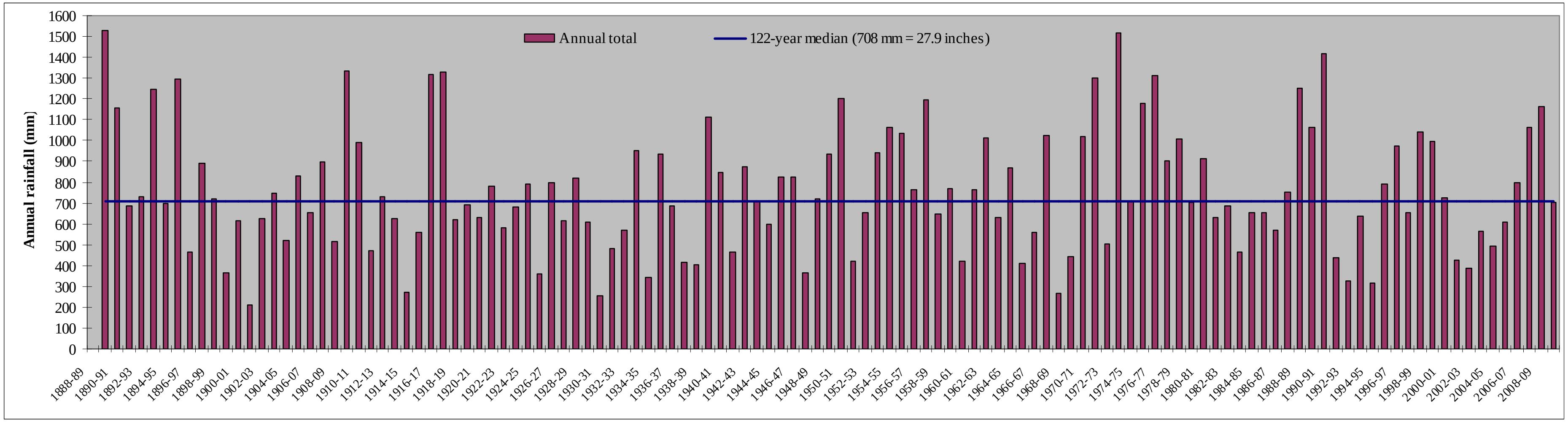
Monthly weather statistics for Swan's Lagoon – derived from Bureau of Meteorology SILO interpolation since 1889

	Median rainfall (mm)	Probability of monthly rainfall exceeding: 25 mm	50 mm	75 mm	100 mm	Average temp (^{O}C) Max	Min	Average daily evaporation (mm)	Average daily radiation (MJ/m^2)
Hot wet season									
Dec	77	85%	69%	51%	39%	34	22	7	24
Jan	146	98%	89%	75%	61%	33	22	7	22
Feb	150	96%	84%	74%	64%	32	22	6	21
Mar	83	84%	68%	55%	40%	32	21	6	20
Apr	24	49%	22%	17%	9%	30	18	5	19
Cool dry season									
May	13	33%	18%	11%	3%	28	14	4	16
Jun	13	36%	17%	8%	6%	25	11	3	15
Jul	4	20%	12%	2%	1%	25	10	4	17
Aug	2	16%	9%	3%	1%	27	11	5	20

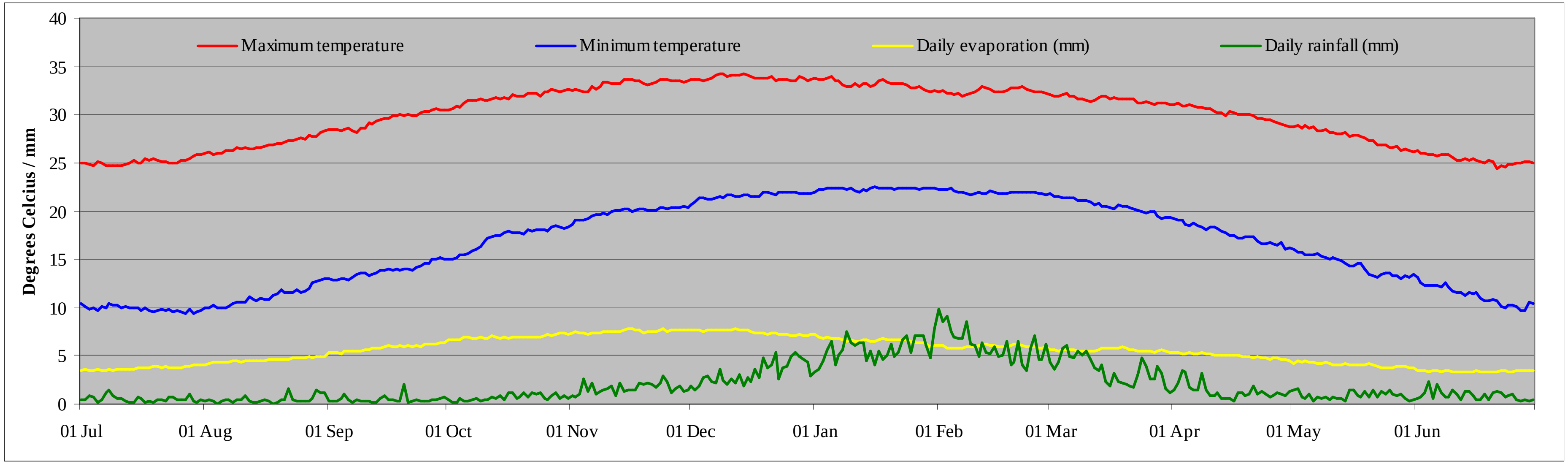
Hot dry season									
Sep	2	17%	7%	2%	1%	29	14	6	23
Oct	9	26%	13%	6%	2%	32	17	7	25
Nov	33	53%	36%	22%	14%	33	20	8	25

Dry: Whirly wind at the office, October 2002
[Photograph: Geoffry Fordyce]

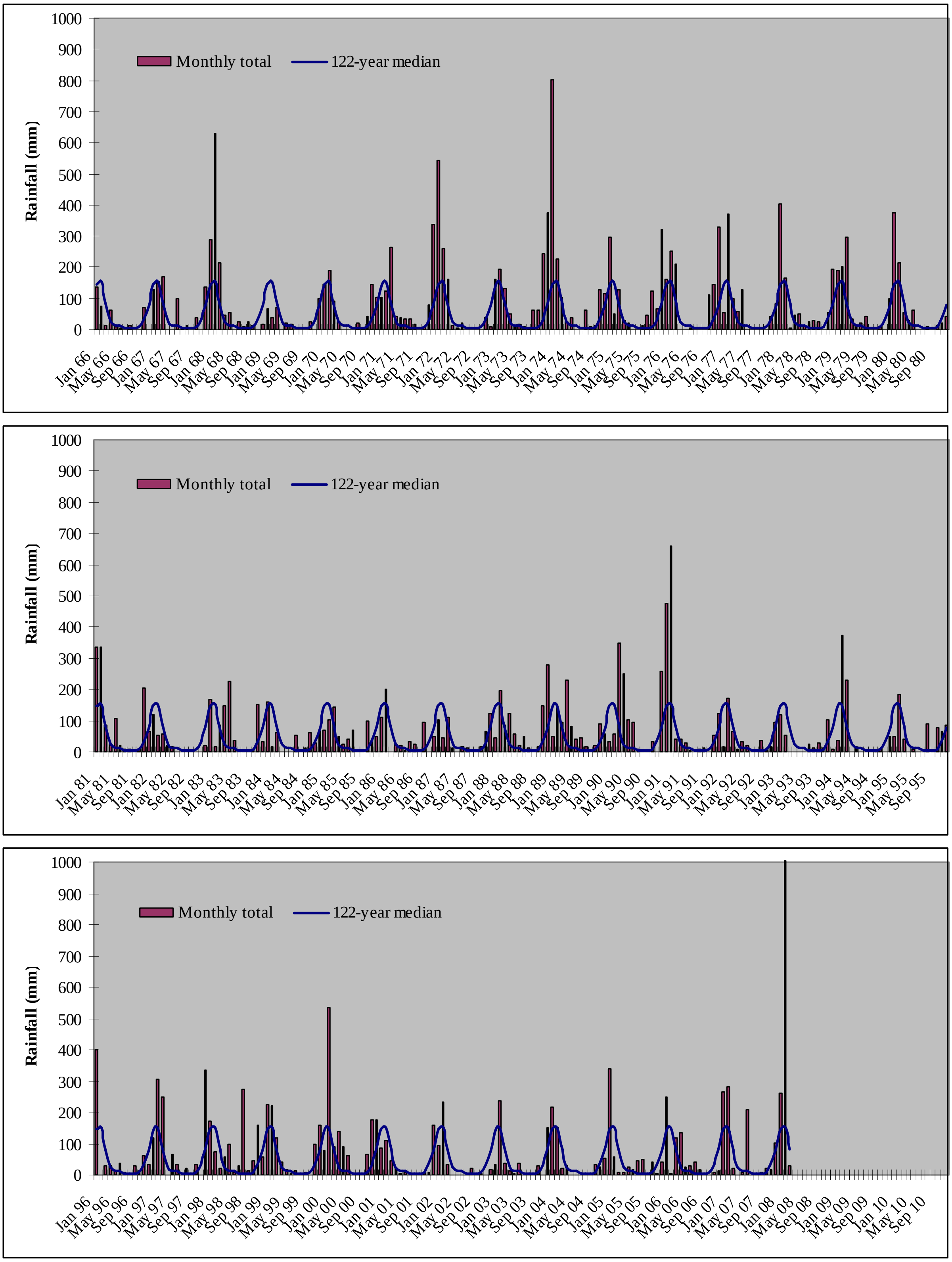
Wet: A2 paddock in the 2007 wet season – it's a water course (Blind Gully)
[Photograph: Stephen O'Connor]



Annual Swan's Lagoon rainfall – derived from Bureau of Meteorology SILO interpolation since 1889



Average daily temperature extremes, evaporation and rainfall at Swan's Lagoon – derived from Bureau of Meteorology SILO interpolation since 1889



Swan's Lagoon recorded monthly rainfall compared with the 122-year median derived from Bureau of Meteorology SILO interpolation since 1889

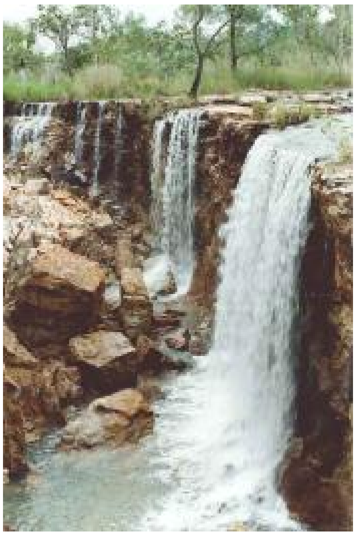
Particularly-severe weather events experienced at Swan's Lagoon include:

- After very low rainfall in 1981-82, 1982-83 was extremely dry, as it was for much of Australia. This event instigated the first whole-herd feeding of fortified molasses at Swan's Lagoon and many stations where molasses was available. A total of approximately 500 tonnes of hand-mixed fortified molasses (mostly molasses with 10% protein meal) was fed, mainly between early November and mid-January. Only one mortality as a result of urea poisoning was known to have occurred. The season broke weakly in late January/early February 1983, but it was not till Anzac Day 1983 that heavy rainfall finally ended this drought. The experiences were very valuable in consolidating much survival supplementation research that had been done, and providing the basis for new research.

- On 04 April 1989 Cyclone Aivu struck causing widespread wind damage and very few paddocks remained stock-proof in the immediate aftermath. Fortunately, the cyclone's rainfall was not unusually high. Within weeks, a massive effort by all staff, with assistance from Townsville-based staff and equipment such as chain saws from around the state, managed to restore normal operations.

- On 11 February 2008, the station experienced about one metre of rainfall over 48 hours. All flood crossing were decimated and fences were extensively damaged. Millaroo Creek was denuded of a high percentage of its vegetation, including very large trees. Expedition Creek was re-sculpted with the falls widening dramatically and moving 100 metres upstream and the beautiful water hole downstream obliterated. The most striking impact in the area was the virtual denuding of Landers Creek which had become a jungle of very large trees over many years of being fed by Millaroo's nutrient-rich, irrigation run-off water.


Expedition hole before and after February 2008
[Photographs: Geoffry Fordyce]




Expedition falls in 2000 and after the 11 February 2008 flood
[Photographs: Stephen O'Connor]

3.1.5 Infrastructure

The station was originally one paddock. As sub-division progressed, paddocks and trial areas were initially named after early explorers to the region. A custom was then adopted of naming them after former Directors of Beef Cattle Husbandry Branch, and those who made significant contributions to the station. Trial areas have been developed as required, particularly in the 1966-1970 period. Some further subdivision occurred in the 1970s and 1980s; eg, McGregor was subdivided in 1984. In 1991 the Townsville Stylo trial area (~40% of the area had previously been fertilised) was redeveloped into a series of 100 ha paddocks named the Winks trial area.

Stan Allan, Peter Dunster and Marcus Platen placing a grid to the lagoon causeway, September 1977
[Photograph: Mark Savage]

A major phase of development started with the acquisition of Expedition in 1978. Electric fencing was established in the first year on the boundaries: power from the lagoon pump was taken over to and along Expedition Pass Creek; power was delivered from the Main yards to the electric fence along the boundary with Landers Creek Station. A barbed wire fence was erected along Millaroo Creek to separate the Expedition breeder paddock from Kelly's Corner in 1979. The development of waters and fences was matched with the purchase of Brahman cross heifers to stock the area. In 1983, the Expedition area was subdivided into 3 paddocks after considerable survey work by Russ Tyler and Dick Holroyd. The central paddock, Burns, was further split in 1995. Geoffry Fordyce surveyed the sub-division of the Kelly's Corner area. The first phase was completed in 1984, and then in 1996 a series of 200 ha and 250 ha paddocks was constructed at the same time as resumed farms were fenced off the eastern side of the station.

Building a new grid at the main yards, 1976
[Photograph: Mark Savage]

The main water supply for the station was initially the main lagoon as no suitable underground water was available. In 1968, a gravel causeway was built across the end of the main lagoon in an effort to secure a permanent water supply. As paddocks were fenced, galvanised pipelines (initially; polythene pipe when it became available) were laid across the 8,000 ha original station area to reticulate water via the central office area. The main pipeline between the lagoon and office was upgraded to 2 inch polythene in 1984. When Expedition was acquired, a second rich and reliable water supply became available at Teddy's Mill. The new areas are watered by 3 dams and 7 bores, which were progressively found and developed during the 1980s. Broken dam was repaired in December 1979. Top and Bottom bores were sunk and equipped in November 1982, the sites being divined by CSIRO's Raymond Jones. Kelly's Corner dam, completed in 1983, was the only dam built during Queensland government tenure. All water sources have been under stress during extended dry conditions; therefore, wherever possible sources were plumbed together to achieve better water security. Teddy's Mill was plumbed into the station network in 1987.

Erecting the high tank at the office circa 1964
[Photograph: Rod Strachan]

With many kilometres of pipeline and fencing to service 150 paddocks, re-fencing, pipeline upgrades and tank replacement have been regular annual activities.

Drilling the new Teddy's Mill bore, May 1988
[Photograph: Geoffry Fordyce]

After the station was first acquired, key roads were gravelled to enable all-weather access. Leichhardt road between the office and the lagoon was gravelled in 1968. Benjonney road gravelling was completed in 1971. In 1972, the causeway over the end of the lagoon on the main access road was concreted. Many years later, in 1990-1994, extensive road development and gravelling occurred to enable better access across the station which by this stage, was much larger.

Swan's Lagoon shed and single mens' quarters operational, 1965
[Photograph: Rod Strachan]

Benjonney road after heavy rain, February 1991
[Photograph: Geoffry Fordyce]

When Swan's Lagoon was first occupied as a research station, there was an old set of yards on the eastern side of the lagoon, just to the south of and opposite the current pump. This yard was operational till the mid-late 1970s. A set of yards designed for handling Shorthorn cattle was built on the site of the current main yards soon after acquisition. Adjacent bull pens were completed in 1967. Power was extended to the yards and stables in mid-1968, mainly to run the spray dip, flood lights and a chaff cutter. The 140 m^2 hay shed with a concrete floor was erected in 1971-1972 adjacent to the main yards at a cost of $1,200. The timber yards became extensively damaged by termites and during 1991-1993 were re-designed and re-built to cater for Brahman cattle and expected research needs. In 1977, a plunge dip was built in these yards to replace an ageing spray race. The first animal to enter the dip jumped high, breaking the fibro ceiling which Public Works deemed the dip must have. In May 1974, a set of pens and a large shed to service them was completed adjacent to the main yards for use in detailed nutritional studies.

Pen complex, September 2004
[Photograph: Stephen O'Connor]

When Expedition was added to the station, Cunningham's yards on the south of Expedition creek, upstream from the Falls were used initially. When block fencing was completed, the cattle were mustered via a cooler opposite the south-west corner of McGregor paddock to the main yards. In 1985, the Expedition yards were completed with wooden rails. These were upgraded to steel in 1997 in the same year as steel horse yards were constructed. A small set of yards was constructed at the back of Millaroo Research Station in the late 1960s to service irrigated pasture studies on Farms 99-103, which subsequently became part of Swan's Lagoon. A "temporary" set of yards to service trials was constructed approximately 40 years ago in the Benjonney area. This yard has received some upgrades over the years. A small set of yards was constructed near the Kelly's Corner dam approximately 10 years ago.

Expedition yards soon after completion, July 1985
[Photograph: Geoffry Fordyce]

Four houses and two sets of quarters that can house eight staff are sited on the station. Two of the houses were constructed during the initial development phase and the second two in 1972. Staff numbers have been as high as 20, especially in the 1970s and 1980s, and during this time extra housing was found in Millaroo township and at the adjacent Millaroo Research Station. In the 1980s, because Millaroo has no facilities other than a social club and primary school, some staff opted to commute daily from Ayr to provide their families with access to better resources.

Construction of the first single men's quarters circa 1964
[Photograph: Rod Strachan]

The small main office was completed in 1965. It became overcrowded by the 1970s. Four scientists, up to six technical staff, a manager, and the administrative assistant had only 7 rooms, and this became even more difficult when the first multi-user computer (an SR72) was installed in 1983.   In 1984 when Millaroo Research Station had reduced operations, a relocatable house was transferred to Swan's Lagoon to provide desperately-needed office space.

The Swan's Lagoon office on completion, 1965
[Photograph: Rod Strachan}

An unreliable telephone line and mail delivered 1-3 times weekly were at the forefront of communication with the world at large for the first 25 years. A switchboard telephone system was installed in 1972.

Though impressive for the times, the switchboard was seen to emit sparks during thunderstorms. In quick succession in the early-mid 1980s, a fax machine and computer (SR-72 with 64 kilobytes of RAM and 8 inch floppy discs) heralded a cultural and technology revolution. An electronic typewriter that replaced the manual version did not last long as personal computers became standard equipment. Email became available in the 1990s.

A motorbike line-up at the single-men's quarters, 1977
[Photograph: Mark Savage]

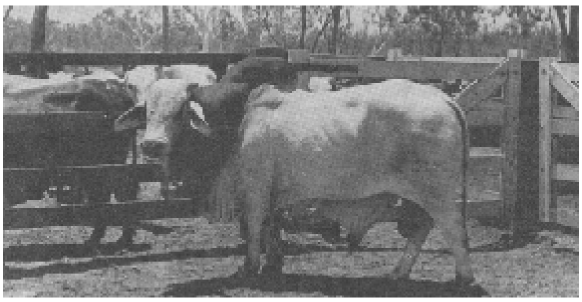
3.1.6 Livestock
A large breeder herd maintained on Swan's Lagoon since its inception has provided the basis for on-station research as well as providing animals for research across Queensland. This has been necessary for two main reasons; conduct of research using cows; and, timely access to representative animals for research from commercial producers, and especially weaners, can be quite difficult. Originally, replacement bulls were purchased from the industry. Then, because of the unavailability of bulls of specific breeding, bulls were bred for many years within the herd.

Howard Reimers loading a horse at R51, a common site on Swan's Lagoon, November 1976
[Photograph: Mark Savage]

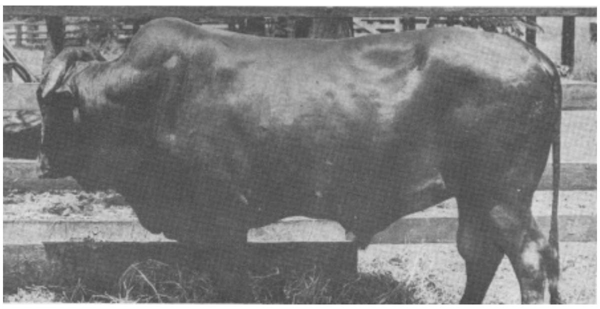
The first breeding herd on Swan's Lagoon was Devon-Shorthorn, the predominant breed in north Queensland at the time. In 1962 the herd size was 160 and the maximum carrying capacity of Swan's Lagoon was considered to be 750 cattle. Carrying capacity in those times was presumably limited by lack of adapted cattle, limited permanent water and virtual absence of supplementary feeding systems.

