Evaluation of a cow-side milk progesterone assay and assessment of the positive predictive value of oestrus diagnosis by dairy farmers in New South Wales

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Objectives The three objectives of this study were to determine the positive predictive value (PPV) of oestrus diagnosis (heat detection accuracy) by dairy farmers, calculate the diagnostic sensitivity and specificity of the P4 Rapid milk progesterone assay for detecting a corpus luteum and assess the economics of using a cow-side milk progesterone assay designed to aid oestrus diagnosis.

Methods Milk samples were collected from 752 cows diagnosed in oestrus by farm personnel on 14 dairy farms. Samples were tested using the P4 Rapid milk progesterone assay to estimate the PPV of oestrus diagnosis at each farm and a crude pooled mean of PPV of oestrus diagnosis across all farms. A further 156 milk samples were collected from cows with luteal tissue status determined by transrectal ultrasound and tested by the P4 Rapid assay to enable calculation of the sensitivity and specificity of the P4 Rapid assay.

Results For pooled farm samples, the PPV was 97.0%, with a range between farms of 88.9–100%. Sensitivity of the P4 Rapid milk progesterone assay for detecting a corpus luteum was 90.1% and specificity was 98.7%. Misclassification of oestrus in cows previously identified as pregnant was the most common cause of false-positive oestrus diagnoses by farm personnel.

Conclusion Routine testing of milk progesterone in all cows diagnosed in oestrus is not economically justified and may even slightly reduce submission rates; conversely, strategic use of cow-side milk progesterone assays can improve herd reproductive performance by facilitating decisions on whether to rebreed cows previously diagnosed as pregnant.

Keywords dairy cattle; heat detection; oestrus detection; progesterone assay

Abbreviations AI, artificial insemination; CL, corpus luteum; GLMM, generalised linear mixed model; OR, odds ratio; PPV, positive predictive value

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Study population The 14 herds selected to participate in the study were current clients of the University of Sydney (a convenience sample) and all these farmers routinely pregnancy test eligible cows on a weekly,
fortnightly or monthly basis. In all of the study herds, cows underwent AI. Herds in which pregnancy testing was performed less frequently than once per month or bulls were running in the lactating herd were not eligible for the study.

**P4 Rapid milk progesterone assay**

The P4 Rapid is an ELISA that utilises a monoclonal anti-progesterone antibody. Milk diffuses up the test strip to give a result in 5–10 min. A visible test line is indicative of a low progesterone result and a visible control line is indicative of a valid test.

**Samples collected by farmers**

**Sample collection.** Farmers were asked to collect at least 15 mL of milk from each cow that they diagnosed in oestrus and intended to inseminate from September 2013 until all allocated sample pots were used or up to December 2013, whichever occurred first. Farmers enrolled in the study were asked to detect oestrus using their existing oestrus detection methods; these varied across farms and included oestrus detection aids, tail crayons and visual observations. Cows undergoing fixed-time AI were ineligible for sampling (even if oestrus was diagnosed). Milk samples were collected into 50-mL sample pots that contained 8 mg bronopol and 0.3 mg natamycin. Samples were stored in the farm refrigerator for up to 1 week before testing with the P4 Rapid assay. Samples were either collected in the milking parlour prior to AI or at the time of AI. Although the P4 Rapid assay is intended to be a cow-side test, all samples were tested away from the farms to ensure that interpretation of results was carried out by only one person and to ensure that farmers remained blinded to the results. The person who tested the milk samples had no knowledge of the individual cow’s reproductive history at the time of testing. We intended to collect 40–50 samples from farms that milked < 300 cows and 50–100 samples from farms that milked ≥ 300 cows.

**Sample testing.** Progesterone levels were assessed using the P4 Rapid assay. A sample that returned only a visible control line was recorded as a valid high progesterone result; a sample that returned both visible control and test lines was recorded as a valid low progesterone result and a sample that returned only a visible test line (and no control line) was recorded as an invalid low progesterone result, but not retested. The invalid low progesterone results were included in the calculation of the PPVs of oestrus diagnosis as interpretable results. The PPV of oestrus diagnosis was calculated as the percentage of P4 Rapid results that were low progesterone. Milk samples that failed to diffuse up the test strip and tests that failed to return any visible lines were retested. Samples that failed to give a result a second time were not retested and recorded as a twice-failed test.

