Nutritional Wisdom at Work in a Grazing Enterprise

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Abstract

A 3-year trial incorporating concepts of "nutritional wisdom" into a wool-growing grazing enterprise has resulted in a number of positive, and often unexpected, changes in the production system. Nutritional wisdom is the ability of livestock to learn from their mothers, and from individual experience, to graze the foods they need to balance their diets naturally and to self-medicate, to reduce intestinal parasites, for example. In order to put these concepts into practice, the stocking rate was reduced substantially, to ensure sufficient quantity of diverse forage, and ewes and lambs were run in "family groups", rather than year-classes. Family group management means that lambs are allowed to wean themselves, while remaining with their mothers to learn nutritional wisdom.

The resultant improvements in the production system include a 27% increase in total lambing rate and increases in wool cut per sheep of 40% in ewes and 23% in lambs. Drenching rates dropped dramatically, to only two drenches of lambs and no drenches of ewes between October 2008 and December 2011. In combination, these changes resulted in higher profitability at lower stocking rates, with improved ecological integrity in the production landscape. Changes in flock dynamics were also observed, with a much higher level of social cohesion and predator deterrence behaviour.

1. Introduction

In October of 2008, I decided to experiment with running my flock of superfine Saxon Merinos in so-called family groups, rather than traditional year classes. This decision resulted from exposure to the research of Prof. Fred Provenza and his students and colleagues into the behavioural aspects of nutrition in livestock. Specifically, they found that livestock can balance their own diets if they are given sufficient choice and quantity of plants to graze, and are provided with experiences needed to associate sensory properties of feeds with the metabolic consequences of eating them. This phenomenon is often referred to as "nutritional wisdom", which can be misleading because it implies an innate wisdom when it actually requires a learning component.

Because nutritional wisdom is learned behaviour, most effectively taught by the ewes over the first 12-24 months of a lamb's life, lambs need to stay with their mothers well past the usual weaning age of 4 months. In starting down this path, my main motivation was to avoid my heretofore chronic requirement of drenching lambs multiple times for nematodirus worm infestations in the first few months after weaning. That objective has certainly been met. In the process, a number of other positive, but completely unexpected, consequences for my enterprise have resulted, which I discuss below.

My decision to trial nutritional wisdom concepts started toward the end of 3-year dry cycle in Tasmania and the beginning of a return to more normal seasonal conditions in winter of 2009. The production gains (wool and fertility) of the 2009 season, however, reflect the previous year's conditions, which were dominantly dry with sparse forage after prolonged drought. By reducing the stocking rate radically in 2009, I was able to mimic an improved season from a nutritional standpoint. In 2010 and 2011, improved seasons allowed me to run additional sheep while maintaining a high quantity and quality of nutrition. So the issue of seasonal change is not an "either/or" proposition—the production gains I have experienced are the result of reducing stocking rate to a level that allows plant biodiversity to flourish and the quantity of forage to be more than sufficient for the nutritional requirements of the sheep.

2. What is "nutritional wisdom"?

Nutritional wisdom is the ability of livestock to distinguish the value of forages for nutrition and health, based on associating taste of food with post-ingestive feedback from cells and organ systems

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that are responding to primary and secondary compounds in the plants they are grazing [Provenza 1995ab, Provenza et al 2003]. Over time, given sufficient forage diversity, each animal develops knowledge of the nutritional content of any plant as well as how much of the plant it can eat before the plant's secondary compounds limit intake. They also learn to use secondary compounds in plants for nutritional benefits, as well as to self-medicate for internal parasites, if plants with appropriate kinds of secondary compounds (e.g. chicory or plantain) are on offer [Villalba and Provenza, 2007; Provenza, 2008].

Secondary compounds in their diets may also bolster immune responses if consumed in appropriate amounts (where excessive intake is avoided) [Provenza and Villalba, 2010]. Consequently, animal nutrition and health can be improved through enabling animals to balance their own diets by selectively grazing across the forage plants that are both known to them and also available. In order for this to work in practice, each animal needs to have the knowledge (based on learning from its mother and individual experiences with foods) and the opportunity to find a diversity of plants in their everyday environment.

Nutrition, self-medication, and immune responses are at the core of most management challenges: growth; wool production; resistance to worm infestation, flystrike and disease; fertility; lambing ease; lamb survival and meat characteristics. Animals that can develop and exercise their own nutritional wisdom have the potential to dramatically reduce those management challenges, and the costs (both labour and chemical) of fixing the consequences of nutritional inadequacy.

3. What does this mean in practice for a grazing enterprise?

In order to take advantage of the learned abilities of livestock to balance their own diets, management of the enterprise has to change to allow two things:

- sufficient quantity and diversity of forage that all sheep can choose the feed they need to balance their diets, and self-medicate (e.g. for intestinal parasites)
- the ability for lambs to remain with their mothers for at least the first year, and preferably two years, of life to learn how to forage effectively in their landscape environment.

The first change means controlling stocking rate according to the available and likely future feed levels. It also means maintaining existing natural plant diversity, and augmenting diversity whenever possible, to provide a wide range of options for sheep to choose from when grazing.

One way to keep lambs with their mothers is to shift from year-classes to "family groups": matriarchal lines incorporating 2 or more generations of ewes (plus wethers, if desired) in a mob. Another way is to run all the sheep on the property in a single mob [Walsh 2009, pers. communication]. This switch away from year-classes, while major in concept, is not necessarily difficult to accomplish logistically, as discussed in the following section.

4. How might management based on family groups work?

When I began this experiment in the lambing season of 2008-9, I had 704 ewes with lambs at foot. Because of the long dry cycle of 2006-2009, by 2008 I had sold all my older ewes and wethers, and was running 3 year-classes and a small flock of twinning ewes as a stud (mixed age). The pasture condition on my property was very poor, after 3 years of half the normal rainfall combined with my management decision to retain the bulk of my flock and feed supplemental grain. The first change I made was to radically reduce the number of sheep, so that there would be sufficient forage without supplementary feeding. This took the stocking rate down to 2.2 sheep/ha from an average of 4.8 sheep/ ha over the four years before the dry.

To shift from year classes to family groups I simply designated each existing year class of breeding ewes by their ear tag colour as "Blue Family" (4 year olds plus their lambs), "Yellow Family (3 year olds plus their lambs) and "Red Family" (2 year olds plus their lambs). The hoggets (1 year olds) I arbitrarily assigned to the family groups in equal numbers, since I did not have good enough records that I could be sure to which "family" they belonged. I kept the Twinning Ewe flock as a fourth "family".

To distinguish family ties, I added a coloured ring that slips over the standard ear tag for each lamb and hogget. These rings (called "micron tags" by the manufacturer) are quite visible in the race, and allowed me to sort sheep by family as required. I also kept records of ear tag numbers for each generation and family, in case the micron tags are lost. Electronic ear tags would make this all simpler.