Silver Link, a foundation 7/8th Brahman bull of the Dasbrahman stud
[Photograph: Lyle Winks]

The first ½ and ¾ Brahman cows were introduced to Swan's Lagoon in 1963. Cross-breeding Brahman bulls with Shorthorn cows was used to grade up the herd. The bulls used were from "Wairuna", "Orient", "Pioneer", "Mt Utchee", "Burnside" and "Belmont". Research using Brahman crosses (steers) commenced in 1967. A high-grade Brahman herd was maintained till 1973 when it was dispersed. This herd was known as the Dasbrahman stud and produced bulls for sale. Bulls were selected (selection criteria, including temperament, were not strict!) and kept on Swan's Lagoon till about 18 months of age. They were then transferred to Ayr Research Station for handling and feeding for several months before sale at the annual Townsville bull sales. Bulls with 75% or more *Bos indicus* were offered for sale.

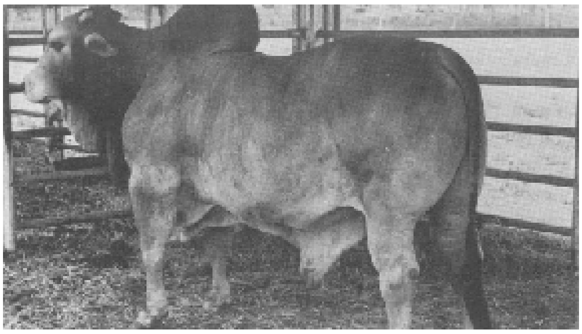


Belmont Archer, a foundation sire of the Swan's Lagoon Brahmans



Belmont A19, a foundation sire of the Swan's Lagoon Africanders

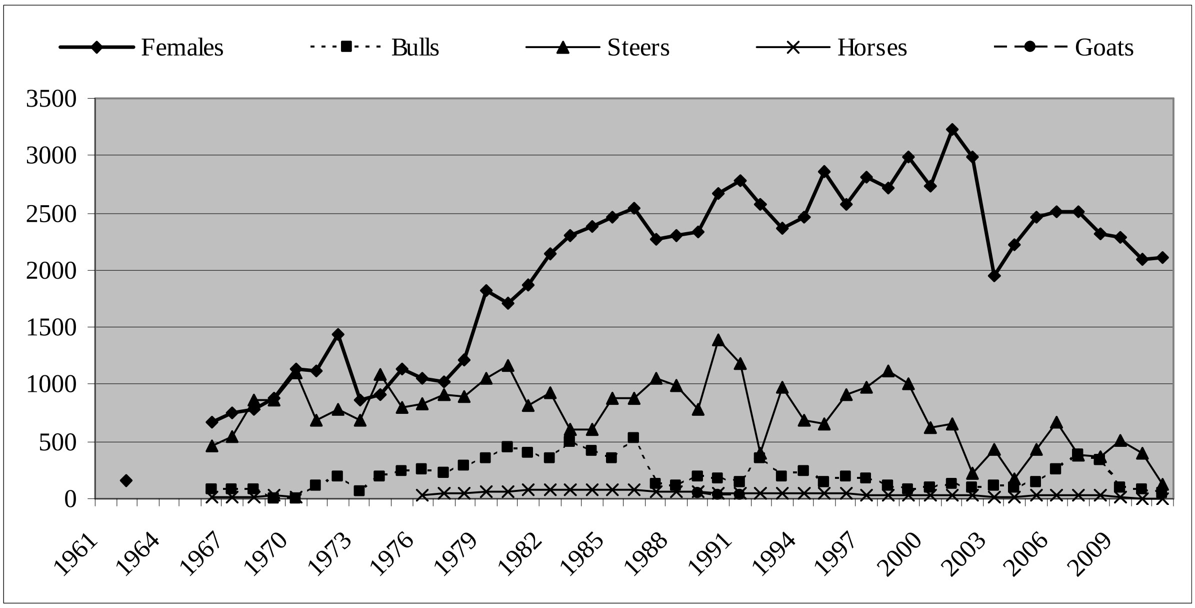
Africander cattle were introduced in 1965 using a base of ½ cross cows and full-blood bulls acquired from Belmont Research Station. This herd was transferred to Toorak Research Station at Julia Creek in 1973. In 1967, the Sahiwal herd was initiated using semen from a full-blood bull over Shorthorn cows. A herd of 190 high-grade Sahiwals was purchased in 1979. A limited number of Sahiwal bulls were sold at the Townsville bull sale, and some Africander bulls at the Cloncurry bull sale.



Ghandi J4, a foundation sire of the Swan's Lagoon Sahiwals. He died of old age on 18 February 1969

No.83 Sahiwal bulls in the Millaroo yards, 1985
[Photograph: Geoffry Fordyce]

Since the acquisition of the Expedition area, the station has comfortably accommodated 1,200 breeding-age females and their followers. Expedition was first stocked with 329 heifers in July 1979. Total cattle numbers have declined since 2000, partly in response to the series of very poor wet seasons experienced, with 2007 being the first year for many when average wet season rainfall was received.



Swan's Lagoon livestock numbers – incomplete as all records are not available

All stock work was conducted with horses until about 2001. As stock were mustered much more frequently than is commercial practice, many station horses were kept, and most staff had 1-2 horses of their own. A stallion was kept to breed horses from 1968 for about 20 years. The first stallion was "Icarus", purchased from Gatton College. Training young horses provided most staff with a secondary interest and enabled suitable stock horses to be developed in an era when sales of good working horses was not common.

The main variation on the cattle and horse theme occurred in 1989-1991 when a small herd of goats was maintained to support research into tropical cashmere production. These goats were expertly tended by Roger Cox. Despite extraordinary efforts, including combined ring-lock and low electric fencing, some dingo predation occurred, and ultimately, the goats had to be removed.

Tony Merrifield on a young horse, November 1976
[Photograph: Mark Savage]

3.2 Station management
The major elements of station management have been infrastructure maintenance and development, livestock management, and research support. All of these have been dictated by on-going and planned projects. Therefore, a major component of Swan's Lagoon operations for most of its operational life has been monthly station committee meetings where on-station staff have planned the operations within the guidelines agreed to with the advisory committee. In the earlier years, technical staff personal development was achieved by them presenting updates of activities and results of the projects they were working on at these monthly meetings.

The role of the manager has been to coordinate planned activities based on agreed long- and short-term plans. A feature of Swan's Lagoon was always the weekly program presented by the manager mid-afternoon each Friday.

Cattle on M8U at Teddy's Mill, November 1994
[Photograph: Geoffry Fordyce]

One of the most stressful periods of the year for both livestock and staff has always been the late dry season, with the concurrence of management to prevent mortalities, and calving. The break in the season is always very welcome. Supplementation using molasses-urea in roller drums dominated research for many years, with a shift to fortified molasses supplements in the 1970s and 1980s. Mortalities were often high before feeding fortified molasses became established practice. In the extreme drought of 1982, 20% of the Expedition breeding herd perished before approval to ramp up fortified molasses was given. Once it began, mortalities almost ceased. After this success, M8U feeding of most cattle occurred for 1-2 months late in the dry seasons of 1987, 1991, 1993, and 1996, and along with good weaning practices and appropriate stocking management was a major contributor to an average annual cow mortality rate of only 0.5% between 1985 and 2000.

John Hughes on Jinx mustering No.01 Brahman heifers, June 2002
[Photograph: Geoffry Fordyce]

Fire has been an annual threat, especially following good grass-growing seasons and extended dry seasons. Wild fires have always been difficult to control because of the mountainous terrain over half the station. In years when they occurred, eg, 1983 and 1991, fires took up to a month to eventually control to the point where they were no longer a threat.

Smoko time, Expedition yards shed, May 2002
[Photograph: Geoffry Fordyce]

The busiest period has always been first round muster usually in April-June. The round entails mustering most station cattle, culling and selection, regrouping cattle, branding, weaning, weaner training, and cattle vaccinations. During this period, waters must be kept operational and experimental measurements must continue! Hence all hands on deck for the first round muster. Even Rudi joined the fray in the early years. First round was a great challenge in the early years of developing the Expedition herd. Mustering one large, heavily-forested paddock populated with brumbies meant an 80% muster after a full day in the saddle was quite an achievement. Fortunately, infrastructure development left those days in the 1980s.

The overall performance of the Swan's Lagoon herd was limited by the environmental conditions. Lyle Winks and Stu McLennan calculated that average annual steer growth on natural pastures was 105 kg. A performance highlight occurred in 1993, when, as part of an observation of nutrition using heifers during maiden mating across the newly-established Winks trial area, 100% pregnancy rates were achieved in all paddocks except AB of Winks where heifers had the lowest growth. Despite the challenging environment, astute management resulted in an average weaning rate of the continuously-mated Expedition herd being sustained at 83% between 1985 and 2000.

Norm Shand, Bruce Miller and assistant tailing out from Expedition yards, September 1987
[Photograph: Geoffry Fordyce]

In 1994, in response to industry criticism of the within-herd variation of the cattle, coupled with the need to reduce animal variation to achieve more even lines of cattle for experiments, a bull breeding nucleus herd was established. By 2000, this 5-month mated herd was achieving an 88% weaning rate, cows with an average mature weight well in excess of 500 kg, and even lines of well-adapted, well-behaved, red cattle with moderate maturity type. Essentially they could be described as Beefmasters. This breeding was discontinued soon after with the decision to use only purchased Droughtmaster bulls.

Kristy Reid, Peter Maddern, John Hughes and Matt O'Connor, June 2005
[Photograph: Stephen O'Connor]

Haymaking on Swan's Lagoon continued up till 1988, after which hay supplies were purchased. Native pasture hay was made in a fenced-off paddock to the east of Gregory paddock (since resumed for farms). Higher-quality hay was made in the verano hay paddock which is traversed by the main road into the station. This hay paddock was initially developed in the late 1960s.

Howard Reimers and Peter Dunster on a break during development of the native pasture hay paddock, November 1976
[Photograph: Mark Savage]

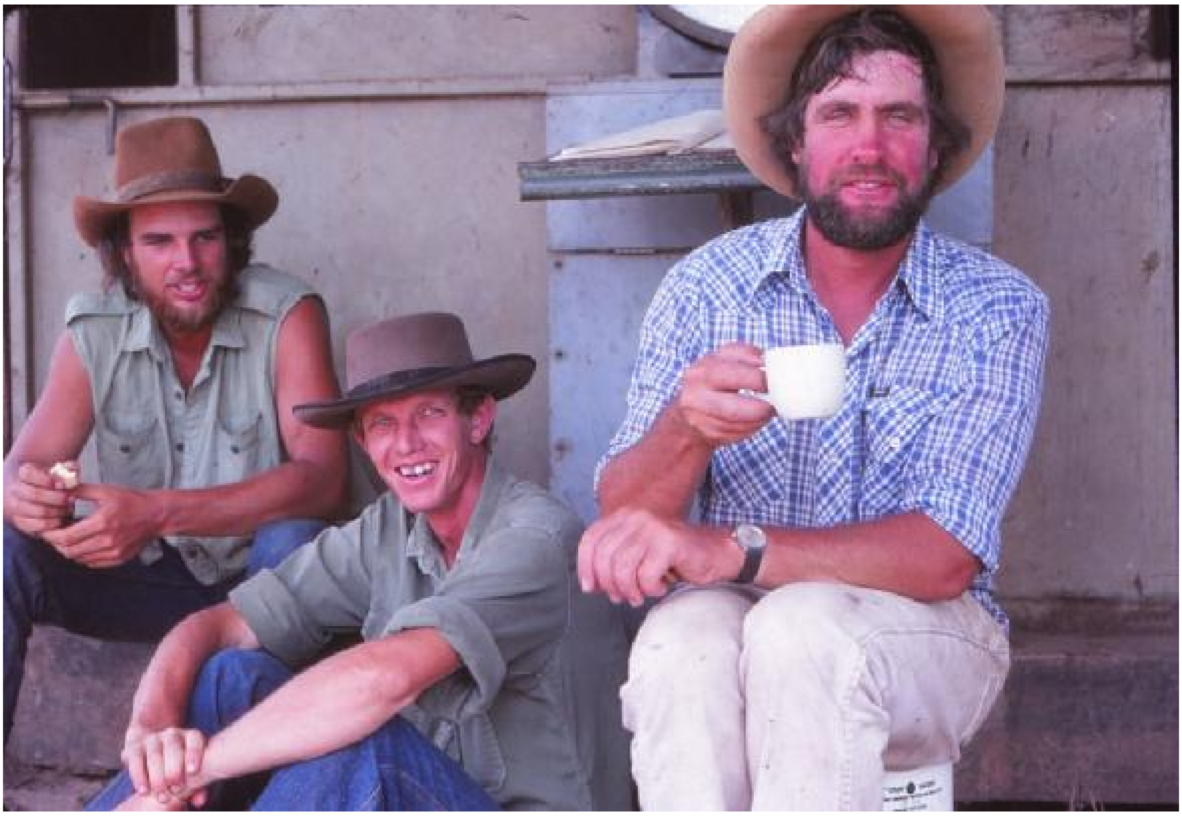
The most economically-important endemic disease caused by micro-organisms at Swan's Lagoon is botulism. Sporadic cattle deaths were difficult to ascribe to this disease until it was diagnosed after an outbreak in early 1985. Since then vaccination against botulism has been a core management activity. Vibriosis was a recurring problem in breeding herds in the first 15 years until it was brought under control using seasonal mating, young bulls, vaccination and good cattle control. Trichomoniasis was diagnosed in the late 1960s, and artificial insemination was used in mating about 300 Shorthorns in 1969-1970 as one method to eliminate this reproductive disease. Neither brucellosis nor tuberculosis was ever found in the station herd. Both neighbours were TB infected. Expedition had to be kept stock-free for 3 months following purchase, followed by two clean tests to achieve disease-free status. Fortunately, regular incursions of cleanskin cattle did not bring either disease into the herd. Blackleg was diagnosed in calves grazing McGregor paddock in 1976, which reinforced the need for 5-in-1 vaccine.

Ticks have a constant presence at Swan's Lagoon. Cattle grazing the north-eastern area of the station have been more affected than elsewhere. Dipping was a regular feature of management in the early years. However, between 1980 and about 2005, the plunge dips at Benjonney and the Main yards were used only to meet regulatory requirements when moving cattle to tick-free areas. One outcome of the adaption of the station herd was that acaracide tick control was necessary only once (1991) in that period.

Feral livestock have been a small and continuing problem as for most north Australian beef cattle stations. Pig populations have varied over the years, with some observations that numbers increase after effective wild dog control programs; the first 1080 program was conducted in 1969. Supplementation research was always partially compromised by pigs when molasses or other energy-dense supplements were used, and most of this research was accompanied by trapping of pigs. Brumbies were a significant problem on Expedition until the mid 1980s when most were eradicated. Small numbers remain in the un-used areas of the station.

4. Research

A massive amount of research has been conducted at Swan's Lagoon in its 50 years. The reports of this research cover many thousands of pages. It is not possible to present many details here, so an overview of the experiments conducted and the principal outcomes of relevance to science and the beef industry are presented. More details can be gleaned from the large number of publications.



Peter Dunster, Russ Tyler and Tony Merrifield, 06 December 1977
[Photograph: Dick Holroyd]

Research is far more expensive than commercial operation, even if management is very close to commercial practice. Creating the infrastructure, organising cattle, and measurements, and then analyses and publication of results create the extra costs. Queensland government has funded most staff and major infrastructure. Almost all of the operational funds for research , including substantial staff funding, has come from the beef industry and associated businesses. By far the largest and most funder has been Meat and Livestock Australia, and other incarnations. The CRC for Beef Genetic Technologies and The cattle and Beef Industry CRC have both provided valuable support. Product provision has been a major element of research support; companies such as CSR and Incitec Pivot have provided significant amounts. Other companies that have provided product, cash and in-kind support include Elanco Animal Health (over about 30 years), CSL Ltd, Fort Dodge, Livestock Nutrition Technologies, Australian Brahman Breeders Association, Mackay Sugar Company, Canefibre Products Ltd, and Peptide Technology.

4.1 Growth and nutrition

4.1.1 Evaluation of nutrition, supplements and delivery systems

Lyle Winks initiated and led many studies from the mid-60s to the mid-70s with focus on supplements and pasture legume to alleviate the primary nutrient deficiency of nitrogen. Stuart McLennan and Alan Ernst continued this work and evaluated many dry season supplements and efficient methods of feeding. Ian Loxton and John Lindsay led several studies of cattle growth, some of which assessed the efficacy of HGPs. Recorded titles of experiments included:

1965-1966 Vitamin A survey
1968-1971 Weaner supplementary feeding

1969-1970	Cottonseed supplementation
1971	Biuret pen trial
1971	Urea-molasses digestibility trial
1971-1973	Salt feeding observation
1970-1975	Level of urea trial - steers
1971-1977	Molasses supplementation on native pastures
1972	Biuret-mineral pen trial
1973-1974	Acceptance of phosphorus supplements
1973-1977	Supplementation trial
1974	Molasses and sulphur pen trials
1974	Sucrose-sulphur-urea digestibility study
1975-1977	"Home brew" pen feeding trial
1975	Grain/biuret supplements on native pastures
1975-1976	Wet season acceptance of phosphorus-molasses blocks
1975-1979	Dry lick feeding trial
1976	Urea, molasses and sorghum in "home brew"
1976	Wet season acceptance of phosphate-molasses blocks
1976-1977	*Ad lib*. molasses trial
1976-1978	Phosphorus deficiency in heifers
1977	Utilisation of supplements and "home brew" ingredients
1977-1980	Molasses feeding trials
1982	Compudose evaluation
1982	Weaner crisis feeding observation
1982	Breeder crisis feeding observation
1982-1983	Compudose and improved pastures
1983-1987	Urea dispenser trial

Early hypotheses that the dry season was excessively depleting liver Vitamin A reserves leading to deficiency, were disproven in drought-stricken Shorthorns. However, it must be remembered that these cattle had access to green browse, and subsequent research has shown the consecutive wet season failures in downs country without access to browse can cause Vitamin A deficiency.

Roller drum for dispensing urea in molasses and water, September 1969
[Photograph: Lyle Winks]

As supplementary feeding based on urea became established within the Queensland beef industry, Swan's Lagoon trials quantified the effects and when responses could be achieved. Key research outcomes included:

- Responses to urea started to occur as early as April when faecal protein level fell below 8%.
- Urea with a balanced sulphur source can increase low-protein pasture intake by between 25% and 100%, though there is little effect on digestibility. This effect was very evident in "run-out" pens, constructed in 1968 and 1969, where grazing steers on different supplements were held for 24 hours for full faecal collections.
- The effects of urea on rumen function (as measured by rumen ammonia levels) persisted for up to 18 hours after intake.
- Liveweight gain was higher with increasing dry season urea intakes; however, levels need to be restricted because of toxicity. Sixty grams of urea daily appeared adequate for steers.
- Liveweight preserved in growing steers was typically about 10 kg annually with up to 100% compensation by the end of the following wet season. This emphasised the futility of this form of supplementation to steers, other than to prevent mortality.
- The liveweight preserved with urea-based supplements is sufficient to prevent dry season mortalities in dry years.
- The principles of supplementation with biuret and isobutylidene diurea were shown to follow those of other non-protein nitrogen sources. Biuret can replace urea in dry licks with the added advantage of being non-toxic. However, biuret is insoluble.
- Delivery of urea-sulpur either in dry licks, through drinking water (usually 2.5 g/L), or in a roller drum mix (0.25 kg molasses per day) were shown to have equivalent effects on growth, despite higher urea delivery using the roller drums.
- Sulphur in molasses balances urea nitrogen, making for an excellent supplement.
- When small amounts (up to 250 g daily) of either molasses, grain or protein meal are fed with urea, eg, in roller drums or dry licks, the small amount of the additional energy has negligible effect on growth. A lot of research with the DPI's "home brew" mix was part of this work.
- The toxicity witnessed with urea in the drinking water when thirsty cattle drink large volumes.
- Cattle were noted to spend more time at liquid urea-based supplements than at urea-based dry licks.

Weighing cattle in the main yards, circa 1965
[Photograph: Rod Strachan]

When molasses was fed alone to cattle grazing native pastures, early experiments showed it to be ineffective as a supplement without a balanced nitrogen source such as urea. This led to the development of fortified molasses, in which various combinations of additives such as urea, protein meals, phosphorus and salt balance the deficiencies in molasses and meet the objectives of feeding it to cattle.

Early experiments in which attempts were being made to find the best intake control mechanism for molasses supplements, established that neither phosphoric acid nor aluminium sulphate was effective.