**Pregnancy testing results.** Pregnancy testing was carried out by transrectal ultrasound at each of the farms during regular veterinary reproductive visits at weekly, fortnightly or monthly intervals and the data were gathered from the farm records. Cows were pregnancy tested if they were at least 32 days post-insemination and not detected as returning to oestrus.

**Diagnostic sensitivity and specificity**

For the purpose of determining the diagnostic sensitivity and specificity of the P4 Rapid assay, milk samples were collected from 156 cows with CL identified by an experienced veterinarian using transrectal ultrasound. Cows sampled for this purpose were those presented at the reference herd’s (herd 11) fortnightly veterinary visits and included cows presented for pregnancy diagnosis and no visible oestrus. Prior to conducting the study the skill of the ultrasonographer was validated via a second experienced ultrasonographer. Each cow contributed only one observation. The ovaries and reproductive tract of each cow were examined by transrectal ultrasound using an Ibex™ Lite portable ultrasound with an L6.2 Linear Repro probe (66-mm linear array, 12-cm scan depth, 8–5 MHz, manufactured by E.I. Medical Imaging). Pregnant cows with a visible CL ≥ 21 mm and non-pregnant cows with a CL ≥ 21 mm were allocated to the CL group and cows that were non-pregnant and had no visible luteal tissue on either ovary were allocated to the non-CL group. An additional 15 cows were examined during the process and diagnosed as not detectably pregnant with CL < 20 mm in diameter. These cows were excluded from sampling.

Milk samples were collected from cows immediately following examination of the reproductive tract and tested by the P4 Rapid assay within 2 h of collection. The ultrasonographer had no knowledge of the P4 Rapid result at the time of ovarian examination. A previous study showed that ultrasonographic examination of the ovaries for CL diagnosis by an experienced operator had a sensitivity of 91.4–96.7% and specificity of 100%.

**Statistical analysis**

**PPV of oestrus diagnosis.** GenStat (15th edn, VSN International Ltd) was used to determine the range of PPVs of oestrus diagnosis observed on the farms. A generalised linear mixed model (GLMM) with logit link and binomial error distribution was used to control for potential clustering within cow (598 cows had 1 oestrus diagnosis and 64 cows had ≥ 1 oestrus diagnosis) and calculate back-transformed means (PPV of oestrus diagnosis) for each farm. The result variable was the P4 Rapid result and farm was fitted as a fixed effect. Cow nested within farm was fitted as a random effect. The 19 oestrus diagnoses that failed to return an interpretable result following two P4 Rapid assay attempts were excluded from the analysis. For the purpose of estimating the PPV of oestrus diagnosis of each study farm, the 21 oestrus diagnoses that returned only a visible test line on the P4 Rapid assay were included in the GLMM and classified as low progesterone. Inclusion of these cows enabled analysis of a slightly larger sample size. Oestrus diagnoses that returned an interpretable P4 Rapid result, yet failed to result in an insemination or failed to yield a recorded pregnancy diagnosis, were included in the analysis, as pregnancy results are not required in the calculation of PPVs of oestrus diagnosis. The crude pooled mean PPV of oestrus diagnosis was calculated as the percentage of all oestrus diagnoses from all study farms with an interpretable P4 Rapid result that were associated with low progesterone P4 Rapid results.

Stata 14 (StataCorp LP) was used to determine the exact 95% confidence interval (CI) of the PPV of oestrus diagnosis of most farms, and exact one-sided 97.5%CIs for the four farms that had a PPV of oestrus diagnosis of 100%. Standard errors adjusted for clustering of sample within farm were used to calculate the 95%CI for the crude pooled mean PPV, although 95%CIs for each farm did not account for clustering of sample within cow. Exact logistic regression
(in Stata 14) was used to calculate exact odds ratios (ORs) and associated P values (herd 11 as the reference farm), with 95% CIs for most farms and one-sided 97.5% CIs for the four farms that had a PPV of oestrus diagnosis of 100%. An intraclass correlation coefficient was calculated by the xtlogit command in Stata 14.