Since I do a modified form of set stocking, requiring a paddock for each age class (previously) the shift to family groups was quite straightforward in terms of mobs of sheep. However, current farming management systems are designed around year-classes, and over the eighteen months of the family groups trial I have had to modify several things to accommodate the change to multi-generational mobs:

- Weaning: I allow the lambs to wean themselves up until their mothers are taken out for joining. Any management interventions normally done at weaning time still have to be done.
- Joining: I take the ewes out of the mobs just before joining, leaving the lambs in their "home" paddocks. The idea is two-fold: avoiding teenage pregnancy and minimising stress on the lambs by leaving them in a familiar environment. During joining, I run the ewes and rams in the paddocks that I previously used to run the weaners. The ewes return to their families at the end of the six weeks of joining.
- Lambing: I lamb with the whole family group present in the mob (more on this later).
- Shearing: While I did not need to separate out year classes (my wool classer didn't object to mixed ages), I did draft off the hoggets in order to have a mob of dry sheep (no pregnant ewes) that could be in the shed more than one night, to ensure having (literally) dry sheep to shear in case of rain.

5. What constitutes forage diversity?

On my farm there is a full spectrum of forage diversity. In ascending order of species diversity numbers:

- Lucerne monoculture with ryegrass allowed to grow in it in recent years (2 species)
- Long-established cocksfoot/ryegrass/clover perennial pasture with various annual weeds (3-5 species)
- A newer perennial mix of winter-active fescue/phalaris/clover/herbs (plantain, chicory and lucerne), also with annual weeds and with some leftover cocksfoot and ryegrass (6-10 species).
- "Semi-native" run country with native grasses and forbs mixed with various exotics and clover (50 or more species)
- Native-dominated rocky hillsides with introduced clover (50-100 species)

In addition to the pastures, I fed grain and hay at different times:

- From 2002 to 2005-06 I fed a grain supplement to pregnant ewes. I also occasionally fed grass hay as a supplement.
- During the 2006-2007 lambing season and into the following winter I fed grain (oats or barley and lupins) extensively in the paddocks, providing about half of their macronutrient requirement over that time. I also provided supplement blocks (bentonite with lupin bypass protein; trace element) during this period.

- From January through July of 2008 my breeding ewes were in a drought lot. They were fed a full ration mix of grain (barley and lupins with supplemental salt and lime) and either grass or lucerne hay to provide fibre as well as macronutrients. They had access to trace element blocks throughout the 7 months in the drought lot. The hoggets were not kept in the drought lot, but were fed grain in the paddocks.
- In early 2009, I destocked quite radically, taking the number of sheep down to about 30% of the pre-dry carrying capacity. Since then, I have not fed any grain or hay, nor provide supplement blocks.

My experience of these wide variations in nutritional diversity can be summarised fairly simply: far and away my best lambing and wool production results have come from allowing sheep sufficient diversity and quantity of forage that they can balance their own diets. Taken together with the reduction in costs from not feeding grain, hay or supplements, my enterprise has also been at its most profitable in the last 3 years.

6. What results have there been to date?

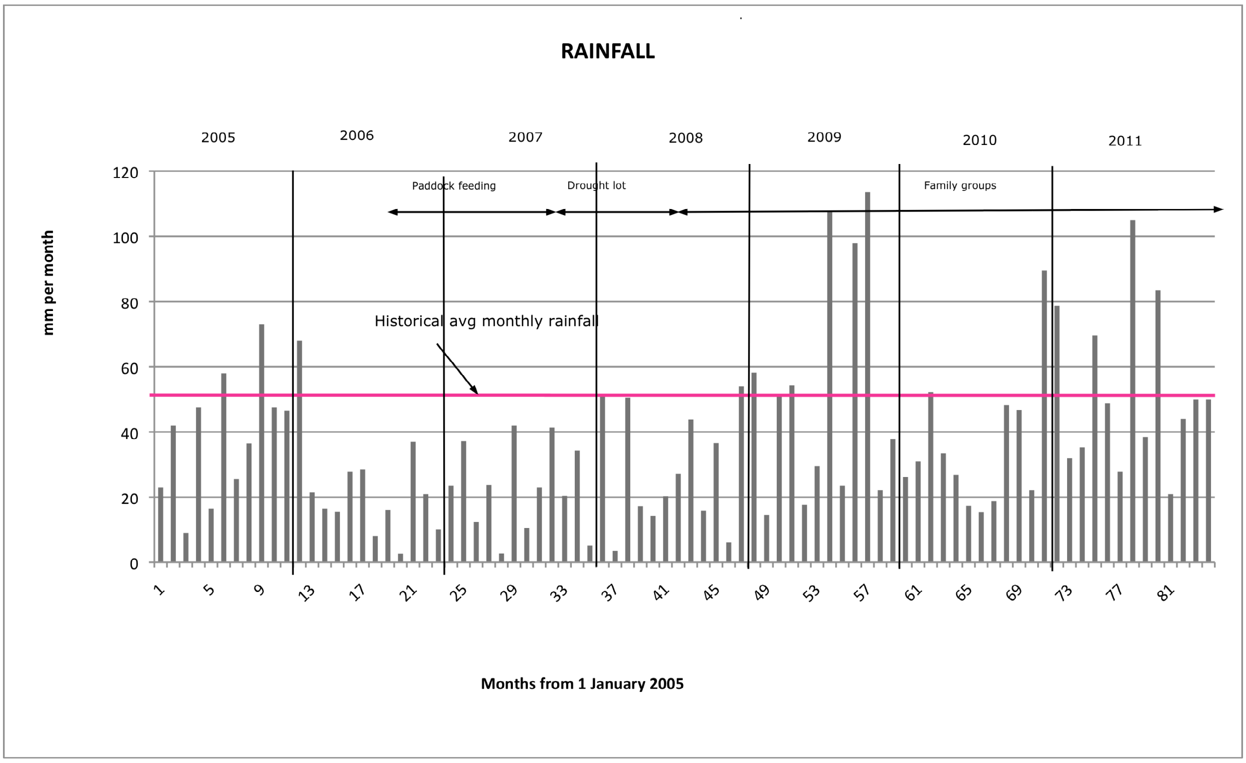
The time frame of management changes to enhance nutrition for my sheep coincided with the last year of the "long dry" cycle of 2006-2009 and the beginning of improved seasonal conditions, with heavier than average rainfall in the winter of 2009. The 2010 and 2011 seasons were similarly improved, with near- or above-average rainfall.

The wool production and lambing results for 2009 reflect a year with most of the growth season (September to June) in serious rainfall deficit, so I would argue that the substantial production improvements seen in 2009 result principally from management changes, not improved seasonal conditions. The bottom line, nutritionally, is that there was more quantity and diversity of feed available because there were fewer animals competing for it. The reduced grazing pressure, in turn, allowed the plant communities to recover and redevelop the diversity of species available for forage into the next year.

There have been a number of unexpected consequences of ensuring that ewes can exercise nutritional wisdom and teach their lambs to do so as well. Some of these consequences are readily quantified, while others are qualitative observations of sheep behaviour. I believe that both quantitative and qualitative changes are useful indicators of change, and will discuss them separately below.