Heifers on a roller drum, circa 1969
[Photograph: Lyle Winks]

Studies with steers in the 1970s found that *ad lib*. fortified molasses intake was reduced with increasing levels of urea (3% to 12%) but urea intake remained relatively constant at about 0.05% of body weight. All mixing was by hand in these early studies and undissolved urea regularly caused intake problems and toxicity. From observations of various mixes in several dry seasons concluding up to 1979, it was concluded that 6-8% urea was a good percentage to control intakes of molasses at levels suitable to maintain weight under very poor pasture quality conditions. This work is likely to have led to the commercial use of M8U by innovative Mackay graziers in the 1982 drought. These graziers were also the first to use a mechanical mixer with excellent results.

Mark Savage rumen sampling a fistulated steer in the pens, August 1977
[Photograph: Mark Savage]

When the first comparisons were made between urea-based supplements and M6U it was shown that the steers on the fortified molasses gained an extra 10 kg, with negligible wet season compensation, ie, the difference remained at the end of the next wet season. Several experiments established the principle that when urea is fed with a significant energy source such as molasses, compensation in the following wet season is approximately half that with low-level supplements.

Tony Merrifield topping up a roller drum, September 1977
[Photograph: Mark Savage]

An observation during the very dry early 1980s showed that fortified molasses supplements could be as effective as protein meals, though urea toxicity problems needed to be resolved; it was subsequently shown that mechanical mixing resolved the issue by dissolving the urea.

Peter Knights topping up with molasses, 1977
[Photograph: Mark Savage]

Mid-1970s studies showed that the direct conversion of fortified molasses to beef was not financially-viable for production at prevailing prices, with this supplement best suited for survival feeding. This provided the basis for major industry adoption of M8U (molasses with 8% urea) during the severe dry season of 1982-83. An observation with calves during the 1982-83 drought showed that addition of protein meal to molasses-urea mixes could significantly increase small weaner growth, spawning the development of this technology.

Trevor Morrison mixing molasses and protein meal at Teddy's Mill, December 1982

On the original Swan's area, soil phosphorus levels are marginal (5-10 ppm). Studies with weaners on native pastures showed with small and variable responses to phosphorus supplements. However, supplementing steers grazing unfertilised Townsville stylo pastures with phosphoric acid in drinking water resulted in significant increases in wet season growth rates, with no responses in steers grazing fertilised Townsville stylo or native pastures. While phosphoric acid produced positive responses, it was very corrosive on storage tanks.

Yearling heifers on a phosphorus block in Bonnet paddock, April 1992
[Photograph: Geoffry Fordyce]

Some pre-registration studies with hormonal growth promotants showed that:

- Treatment with a zeranol implant over two wet season increased growth by an average of 16% in both years with no observable effect on carcass fatness.
- Oestradiol implants can increase wet season growth by 13-26% over 200 days.

4.1.2 Improving dry season, annual and lifetime growth of cattle using combinations of strategies
This program ran for over 20 years, led by John Lindsay. Both pen trials over several months and paddock trials over several years were conducted. Complementing this work, Geoffry Fordyce and Stu McLennan have led systems studies to examine practical application of these strategies. The experiments conducted have been:

1978	Urea-S and formaldehyde casein and the utilisation of native pasture hay
1979	Monensin and formaldehyde casein
1979	Graded levels of formaldehyde casein plus urea-S and the utilisation of native pasture hay
1978-1979	Monensin, Ralgro and the grazing animal
1979-1980	Monensin and the grazing animal on native pasture
1979-1981	The use of growth promotants
1980	Two sources of protected protein and energy
1980	Alkali treated hay and nitrogen supplements for breeders
1980	Alkali treatment of native pasture hay
1980	Monensin or zeranol for steers grazing Townsville stylo swards
1981	Various sources of protected protein and energy as supplements for growing steers
1981	Two sources of NPN and molasses
1981-1982	Grazing weaners supplemented with protected protein
1981-1984	Carryover effects of weaner supplementation and zeranol implantation responses
1982	Graded levels of protected protein plus urea-S
1982	Graded mixtures of formaldehyde cottonseed meal and meat and bone meal
1982	Sources of non-protein nitrogen and energy with dry season hay
1982	Supplement for growing cattle
1982-1983	Protected protein for grazing weaners
1983	Frequency of feeding protected proteins
1983	Graded mixtures of protected proteins
1983	Sources of non-protein nitrogen and phosphorus for inclusion in molasses mixtures
1983	Graded levels of molasses with protected protein plus urea-S
1983-1986	Carryover effects of weaner supplementation and oestradiol 17β responses
1984	Protected protein and graded levels of energy
1985	Graded levels of protected protein with two levels of molasses-urea
1985	Graded levels of monensin in molasses-urea and protected protein mixtures
1985-1988	Dry season supplementation and the subsequent use of growth promotants
1986	Graded levels of avoparcin in molasses, urea and protected protein mixtures
1986	Whole cottonseed as a crisis supplement
1986-1989	Avoparcin and oestradiol 17β with dry season supplements
1986-1990	Age of transfer in two environments
1987	Amino acids with protected protein supplements
1987	Rice husk as an ingredient of cattle feed
1987-1990	A comparison of three rumen modifiers added to dry season supplements
1988	Avoparcin and oestradiol 17β to improve growth in the wet season
1988	Graded levels of tetronasin in molasses-urea or protected protein supplements
1988	Nutrient additives for molasses or protected protein supplements
1988-1991	Monensin and avoparcin as additives for molasses-urea supplements
1989	Monensin, avoparcin and oestradiol 17β to improve growth during the wet season
1989	Fat and energy additives for molasses-urea dry season supplements
1989	Fat and protein containing supplements for molasses based diets
1989	Sodium tripolyphosphate as a water-soluble source of phosphorus
1989-1992	Trenbolone acetate and oestradiol plus dry season supplements
1989-1992	Growing out young weaners from two months of age

1990	Nutrient additives and level of avoparcin with cottonseed meal-based dry season supplements
1990	Length of daily access to molasses-urea supplements and levels of cottonseed meal inclusion
1990-1993	Trenbolone acetate plus cottonseed meal in the dry season
1990-1993	Reducing post-weaning stress and growing out from 70 kg at weaning
1990-1995	Transferring steers to finishing pastures
1992-1994	Levels of cottonseed meal or grain plus HGP
1992	Frequency of feeding and additives to grain supplements
1992	Graded levels of grain in a molasses-urea mixture
1992-1995	Comparison of grain and molasses for radical weaners
1992-1995	High intake supplements and HGPs to boost liveweight gains
1993	Molasses-based diets for hand-feeding weaned calves of 80-105 kg liveweight
1993	Comparison of whole cottonseed and cottonseed meal as supplements for young steers fed low-quality roughage
1993	Virginiamycin to boost growth with cottonseed meal
1994-1996	Adding grain to molasses-based production rations
1994-1997	Growth recovery of early-weaned calves
1995	Beef production from once-bred heifers (cow heifers)
1995-1997	Boosting seca and verano pastures with molasses supplements
1995-1998	Growing out Limousin crossbred cattle
1996	Self-regulation of supplements offered free choice during the dry season
1996-1999	Using molasses-based supplements to reduce age of turn-off from Seca and Verano pastures
1996-1999	Growing out early-weaned calves
1997-2000	Growing out early-weaned calves
1998	Molasses production mixtures at pasture and in the feedlot
2007-2012	Growth pathways optimisation

Metabolism cage studies in 1980 showed that urea or protein supplements can increase pasture intake by as much as 100%, with little effect on the digestibility of the base forage. However, alkali treatment of the hay increased its digestibility from 44% to 53% and, with the combined effect of a supplement, increased feed intake by 170%.

Feeding of protected protein supplements was found to increase their effect on cattle weight gain, with feed intake increased by up to 44% using urea or unprotected protein, and by up to 80% with protected protein. Note that the practices of feeding protected (formaldehyde-treated) protein meals and meat meal used 30 years ago are no longer approved.

Small weaner steers growing with cotton seed meal supplementation in C1 of Burning Trial, September 1990
[Photograph: Geoffry Fordyce]

The research program established that the use of MUP (typically molasses with 3% urea, 10% protein meal, 1% DCP, 1% salt plus monensin), grain or protein-meal supplements with additives typically increased annual growth by 20-30 kg (after wet season compensation). Stylo-based pastures with P fertiliser or supplements were very effective in increasing annual growth by 30-60 kg per year compared with steers on native pastures. The primary advantages are younger age at turn-off, either to slaughter or to finishing, ultimately with higher value carcasses. Supplements alone may reduce slaughter age by 6 months, but a combination of stylo pastures, HGPs and supplements can reduce slaughter age by a year. This must be (and was) compared with growth of 150-250 kg/year achievable on more fertile “fattening” country.

The effects of this form of supplementation were further enhanced by:

- Having heavy weaners available.
- Using crossbreeding, eg, one study showed a 9% advantage.
- Using steers rather than heifers; one study showed a 13% advantage.

Weaning steers at a young age was not found to suppress subsequent growth when they were given energy-dense supplements. Calves weighing less than 100 kg when weaned in April and fed fortified molasses produced half the growth through to August of suckling contemporaries (0.3 *v* 0.6 kg/day). Much of the difference in weight that resulted remained for up to 3 years.

Testing of a range of energy-dense supplements designed to achieve dry season growth found that:

- Isobutylidene diurea (biuret) was found to achieve similar effects to urea when used to fortify molasses but it is not soluble and does not offer a practical alternative.
- It was confirmed that 6% urea is excessive in a MUP mixture, and that linear responses to the amount of protein meal added to molasses-urea occurred.
- A phosphorus source needs to be included when production feeding to prevent secondary deficiency.
- Dry season M8U increases annual growth by up to only about 10 kg.
- Urea-sulphur supplements increased roughage intake by 10-50%. Adding protected protein to a urea supplement further increased roughage intake.
- Grain, protein meal or fortified molasses supplements can achieve equivalent growth during the dry season, even for feeding weaners as light as 84 kg offered a basal hay diet. A major effect is to increase roughage intakes by as much as 73%.
- MUP fed at 0.5-1.5% body weight can achieve dry season steer growth of 0.3-1.0 kg/day and when fed in a feedlot-type environment, growth rates of 1.3 kg/day were achieved.
- The benefits of fortified molasses are equal when access is either continuous or infrequent such as in the paddock. Frequency of feeding was also found to not affect liveweight responses to grain-based supplements with added virginiamycin to control acidosis.
- Whole cottonseed and cottonseed meal were equally effective as supplements at similar average daily intake. Voluntary intake of whole cottonseed is considerably less than of the meal; when consumed at 0.5% of liveweight, no substitution for pasture occurs.
- Copra meal and cottonseed meal achieve similar growth responses when the same daily amounts are fed.
- The research with vegetable-derived protein meals contributed to their replacing ruminant-derived protein meals which suffered palatability issues and finally a feeding ban to ruminants.
- Rice pollard, but not ground rice husk, as a supplement has similar effects on growth to whole cottonseed.
- The efficiency of use of protein meal supplements can be increased when protected methionine and lysine are also fed.
- Either replacing molasses with grain or adding grain to fortified molasses fed *ad lib*. increases growth but the response is not linear.
- Addition of whole cottonseed, oil or protected lipid to *ad lib*. MUP does not increase dry season growth; unprotected oil usually reduces growth.

Tony Merrifield feeding ad lib. molasses with 3% urea, December 1980
[Photograph: Dick Holroyd]

Rumen modifiers such as monensin are now regular additives to fortified molasses formulated for production feeding, primarily to prevent the risk bloat and to prevent coccidiosis in weaners. It was shown that if moderate growth rates, eg at least 0.5 kg/day, are achieved either during wet or dry seasons, addition of rumen modifiers (monensin; lasalocid; avoparcin – no longer registered) may sometimes have small benefits in growth enhancement and feed conversion efficiency, but cost-effectiveness is variable; eg, rumen capsules delivering between 120 and 250 mg/day of monensin did not increase wet season growth rates of steers. At lower growth, achieving benefits from rumen modifiers appears is unlikely; eg, tetronasin was unable to show effects when growth averaged 0.24 kg/day. The potential growth benefits of monensin in supplements may be partially countered by its intake suppressive effect of 5-15% when fed at more than 50 mg/day. Virginiamycin causes small, but not cost-effective, increases in growth; its main use is in preventing acidosis, especially in irregularly-fed grain supplements.

Cows on M8U in G paddock of McGregor, October 1986
[Photograph: Geoffry Fordyce]

Considerable work with HGPs established that:

- Most HGPs increase growth during their active period by 5-25%. The response to HGPs appears to be greater in steers that were managed to grow as weaners. Little of the benefits of oestradiol HGPs on the first year of post-weaning growth appear lost in subsequent years.
- A range of HGPs achieved no effect on dry season growth, even when given with energy-based supplements such as protein meal.
- As well as increasing growth, a HGP delivering Trenbolone acetate (TBA) with oestradiol produced leaner carcasses. The growth enhancement of TBA appeared limited to 2 years.

Other nutritional principles found during pen trials included:

- Yeast products, probiotics and volatile fatty acids are not effective supplements for increasing dry season growth on low-quality pastures.
- Sodium tripolyphosphate was shown to be a suitable alternative for phosphorus supplementation through drinking water.
- Alkali-treated bagasse is an effective roughage source in balanced cattle rations.
- Cattle do not have significant nutritional wisdom; eg, when offered a free choice of supplements, cattle tend to consume excess protein and insufficient energy.

The systems studies with fortified molasses led by Geoffry Fordyce are discussed in section 4.2.2.

Tom Mullins feeding cottonseed meal to pregnant cows in the first of the experiments that led to spike feeding, October 1986
[Photograph: Geoffry Fordyce]

The incomplete growth pathways optimisation project is comparing weaning to slaughter performance of cattle using combinations of high, moderate and low supplementation or leucaena in their initial 2 dry seasons. Weight, body condition, skeletal development, subcutaneous fat, and eye muscle measures are all being monitored in live animals, with all carcass and meat parameters taken during MSA assessment of carcasses (Meat Standards Australia, a standardised system for animal and carcass management to achieve a high probability of high-quality beef). A milestone report extract states, “Early indications are that high input supplements can reduce the age of slaughter by up to 12 months, that the cost-efficacy of treatments will be highly dependent on seasonal conditions, that hormonal growth promotants will largely preclude compliance with MSA grading for *Bos indicus* cattle in northern Australia but increase economic returns through their growth stimulus, and that leucaena finishing pasture will reduce age at slaughter relative to high-input supplementation of cattle grazing native pastures in north Queensland”.

Brahman steers nearing slaughter weight in the Growth Pathways Optimisation project, March 2010
[Photograph: Geoffry Fordyce]

4.2 Female cattle management and nutrition

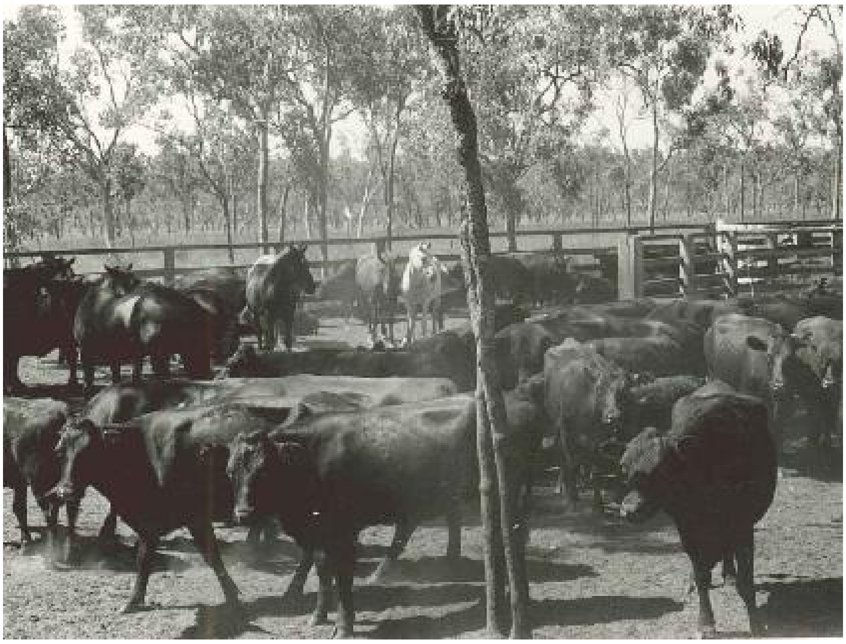
4.2.1 Breeding female herd management

Initial reproduction studies were led by Tony Plasto and then Peter Allan. From 1974 to 1985, the work was led by Dick Holroyd and from then by Geoffry Fordyce, with some studies in that period led by Ian Loxton and Stuart McLennan. Experiments conducted have been:

1963-1968	Time of mating in Shorthorn cows
1960s	Oestrus synchronisation
1971	Weaning observation
1975-1987	Early seasonal indicators to aid management of cattle properties in north Australia
1976-1979	Time of weaning trial
1977-1980	Time of weaning trial
1977-1983	Breeder supplementation and time of weaning
1967-1974	Artificial insemination studies
1968-1985	Causes of foetal and neo-natal losses
1977-1979	Plasma oestrogens in pregnancy
1979-1981	Pre-mating plasma cortisol levels
1980	Embryonic mortality
1981	Oestrus cycles in Brahman cross heifers
1982	Condition scoring observation
1983	Cow survival feeding observation
1983	Weight and dimension of conception products
1985-2000	Breeder herd management and production
1987-1988	Early weaning effects on breeder and calf performance
1987-1988	Segregating at-risk cows prior to drought
1987-1988	Early weaning effects of breeder and calf performance
1987-1994	Brahman cross herd studies
1989-1994	Visual assessment of breeder fertility
1991	Neonatal calf measurements
1994-2000	Bull-breeding nucleus herd
2003-2006	Minimising pregnancy failure and calf loss
2006	Neonatal calf loss in cattle breeding herds of the northern tropics
2007	Seasonal effects on cyclicity in Brahman cows
2007-2012	Northern beef fertility (Cash cow) project

The first cow studies on Swan's Lagoon were with Shorthorns in the 1960s and showed:

- Cows mated for different 9-week periods had similar annual pregnancy rates (61%) with a trend to highest rates in the early wet season; however, pregnancy rates were 20% higher when continuously-mated, mainly as a response to weaning.
- Conception rates in dry cows were higher than in wet cows (76% v 49%); cows that conceived had higher growth during mating (0.35 v 0.25 kg/day).
- When Shorthorn cows were weaned, a dramatic increase in the number showing oestrus with high pregnancy rates occurred within three weeks.
- Average calf birth weight was lightest at the end of the dry season and heaviest at the end of the wet season (25 kg *v* 31 kg), respectively), reflecting pregnancy nutrition.
- Suckling growth rate was highest in calves born in the late dry season and lowest in those born in the late wet season, reflecting the effects of nutrition on milk production, and the availability of green grass for calves.



Shorthorn cows and horses in the main yards circa 1965
[Photograph: Rod Strachan]

Artificial insemination research in the 1960s achieved first-service conception rates of 45-50% and overall conception rates of 70-80% in Shorthorn and Africander cows. Rates were much lower in Brahman and Sahiwal cows. The reason for this was not evident, but it was found that uterine massage increased pregnancy rates by over 10%, with heifers responding better than cows. Oestrus detection was identified as the key limitation to success, and the use of Kamar heat detectors was found to be highly efficacious. The costs of oestrus detection were high when cattle were yarded due to feeding requirements. However, good facilities were found to be essential for conducting the insemination. The first oestrus synchronisation methods examined both oral and injectable progesterone, but were unsuccessful.

Oestrus cycle length was found to vary substantially in Brahman cross heifers, with normal cycles being 18-24 days. Embryo mortality appeared to occur after about 1/3rd of matings. Embryo loss was higher and final pregnancy rate was higher in heifers that had higher rectal temperatures; these heifers also had lower weights.

Brahman cross mating group in Lagoon paddock, February 1988
[Photograph: Geoffry Fordyce]

Detailed investigations using ultrasound to monitor reproduction in Brahman heifers and cows in 2003 and 2004 (See section 4.5.1) found that pregnancy rates achieved per 21-day period (average length of the oestrus cycle) in cycling animals was approximately 50% at Swan's Lagoon. This was lower than the benchmark level established for disease-free beef females under north Australian range management of 2/3rd pregnant per cycle. The reason why the Swan's Lagoon rate was depressed is unknown; there was some evidence of pestivirus transmission, though the animals were vaccinated with no measurable impacts on final pregnancy rates or progeny survival.

Brahman cross cows in C of McGregor, 1992
[Photograph: Geoffry Fordyce]

Over the year, observations of confirmed pregnancy to weaning losses showed that:

- In the first 10 years of cow studies at Swan's Lagoon, foetal and calf loss between confirmed pregnancy and weaning in Shorthorn, Brahman and Africander breeds averaged 10%. Shorthorn cows calving in the early dry season had the highest calf loss rates, averaging 15%. However, the time of loss and reasons for loss were not identified.
- In cow supplementation studies, calf losses averaged 4-6% following abortion rates of 2-7%.