Sensitivity and specificity of the P4 Rapid assay for detecting a CL. Sensitivity and specificity were calculated manually using the ovarian ultrasound data and corresponding P4 Rapid assay results. Sensitivity was the percentage of CL-positive cows that had a high progesterone result. Specificity was the percentage of CL-negative cows that had a low progesterone result. The standard error and 95% CI were calculated manually for both sensitivity and specificity. A kappa statistic was calculated using GenStat.

Calculation of the cost of detecting one false-positive oestrus diagnosis with routine use of the P4 Rapid assay

The PPV of oestrus diagnosis of the pooled data (from all 14 farms) was used to determine the average number of oestrus diagnoses tested by the P4 Rapid assay required to detect one false-positive oestrus diagnosis, \[ \text{no. oestrus diagnoses per false positive} = \frac{1}{(1 - \text{PPV of oestrus diagnosis})} \]. This figure was multiplied by the cost of a P4 Rapid test strip and then adjusted for the proportion of cows requiring retesting, \[ \text{cost of P4 Rapid assay} \times \frac{\text{no. oestrus diagnoses per false positive}}{\text{cost of P4 Rapid test strip}} \]. Considering that some oestrus diagnoses will still fail to yield an interpretable P4 Rapid result after the second test, the resulting calculation is an estimate of the minimum expenditure required to detect one false-positive oestrus diagnosis.

Collation of further results

Insemination dates, pregnancy testing results and P4 Rapid results for the 22 cows that recorded high progesterone test results and the 20 cows that had previously been diagnosed pregnant prior to sampling were collated. Statistical analysis was not attempted because of the small sample size for each group.

Descriptions of herds and summary of data

All participating farms were year-round calving Holstein herds from three dairy farming regions of New South Wales. Six of the study farms were located in the Illawarra region, five were located in the Lachlan Valley and three were located in close proximity to Sydney. Eleven of the herds were pasture-based or partial mixed ration herds and three of the herds were free-stall housed, total mixed ration herds. Milk yields ranged from 20 L/cow/day in herd 2 to 40 L/cow/day in herd 6. 75% of AIs sampled within the collection period ranged from 5.6% to 100% with a median of 66%. AIs not sampled included oestrus diagnoses that were inadvertently not sampled by the farmer as well as synchronised fixed-time AIs. In 10 of the herds, < 90% of AIs that occurred within the collection period were sampled, with 77% of AIs sampled in herd 3, 72% in herd 5, 75% in herd 6, 13.8% in herd 7, 63% in herd 9, 61% in herd 10, 34% in herd 11, 66% in herd 12, 14.7% in herd 11 and 5.6% in herd 12. The pregnancy per AI achieved for sampled AIs was notably different to the pregnancy per AI for the collection period in four of the herds. In herd 9 the pregnancy per AI for sampled AIs was 34.3% (vs 23.2% for the period), in herd 11 it was 35% (vs 26.9%), in herd 13 it was 43.2% (vs 19.8%) and in herd 14 it was 34.1% (vs 49.7%). These herds cannot be adequately assessed for selection bias as we do not know what percentage of unsampled inseminations were fixed-time AIs.

PPV of oestrus diagnosis

Table 1 shows the number of interpretable P4 Rapid results identified at each farm with the corresponding PPV of oestrus diagnosis and associated ORs. The PPV of oestrus diagnosis (and CI) reported for each farm in Table 1 can be interpreted as either back-transformed means or crude means, as the back-transformed mean and crude mean were the same for each of the 14 study farms. The ORs calculated are relative to herd 11 being the reference farm. PPV of oestrus diagnosis ranged from 0.889 (95%CI 0.517–0.997) in one of the study farms to 1.000 in four of the study farms. The crude pooled mean PPV of oestrus diagnosis was 0.970 (711/733) (95%CI 0.95–0.99). GLMM with logit link and binomial error distribution did not detect a difference in PPV of oestrus diagnosis between the 14 farms (P = 0.490) when farm was fitted as a fixed effect and cow nested within farm was fitted as a random effect, although the power was inadequate in the GLMM to confirm a lack of difference between farms. The ORs in Table 1 show that farms 8, 10, 12, 13 and 14 had significantly better odds of diagnosing oestrus accurately compared with herd 11. The intraclass correlation coefficient was 0.15 (95%CI 0.03–0.48, P = 0.009). Inclusion of the
21 invalid low progesterone results had little effect on the result and if excluded the crude pooled mean PPV becomes 0.9691 (95%CI 0.95–0.99).