To put the changes into historical context, I have analysed a number of variables over the last 5 to 10 years. This has been a period of extreme variability in rainfall (Figure 1), which has affected the forage quantity and diversity. In 2006, 2007 and most of 2008 we averaged about half of the normal rainfall. We finally returned to something more like normal rainfall by mid-2009, about three months before the 2009-10 shearing. 2010 had less than average rainfall, with little winter rainfall. 2011 was a wetter than average year.

Figure 1: Rainfall history



6a. Timeline of production operations 2005-2011

Because of the variations in seasonal conditions and management approaches over the time period of interest, it might be useful for the reader to have a timeline of production operations as a guide to what stayed the same and what changed (Table 1). I consistently shear all sheep once a year, pre-lambing, in September. Other operations change from year to year.

Table 1: Timeline of production operations

Year	Summer crutching	Weaning	Jetting	Lambing	Other
2004-05	February	February	November	October	Supplemental grain fed to ewes before lambing
2005-06	January	January	January March December	October	Paddock feeding (pellets, all sheep) Oct-Dec
2006-07	February	February	March November	November	Paddock feeding (grain, all sheep) Jan-Sep; Nov-Dec
2007-08	January	January	February December	October	Drought lot from Jan-July (ewes only) Paddock feeding hgts: Jan-Sep; ewes: July-Sep
2008-09	January	n/a	March December	October	Family groups from January onward
2009-10	April	n/a	February November	October	No sheep sold—all lambs with mothers
2010-11	March	n/a	January February	October	400 surplus ewes and hgts sold

6b. Quantitative results

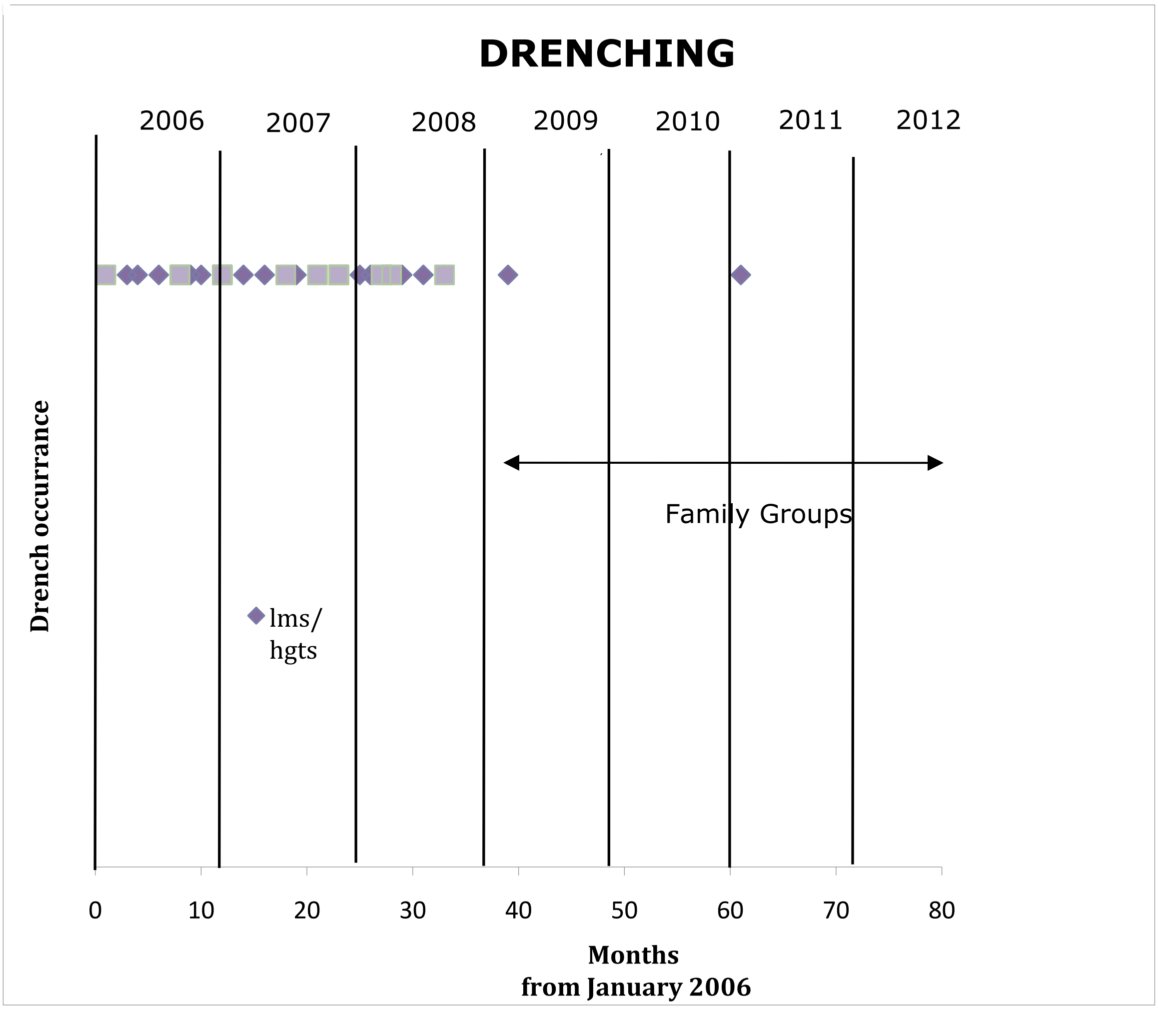
- **Drenching frequency (lambs and ewes)**

My original motivation for adopting a nutritional wisdom approach was to try to improve the drenching rate for my lambs. The lambs are susceptible to worm infestations of nematodirus, which don't seem to affect adult sheep, but can cause ill-thrift and death in weaners. I normally drench the lambs 2 or 3 times between weaning and mid-winter.

Figure 2 shows the frequency of drenching in earlier years, for both lambs and ewes, compared to the last three years where the sheep have been run in family groups. No ewes have been drenched since October 2008. Lambs were drenched in early 2009 and again in early 2011.

Since 2007 I have done worm egg counts before most drenches, so I know that those drenches were in fact were required based on the worm burdens at the time. It should be noted that 2006-2009 were exceptionally dry years, with little worm burden seen in the region, whereas the much wetter 2009-2010 and 2010-2011 seasons were characterised by higher worm burden in the area. Dramatically reduced drenching frequency, I would argue, results from management changes, not improved seasonal conditions.