- Pregnancy to weaning losses in seasonally-mated Brahman crosses averaged 10% and varied between 7% and 14% with wild dogs and dry years increasing loss.
- Pregnancy to weaning loss in continuously-mated Brahman crosses averaged 8%, rarely exceeded 10%, but occasionally reached 15% in paddocks when dingo populations were high. Losses also occurred in dry years when body condition of cows was lower, presumably because of lower milk yields of cows and poorer protection they may afford calves.
- In a 1987-88 comparison of weaning young calves in April rather than August, calf loss to confirmed weaning was reduced from 13% to 7%. This was associated with poorer cow body condition in August-weaned cows.
- Detailed observations of confirmed pregnancy to weaning losses, especially of Brahman and Sahiwal cross cows rates revealed that:
  - Most losses are from unknown causes.
  - Losses were higher in first-lactation females than in cows.
  - There was no consistent effect of vaccination against leptospirosis.
  - Stillbirths and bottle teats were common causes.
- An analysis of data on 239 calves born in 2006, of which 3% died within a week of birth, showed that heavier calves (33 *v* 27 kg) and calves showing greater vigour at birth had higher survival chances. The dams of most calves that died had udder and teat scores of 3 (moderate) to 5 (very large). Neither maternal temperament, ambient temperature, nor humidity had any apparent influence on calf survival.

Tom James weighing a calf, November 1976
[Photograph: Mark Savage]

A 2005 review concluded that the benchmark levels for reproductive wastage were: 10% fertilisation failure, 20% early embryonic loss, 5% late embryonic loss, 3% abortions, 5% loss within a week of calving, and 1% mortality in suckling calves older than one week – these are percentages of those in the preceding stage. Reducing rates below these levels does not appear to be achievable (without chance) in the dry tropics.

Brahman cross cows prior to calving at Top bore in Sandalwood, December 1997
[Photograph: Geoffry Fordyce]

Observations over many periods showed that cow mortality rates were much higher if calving occurred during the dry season (up to 16%). However, progeny of surviving cows had the highest sale weights. In the very severe drought of 1982-83, 20% of the Expedition breeders died. The primary risk factors causing death were poor body condition, advanced pregnancy or lactation and being over 8 years of age, presumably because of deteriorating dentition. Segregating cows on reproductive status and body condition delayed need for survival feeding in low-risk cattle by 6 weeks.

Geoffry Fordyce foetal ageing, September 1989
[Photograph: Geoffry Fordyce]

Productivity of a 450 ½-¾ Brahman cross cow herd was described when managed using 3-month mating:

- Analysis of 12 years of reproduction records from this herd found that 68-84% of the variation in pregnancy rate of mature lactating cows could be explained by the August-October Southern Oscillation Index, total rainfall in July-November, date of seasonal break, or the pasture growth days between July and November.

- Abattoir measures of uterine contents of cows at known stages of pregnancy, combined with measurement of neonatal calves contributed to the development and validation of equations for the correction of weight due to stage of pregnancy, and equations to predict components of the pregnancy, including foetal size, at specified stages of pregnancy. Age and breed of the cow and sex of the foetus had no significant effect on foetal and uterine growth.
- Birth weights of calves averaged 28.3 kg for males and 26 kg for females. However, average birth weight varied between years by more than 20% with lowest weights after extended poor dry seasons.
- Progeny of mature cows weighed 2 kg more at birth and grew 0.02-0.05 kg/day faster during suckling than calves of first-lactation cows.
- Growth of juvenile bulls was 8% higher than that of heifers.
- ¾ crosses grew faster, and had higher calf output under poor seasonal conditions than ½ crosses; the reverse occurred under good seasonal conditions.
- Weights of heifers at weaning, at 18 months and prior to mating at 2 years were all related to conception rates. Expected pregnancy rate after three months mating was: -227 +2.06 x Start of mating weight (SOMW) – 0.0034 x SOMW squared; heifers needed to weigh at least 270 kg at the commencement of mating to achieve an 80% probability of conceiving.
- Heifers mated at the same weight at two years of age had higher pregnancy rates when growth in the dry season after weaning was higher.
- Average long-term weaning rate was approximately 73%, 10% units lower than the continuously-mated herd.

Andrew Beattie, Tom Mullins and Neil Cooper weighing cows, 1987
[Photograph: Geoffry Fordyce]

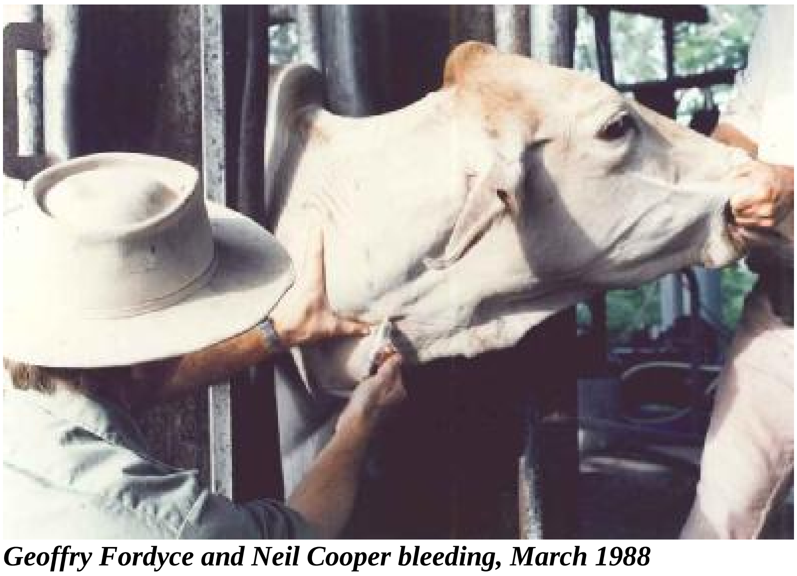
Weaning is one of the most important husbandry practices available for cow management. A number of component research studies found that:

- Weaning in April preserved 30-40 kg cow live weight in comparison with weaning in August. The weight and body condition disadvantage caused by later weaning suppressed pregnancy rates in the following year by as much as 30% in lactating females.
- Calves weaned in April experienced a small weight loss by August, whereas August-weaned calves gained 40 kg. The 50 kg weight difference between steers weaned in April and July was reduced to 5-15 kg after 3 years with compensation complete by 4 years of age. The same difference was reduced to 12-27 kg by 2 years of age in heifers, with only a very small pregnancy rate advantage to those weaned later.

- A 1987-88 demonstration of the benefits of weaning young calves in April rather than August showed that weaning conserved 40 kg of cow live weight, 89% of weaned non-pregnant cows conceived within 3 months, and unweaned calves fed MUP grew at 0.3 kg/day while suckling contemporaries grew at 0.4 kg/day.

In 1984, stepped mating of previously-seasonally-mated Brahman cross cows established a continuously-mated herd that was monitored from 1985. The objectives were to assess subsequent performance of cows and progeny in the dry tropics when weaning at a range of ages down to 3 months occurred in either April-May or August-September. Maidens were objectively selected at 18 months on growth, temperament, ability to hold condition in the dry season, fly and tick burdens and physical normality and then mated at 2 years. Cows were culled at 9 years with earlier culling only for abnormalities. Weaning of all calves weighing 100 kg or more occurred twice yearly in April-May and August-September. Fortified molasses was provided to cows only in very dry years to prevent mortalities. All cattle were vaccinated against botulism, cows against leptospirosis, and bulls against vibriosis and bovine ephemeral fever (commonly known as 3-day sickness). The Brahman cross herds were integrated with this herd in 1994. Production parameters for this herd included:

- Peak calving occurred in November and December with typically about 50% of all calves born in these two months.
- Weaning rate was sustained at an average of 83% (72%-92%) over the 15 years.
- 60-90% of calves were weaned at the first round in April-May.
- An average of 30% of calves was weaned at 100-150 kg.
- Body weights of cows rearing calves usually averaged 40-60 kg and 30-40 kg less in April and August, respectively, than those of cows not rearing a calf; this is equivalent to 0.5-1.0 body condition scores.
- Cow mortality averaged 0.5%, but in the drought year of1991, it was as high as 3% in mature cows.
- A P-screen test in 1995 indicated that the cows were grazing acutely-phosphorus deficient pastures. Phosphorus supplementation was not practised, and yet cow productivity was very high. This appears due to management such as appropriate stocking rates, adequate waters, and good weaning practices that focused on cow needs. In contrast, phosphorus deficiency was not apparent from blood, rumen or performance measures in cows when grazing trial areas on the old Swan's Lagoon area.



Geoffry Fordyce and Neil Cooper bleeding, March 1988
[Photograph: Geoffry Fordyce]

A system for visual assessment of cow production efficiency promoted by South African, Professor Jan Bonsma, was used to assess all cows in the Swan's Lagoon Brahman cross herd with available production data, and a group of 1987-weaned heifers which were then monitored for six matings. The scores were moderately repeatable, and were biased towards cows in better body condition, lactating and of red or grey colour. There was no relationship with calf production. This system appears suitable for selecting cows of a certain conformation and its use may increase the likelihood of identifying unwanted abnormalities within potential breeding cattle.


Weaner heifers in Tyler paddock, August 1988
[Photograph: Geoffry Fordyce]

To reduce large variation in the Swan's Lagoon genotype and to increase selection efficiency, a specific bull breeding herd was established in 1994. Management was as for the continuously-mated herd, but with 5-month mating and weaning down to 120 kg. An open nucleus was operated, ie, heifers from across the station were eligible for selection. Objective selection emphases were on reproduction, growth, moderate maturity, adaptation (ticks and body condition), temperament, structural soundness and straight colour. The result could be described as a Beefmaster. By 1999, average parameters for this herd included:

- Weaning rates were approximately 90%.
- Cows were 2.5% taller, 20% heavier and 0.5 condition score units better than breeder herd cows.
- Mature weight of score 3 mature cows exceeded 500 kg at a hip height of 140 cm.


One of the foundation bulls (880015) for the nucleus bull-breeding herd, March 1995
[Photograph: Geoffry Fordyce]

Routine monitoring of the cow and bull-breeding herds discontinued in 2001. From this time, all new bulls were purchased Droughtmasters.

Two breeding groups on Swan's Lagoon are in the group of about 150 north Australian management groups being studied to develop benchmarks for reproduction across the region. The drivers of these benchmarks are being explored as part of new ways to measure reproductive efficiency. Individual beef businesses will be able to assess where their operation is in relation to benchmarks for their specific situation.

4.2.2 Responses to supplements in breeding cattle

Within the first 10 years of operations, cow supplementation studies were underway led by Peter Allan, with Dick Holroyd and Ian Loxton completing the series of studies. Subsequently, John Lindsay conducted a series of experiments with breeding cattle in parallel to his group's studies of supplements on steer growth. Geoffry Fordyce led more recent systems studies of breeder herd supplementation. The experiments conducted included:

1969-1973	Breeding supplementary feeding trial
1969-1970	Supplement effects on conception rates in mature, dry Shorthorn breeders
1970-1971	Fluorosis study
1973-1977	Breeder supplementation trial
1981	Alkali treated native pasture hay and nitrogen supplements as survival rations for pregnant cows
1983	Liveweight and reproductive responses to dosing heifers with trenbolone acetate
1983-1985	Liveweight and reproductive responses to protected protein supplementation
2003-2006	High-input management systems for northern breeding herds
2003-2006	Nutritional management of skeletal bone growth in the dry tropics

An early study that examined cottonseed meal and molasses-urea supplementation in cows was compromised by vibriosis and yielded no useful fertility outcome.

When cows grazed phosphorus-fertilised Townsville stylo-based pastures, they achieved a 12% higher pregnancy rate than those grazing native pasture. This effect coupled with double the stocking rate on fertilised pasture compared with native pastures increased cow and calf live weight production from 40 to 96 kg/ha/year. Cottonseed meal and urea-molasses (roller drum) supplements with the same energy levels both reduced dry season weight loss by 0.1 kg/day. Urea in the dry season conserved 10-20 kg live weight and had the biggest impact on pregnancy rates, increasing them by an average of 12%; wet season phosphorus supplements could not consistently increase pregnancy rates further. The weight preservation achieved by feeding urea-based dry-season supplements reduced mortality rates by more then 5% in some years. With pregnancy rate at 68% in controls, dry season urea and wet season phosphorus increased weaner weight per cow mated from 104 kg to 136 kg; urea alone achieved 129 kg of weaner weight per cow mated.

Shorthorn cows on a grain self-feeder, April 1967
[Photograph: Lyle Winks]

In a supplementation study using Brahman and Shorthorn cows, there was no clinical evidence of fluorosis after two years of feeding phosphoric acid that contained fluorine.

A pen trial with pregnant cows demonstrated that liveweight loss could be reduced and even reversed with various supplements. The primary effect was due to the amount of nitrogen in the supplements, which increased roughage intake by up to 93%. The calves of un-supplemented cows were up to 11 kg lighter at birth than those of supplemented cows.

A 1979 observation with Sahiwal cows demonstrated that *ad lib* intake of fortified molasses (3% urea was added) compared with a dry lick given as a "home brew" was very effective in preventing cow mortality (4% *v* 36%) and reducing calf death rates (20% *v* 80%). Despite non-pregnant cows being in poorest condition at the beginning of the observation, most mortalities occurred within the pregnant and lactating cows.

A protein supplement (0.5 kg/day) given in the pre-mating dry season of maidens increased weight by 35 kg and subsequent pregnancy rates from 57% to 92%. A similar supplement regime (0.75 kg/day) during maiden pregnancy increased conception rates during the subsequent lactation from 50% to 75%. These Brahman crosses had average mid-lactation milk yields of 4-6 kg and 5-7 kg daily during their first and second lactations, respectively.

Neil Cooper about to place a rumen bolus with Cr_2O_3 as part of feed intake studies in B of McGregor, April 1992
[Photograph: Geoffry Fordyce]

Trenbolone acetate was used as a HGP in some maiden heifers. During TBA payout, heifers grew faster but were clearly masculinised and many suffered temporary sub-fertility, the consequence of which was pregnancy rates reduced from 74% to 40% and average conception date being delayed by 1.5 months.

A Brahman cross steer weighing 550 kg at 2.5 years of age after receiving MUP in his first two dry seasons, May 2006
[Photograph: Geoffry Fordyce]

A major systems project to assess the efficacy of fortified molasses in enhancing herd reproduction and growth was established at 3 north Queensland sites, one of which was Swan's Lagoon where a strategic low-input management system (SLIM: as used in the breeder herd management and production project, except for urea-based licks in the dry season for all cattle) was compared with a high-input management (HIM) system. In the HIM systems, weaners and steers were fed dry season MUP, heifers were mated as yearlings, all mating was for 3 months, and all pregnant females received spike feeding. Outcomes from this project included:

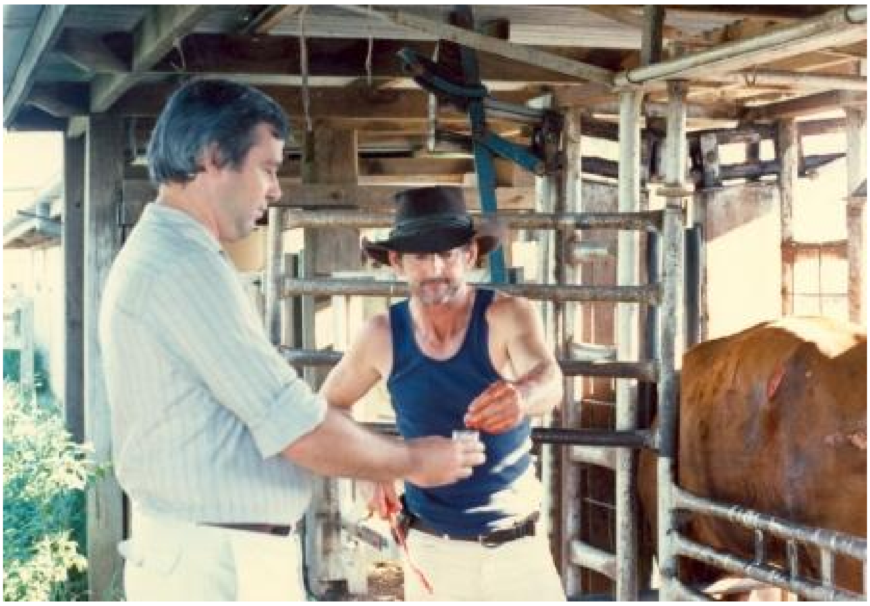
- The study demonstrated the complexity of profitable application of research outcomes to commercial business, even when component research suggests that specific strategies may increase growth and reproductive efficiency and/or be more profitable. Because of the higher level of management required, higher costs and returns, and higher susceptibility to market changes and disease, HIM systems should only be applied after SLIM systems are well developed. To increase profitability, any strategy must ultimately either increase steer growth and sale values and/or enable a shift to high pregnancy rates in yearling heifers.
- *Ad lib*. intakes of M8U and MUP averaged 0.5% and 1% of live weight, respectively.
- Due to weaning weights and annual growth each being at least 30kg higher, up to 100% of HIM steers reached 500 kg at 2.5 years, whereas very few SLIM steers reached this target.
- Steer weight and skeletal development were retarded during dry seasons. About 50% of the dry season weight advantages due to MUP feeding were lost during the subsequent wet season, but no compensation in skeletal development occurred.
- HIM was most profitably applied to steers. Similar growth responses were achieved in all age groups, but MUP intakes were much higher in older steers; ie, response efficiency was highest in weaners.
- Only where HIM was able to achieve high pregnancy rates in yearlings, could its application be recommended in females selected for potential mating.
- High yearling pregnancy rates are achievable, but weight and condition of pregnant heifers must be sustained or calf loss may exceed 20% and cow mortality due to dystocia at 2-year-old calving may reach 10%. Birth weight of calves from heifers experiencing dystocia at 2-year-old calving was higher than of calves from normal births (34 kg *v* 28 kg).
- Pregnancy rates of 90% in the subsequent lactation are achievable by spike-feeding pregnant yearlings and cows.
- A HIM herd has 10% fewer cattle than a SLIM herd with the same total pasture intake.

- Well managed, appropriate HIM systems increased profits by around $15/adult equivalent at prevailing beef and supplement prices. However, a 20% supplement price rise without a commensurate increase in values for young slaughter steers would generally eliminate this advantage.

Yearling Beefmaster heifers supplemented with fortified molasses, December 1995
[Photograph: Geoffry Fordyce]

4.2.3 Developing cost-effective strategies for improved fertility in *Bos indicus* cross cattle
As part of a major collaborative project with James Cook University and CSIRO, a series of experiments was conducted with heifers and cows to better understand the biology of reproduction in the dry tropics as a basis for developing more efficient female cattle management practices. Major objectives of this work were to increase heifer production efficiency and reduce lactation anoestrus. On Swan's Lagoon, this research was led by Geoffry Fordyce, and experiments included:

1986-1988	Pre-partum supplementation effects on post-partum ovarian activity and fertility
1987-1988	Avoparcin to enhance supplement effects on fertility
1988-1989	Pre-partum supplementation effects on subsequent fertility
1990	Creep feeding effects on post-partum fertility
1990-1991	Spike and creep feeding effects on post-partum fertility
1990-1991	Melatonin effects on post-partum fertility
1992-1993	Wet season nitrogen supplements for lactating cows
1987-1994	Post-weaning dry season growth effects on the subsequent fertility of heifers
1989-1994	Heifers weaning age effects on subsequent fertility
1990-1994	Effects of post-weaning growth and an androstenedione vaccine on reproductive development and fertility
1990-1995	Yearling mating of heifers in the dry tropics
1991-1995	Weaner heifer management and nutrition effects on subsequent fertility
1993-1995	Effects of supplements and hormonal intervention on reproductive development in weaner heifers and the added effects of mating management on subsequent calf output



Lee Fitzpatrick (James Cook University) and Neil Cooper recovering ovaries for laboratory studies, January 1989
[Photograph: Geoffry Fordyce]

Lactation anoestrus
Spike feeding was developed. This is the feeding of an energy-dense supplement for at least 50 days prior to calving late in the dry season. Suitable supplements include M8U or protein meal. This strategy was found to consistently increase pregnancy rates in first-lactation cows by an average of 20%, except in severe dry seasons where a break in the season was months after the start of calving. The effect produced was independent of effects on cow weight or condition and appeared to result from substantially-enhanced follicle development in the ovaries. Detailed studies after calving found that oestrogen from the ovary was exerting strong negative feedback on LH release and that spike-fed cows were less sensitive to these effects.

The Late Ian Kendall during spike feeding research with M8U, October 1990
[Photograph: Geoffry Fordyce]

Addition of a rumen modifier to spike feeding supplements was found to reduce rate of weight loss, but did not enhance the spike feeding effect.

Geoffry Fordyce preparing ovaries for laboratory examination, March 1988
[Photograph: Geoffry Fordyce]

Supplemental nitrogen for breeders during the late wet season had little effect on growth, but did increase pregnancy rates by as much as 25% when average supplemental nitrogen intakes reached 10 g/day. No effects were achieved with urea-based supplements in the early-mid wet season.

Geoffry Fordyce, Rodd Dyer and Neil Cooper faecal sampling, April 1992
[Photograph: Geoffry Fordyce]

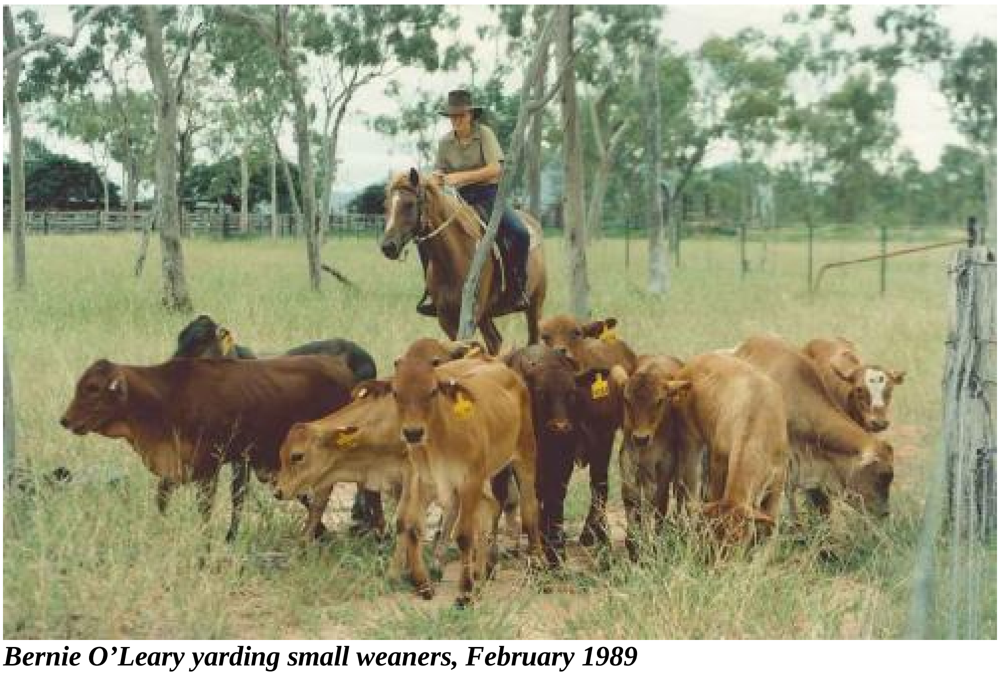
Creep feeding, which is the supplementation of suckling calves during the preferred mating period without supplementing cows was found to have no effect on pregnancy rates. Milk yields of first-lactation cows were 3.6 kg/day with no effect due to creep feeding. Similarly, melatonin implants had no effects on cow fertility.

Heifer production efficiency
Heifers that were supplemented to achieve low growth (+0.10 kg/day) as weaners had 10-20% higher pregnancy rates in the first three months of mating at 2 years at the same mating weight than un-supplemented heifers. The un-supplemented heifers averaged 19 kg lighter at the end of the post-weaning dry season and 14 kg lighter at two-year-old mating. The pregnancy rate effect occurred because supplemented heifers reached first oestrus at an average of 19 kg lighter than un-supplemented heifers; this is alternatively expressed as the average weight at puberty increased by ~5 kg for each month delay caused

by poorer nutrition. Within nutritional treatments, faster growers in the post-weaning dry season also reached puberty at lighter average weights. There was no further effect of early nutrition on reproduction other than advantages gained as a heifer. Average age at puberty ranged from 1.5 to 2.5 years; the variation for most heifers within year group was 100 kg and 10 months for weight and age, respectively.

Brahman cross weaner heifers being supplemented with cottonseed meal in K of Leichhardt, July 1987
[Photograph: Geoffry Fordyce]

Weaning age had no independent effect on weight and age at puberty; ie, puberty was later simply because of age.



Bernie O'Leary yarding small weaners, February 1989
[Photograph: Geoffry Fordyce)

Vaccinating heifers against androstenedione had no effect on growth and did not consistently affect pre-pubertal development with no significant influences on conceptions either as heifers or cows.

The measurement of puberty in this research was by progesterone blood levels which become elevated when a female cycles and produces a corpus luteum (CL) in the ovary. It was found in heifers up to one year of age at least, that using this test was not possible as the stress of handling to get the blood sample caused the adrenal glands to release large amounts of this hormone. This was one major reason for shifting to the use of ultrasound to monitor ovarian development in subsequent research (See section 4.5.1).

Two-year old Beefmaster heifers on the lagoon, December 1994
[Photograph: Geoffry Fordyce]

Many north Australian heifers are not effectively segregated from bulls. Yearling pregnancy with or without weaner supplementation was found to increase lifetime calf output by 0.2-0.4 calves. Heifers heavier at weaning or given above-maintenance supplementation as weaners had higher yearling pregnancy rates. It was noted that dystocia occurs in a small percentage of heifers calving at 2 years of age, causing mortality of both the cow and calf, especially in years when pregnancy nutrition was not at least maintenance and in late-conceiving heifers. This appears related to disproportional development of the calf and dam caused by under-nutrition in early-mid, but not late pregnancy. Stunting appeared to occur only when heifers produced a calf each year to 4.5 years of age, which is when skeletal maturity occurs.

Yearling-mated heifers prior to first calving in Kelly's Corner, November 1994
[Photograph: Geoffry Fordyce]

4.2.4 Improving cost-effectiveness of supplementation systems for breeder herds in northern Australia

This 1994-1998 program was led by Dr Rob Dixon. The primary objective was to develop systems that achieved target average supplement intake and reduced intake variability within groups, thereby increasing cost-effectiveness. The experiments conducted included:

1994	Effects of a high level of supplementation post-partum during the wet season on fertility in first-calf crossbred cows
1994-1995	Training weaners to consume dry lick supplements
1995	Effects of supplement type on variability of supplement intake
1995	Preliminary observations on intake of wet licks containing molasses and high levels of urea and phosphoric acid
1995	Effect on the distribution of intake of a molasses/urea/phosphoric acid supplement by cows and calves
1995-1996	Variability in intake by heifers of salt/kynophos dry lick supplements fed during the wet/early dry season
1995-1997	Effect of dry lick supplements fed during the early and/or late dry season on productivity of *Bos indicus* x Shorthorn cross breeder cows
1996	Further studies on the training of weaners to consume dry lick supplements
1996	Effect of inclusion of CSM in dry lick supplement on intake and variability of intake by weaners
1996	Effect of previous experience of supplements and inclusion of CSM in dry lick supplement on supplement intake by weaners
1996	Effects of previous exposure of yearling cattle and palatability of dry lick supplement on intake and variability of intake under wet season conditions
1996	Effects of various additives for molasses supplements on intake and variability of intake
1996	Rumen microbial protein production in heifers fed spear grass hay and dry lick or M8U supplements
1996-1997	Effect of dry season dry licks containing dried molasses or cottonseed meal for first-calf heifers
1997	Rumen microbial protein production in heifers fed spear grass hay and supplements of urea
1997	Variability in intake by heifers of dry lick supplement fed during the wet/early dry season
1997	Distribution of intake of a molasses/urea/phosphoric acid supplement in a mob of cows and calves
1997	Effect of early exposure as weaners on subsequent intake of dry lick supplement by 3-year-old steers
1997	Wet season supplementation of cattle: Effects of siting on intake and paddock use
1997-1999	Effect of time of weaning and urea-based dry lick supplements fed during the dry season on productivity of second-calf cows
1998-1999	Effect of plane of nutrition and time of weaning on breeder liveweight loss during the dry season and subsequent fertility
1999	Acceptance by cattle of dry lick supplements containing a new source of calcium phosphate
1999	Intake of molasses-phosphoric acid supplements by heifers

Supplement intake

Cattle with higher need, eg, poorer condition or lactating, were found to consume more dry lick and fortified molasses supplements. Calf intakes are proportional to their dam's intake. Previous experience, eg, weaning training, usually had only short-term effects on intake. The proportion of cattle not consuming any supplement and the within-mob variation in supplement intake both increased as the level of average daily intake decreased, and available trough space decreased; eg, one small dry lick feeder for 100 cattle resulted in only 60% of animals consuming supplement. Average expected intake of any dry lick supplement should be at least 50 g/day to avoid some cattle not having access. Variation between animals within mobs is usually high, with the coefficient of variation for dry lick sometimes exceeding 100%; the variation in intake is usually half this for protein meals or fortified molasses, for which very few animals were generally shy feeders.

Lick trough for yearling heifers at Heatley paddock bore, September 1993
[Photograph: Geoffry Fordyce]

Daily intake of urea-based supplements was proportional to increased pasture intake and efficiency of microbial protein synthesis (typically by 25% and 100%, respectively, at recommended urea intakes), even at intakes 4 times prevailing supplement intake recommendations. However, no changes were made in recommendations for daily urea intake. Addition of protein meal to urea-based supplements, primarily by replacing salt, did not affect nutrition directly, but achieved higher intake of the dry lick with reduction in intake variation, and is therefore useful as an intake control mechanism.

Intakes of fortified molasses are reduced by increasing urea percentage, such that total daily urea intake is the same. Inclusion of monsensin, which is unpalatable, in fortified molasses can reduce intake by 30%. Neither increasing urea levels nor monensin inclusion appears to affect within-mob variation in fortified molasses intake. M8U can increase pasture intake by 25% and treble microbial protein synthesis.

Attempts to cost-effectively deliver wet season phosphorus to cattle in fortified molasses were not successful.

Supplement effects
Allowing cows to continue lactation during the early dry season increased weight loss by 10-15 kg/month. Weaning effects were generally in addition to the benefits of urea-based dry licks fed to young pregnant cows in very dry years that reduced dry season liveweight loss by up to 10%. The combined effect for backward-condition cows was a 5% increase in pregnancy rates for each 10 kg extra weight at the start of mating. Building on previous studies, urea-based supplements in the late wet season also increased weight and pregnancy rates of cows in backward condition, but not those in moderate or better condition.

Availability of green pasture as the result of storms during the usual dry season period negates the benefits of urea-based licks. Cows may still lose considerable weight, and subsequent fertility remains related to condition score in the late dry season.

Supplementing cows with protein meal for 50 days in the mid wet season increased cow condition by nearly half a score, but had no effect on fertility.

Economic evaluation showed that, despite consistent effects on weight and fertility in dry years, urea-based supplements are consistently cost-effective only when they reduce mortality rates, or when they are fed using low-cost delivery systems such as water medication.

4.2.5 Contraception in female cattle
A series of experiments managed by Geoffry Fordyce examined contraceptive methods for female cattle, and the growth implications. The experiments included:

1990	Immunological spaying
1993	Efficacy of low-dose progesterone implants as contraceptives
1997-1998	Growth promotants in spayed heifers
1997-1998	A GnRH agonist implant as a reversible contraceptive in heifers
1990-1992	Spaying effects on heifer growth

Flank spaying of heifers whether at weaning or two years of age causes a temporary growth disadvantage, but by 2 months after spaying and thereafter, no differences in weight, height or condition are detectable. Surgical spaying may cause death, either from haemorrhagic shock or through increased susceptibility to infectious diseases such as BEF (commonly known as 3-day sickness).

The Willis dropped-ovary technique of spaying was found to confer no growth advantages. An oestradiol HGP over a wet season in both spayed and entire heifers increased liveweight gain by 0.1 kg/day and hip height by 1 cm.


Head of the tool used for the Willis dropped-ovary spaying technique
[Photograph: Geoffry Fordyce]

Low-dose progesterone administered via an ear implant was found to have no contraceptive effect in cycling heifers.

An anti-GnRH vaccine (Vaxstrate®) given twice before exposure to bulls, was effective in preventing pregnancies in most heifers for at least 3 months.

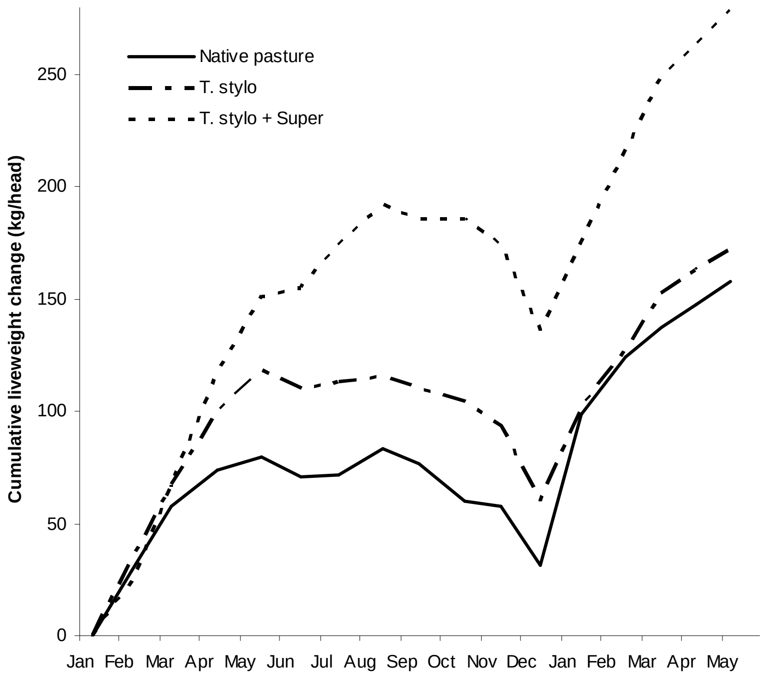
Ear implants formulated to release low or moderate doses of deslorelin were able to prevent pregnancies in all heifers for at least 4 and 6 months, respectively. There was no effect on growth. Heifers were mated after implant removal and almost 100% conceived within 60 days with no effect of previous implantation. Though this technology may be very useful in the beef industry, its high cost has precluded registration.

4.3 Pasture management and utilisation
Detailed studies with grazing steers to examine the development and use of pastures continued from the 60s to 1991, initially under the stewardship of Lyle Winks, and then under direction of Stuart McLennan. David Smith oversaw a large systems project at several north Queensland sites where stocking rate effects on cattle and pastures were examined. The observation at Swan's Lagoon was led by Geoffry Fordyce. Dick Holroyd conducted relocation studies. The experiments conducted included:

1964-1987	Townsville stylo grazing trial
1968-1971	Discing and superphosphate fertilizer on native pastures
1974-1979	Management of Townsville stylo pastures
1979-1986	Burning management trial

1981-1991 Perennial stylo grazing trial
1983 Effect of Anthracnose on Townsville stylo pasture
1994-1995 Weight loss of steers relocated to fattening country
1995-1999 Set low and high stocking rates *v* variable stocking for efficient pasture utilisation

Stan Miller and Darcy Schefe mixing Townsville stylo seed and superphosphate, February 1970
[Photograph: Lyle Winks]



Cumulative weight gain of steers grazing native pasture, Townsville stylo-based pastures (TS), and TS pastures fertilised with superphosphate in 1967-1968

In a 22-year study, Townsville stylo-based pasture with or without fertiliser was compared with native pasture at moderate and high stocking rates. For the first 14 years, superphosphate was applied at 125 kg/ha to fertilised paddocks. The stylo was established into disced native pastures. As a result, percentage of native grasses in the pasture declined over time till pastures were virtually pure legume after four years. Annual grasses began to invade the fertilised areas at this stage and their contribution to pasture yield increased with time. Dicotyledonous weeds also invaded the fertilised paddocks over time. Subsequently stylos were sown into burnt pasture without further treatment of the ground. Fertiliser application more than doubled pasture yields with legume presentation yields in April reaching 6 t/ha in good years but supported significant weed invasion, with yield often 0.5-2.0 t/ha; in comparison, stylo tended to dominate pasture yields when unfertilised.

Loading fertiliser for aerial application in front of the Swan's Lagoon office, circa 1967
[Photograph: Lyle Winks]

In the driest years, the high stocking treatments had to be destocked. Stylo alone did not improve annual steer growth which averaged 99 kg (12-178 kg range). The biggest effects of fertiliser were in the driest years. Fertiliser on moderately-stocked pastures increased average annual steer growth from 103 to 160 kg; the range of 112-209 kg indicated the safety of this strategy. These effects were mediated by the treatment effects on pasture: nitrogen content of stylo pastures was much higher, and phosphorus content was 3-5 times higher in samples of fertilised pastures. Growth was extended to as late as August-September on fertilised low-stocking pastures. Steers grazing unfertilised stylo pastures were phosphorus-deficient during the wet season and were regularly observed to chew bones. Supplementation with phosphorus during the wet season resulted in significant growth responses in steers on the unfertilised stylo pastures.

Loading super for aerial application, 1960s
[Photograph: Lyle Winks]

Townsville stylo was found to be readily established with application of copper, zinc and molybdenum increasing dry matter yields. Anthracnose decimated Townsville stylo in 1974. A controlled study showed that this disease reduced its yields by ~2/3rds. Prior to anthracnose, moulds on hayed-off stylos in the dry season reduced its digestibility from 50% to 40%. This was managed by a system of grazing stylo during the wet season and shifting cattle to native pasture with urea-based licks in the dry season.

Alan Laing on the JK fence of the Townsville trial area, 8th March 1967 - superphosphate was applied on the far paddock
[Photograph: Lyle Winks]

A study that examined integrated use of stylo pastures with native pasture found that allowing continuous unrestricted grazing of the combined pastures achieved the highest weight gains. Annual weight gains when using restricted access were up to 30 kg lower.

Steers with phosphorus supplements grazing Townsville stylo fertilised with superphosphate, March 1970
[Photograph: Lyle Winks]

A 1969 study showed that discing of native pastures can markedly increase annual steer growth (additional 100 kg), but the effects remained for only one wet season.

Rod Strachan (kneeling!) in a Townsville stylo pasture, circa 1964
[Photograph: Rod Strachan]

Stylosanthes scabra cv Seca and *Stylosanthes hamata* cv Verano were strip sown with legume seed into 18 ha native pasture paddocks that had previously had 20% and 80% fertilised; the prevalence of Townsville stylo was low in these areas. Four sowings (early in the wet seasons of 1980 to 1983) were required to achieve suitable establishment because of the prevailing severe dry conditions. Good spread by cattle dung was achieved five years after initial plant germinations. The long-term average effect of over-sowing with Seca was 20 kg extra annual steer growth, whereas over-sowing with Verano had no effect on steer growth. Superphosphate fertiliser application with either species increased annual steer growth by 15 kg for at least 20 years after fertiliser was last applied (1972); coupled with a 40% higher stocking rate, liveweight gain per ha was increased by 50%. These legumes reduce dry season loss, but a substantial proportion, eg, half, of the advantage gained is lost in the subsequent wet season; ie, they act in much the same way as energy-based supplements such as fortified molasses or protein meal.

Shorthorn bullocks on Townsville stylo with phosphorus, May 1969
[Photograph: Lyle Winks]

The impacts of burning pastures every three years, with and without the provision of dry season supplements found that pastures usually take up to two wet seasons to fully recover from a burn when they continue to be grazed because of apparent selective grazing of burnt areas. When winter rain was experienced, grass growth was higher in burnt areas and recovery was reduced to a year. There was no animal growth response to burning, but consistent annual steer growth responses of 15-20 kg to dry season supplementation. Burning did not achieve any apparent changes in pasture botanical composition.

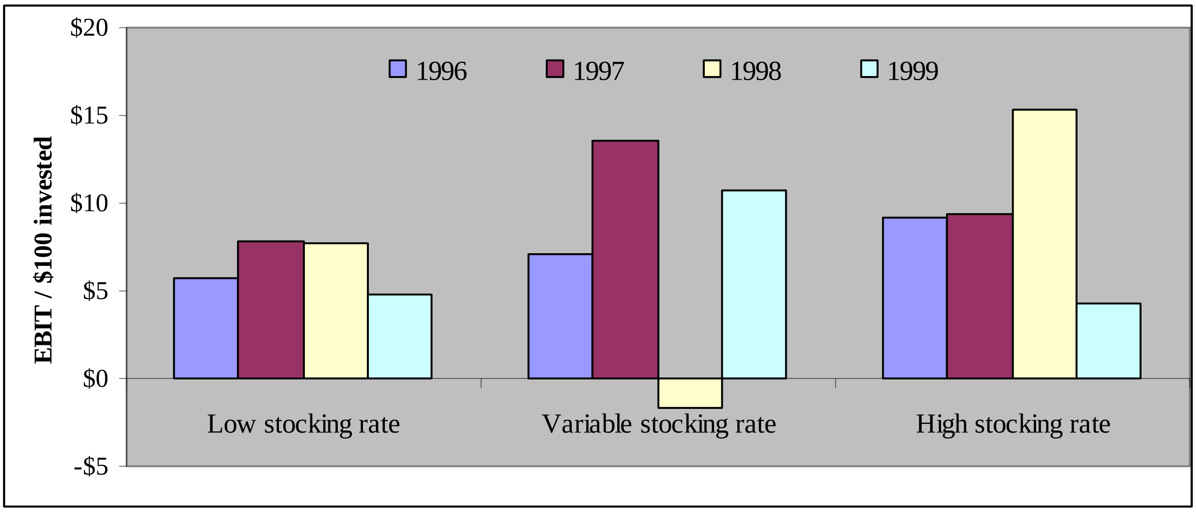
Science group discussing Townsville stylo trial, 1966
[Photograph: Rod Strachan]

Anecdotal suggestions that relocation of steers from low- to high-growth areas is detrimental to steer growth was not supported by controlled studies of steers relocated to high-growth pastures in central Queensland.