Figure 2: Drench frequency



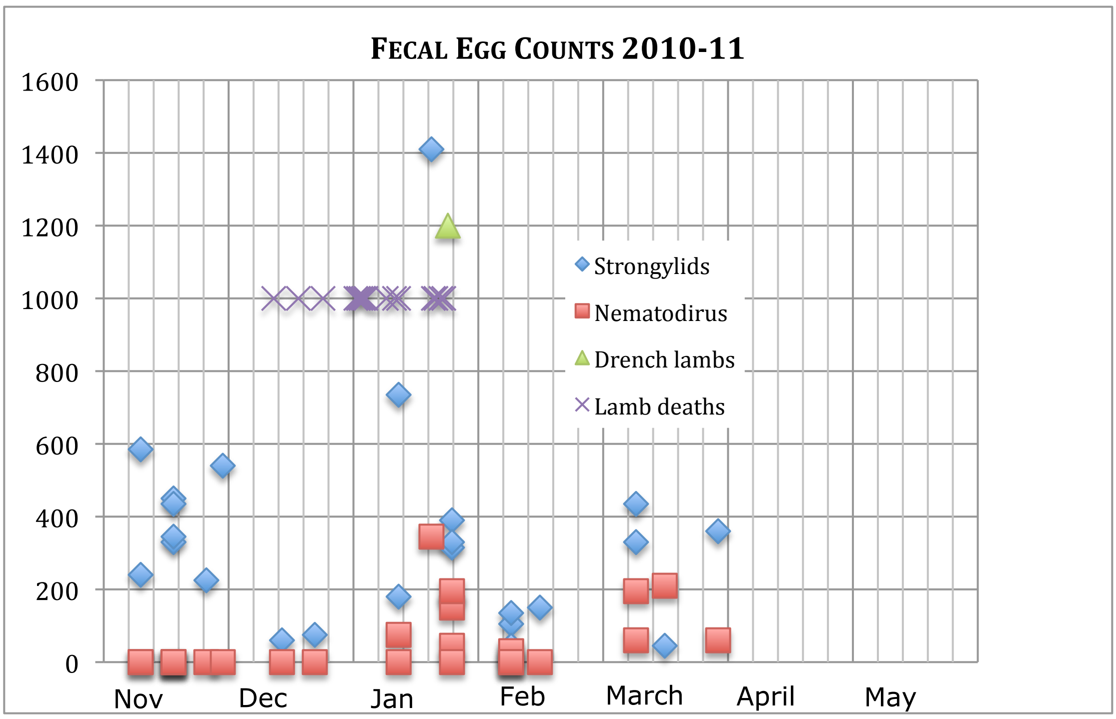
In 2009, the first year of running family groups, the lambs were drenched once, on a nematodirus fecal egg count (FEC) of 250—debatable whether it was required, but nematodirus can be quite sneaky with their sporadic egg-laying, and I decided not to take the risk. In 2010 I chose not to drench on the same count, but rather took steps to improve the nutrition available to the flock as a whole. I moved the flock from cocksfoot/ryegrass/clover where they had been grazing rotationally through the summer onto "semi-native" country where increased species diversity complemented the basic exotics. After about a week all signs of scour disappeared.

In 2011 the very wet summer conditions were conducive to strongylid development. I was monitoring FEC weekly from November 2010 through March 2011 (Figure 3). The relatively high strongylid counts in November were not associated with any clinical signs of worm overburden in either the ewes or lambs. Three lambs died in December without obvious clinical signs, but in hindsight must have been worm-related deaths. When the fecal egg count rose quickly in January, accompanied by several more lamb deaths, I made the decision to drench all the lambs (but not the ewes).

All of the lambs that died were from scanned twinning ewes—so were known twins. My suspicion is that the single lambs would have weathered the worm episode without drenching, but I wasn't willing to risk it. It is worth noting that the FECs during this period were quite high, and invariably came back with advice to drench. That the ewes, and possibly the single lambs, showed no clinical signs—and no wool break, for that matter—suggests that well-nourished sheep can tolerate a much higher worm burden than sheep on a lower nutritional plane.

We also noticed during the period of high worm challenge that whenever a mob of ewes got close to an area with chicory and plantain, they became quite excited and grazed very avidly. In fact, it was virtually impossible to move them away from those areas until they had eaten their fill. When the worm burden was low, they did not show the same determination to graze those areas.

Figure 3: Fecal Egg Counts—Summer of 2010-11



- **Benefits of parasitism**

There is a tendency to consider intestinal parasites as an evil to be eradicated. Increasingly, though, there is solid scientific evidence that parasitism may play an important, positive role in animal health, including humans. Parasites interact with the immune system in ways that may assist the host—preventing allergic reactions and possibly preventing or diminishing auto-immune diseases like multiple sclerosis in humans. While I know of no research on the benefits of parasitism in sheep, I think it likely that my sheep are healthier as a result of little or no drenching than they were when they were being drenched often.

- **Lambing**

One of the issues often raised by other farmers when I talk about allowing lambs to wean themselves is a concern that the ewes will be "pulled down" by the lambs, and will not cycle or conceive well. I found the opposite to be the case: we had a 27% increase in total lambing rate (i.e. dead and live lambs born per 100 ewes mated) for 2009-2012 compared with the previous four years (Table 2). Because weather plays an important role in lambing mortality, the total lambing rate is a more useful statistic than the percentage of lambs marked.

Table 2: Lambing Statistics

Parameter	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Ewes joined	926	986	741	704	433	553	323
Lambs at marking	763	858	636	585	425	551	274
Lamb deaths during lambing	98	71	24	40	59	131	73
Ewe deaths during lambing	14	10	4	11	4	3	1
Lambing interventions[2]	18	7	6	7	1	1	1

Table 3: Fertility Percentages

Parameter	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12 A[3]	2011-12 B[4]
Total lambing rate[5], incl twins	<92%	<95%	87%	98%	>112%	>123%	>107%	>118%
Lambing mortality (lambs)	10%	8%	4%	6%	12%	19%	21%	21%
Lambing mortality (ewes)	1.5%	0.5%	0.5%	1.6%	1%	0.5%	0.3%	0.0%
Lambing % at marking	82%	87%	86%	83%	98%	100%	85%	97%
Twinning ewe rate	n/a	n/a	2%	6%	> 12%	>23%	>7%	>118%
Dry ewe rate	>7%	>6%	11%	8%	n/a	n/a	>7%	n/a
Lambing % at weaning or joining (2008 - 2011)	80%	82%	85%	82%	98%	97%	n/a	n/a

[2] Pulling of lambs, uterine prolapse, etc.
[3] All ewes joined, including high percentage of maiden ewes.
[4] Percentages for the two mobs with 33% maiden ewes.
[5] Total of live and dead lambs born per hundred ewes mated.

In 2011-12 the total lambing rate was somewhat lower because I joined a much higher percentage of maiden ewes: 41% compared to 20-25% in previous years. These first-timers are significantly less likely to become pregnant or to have twins. One of the three family groups just happened to have the bulk of the maiden ewes; the other two mobs each had 33%. In the two family groups with 33% maiden ewes in 2011-12, the total lambing rate was 118%, which is comparable to 2009-11. The statistics in Tables 2 and 3 indicate that the increase in lambing rate is attributable to a greater twinning percentage in the 3 years since reducing the stocking rate and introducing family groups: up from an average of 4% to 18% averaged over 2009-12.

So, the fear of ewes not conceiving if their lambs are not weaned is baseless, so long as there is adequate and diverse feed available for the ewes throughout the year. In other words, don't try this if you are not willing to reduce your stocking rate sufficiently to ensure the ewes can feed themselves adequately.