Alan Laing enjoying smoko during an Expedition muster, February 1986
[Photograph: Geoffry Fordyce]

In a large breeding cow study, published methods based on rainfall and its efficiency of use for pasture growth, were used to set stocking rates to achieve 30% (safe) and 60% (high) utilisation; an intermediate treatment examined annual (April) variation to achieve 50% utilisation of denuded pasture over the dry season. The major outcomes of this were:

- There were no treatment effects on pasture composition or tree populations after 5 years.
- Pasture yields were depressed by 30% under high stocking; cow weights were 25 kg lighter, ie, about half a condition score.
- Weaning rates were unaffected, but high stocking delayed average conception date by 2 weeks, reduced average weaner weight by 10 kg, and shifted 10% of weaning from April to August.
- Pregnancy to weaning calf losses remained at 6-8% in all treatments. High stocking increased cow mortality from 0.5% to 2%.
- Overall production efficiency varied substantially between years, but in general, when crisis supplementation was not required, higher stocking rates increased both net weight produced and gross margins per ha. However, under very dry conditions, the high stocking rates lost all advantage and profitability crashed.

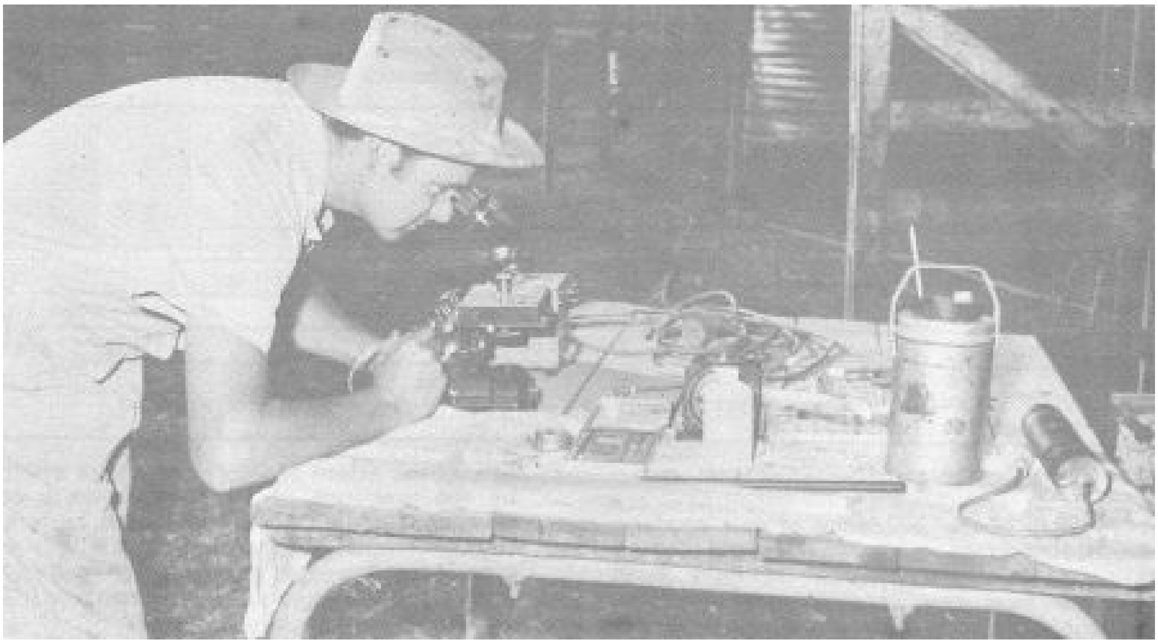


Stocking rate effects on cow herd business efficiency (1996-1999 cattle prices)

4.4 Bull selection and management

At Swan's Lagoon, Dick Holroyd, Geoffry Fordyce and Michael Auld have led a number of experiments. Bull Power studies at Swan's Lagoon were part of a multi-agency study at sites across north Australia.

1976-1985	Brahman cross and Sahiwal cross bull reproductive study
1979-1980	Libido and serving capacity of zebu bulls
1981	Protected protein supplements for bulls
1994-1998	Calf-getting ability in Brahman cross bulls
1999-2002	Pregnancy rates achieved by mating bulls with different percentages of morphologically normal sperm
2000-2001	Fertility of 5/8 Brahman yearling bulls
2001-2002	Herd dispersion and mating ratio effects on conception patterns
2001-2002	The effects of relocation on reproductive traits of Brahman and Composite bulls
2003-2004	Sperm chromatin (DNA) instability and reproductive wastage
2007	Determination of normal scrotal development in tropically-adapted beef bulls



Dick Holroyd assessing bull semen, 1975

Studies in the late 1970s and early 1980s led by Dick Holroyd and Keith Entwistle (James Cook University) are discussed in section 4.5.1 (Genetics).

In a pen study, bulls fed a protected protein supplement with native pasture hay were able to maintain weight and scrotal size, while un-supplemented bulls lost 10% of their body weight and scrotal size reduced by 2 cm.

Serving assessment, with minor modifications to the test, was found to be possible in Brahman cross, but not Sahiwal cross bulls as the latter could not be differentiated in the test situation. Overall, zebu bulls showed fewer sexual behaviours during serving assessment than reported for *Bos taurus* bulls. Non-oestrus cows can be used, but oestrus cows appear more receptive. Substantial logistics are required to conduct serving assessment so that suitable animals are available at the right time, and their behaviours are not influenced by other motivations such as hunger, thirst, or competition.

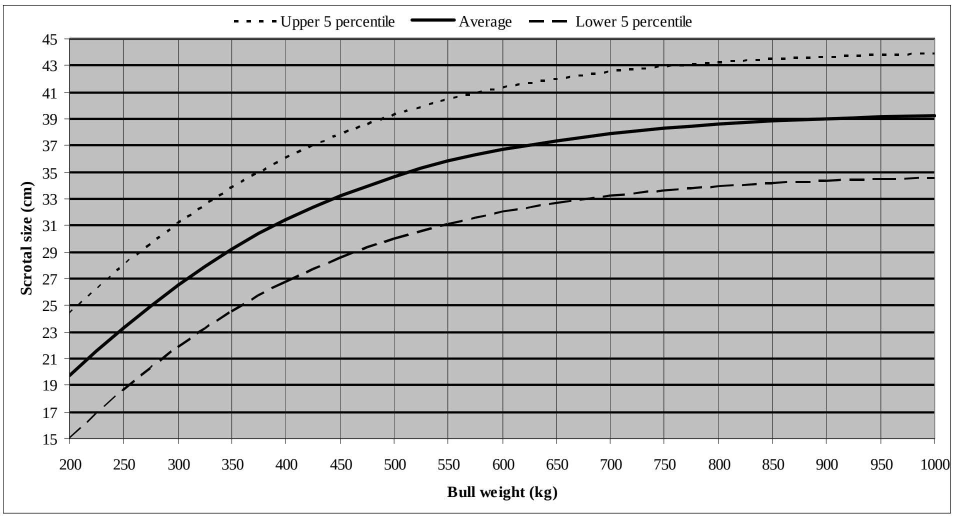
Serving assessment of bulls, August 1995
[Photograph: Geoffry Fordyce]

In a 5-year study in a multiple-sire mated Brahman cross herd:

- Bull physical measurements were highly repeatable, but serving assessment measures were not repeatable.
- The serving assessment measures were equivalent with restrained and unrestrained oestrus heifers.
- Calf output as measured by DNA finger printing was repeatable across years for this stable bull group. DNA finger printing was highly efficient in identifying the sire of 98-100% of calves.
- 80% of calves were sired by 2% bulls, despite a bull:female mating ratio of 3.5%.
- Of all traits measured, including percent normal sperm which was above 50% for all bulls and other semen traits such as heparin binding proteins, none was predictive of calf output other than dominance, where more dominant bulls had higher calf output.
- Territorial behaviour of bulls was shown to be strong with the most territorial bulls having movement ranges of less than 750 ha and siring more calves. A 3.5% bull:female ratio appears to be at the threshold, above which aggressive behaviour between bulls causes problems, and this includes reduced body condition.

Bull Power studies cattle in Sandalwood paddock, June 1997
[Photograph: Geoffry Fordyce]

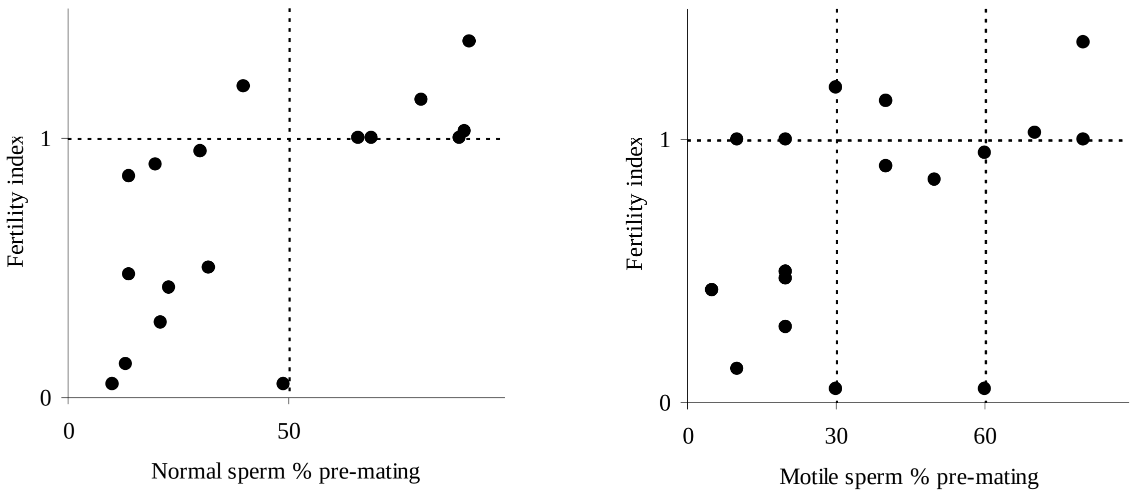
Bull weight was a good predictor of scrotal size, with breed, age and condition score being poorly related to scrotal size after adjusting for weight.



Normal range of scrotal size in relation to bull weight

Bulls with at least 50% normal sperm and 30% motile sperm pre-mating achieved normal fertility when single-sire mated, while most below these thresholds were sub-fertile. Post-mating semen traits had poorer relationships with pregnancy rates. This and other studies provided the basis for national standards for bull breeding soundness evaluations implemented in 2003 by the Australian Cattle Veterinarians.

When sperm from Swan's Lagoon bulls was examined for sperm chromatin instability, a trait related to embryo mortality in other species, the measure was found to be repeatable, but only one bull was found to have a DNA fragmentation index suggestive of instability. This was consistent with the broader finding that a vast majority of north Australian bulls produce sperm with a stable chromatin structure.



Pre-mating sperm traits and fertility index (1 = pregnancy rate achieved per 21 day period by fertile bulls) for 17 tropical bulls in single-sire herds over three Swan's Lagoon studies

When weaner bulls were supplemented with MUP, many did not reach sexual maturity as yearlings. Within those that passed a bull-breeding soundness evaluation including sperm morphology, the conception rate they achieved was lower than that achieved by mature bulls.

When Brahman and Composite bulls were relocated from central Queensland to Swan's Lagoon, there were no significant effects of relocation on any reproductive parameters, either immediately after relocation or in the ensuing 12 months, which, together with other studies, showed that well-managed relocation does not cause bull sub-fertility.

Reducing bull:cow ratio to 2.5% did not affect conception patterns in the continuously-mated Swan's Lagoon breeder herds. When the ratio was further reduced to 1.1-1.5%, there was still no significant effect on herd conception patterns, even though bulls had to range at least 5-10 km. Combined with other studies, this supported the recommendation that a joining ratio of 2.5% vetted-sound bulls is adequate in north Australian beef herds.

4.5 Genetics

4.5.1 Performance of Brahman and Sahiwal herds

Breed comparison observations were initiated at Swan's Lagoon in the late 1960s. They were led by Lyle Winks, Peter Allan and Dick Holroyd. Experiments conducted included:

1981-1982	Puberty in *Bos indicus* cross bulls
1968-1986	Genotype evaluation studies
1978-1986	High grade Sahiwal evaluation
1979-1983	Testicular growth patterns and development of spermatogenesis in Brahman cross and Sahiwal cross bulls

1982-1983	Growth rate, mature size, weight loss and efficiency in beef cattle in the tropics
1980-1983	Bottle teat observations
1985-1987	Genotype x environment interaction

When Brahman cross cows were compared with Shorthorns, there were no consistent fertility differences. However, Brahman crosses were in better body condition than Shorthorns throughout the 4-year study and half as many required survival feeding late in the dry season; further, Shorthorns also required more dipping to control ticks. Brahman cross daily milk yield averaged 4.5-5.5 kg, whereas Shorthorns yielded an average of 3-4 kg. The adaptation of Brahman crosses in comparison with Shorthorns was clearly expressed in steers as they gained 40-45 kg more during the wet season. An added advantage was higher dressing percentages in Brahman crosses. Brahman crosses also had other advantages such as a low incidence of blight (pink-eye; infectious bovine keratoconjunctivitis) in comparison with Shorthorns.

Two-year-old Brahman cross heifers in F paddock of McGregor, December 1997
[Photograph: Geoffry Fordyce]

The Sahiwal was introduced from Pakistan as a dual purpose breed. It was used to develop the Australian Friesian Sahiwal, a tropical dairy breed. Its potential as a beef breed was evaluated at Swan's Lagoon by comparing ½ and ¾ Brahman and Sahiwal crosses with high grade Sahiwals. Each genotype was maintained as a closed herd of ~150 breeding-age females with bulls being objectively selected within the herd with emphasis on growth, fertility, temperament and tick resistance. Six mating groups (4 high-grade Sahiwal groups) of each genotype were single-sire mated for 3 months each year.

Brahman cow and calf, February 2006
[Photograph: Stephen O'Connor]

Initial studies with first-cross Brahmans and Sahiwals found little growth differences between them. However, in later generations, weights and growth throughout life were about 5% higher in Brahman than Sahiwal crosses. Mature Brahman cross cows were 12% or 40 kg heavier than mature Sahiwal crosses. Three-quarter crosses had similar growth on average to ½ crosses, but their dressing percentage was slightly higher. Half *Bos indicus* cross steers transferred to fattening country outgrew ¾ crosses, whilst the reverse occurred within their contemporaries at Swan's Lagoon, which was a more stressful environment.

The heritabilities of weight and growth rates were moderate (0.08-0.46). The genetic correlations between seasonal growth rates were high (0.9), but were consistently negative between pre- and post-weaning growth, indicating that selection for growth to weaning will result in lower post-weaning growth. Because single-sire mating was used, pedigree information was available, and these data were valuable in establishing the base parameters for Breedplan analyses.

There was little difference in average weaning rate (58-59%) between Brahman and Sahiwal crosses and between ½ and ¾ crosses; but it was much lower in high-grade Sahiwals (50%). The higher pregnancy rates in Sahiwal crosses were countered by their higher neo-natal calf losses; these losses were quite high in high-grade Sahiwals, resulting in higher culling rates.

In Brahman crosses, 3%, 3% and 5% of calves were lost as abortions, within 24 hours of birth and during suckling, respectively. Losses after birth were 12%, 14% and 20% in ½, ¾ and high-grade Sahiwals, respectively. Bottle teats were the main identifiable cause of calf loss in Sahiwals (4% *v* 0.5% for Brahman crosses). The proportion of cows having at least one bottle teat in different years was 1-4% and 9-18% in Brahman and Sahiwal crosses, respectively. More than 1/3^rd^ of high grade Sahiwals had at least one bottle teat. Bottle teats contributed to Sahiwals having higher culling rates.

Brahman cross cows at Top bore in Sandalwood, November 1996
[Photograph: Geoffry Fordyce]

One of the 10 Sahiwals originally imported into Australia carried a lethal gene, which by chance was transferred to bulls that had a large contribution to subsequent generations. It was estimated that one third of the Swan's Lagoon Sahiwals were carriers. Calves carrying two copies of this gene are born with skin missing around the mouth, anus, and lower limbs, a condition called *epitheliogenesis imperfecta*. This was the second identifiable cause of high calf loss in Sahiwals in comparison with Brahman crosses. Half the calf losses had no identifiable cause; the herd was free of the major transmissible reproductive diseases.

Sahiwal calf with epitheliogenesi imperfecta, an inherited genetic defect, January 1986
[Photograph: Geoffry Fordyce]

Within breed, cows that held condition better in the dry season were found to have higher lifetime calf output, which indicates that adaptation is vital for optimum reproduction. The average annual mortality rate of cows between 1972 and 1991 was low at 1.2%.

Typical lifetime productivity was 3.2 calves reared over 4.8 years in the herd. Weaning to 2-year-old growth explained 5-6% of the variation in lifetime productivity (cow growth and calf weight weaned). Three-quarter Brahmans were the most productive genotype. Culling rate for low productivity averaged 9% annually, with highest culling in the first year of breeding (27%), and levels increasing beyond 7 years of age. It was demonstrated that under the management used, the herd was not sustainable if culling was based on any failure to rear a calf to weaning, even if lactating 3-year-old cows not rearing a calf (55%) were retained.

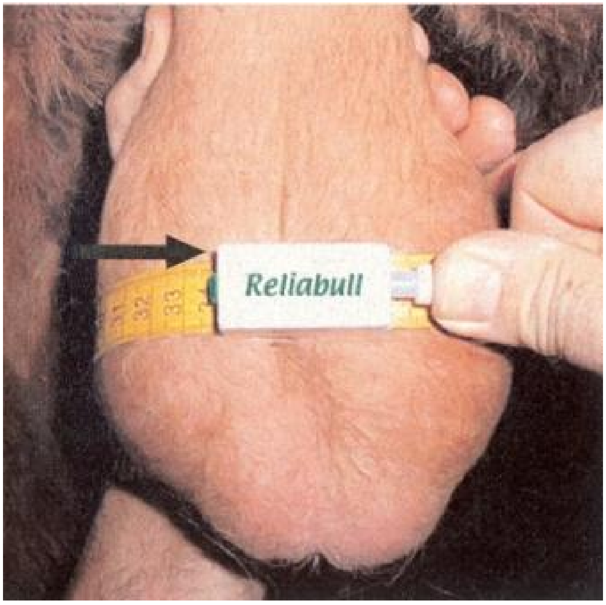
Yearling Brahman heifers in a Beef CRC study, February 2002
[Photograph: Geoffry Fordyce]

As for pregnancy rates, there was a trend for male fertility traits to be better in Sahwial crosses, ie, scrotal size was slightly higher, testicular weight was higher and there was a trend for fewer to have a low percentage of normal sperm. Three-quarter crosses had better quality semen. Average scrotal size at two years of age was influenced by nutrition, being lowest (24 cm) after poor seasons, and highest (31 cm) after good seasons. Testicular growth in young bulls continues, even when they suffer very poor nutrition; further, puberty is attained under these conditions. Pregnancy rates were lower for mating of 2-year-old bulls than of 3-year-olds, mainly because sub-fertile bulls were identified and culled after 2-year-old mating. Only sperm motility and percent normal sperm were related to pregnancy rates (correlation coefficients of 0.25 and 0.43, respectively).

18-month-old bulls in C2, April 2001
[Photograph: Geoffry Fordyce]

The heritability of scrotal size was moderate (0.32) and its genetic correlation with post-weaning growth was negative (0.4-0.8), the opposite of most other reports.

Half *Bos indicus* crosses carried twice the tick burdens of ¾ crosses, but there was no genotype effect on buffalo fly infestations.



Measuring scrotal size

4.5.2 Lifetime reproduction

Swan's Lagoon was one of the four major sites for female production genetics studies within Program 4 of the CRC for Beef Genetics Technologies. Swan's Lagoon research, in which 450 Brahman cows were intensively studied, was managed by Geoffry Fordyce. The experiments conducted were:

2001-2006	Links between the genetics of beef quality and components of herd profitability in northern Australia
2006-2011	Gene discovery for post-partum re-conception and age of puberty
2006-2011	Early indicators of lifetime reproductive performance

Neil Cooper leading yearling Beef CRC Brahman weaners, January 2002
[Photograph: Geoffry Fordyce]

The major objective when this project was first established has been resolved: selection for better steer carcass and meat quality traits will not counter selection for more productive cows in breeder country.