Further examination of Table 3 shows that lambing mortality has been about 10% higher in the past three years, although the much higher twinning rate has offset that additional loss. The higher mortality is partly attributable to unusually prolonged bad weather during the past three lambing seasons, and presumably partly to the much higher incidence of twin lambs.

My stockman and I noted two other changes in lambing since the introduction of family groups and reduction in stocking rates. First, the incidence of what might be termed lambing interventions (Table 2) has dropped dramatically. There were no cases of prolapsed uterus in the past three years, compared to 8 cases in 2008-09 after the drought lot. We have had to assist in only one birth per year during this time, as compared to as many as 10 in previous years. The ewes are able to give birth naturally, with no increase in ewe mortality. From a farm labour perspective this is a major advantage.

Second, we noticed that have not had the usual "rush" of lambs over 3-4 days early in lambing. Invariably, and not coincidentally, that rush occurs with the advent of stormy weather, which triggers release of oxytocin and the advent of labour [Dvoraka, 1978]. This weather-induced rush of lambs results in the major losses of many lambing seasons. By contrast, in 2009, 2010 and 2011, the lambs trickled out fairly steadily throughout the entire 6 weeks, despite a number of rainstorms and even a few snowstorms! I believe this is also a beneficial consequence of allowing weaning to occur naturally—the ewes' biological clocks are not all reset to the same date, as happens when weaning is forced. From a lamb mortality perspective, I think steady lambing rather than a rush of lambs is highly preferable.

- **Wool production**

Significant improvements in wool production have resulted from managing for nutritional wisdom (Table 4). While some change would not be unexpected, given the importance of nutrition to wool growth, the magnitude of the changes certainly surprised me. The shearing of September 2009 was the first after the reduction in stocking rate and introduction of family groups where lambs were allowed to wean themselves.

Table 4: Wool production statistics

Parameter	2004	2005	2006	2007	2008	2009	2010	2011
GFW/ewe (kg)	3.8	3.9	4.1	3.4	4.1	5.1	5.2	5.4
GFW/hogget (kg)	1.8	1.4	1.4	1.7	1.4	1.9	1.6	2.0
Staple length, ewes (mm)	76	81	85	69	81	92	80	83
Staple length, hogget (mm)	68	66	67	67	68	73	73	74
Weight-averaged micron	17.2	17.7	17.3	16.5	16.8	17.9	17.5	17.0
Weight-averaged staple strength	44	41	42	42	28	40	42	40
Weight-averaged yield, %	70.1	67.7	68.5	66.5	60.7	69.5	71.6	71.2
Number of sheep shorn	1651	1503	1739	1434	967	721	1125	1253
% hoggets	23	21	29	32	19	22	38	43

To make a sensible comparison year on year, it is important to factor in the percentage of hoggets (one year old at shearing time) in the flock, since hoggets cut less than half of the wool that ewes produce. The ratio of hoggets in the flock has varied between 19% and 43% over the years shown in Table 4.

The ewes produced an astonishing 36% more wool per sheep, averaged over 2009 to 2011 compared to the previous 5 years, going from an average of 3.86 kg/sheep to 5.26 kg/sheep. The hoggets improved by 19%, from 1.54 to 1.83 kg/sheep. At the same time, the yield improved by 4%, so that in clean wool terms, the improvement is 40% more wool per ewe and 23% more wool per hogget. It should also be noted that there were no adult wethers (castrated male sheep) shorn from 2007 through 2011, while in previous years wethers made up a varying proportion of the flock. Wethers generally cut substantially more wool than ewes.

The quality of the wool since 2009 is better than or comparable to the earlier years. Yield variations mostly reflect dust levels in my wool, and maintaining a lower stocking rate/higher level of ground cover has allowed the yields to improve even more over time. The drought lot was particularly dusty, reflected in the very low yield for 2008.

Tensile strength variations generally reflect abrupt changes in nutrition, either from good to bad or vice versa. In 2008 I created a break in the wool by taking the lactating ewes abruptly away from their lambs and putting them on a full ration of feed in the drought lot—substantially better than what they had available in the paddock at that point in time. In other years, the tensile strength has been more or less steady in the 40 N/kt range, which is considered quite good. Staple length has increased in the last three years, by 8% in the ewes and 9% in the hoggets.

The average fibre diameter has increased slightly in the last 3 years—up 0.4 microns from 17.1 to 17.5, reflecting improved nutrition. As an aside, one way to make wool finer is to reduce the nutrition available. This has at least two unhappy side effects—less than optimally healthy sheep and a tendency to weakness in the wool fibre. An obviously much preferable means of getting finer wool is to use genetics to reduce the micron to whatever level is desired, and to feed the sheep adequately for overall health and wool production. While lower micron wools with high tensile strength generally attract higher prices per kg, the total weight of the clip will generally drop with fibre diameter. Part of the trick in making fine wool profitable is to maintain the fleece weight and tensile strength (an important issue for high speed spinning technology) while keeping the micron low enough to be in the premium wools.

- **Wool production profitability**

The large increases in wool per sheep in 2009-11 were of course accompanied by a much-reduced stocking rate. To what extent did that trade-off affect profitability? Table 5 outlines the stocking rates, wool income and principal costs of wool production over the last 8 years. I've chosen only to include the costs for drench, fodder and shearing/crutching labour, as these are common to all sheep enterprises. Other fixed and operational costs will vary between enterprises and make direct comparisons difficult. The drench and fodder costs do not include labour.

Table 5: Wool Production Profitability

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Stocking rate sheep/ha	5.0	4.6	5.3	4.3	2.9	2.2	3.4	3.8
Clip average wool price $/kg	$6.93	$7.09	$8.44	$8.49	$8.90	$9.46	$13.93	$13.70
Wool income $/sheep	$27.30	$30.44	$29.84	$28.29	$33.98	$53.20	$57.82	$59.71
Drench cost $/sheep	$0.69	$1.06	$2.05	$0.70	$0.17	$0.00	$0.00	$0.03
Fodder[6] cost $/sheep	$1.20	$2.76	$29.85	$45.13	$19.89	$0.00	$0.00	$0.00
Shearing labour cost $/sheep	$5.09	$6.16	$6.14	$6.20	$6.68	$7.51	$6.26	$6.73
Wool operating margin[7] $/sheep	$20.32	$20.46	($8.20)	($23.74)	$7.24	$46.71	$51.56	$52.95
Wool operating margin $/ha	$101.68	$93.17	($43.22)	($103.16)	$21.21	$102.05	$175.77	$201.04

The years from 2006 to 2008-09 are an object lesson in the financial futility of feeding grain and supplements on a large scale in order to maintain flock numbers through an extended dry period.

In terms of nutritional wisdom, though, the more compelling result comes from a comparison of wool operating margin per hectare between 2004-2006, before the 3-year dry period and 2009-10, where the wool operating margin is essentially the same, but the stocking rate is less than half. This has major implications for managing the landscape and improving biodiversity in a grazing enterprise, without losing profitability. The margins increase rather dramatically in 2010 and 2011, due mostly to an increase in wool prices.

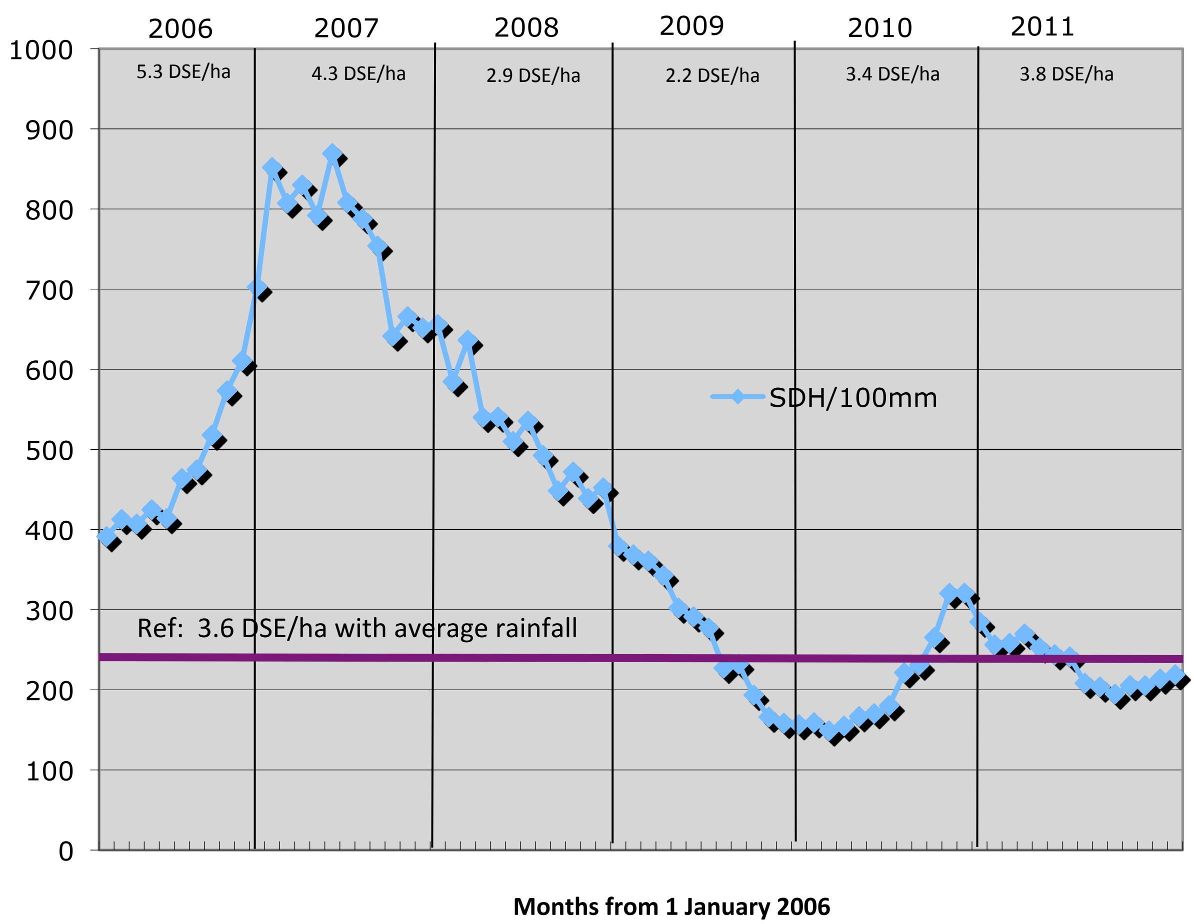
[6] Fodder costs include nutritional supplement blocks.
[7] Operating margin here is wool income less drench, fodder and shearing and crutching labour costs.

- **What about stocking rates?**

Optimal stocking rates will be a moveable feast, depending not only on the current season and likely future season, but also on the recent past history of grazing pressure. For example, my very low stocking rate in 2009-2010 (2.2 sheep/ha) was appropriate for the condition of the pastures coming out of a deep 3-year dry cycle coupled with relatively high stocking rates.

One way to look at long-term stocking rates is to use some form of grazing chart that provides a running average of grazing pressure (dry sheep equivalent or DSE) and pasture growth (usually rainfall as a proxy). The variable plotted in Figure 4 is a standard such function, averaged over the twelve months previous to the date of each point shown. The concept is that the grazing variable should be maintained within +-15% of a reference indicative of average rainfall and appropriate pasture condition. Points above the line are "overgrazed" relative to the (hopefully) optimum reference line and points below are "undergrazed". The low to moderate stocking rates of the last three years have kept me more or less within the 15% envelope around a reference corresponding to 3.6 DSE/ha and the average rainfall in my district.

Figure 4: Grazing Chart for 2006-2011



Based on my stockman's 70 years of experience in this area, and on the results of the last three years, my best guess is that a stocking rate of around 3.6 sheep/ha is a realistic maximum for the long term, so long as I manage the pasture condition more adroitly through dry cycles, through early destocking. In 2010-11 there was an excellent pasture base following good rains and low stocking rates in 2009-10. With continuing good rainfall in 2011, a "moderate" stocking rate of

3.8 sheep/ha has allowed all sheep to be as well-nourished as they were in 2009-10 and 2010-11.

Clearly, stocking rates will have an impact on overall profitability of the enterprise, through the selling of surplus sheep. While I do not have statistics to argue that the value of surplus stock will increase with better nutrition, it is at least possible to model the likely effects of stocking rate on profitability. Using statistics from the past few years and taking into account the observed changes in lambing percentage and wool cuts attributed to improved nutrition in 2009 through 2011, estimates of income for different stocking rates are given in Table 6.

Table 6. Estimates of profitability for different stocking rate levels

	Low Rate	**Moderate**	**High**	**Very high**
Stocking rate, sheep/ha	2.2	3.6	4.8	5.5
% Ewes joined	60	60	60	60
Lambing % Lambs	100	100	85	85
% Sheep deaths	1.8	1.8	1.8	1.8
% Surplus sheep	56.8	56.8	48.9	48.9
kg wool/ewe	5.23	5.23	3.86	3.86
kg wool/hgt	1.83	1.83	1.54	1.54
kg wool/sheep	3.84	3.84	3.2	3.2
$/kg	11.02	11.02	11.02	11.02
$/sheep--wool	$42.32	$42.32	$35.26	$35.26
Price per sheep	$32.00	$32.00	$32.00	$32.00
Wool income/ha	$93.10	$152.34	$169.27	$193.95
Sheep income/ha	$42.24	$69.12	$78.34	$89.76
Total income/ha	**$135.34**	**$221.46**	**$247.60**	**$283.71**
Drench cost/ha	$-	$-	$8.64	$9.90
Fodder cost/ha	$-	$-	$76.80	$88.00
Shearing cost/ha	$16.50	$27.00	$36.00	$41.25
Production cost/ ha	**$16.50**	**$27.00**	**$121.44**	**$139.15**
Production profit/ha	**$118.84**	**$194.46**	**$126.16**	**$144.56**
Production margin	88%	88%	51%	51%

In order to model the different scenarios, I've used the statistics discussed earlier for lambing percentages and wool productivity. Because the number and value of sheep sold varies widely with season, I've simply calculated the 10-year average price per sheep ($32) and used that to estimate income from surplus sheep. I have also used the 8-year average price per kg of wool.