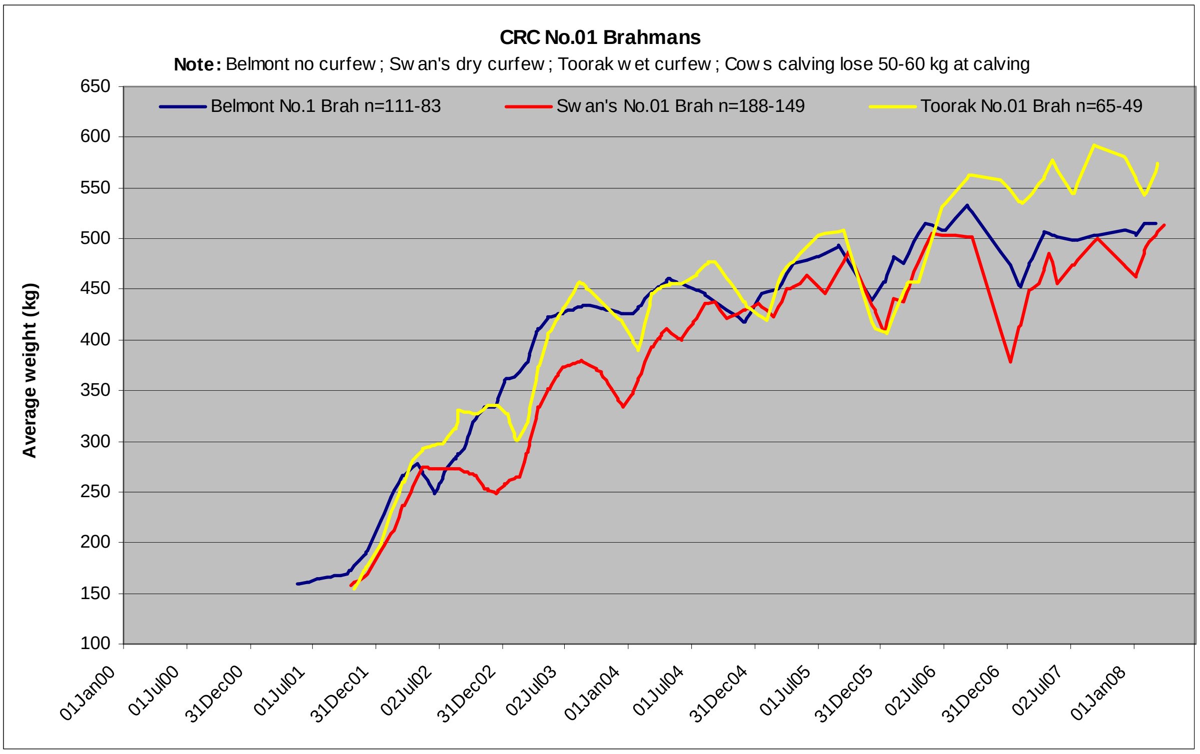
Data to attain the major objectives for the second phase of the work are now being analysed and published: how heritable are all the steer, cow and bull performance traits; and, developing genetic markers to increase the accuracy of selection at a young age.

The intensive monitoring of more than 2,000 steers at slaughter at 300 kg carcass weight, more than 2,000 of their sisters to 8.5 years of age, and about 4,000 bull progeny to two years of age, with half each being Brahman and tropical composites has provided one of the best data sets for describing the biology of these cattle ever developed. All facets of growth, carcass and meat attributes, adaptation, and heifer, cow and bull reproduction were studied. All pedigrees are known and DNA and other samples have been stored. The data collection has only just been completed, and therefore data analyses and publication are quite incomplete.

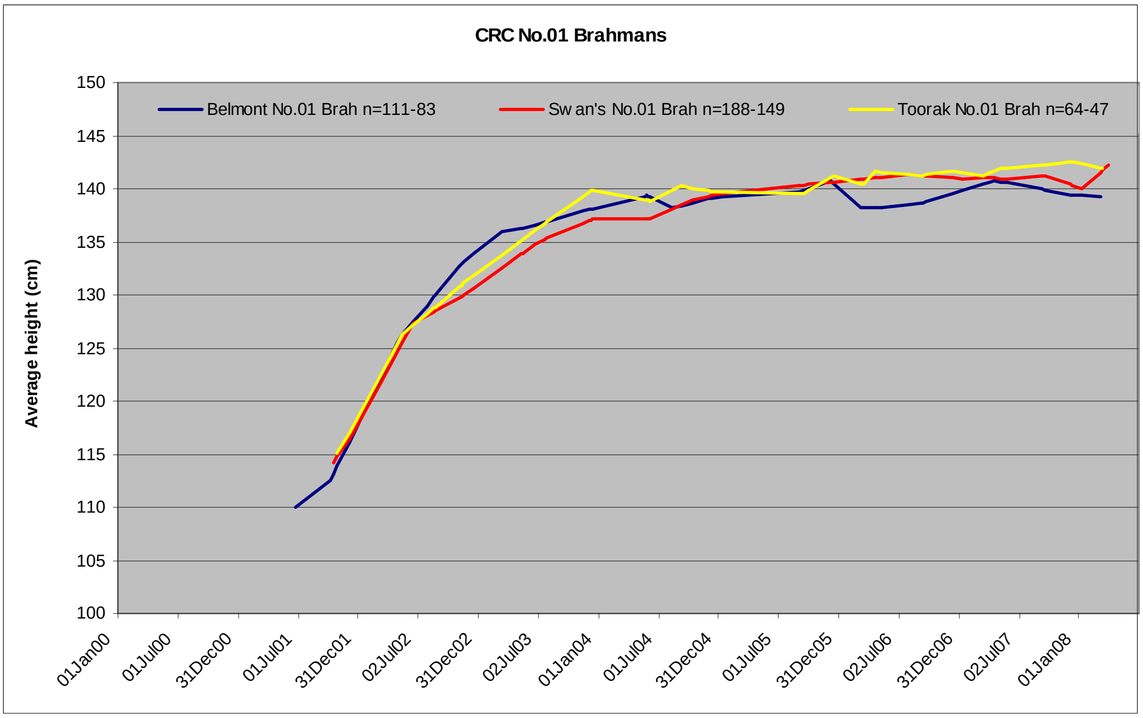
Geoffry Fordyce and Paul Williams (CSIRO) conducting reproductive tract, fat and muscle scanning of a Beef CRC cow, May 2011
[Photograph: Geoffry Fordyce]

Some basic descriptions of modern Brahman female growth are:
- The cows reached an average mature height of about 141 cm by 4 years of age and an average mature body weight (score 3, not pregnant, un-fasted weight) of 513 kg at an average age of about 5 years.
- With good reproductive management and without severe environmental stress, stunting did not appear to occur.
- Weight, growth rates, body condition, fat reserves, and muscle size are all highly related to each other and seasonal conditions.
- P8 fat depth (measured on the rump, adjacent to the highest point above the hips) is about double that of rib fat depth.

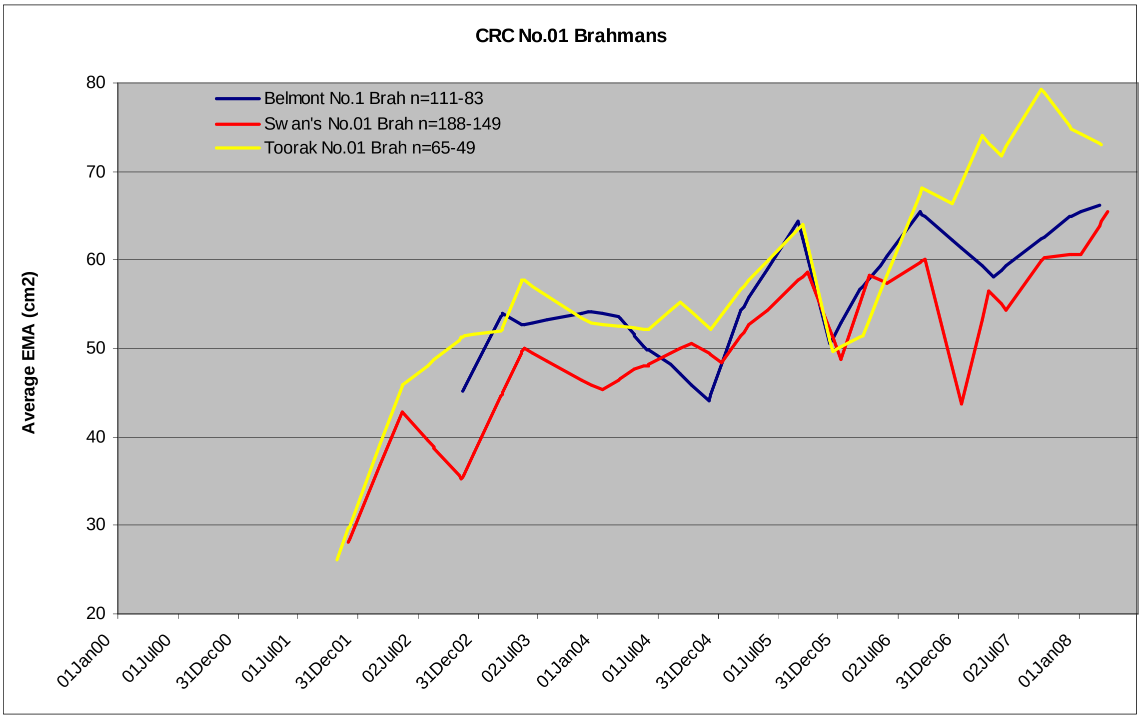
- Though seasonal conditions caused substantial variation in P8 fat and eye muscle area (which is as much a measure of body condition as musculature), there was a gradual increase in each of these traits between weaning and about the time of weight maturity. Approximate average values for females in moderate (score 3) body condition are 2 mm and 8 mm of P8 fat, and 33 cm^2 and 60 cm^2 eye muscle area at weaning and weight maturity, respectively.



Average unadjusted weight of Brahman cows up to seven years of age at three sites



Average height of Brahman cows up to seven years of age at three sites



Average eye muscle area of Brahman cows up to seven years of age at three sites

Some key findings from genetic analyses of Brahman heifer growth and adaptation are that:

- Weight and fatness measures have about 40% heritability, but hip height heritability is close to 60%, while eye muscle area is close to 25% heritable.
- Blood level of a liver hormone called IGF1 (which has a critical role in growth control) at 18 months of age is 40% heritable, and higher levels are genetically related to being heavier and fatter. IGF1 in females is also genetically related to more fat in steers.
- Heritabilities of tick and fly loads were low, but were moderate for rectal temperatures, flight speed and faecal (worm) egg counts.

A young Brahman calf, December 2005
[Photograph: Stephen O'Connor]

Findings on puberty in Brahman heifers have been:

- The major determinant of puberty appears to be weight.
- The average weight was 334 kg, which is 2/3rd of mature weight; however, the variation is very large, ie, plus or minus 100 kg of the average. Given the growth rates in north Australia, a high proportion of heifers reach puberty at about 2 years of age. Puberty can be reached as late as four years of age.
- The heritabilities of weight and age at puberty were very high at 50-60%. The variation in average weight at puberty for sire groups is over 100 kg; ie, the average weight at puberty for the heifer progeny of some bulls is in the vicinity of 280 kg, while the average for bulls at the other extreme is around 380 kg. This helps explain why some Brahman operations have low maiden heifer pregnancy rates. There is a huge opportunity for genetic improvement.
- There is a strong genetic relationship between 18-month IGF1 blood levels and weight at puberty, which offers one potential method to select for this trait.
- Heifers that have higher weight per day of age reach puberty earlier; however, heifers that have lower fat levels at set ages (suggesting later maturity type) reach puberty at heavier weights.
- Heifers with sleek coats in the cool dry season after weaning reach puberty earlier.

Two-year-old Beef CRC Brahman heifer, September 2004

Brahman cow reproduction has been a major focus with very interesting interim findings:

- Teat and udder scores (1 to 5 scale with 1 being very small) averaged 0.5-1.0 score units higher at birth than during the subsequent lactation. These scores appear heritable, though analyses have not been completed.
- As previously known, and being confirmed with this work, the ability of cows to cycle during lactation is affected by a combination of inherent variation independent of calves, and a very specific effect driven by the presence of their suckling calf. There is substantial variation in sensitivity to both components.
- The ability of Brahman cows to cycle in their first lactation (lactation cyclicity) is highly heritability, which is contrary to previous thinking. The heritability is lower in subsequent lactations.
- Lactation cyclicity has a strong genetic correlation with percent normal sperm (morphology) in 2-year-old bulls, which itself has been shown elsewhere in the project to be moderately heritable.
- A higher chance of lactation cyclicity, lighter weight and earlier age at puberty, higher bull scrotal size and higher percent normal sperm are all related to each other.
- The above findings provide a very real opportunity to breed bulls whose daughters have substantially better reproductive efficiency, and this is a major focus of near-future activities.

Beef CRC Brahman cow and calf
[Photograph: Geoffry Fordyce]

As reproduction traits are expressed after cattle are selected to breed, methods to increase the accuracy of genetic merit estimates at a pre-breeding age are being developed. One of these is the use of gene markers, or as they are known in science, SNPs (pronounced "snips", and stands for single polymorphic nucleotides). Recent discoveries using our data are:

- In Brahmans, 169 SNPs for age at puberty were found, with 41% of these on chromosome 14.
- 32 SNPs have been discovered that influence age at puberty in both heifers and bulls and all are located on chromosome 14.
- 68 SNPs have been discovered for the ability to cycle during lactation, with a concentration of these on chromosomes 3 and 14.
- Unfortunately, these SNPs do not overlap with those explaining genetic variation for the same traits in tropical composite cattle. A lot more development and validation is needed before commercial use.
- There is a lot more consistency within and between breeds for SNPs explaining variation in fat, weight, and blood IGF1 concentration.
- At this stage, only a small percentage of the total genetic variation can be explained by these SNPs, but there is promise that if we can do the research, we can explain more than 50%, thus achieving high accuracy for genetic merit estimates for a range of traits at a young age.

A Brahman calf nursery, December 2008
[Photograph: Stephen O'Connor]

4.6 Health management
Over many years, a series of studies of plant toxicities and of endemic infectious diseases caused by parasites, protozoa, bacteria and viruses were conducted. These studies, variously led by Dick Holroyd, Ross Dodt, Geoffry Fordyce and Brian Burns, included:

1967-1979	Tick larval studies
1968-1974	Pasture spelling trial
1970-1973	Blight studies
1971	*Wedelia* feeding trial
1971-1973	IBR-IPV epidemiology
1971-2000	Sentinel herd
1974-1979	Investigation of calf wastage – *L. hardjo* vaccination trial
1974-1980	Dung beetle monitoring
1975-1982	Tick evaluation trial
1976	Tick larval survival studies
1977-1980	Buffalo fly evaluation
1977-1978	Epidemiology of bovine anaplasmosis
1977-1984	Genitalia studies
1980-1981	Onchocerciasis chemotherapy trial
1980-1982	Avermectin chemotherapy trial
1980	Tick resistance and the major histocompatibility system
1981-1984	Identification of tick resistance in cattle
1981-1984	Post-weaning diarrhoea
1982-2009	Observations of tail rot
1983	Studies on bovine spumavirus
1985	Studies on bovine viral diarrhoea virus
1987	Supplementation with combinations of rumen modifiers, cottonseed meal and molasses to counteract the post-weaning diarrhoea syndrome.
1989	Feeding early weaners and coccidiosis control
1990	Reducing post-weaning stress
1991	Weaning age and nutrition effects on post-weaning coccidosis
1992	Botulism vaccination in calves
1997-2002	Commercial-in-confidence vaccine studies
2003-2006	Improved diagnosis of reproductive disease in cattle
2004-2007	Investigations of pestivirus and *Neospora* in beef herds in Eastern Australia

A 1971 pen study found that *Wedelia spilanthoides* was not toxic.

A series of studies of the genitalia of sub-fertile females at slaughter found no evidence of any pathology, though immaturity was regularly noted in non-pregnant heifers. Infectious bovine rhinotracheitis was found not to cause foetal loss in cattle. Both leptospirosis and vibriosis appeared to have contributed to reproductive wastage. Vaccination against leptospirosis was found to reduce abortion rates by only 2%. Pregnancy rates were an average 15% higher in cows vaccinated against vibriosis.

As part of a large multi-agency study, new PCR (polymerase chain reaction: a method to vastly increase a specific sequence of DNA for analysis, eg, for disease testing, for parentage identification, or for detecting a genetic attribute) assays were developed with very high sensitivity (positive test with very few organisms present) and specificity (not confused with similar often-harmless organisms) for vibriosis and trichomoniasis in cows and bulls. The tricamper was found to be the best sampling tool.

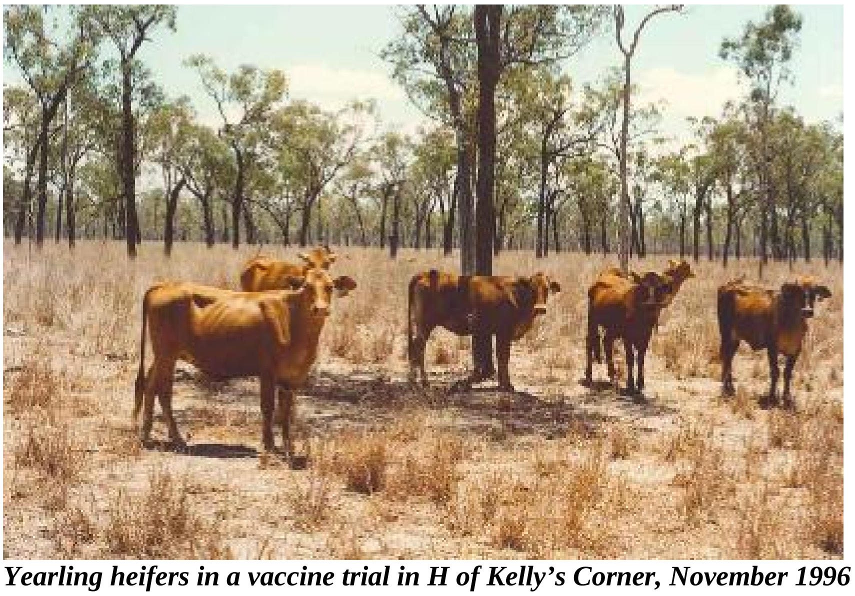
The tricamper head which was modelled on a device Dick Holroyd saw in south America
[Photograph: Geoffry Fordyce]

Swan's Lagoon was part of the Australia-wide network of sentinel herds to monitor insect vectors of disease and insect-borne viruses such as BEF (commonly known as 3-day sickness), Akabane, Aino, D'Aguilar, Polyam and Simbu viruses.

BVDV (pestivirus) was shown to be endemic in the Swan's Lagoon herd in 1983 at low prevalence in home-bred cattle. Some introduced cattle had a high prevalence of antibody, which may have been caused by contracting the disease before transfer to Swan's Lagoon. The prevalence of spumavirus antibodies was 40% in a study of Swan's Lagoon cows. This virus, which is rarely transmitted before two years of age, causes no clinical disease and is a good model for study of other retroviruses.

Brahman cross cows from Holroyd paddock, September 2001
[Photograph: Geoffry Fordyce]

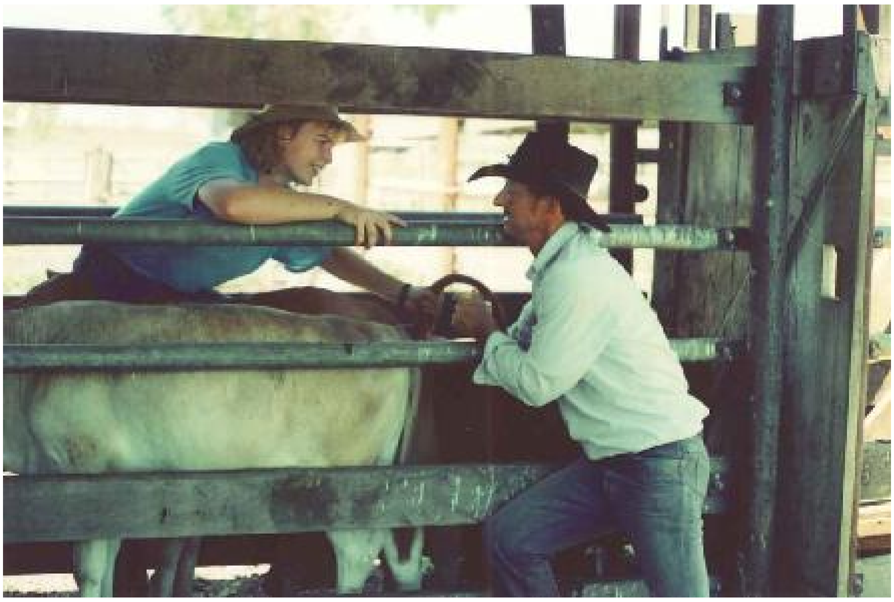
The Beef CRC Brahman herd at Swan's Lagoon was one of a large number of herds on eastern Australian properties where low levels of horizontal transmission of *Neopora caninum*, a widespread protozoan parasite that is known to cause abortion in more intensive production systems, were shown. However, no significant increase in abortions was detected in cows infected with this parasite. Parallel studies with this herd also demonstrated that transmission of pestivirus is well-controlled using vaccination.