To calculate costs, I've assumed a drench cost, including labour, of $0.60 per sheep per drench, with three drenches per year. Estimating fodder cost is trickier, both because the need for fodder varies so much from year to year, and because the labour, fuel and depreciation costs associated with feeding out are difficult to estimate. I've used my average direct fodder cost for the full 8 years, assuming that even at a higher stocking rate I would not have needed to feed supplementary hay or grain during the last three good seasons. That direct fodder cost is $12.35 per sheep. I've further assumed that the labour cost of feeding out would add another 30% to that, for a total of $16 per sheep per year on average. While these numbers can certainly be debated, they are a fair representation of my actual costs at higher stocking rates.

Under the assumptions made, the profitability of wool plus surplus sheep is highest for my enterprise at a moderate stocking rate, despite the lower number of surplus sheep, and without taking into account any gain in the value of surplus sheep as a result of improved nutrition. This is attributable to the combination of much higher lambing percentage and value of wool per sheep and the avoidance of supplementary feed and drenching costs in the low and moderate stocking rate scenarios.

Two other scenarios might help to bracket the likely variations in profitability as a function of stocking rate. The first is to reduce the average fodder cost by 50% (Table 7), and the second is to increase the price per sheep and wool to reflect the high end of the market that we have experienced in 2011-12 ($75 per sheep and $13.70 per kg of wool), while also keeping the fodder bill down 50% (Table 8).

Table 7: Estimates of profitability with reduced fodder costs

	Low Rate	**Moderate**	**High**	**Very high**
Stocking rate, sheep/ha	2.2	3.6	4.8	5.5
% Ewes joined	60	60	60	60
Lambing %	100	100	85	85
Lambs				
% Sheep deaths	1.8	1.8	1.8	1.8
% Surplus sheep	56.8	56.8	48.9	48.9
kg wool/ewe	5.23	5.23	3.86	3.86
kg wool/hgt	1.83	1.83	1.54	1.54
kg wool/sheep	3.84	3.84	3.2	3.2
$/kg	11.02	11.02	11.02	11.02
$/sheep--wool	$42.32	$42.32	$35.26	$35.26
Price per sheep	$32.00	$32.00	$32.00	$32.00
Wool income/ha	$93.10	$152.34	$169.27	$193.95
Sheep income/ha	$42.24	$69.12	$78.34	$89.76
Total income/ha	**$135.34**	**$221.46**	**$247.60**	**$283.71**
Drench cost/ha	$-	$-	$8.64	$9.90
Fodder cost/ha	$-	$-	$38.40	$44.00
Shearing cost/ha	$16.50	$27.00	$36.00	$41.25
Production cost/ ha	**$16.50**	**$27.00**	**$83.04**	**$95.15**
Production profit/ha	**$118.84**	**$194.46**	**$164.56**	**$188.56**
Production margin	88%	88%	66%	66%

Table 8: Estimates of profitability with higher sheep and wool costs and reduced fodder costs

	Low Rate	Moderate	High	Very high
Stocking rate, sheep/ha	2.2	3.6	4.8	5.5
% Ewes joined	60	60	60	60
Lambing % Lambs	100	100	85	85
% Sheep deaths	1.8	1.8	1.8	1.8
% Surplus sheep	56.8	56.8	48.9	48.9
kg wool/ewe	5.23	5.23	3.86	3.86
kg wool/hgt	1.83	1.83	1.54	1.54
kg wool/sheep	3.84	3.84	3.2	3.2
$/kg	13.7	13.7	13.7	13.7
$/sheep--wool	$52.61	$52.61	$43.84	$43.84
Price per sheep	$75.00	$75.00	$75.00	$75.00
Wool income/ha	$115.74	$189.39	$210.43	$241.12
Sheep income/ha	$99.00	$162.00	$183.60	$210.38
Total income/ha	**$214.74**	**$351.39**	**$394.03**	**$451.50**
Drench cost/ha	$-	$-	$8.64	$9.90
Fodder cost/ha	$-	$-	$38.40	$44.00
Shearing cost/ha	$16.50	$27.00	$36.00	$41.25
Production cost/ ha	**$16.50**	**$27.00**	**$83.04**	**$95.15**
Production profit/ha	**$198.24**	**$324.39**	**$310.99**	**$356.35**
Production margin	92%	92%	79%	79%

In all three scenarios, the moderate stocking rate is more profitable than the higher rates, with the single exception of the very high stocking rate in Table 8, where I believe the low fodder cost is not realistic.

6b. Behavioural results

Although they are difficult to quantify, the behavioural changes are among the most interesting of the unexpected consequences of managing for nutritional wisdom. Fairly soon after establishing the family groups in early 2009, I began to notice that my sheep were developing “attitude”: a social cohesion and confidence that I have come to attribute to individuals knowing they have their families at their backs. Ewes that will defend their lambs are a common experience in grazing. Less common (I had never seen it) is a 5-month ewe lamb emulating her mother by standing and stamping her front foot at a dog. By maintaining the strength of the family connections within the flock we are apparently returning to more natural social and predator-related behaviour. At the same time, the mobs are generally easier to move than the old year-classes—a literal cohesiveness as well as a psychological one—you just need a dog that will stand up to a ewe who is standing up to him!

A second behavioural change we noted was during lambing. In past years I’ve referred to the dry ewes in a lambing flock as “party girls”, because they basically don’t have job, and are the first to take off in flight when startled, generally taking the lambing ewes with them, mismothering as they go. I had even started taking the dry ewes out during lambing to prevent party-girl syndrome. So it is fascinating to see the difference when the dry sheep in the lambing flocks are just the hoggets whose mothers and grandmothers are lambing. We often find the mob split into two groups, near each other in the paddock—one group the lambing ewes and the other the hoggets. This seems to be mostly an effect of the ability of the hoggets to graze away more quickly than ewes and lambs. When disturbed, all that happens is that the hoggets run back to their mothers, and then settle down. We have had not a single instance of mismothering during the last three lambing seasons.

A third behavioural change that we think is occurring is that the flock members are unwilling to move away from other family members. From January to March 2010 we ran the family groups all together in a single large mob. We often noticed a group of 15-20 sheep just a bit separate from the main mob. My hypothesis is that these are extended family groups, comprised of the original 3 year-classes of ewes (who were of course mothers/daughters/granddaughters, and were reunited in the one big mob), plus their associated daughters, granddaughters and great-grandchildren. In one tantalising episode, a group of this size was feeding away from the mob. I moved the main mob past them, thinking they would join it. They didn't, and when I went to see why, there was a cast ewe among the smaller group. I believe the smaller group was the extended family of that cast ewe, and they were unwilling to leave her behind until forced to by the presence of my working dogs.

Finally, I have two anecdotes about teaching bottle (pet) lambs nutritional wisdom. Most years I have managed not to have to raise any pet lambs, since my stockman is a wizard at finding foster mothers. In 2009, though, the mother of twin lambs (Anne and Emily) died when they were about a week old. We were unable to find a foster mother and I took on the task, somewhat daunted by what I now know is the responsibility of a "proper" mother of lambs. I found it relatively easy, though time-consuming, to teach my lambs to try different plants, simply by taking them for a walk and stopping in front of a plant I wanted them to try. I started doing this within a couple of weeks, and continued it for 3 months. By the time I introduced them back into the flock, they were familiar with at least 10 species. They have thrived on their own in the flock, and I was amused to see Annie trying the perennial weed roadside mignonette on her own (not one I had taught her to eat) when the rest of the mob was still eyeing it warily. Fred Provenza's group's research has shown that the more types of fodder an animal is exposed to, the less hesitation there is in trying something new. I couldn't have been prouder of Annie if she'd done well on her university entrance exams!

In 2011, my one pet lamb, Hector, and my one lambing intervention ewe (later named Jaqueline) taught me a rather different lesson about the power of mothering in nutrition. Jaqueline had twin dead lambs that I had to pull. I did that operation near Hector's pen, and his cries (to me for his feed) seemed to spark a mothering instinct in Jaqueline. She was very weak and unable to get up for a couple of days after the intervention, so there was never a question of her feeding Hector. However, once she was back on her feet, she began mothering him, although by then she had no milk. So, she and I began to share the responsibility of raising Hector—he got his milk from me and his nutritional wisdom from Jacqueline.

At this point Hector was just 2 weeks old, and on that rising demand for formula where it is easy to overfeed, because they will drink more than is good for them. To my astonishment, within 24 hours of Jacqueline taking over the nutritional wisdom role, Hector's consumption of formula dropped by 50% and remained at that level. The only explanation I can come up with is that Jacqueline taught Hector what he needed to know to start metabolising plant food almost immediately. This has major ramifications for bottle-fed animals (e.g. dairy calves), and also gives us some additional insight into the adaptive advantages of mothers developing nutritional wisdom and passing it on to their progeny—if nothing else, the faster that lamb is metabolising plants, the less burden there is on the ewe to make milk.

7. Landscape implications

There are several advantages for the landscape in applying a low stocking rate/high biodiversity approach to production. The most obvious is maintaining better ground cover to discourage annual weed germination and various forms of erosion. Setting the bar a bit higher, this approach *requires* biodiversity for production reasons, and therefore values the very thing that makes the landscape resilient to short- and long-term climatic changes. In fact, it will not be possible to make the kinds of production gains I have described without maintaining the landscape at a high level of biodiversity and function, thus providing a conscious production motivation for preserving ecological integrity.

On a practical basis, running the sheep in family groups has allowed me to rest my semi-native country for all of summer and into early autumn for the first time since I began farming 10 years ago. This is the primary growing season for native forbs and warm-season grasses, which are most at risk to overgrazing. As a result of that prolonged rest and the generally lower stocking rates, most of the plants (native and exotic) on my property were allowed to set seed in 2010 and 2011, providing both a highly nutritious and palatable food source for sheep (who love browsing seed) and habitat for birds and other animals, as well as regenerating the seed bank.

8. Conclusions

The first 3 years of trialling a nutritional wisdom approach to wool production has resulted in a number of improvements in the enterprise, including:

- No drenching of ewes since October of 2008, and only two drenches of lambs (once each in January 2009 and January 2011). The expectation is that this will continue into the future, so long as the forage system is managed appropriately—meeting the expected grazing demand without compromising forage quantity or diversity.
- A 27% improvement in total lambing rate over the average value for the previous 4 years (93%) to 118%.
- An increase in wool cut per sheep of 40% per ewe and 23% per hogget, with an overall increase in wool quality (length, strength and yield)
- An operating margin for wool production as high as in previous “good” years (i.e. before the “long dry” of 2006-2009), at less than half the stocking rate.
- Estimates for overall enterprise profit (wool plus surplus sheep) that are as high for moderate stocking rates as for more traditional, higher stocking rates.
- A return to more natural social dynamics within the flock.

The magnitude of improvements in lambing percentage and wool production is quite staggering. Improvements of a few percent are generally considered very good in modern agriculture, where most of the major genetic gains were made decades if not centuries ago. And, these sheep were certainly considered to be well-fed in previous years, so the improvements are not the result of correcting major nutritional deficiencies, at least as conventionally understood. However, there is clearly a capacity in these individual animals to respond markedly to an improved opportunity to exercise their nutritional wisdom. Presumably the same level of improvement will be found in any flock of wool-producing sheep given a similar nutritional opportunity.

The level of production improvement has led me to the conclusion that merinos in general are chronically undernourished. Culturally, I believe this has been because, unlike crossbreds, merinos can survive on very little (they will “do”), and still grow some wool. However, the consequences of that under-nourishment are precisely the characteristics that give merinos a bad reputation in an increasingly demanding production environment: a belief that they have low fertility and are not good mothers, they are inherently susceptible to flystrike and worm, they do not have good meat carcasses, and, with wool prices low anyway, are not really worth the effort and costs of raising them. What I’ve seen in my own system is that all of those issues, bar the low price of wool, are ameliorated by the provision of sufficient quantity and diversity of forage to encourage the development of nutritional wisdom.

Inadequate nutrition for merinos leads to what I call a "spiral of insufficiency": sheep that are lacking balance in their diet will inevitably graze forbs preferentially over grasses, trying to find the nutrients they are missing. Chronically under-nourished merinos have undoubtedly grazed the forbs in their systems to a point of non-existence, trying to maintain nutritional balance, before then reducing the grasses to a low level. Without adequate grass cover to provide shelter or a viable seed bank to provide recruitment, the forbs will struggle to re-establish, making the nutritional balance even worse, and the landscape ecology progressively less resilient or functional. Without short-circuiting this downward spiral by reducing grazing pressure, the cycle of insufficiency will continue indefinitely.

While most of the production gains made over this 3-year trial period primarily reflect improved nutrition opportunities, the subtler benefits of running in family groups are emerging, for instance the reduction in drenching of hoggets. Over time, I believe the depth of inter-generational knowledge about what to eat and where to find it will become a major factor in the health of individual animals and the profitability of the enterprise as a whole.

The production gains I've observed to date from allowing sheep the opportunity to develop and exercise their nutritional wisdom have major implications for grazing enterprises. If we can cut more wool off fewer sheep, with higher fertility, while simultaneously reducing costs associated with wool production, it will be possible to re-establish profitable grazing enterprises that protect and even enhance the ecological integrity of the landscape.

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Without the wisdom and experience of my stockman, Mr David Carnes, I would not have had the confidence to try these changes. Knowing that David's deep knowledge of sheep management and insight into sheep behaviour would keep me from getting too far off the track gave me the courage to try putting Fred Provenza's research into practice in my enterprise. David and Fred, while coming from vastly different backgrounds, share a willingness to experiment and an abiding interest in the way things work and are connected in natural systems. It has been a wonderful experience for me getting to work with both of them.

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