Yearling heifers in a vaccine trial in H of Kelly's Corner, November 1996
[Photograph: Geoffry Fordyce]

Regular cattle mortalities were confirmed in January 1985 as being caused by botulism when 45 cows died overnight in McGregor. After that time, several botulism vaccine studies were conducted. When protective antibody levels in calves given 0, 1 or 2 botulism vaccinations were compared, a single injection produced protective immunity against botulism in half as many calves as two injections. It was noted that maternal antibodies were present in one- to three-month-old calves.

Several commercial-in-confidence vaccine studies were conducted under contract with commercial companies. These trials invariably established very high efficacy of the vaccines and lead to significant industry use.



Kay Taylor and Neil Cooper faecal sampling weaners for coccidian, February 1989
[Photograph: Geoffry Fordyce]

When weaners were treated with avermectin in a study of onchocerciasis control, a 20-40 kg weight advantage was achieved; this was reduced to 10-20 kg after 2 years. In heifers there was no consistent effect on pregnancy rates.

Small weaners with coccidiosis being offered medicated fortified molasses for treatment, July 2008
[Photograph: Geoffry Fordyce]

Swan's Lagoon research has shown that the commonly-seen post-weaning diarrhoea is due to coccidiosis. This disease causes acute weight loss of 10 to 30 kg. The causative protozoan parasite is a normal gut inhabitant, but causes clinical disease about a month after calves suffer immune depression brought on by the stress of weaning; a major factor is thought to be failure to start weaner feeding immediately after separation from their dams. Stress hormone injection was shown to dramatically increase coccidian populations. Prevention of stress in weaners, primarily by adequate yard and pasture nutrition with supplementation to achieve at least weight maintenance is the primary strategy to reduce the incidence of coccidiosis. The disease can also be prevented by low-dose monensin (~25 mg/day) in supplements. Weaning age *per se* does not appear related to susceptibility to this stress-induced condition, though in a 1986 urea dispenser trial, heifers that developed coccidiosis were lighter on average at weaning. Addition of a probiotic to weaner supplements had no effect on the potential for the weaners to contract coccidiosis.

Despite perceptions usually being that buffalo flies have substantial impact on growth, when flies were controlled completely, annual growth was unaffected in yearling steers but in 2 of 4 years, finishing steers grew faster by up to 0.05 kg/day. In untreated steers, darker and older steers carried more flies, and those with more flies had higher growth in 2 of 4 years, possibly because animals with higher testosterone levels attract more flies at the same time as having a growth advantage because of more testosterone. Fly-free steers had few lesions, which are associated with a parasite (*Stephanofilaria*) carried by the flies.

The inclusion of altosid in wet season blocks was found to have only 10% efficacy in reducing buffalo fly larvae hatchings from dung.

The release of at least eight dung beetle species in the mid-1970s resulted in variable survival of the species. Buffalo fly numbers did not appear to be significantly affected by the introductions.

Tick resistance is a very important trait in cattle tick-endemic areas. The earliest studies on Swan's Lagoon showed that Brahman crosses carried about one third the ticks that Shorthorns did. Selection for this trait requires objective assessment of tick burdens after natural or artificial challenge. Tick burdens, and expression of resistance, were found to be highly repeatable. However, in assessment of a potential method for resistance assessment using a blood test, attempts to relate bovine major histocompatability antigens (on the surface of white blood cells) to level of resistance were not successful.

Tick larvae were found to survive for only a week in mid-summer, but larvae hatching in April could survive till at least September. Rain washes away larvae, thus reducing infective populations. Larvae that hatch on light soils had shorter survival times than those on heavy soils.

Ian Kendall vaccinating cows at Expedition yards, August 1987
[Photograph: Geoffry Fordyce]

Tick populations increased over the dry season and peaked in January in cows. Dipping every 21 days increased wet cow conception rates by up to 30% in some years and reduced weight loss over a reproductive cycle by 25 kg. Weaner heifers from cows in which ticks were controlled weighed 20-24 kg more. This difference had disappeared within 2 years and there was no effect on pregnancy rates.

Breeding cattle at Sandalwood dam, November 1996
[Photograph: Geoffry Fordyce]

Tail rot (ischaemic necrosis) has been observed to occur in up to 1% of cows in very wet seasons. Observations of cows at Swan's Lagoon and elsewhere concluded that it is caused by a fracture that can be high or low in the tail, which disrupts blood flow. The fracture is often associated with tail switching flies with the switch being caught on trees and other structures. Dry tail rot, usually with low fractures, heals itself with the tail falling off below the fracture. Progressive tail rot, where the fracture is usually high, may require tail amputation.

In a 1992 study, 8% and 84% of 3-month-old calves showed no previous exposure to *Babesia bovis* and *Anaplasma*, respectively, indicating high susceptibility of the group to the latter parasite and justifying routine weaner vaccination.

4.7 Husbandry and behaviour

4.7.1 Husbandry practices
Routine husbandry practices have been irregularly subject to further development and investigation. Most of the following experiments were led by Ross Dodt, Joe Mawn, Ian Loxton, Jennifer Wythes, Bob Gannon, Geoffry Fordyce and Dick Holroyd.

1970-1977	Dentition studies
1973-1981	Horns and bruising
1975-1981	The effect of age at dehorning on live-weight performance
1976-1977	Bruising trials
1978	Fasting and bruising study
1979	Fasting trial
1979-1980	Method of dehorning trial
1979-1980	Liveweight loss during fasting and realimentation
1977-1980	Time of eruption of horns in cattle
1980-1981	Live animal assessment of body condition and fatness

1983 Giving steers access to water until a short journey and slaughter
1985 Evaluation of chemical castration
2010 Comparative efficacy of ultrasound machines in measuring subcutaneous fat

The average age of permanent incisor eruption was found to be 2-4 months later in Brahman cross than Shorthorn steers:

- Brahman cross age of eruption (months) = 17.5 + Pair number * 8
- Shorthorn age of eruption (months) = 16 + Pair number * 7.5

A large percentage of eruptions were within 12% of the average age at eruption. Calves heavier at birth had earlier eruption of their first two pairs of incisors than lighter calves. Otherwise, age and weight had no significant effect on eruption time.

Dehorning reduced the incidence of bruising and the level of carcass trim at slaughter. Six studies, one being at Swan's Lagoon, concluded that tipping had no significant effect on reducing the level of bruising caused by horns.

Horn eruption and growth sufficient to enable cup dehorning were found to occur at an average age of approximately 4 months in Brahman crossbreds. At six months of age, 20-40% of Brahman crossbreds did not have sufficient horn for effective cup dehorning.

Dehorning studies over a number of years and drafts in which dehorning was done at between 4 months and 2.5 years of age, concluded that:

- Dehorning causes short-term (6 weeks) weight differences compared with non-dehorned animals, but thereafter, complete compensation occurs, irrespective of age or gender.
- Healing is complete in most animals within 4 weeks of surgery.

When knife, scoop and cup dehorning were compared, some regrowth occurred with all methods. Post-surgical growth was slightly lower (about 5 kg) in calves dehorned using scoops than for the other methods and polled calves.

Horned steers in a bruising trial, 1970s
[Photograph: Lyle Winks]

After evaluation of a USA-registered lactic acid product for intra-testicular injection to sterilise bulls was conducted, registration was denied in Australia. The reasons were that the technique required considerable time and skill, it was potentially dangerous for the operator, it appeared painful to the animals, healing was protracted, and residual steroidogenic tissue resulted in behaviour control difficulties and carcasses being graded as bull at slaughter.

Geoffry Fordyce injecting lactic acid in a drug evaluation trial, July 1985
[Photograph: Geoffry Fordyce]

There was no significant difference in the weights of calves “branded” (branding, dehorning, castration, ear marking) either during suckling or at weaning. Weaning and post-weaning training both reduced flight speeds, ie, improved temperaments.

Body condition and fat scoring systems were shown to have substantial variation in their ability to predict subcutaneous fat depth at the 12-13 rib. However, on average, the AUSMEAT fat scoring system (1-6) and the Livestock Market Reporting Service condition score both predicted an average fat thickness of about 2.5 mm at score 2 and 7 mm at score 4.

A study of ultrasound machines found that several desktop and hand-held B-mode (real-time imaging) and A-mode (digital read-out) machines were all quite accurate, though the A-mode machine tested provide accurate readings only when subcutaneous fat exceeded 3mm.

Pre-slaughter fasting of steers for 2 two-day periods reduced carcass weight by 4-5%, and live weight by 8%, irrespective of whether the total fasting period occurred over 4 or 8 days. Fasting had no effect on fat scores, bruising or post-mortem muscle pH. Number of truck stops during transport was found to have no impact on carcass bruising. Various mixing strategies and timings prior to trucking were also ineffective at altering bruising rates.

Fasting 400 kg steers in a May-June 1979 study lost 5% of their weight in 8 hours, and then lost 0.15% of weight per hour for the next 2.5 days to lose a total of 15% of live weight. Minor weight recovery was achieved when fasted steers were offered only water at the end of fasting. Full weight recovery when steers were returned to the paddock had still not occurred three weeks after a 3-day fast.

Fasted steers in a 1980 study lost approximately 4% of their live weight in 6 hours, and a further 3% in the following 18 hours; ie, 2/3^rd^ of a percent of weight per hour in the first 6 hours and 1/3^rd^ of a percent of weight every two hours thereafter, with an overall effect of 0.3% of weight loss per hour over 24 hours. When returned to water only for 24 hours after fasting for between 6 and 24 hours, all groups were 7% lighter than pre-fasting weight. The steers were then put back on pasture and they had fully regained their weight a week later.

The Swan's Lagoon trials combined with others in Queensland, demonstrated that a dry curfew for sale cattle causes significant stress in cattle, and achieves no significant advantages over a wet curfew. These trials were instrumental in changing to current saleyard water and feed management policies.

A pre-slaughter study with steers showed that access to water prior to slaughter had no significant effect on slaughter outcomes or carcass quality. Extending pre-slaughter holding at the abattoir did reduce carcass quality, including increased bruising.

4.7.2 Cattle behaviour management and temperaments
Behaviour studies aimed at improving animal welfare and increasing production efficiency have been part of many projects under the leadership of Alan Ernst, Geoffry Fordyce and Carol Petherick. Experiments conducted included:

1971-1974	Observations of cattle behaviour
1981-1986	Temperament studies
1991	Observations on feeding P supplements
1995	Trough space and design effects on supplement intake
1996	Design of shelter sheds for wet season supplementation of cattle
1996	Effect of distance of supplementation site from water on supplement intake
1996-1997	Siting of supplement points: Effects on supplement intake and paddock use by small groups of cattle
1996-1997	Effect of different weaning practices on the performance and temperament of weaned cattle

Supplement intake behaviour
The main observations of cattle with dry licks in the dry season were:
- Cattle visited licks more often and spent more time at licks as the season became drier.
- Higher urea concentrations reduced the time spent licking.
- Though there were no breed effects, dominance effects on lick access were pronounced, with horns conferring high dominance order.
- There was large variation between animals in lick intake.
- Night-time supplement intake occurs in large paddocks, but is not common in small paddocks.

Cows fed cotton seed meal in McGregor, October 1986
[Photograph: Geoffry Fordyce]

Training cows to eat supplements is a slow process, and changing supplements should be done carefully and slowly to avoid reduction in intake. More palatable supplements provide a lesser challenge, but satisfactory intakes of most target supplement ingredients can be achieved by adapting to carefully-observed behaviour of the cattle eating the supplement. Intakes by calves should be accounted for when feeding supplements.

Feeder type did not affect average supplement intakes or variation; eg, closed sheds, which protected supplements from rain, did not reduce average dry lick intake or intake variability compared with troughs in open-sided sheds. How troughs filled with M8U were placed in relation to each other also did not significantly affect intakes. With adequate trough access, dominance had no effect on intakes.

Siting supplements two km from water reduced intake of blocks and fortified molasses by 20-30%, a strategy that may be used to control intake. Siting of supplements also had no discernable effects on preferred grazing areas within paddock.

Temperament
New tests were developed to measure the temperaments of cattle. Application of these tests within the breeder herd studies showed that:

- Temperament is a highly heritable trait when measured in open-field situations, but low when measured in restrained animals.
- Temperament is unrelated to dominance in cattle, the main reason being that temperament is related to fear of being handled, which has no direct association with relationships between cattle.
- The heritability of open-field temperament tests such as minimum approach distance, is as high as 70%.
- No unfavourable genetic correlation of temperament with either fertility or growth traits were found. Rather, animals with higher growth tended to have better temperaments.

Ken Bradshaw and Wayne Heath drafting weaners at Main yards, June 1984
[Photograph: Geoffry Fordyce]

4.7.3 Reducing cattle management costs
To help reduce the high cost of cattle handling, and improve the welfare of extensively-managed cattle, mechanisms and methods for automatic handling and husbandry of cattle were developed. Much of this work was led by David Hirst.

1987-1988	Hirst short arm spear gates
1988	Intelligent trap gate
1987-1990	Audio-conditioning (Mustering with sound)
1987-1996	Automated weaning using a cow and calf separator
1987-1989	Application of pour-on medicaments at the spear gate
1989	Buffalo fly rubbing post
1989-1996	Cattle handling systems
1991-1993	Use of implanted electronic identification devices in cattle
1990-1996	Automatic drafting on weight
1994-1995	Evaluation of the buffalo fly trap with beef cattle under field conditions

A steel short-arm spear gate for cattle traps was developed as an alternative to the traditional long-arm wooden spears. The Hirst spear gates were extensively tested to arrive at an effective and robust final design and quickly became widely used in the beef industry.

Hirst short-arm spears operating in the Charters Towers area
[Photograph: Geoffry Fordyce]

Following failed attempts to develop electronic animal measuring, monitoring and drafting systems, a new animal-powered cow-calf separator was developed. The device was subsequently successfully tested and demonstrated to achieve near 100% calf separation under commercial conditions. The separator was used in creep feeding studies on Swan's Lagoon. Despite its potential for low-stress calf separation, its use requires complementary infrastructure and training and re-training of cattle. A transportable cattle handling module was developed to complement the separator.

The cow-calf separator in action for creep feeding research in B of McGregor, February 1990
[Photograph: Geoffry Fordyce]

A novel double-sided crush gate was developed and installed at the Expedition yards in 1992. This gate made holding cattle much easier as it closed from both sides.

Cattle using Hirst short-arm spears on Gleeson Station, Cloncurry
[Photograph: David Hirst]

Heifers were successfully trained to come to a feeding point when a horn was sounded. However, during lactation, many cows did not respond to the horn, which eliminated this technique as a cow herd mustering aid.

The failure rate of glass-encapsulated transponders for electronic identification between implantation (at the base of the ear) in calves and 24 months of age was 10% when implant technique was good, mainly due to breakage. Incomplete recovery of unbroken and broken implants created meat contamination. Rumen boluses or ear tags appear to be the only safe method to carry the transponders.

The “Lapweigh” walk-over scale for automatic weighing when linked to electronic identification tags was found to usually weigh cattle to within 5% of true weight, with up to 7 weights required to achieve accurate weights for animals weighing more than 32 kg. Subsequent development incorporated a drafting mechanism and had no operational faults when tested using 1,000 cattle.

A backline roller fitted to a spear gate was successfully developed for commercial use. The roller dispensed a range of pour-on chemicals for the control of ectoparasites. Support for development to commercial release was also provided for the Sapuppo post, which was a vertical version of a back rubber for transfer of chemicals to control ectoparasites.

David Hirst collecting first prize at Townsville's North Queensland Field days for the cow-calf separator which was voted best invention in the under $500 category, May 1990
[Photograph: Geoffry Fordyce]

A CSIRO-developed buffalo try is a short dark tunnel, which has brushes that cause the flies to rise into side panels where they perish. Few animals used the buffalo fly trap unless they were forced to negotiate it on either entry to or exit from water. Cattle have to be trained to use this device. However, once trained, the device removed approximately 60% of flies at one pass, though the efficiency of the device reduced when the brushes became worn.

4.8 Goat productivity
Goat rearing is an alternative to beef production in the dry tropics. Experiments led at Swan's Lagoon by Roger Cox included:

1988-1990 Cashmere production in the dry tropics

Goat growth and cashmere production appeared similar to that of goats elsewhere in Queensland. However, shearing time appeared more critical.

Swan's lagoon cashmere goats, December 1988
[Photograph: Geoffry Fordyce]

5. Delivery of research to the beef industry

A wide range of methods have been used to deliver research outcomes to beef producers. The most important has been publications (section 6), not least of which has been the annual report; unfortunately no reports have been published beyond 1999, just before science leaders were transferred off the station. Direct contact between beef industry advisers and scientists has continued to be a critical conduit for technical information. These networks have been important in establishing producer demonstration sites, examples of which include several demonstrations of spike feeding, production feeding, pasture development and automatic cattle management. Science staff have regularly contributed to cattle conferences throughout Australia. Mass media has been used extensively through rural press articles, radio interviews, and televised reports. A film was made in 1974 to provide the beef industry and community with an up-to-date perspective on Swan's Lagoon research.

"Stationhand" doing a spike feeding story with Geoffry Fordyce and Keith Entwistle (James Cook University), September 1990
[Photograph: Geoffry Fordyce]

Direct association between scientists and beef producers occurred within the Advisory Committee which received detailed technical presentations each time it was convened. The station encouraged visits by individual producers and small groups while scientists were based there up to 2002. These were felt to provide better information transfer than large field days. However, a limited number of large open days were held on the station, usually in September, in 1967, 1970, 1975, 1985, 1988, 2001 and 2007, with attendances of 100-500 people. Staff were always present at the biennial NQ field days in Townsville, and often at the Richmond field days and Cloncurry show to meet producers. Technical presentations to groups of producers across north Australia have occurred throughout the operational life of Swan's Lagoon.

Rebecca Hall and Geoffry Fordyce addressing the NBRUC field day crowd in McGregor with Beef CRC cows, March 2007
[Photograph: Wayne Hall]

Current Swan's Lagoon station staff: Lisa Hutchinson, Tex Hartwell, Lara Hartwell, John Hughes, Gavin Jones

6. Publications

This section includes only major publications. It does not include the very large number of popular-press and newsletter publications that have facilitated the extension and adoption of Swan's Lagoon research outcomes.

Bruno Wyburg skiing on Swan's Lagoon, February 1978
[Photograph: Mark Savage]

6.1 Peer-view journal publications

Allan, P.J. and Mutch, C.B. (1971). The effect of vaccination against bovine vibriois on pregnancy rates in heifers in a northern Queensland beef herd. *Australian Veterinary Journal* **47**:184-185.

Allan, P.J. (1972). A field evaluation of vaccination of bulls against bovine vibriosis. *Australian Veterinary Journal* **48**:72-73.

Allan, P.J., Dennett, D.P. and Johnson, R.H. (1975). Studies on the effects of infectious bovine rhinotracheitis virus on reproduction in heifers. *Australian Veterinary Journal* **51**:370-373.

Barwick, S.A., Johnston D.J., Burrow H.M., Holroyd, R.G., Fordyce G., Wolcott, M.L., Sim, W.D. and Sullivan, M.T. (2008). Genetics of heifers performance in "wet' and dry' seasons and their relationships with steer performance in two tropical beef genotypes. Animal Production Science, **49**:367-382.

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Bond, J.H., Gannon, R.G., Lindsay, J.A. and Arthur, R.J. (1982). Live and carcass weight changes of steers subjected to intermittent feeding and watering during four and eight days of fasting. *Journal of the Australian Institute of Agricultural Science* **47**:172-174.

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Coates, D.B., Dixon, R.M. (2008). Faecal near infrared reflectance spectroscopy estimates of diet quality and responses to nitrogen supplements by cattle grazing Bothriochloa pertusa pastures. *Australian Journal of Experimental Agriculture* **48**:829-834.

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Dixon, R.M., Playford, C, Coates, D.B. (2011). Nutrition of beef breeder cows in the dry tropics. 1. Effects of nitrogen supplementation and weaning on breeder performance. *Animal Production Science* **51**:515-528.

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Alison Healing (James Cook University) processing blood samples in the Expedition yards lab, February 1987

[Photograph: Geoffry Fordyce]

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McGregor's Bonnet, June 2002
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Rebecca Hall and assistant tagging a newly-born calf, 2007
[Photograph: Rebecca Hall]

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Swan's Lagoon, October 2002
[Photograph: Geoffry Fordyce]

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Cows on M8U in Sandalwood paddock, December 1992
[Photograph: Geoffry Fordyce]

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Yearling Brahman heifers in a Beef CRC genetics study being mustered from ABKC, June 2002
[Photograph: Geoffry Fordyce]

Swan's Lagoon, September 2004

The name was reportedly taken from a postman whose surname was Swan
He used it frequently to camp on his run
[Photograph: Stephen O'Connor]