Diagnostic sensitivity and specificity of the P4 Rapid assay for detecting a CL
Of the 81 cows in the CL group, 73 had a P4 Rapid result consistent with high milk progesterone and 8 had a P4 Rapid result consistent with low milk progesterone. The sensitivity of the P4 Rapid assay was 0.901 (95%CI 0.836–0.966) with standard error of 0.033.

Of the 75 cows in the non-CL group, 1 had a P4 Rapid result consistent with high milk progesterone and 74 had a P4 Rapid result consistent with low milk progesterone. The specificity of the P4 Rapid assay was 0.987 (95%CI 0.961–1.00) with standard error of 0.026.

The kappa statistic was 0.885 (95%CI 0.824–0.945), indicating a high degree of agreement between the ultrasound CL status and the P4 Rapid assay.

Calculation of the cost of detecting one false-positive oestrus diagnosis with routine use of the P4 Rapid assay for confirmation of oestrus
On average, one false-positive oestrus diagnosis per 33.3 tests is expected for a test with a PPV of oestrus diagnosis of 97%. At A$5 per test strip a farmer would expect to spend an average of A$166.66 for P4 Rapid test strips to detect one false-positive oestrus diagnosis. Considering that 75 of the 752 P4 Rapid test strips evaluated in the present study returned an invalid result and had to be retested, the adjusted minimum cost of detecting one false-positive oestrus diagnosis was an average of A$183.28 for oestrus diagnoses that led to a first-service insemination.

Cows with high progesterone P4 Rapid results
In this study, a total of 22 oestrus diagnoses recorded a high progesterone P4 Rapid result. For half of these (11/22) the cow was already pregnant at the time of sampling; 8 had already been diagnosed pregnant at a veterinary visit on an earlier date and 3 had not yet been pregnancy tested (all 3 ranging from 34 to 42 days pregnant at the time of sampling). All 11 cows were pregnancy tested again on a later date to verify that they were definitely pregnant on the day of the oestrus diagnosis. The 8 cows that had known pregnancy testing status were not rebred by the farmer, whereas the 3 cows with unknown pregnancy status were rebred by the farmer. Eight of the sampled pregnant cows belonged to one farm (farm 11) and one each of the remaining belonged to different farms (farms 4, 6 and 9).

The remaining half (11/22) of the cows diagnosed in oestrus that had a high progesterone result had no record of pregnancy prior to sampling. Considering that the sensitivity of the P4 Rapid assay is 0.901 (95%CI 0.836–0.966) it would be expected that most of these cows were either non-pregnant and in the luteal phase of the oestrous cycle or were pregnant at the time of oestrus diagnosis but underwent fetal loss before subsequent pregnancy testing was carried out. All 11 cows were bred by their owners and 1 cow conceived. The non-pregnant cows belonged to seven different farms (farms 3, 5, 7, 10, 11, 13 and 14).

Cows conceiving prior to sampling
In this study, 20 of the study cows diagnosed in oestrus had already conceived within the 6-month period prior to sampling. These cows either had a positive pregnancy diagnosis prior to oestrus diagnosis with no subsequent negative pregnancy diagnosis or did not have a pregnancy diagnosis recorded at the time of oestrus diagnosis but were later found to be pregnant at a stage of gestation consistent with low milk progesterone. The sensitivity of the P4 Rapid assay was 0.97 (95%CI 0.95–0.99).
with an insemination before oestrus diagnosis. Of these 20 cows 15 were reconfirmed pregnant following the oestrus diagnosis date and 5 were confirmed to have lost the pregnancy after the sampling date. Of the 15 pregnant cows, 11 (73.3%) recorded a high progesterone P4 Rapid result and 4 recorded a low progesterone P4 Rapid result. All 5 (100%) of the cows that lost the pregnancy recorded a low progesterone result. Of the 20 cows, 17 had farm records at the time of sampling that indicated they were already pregnant and were not rebred by the farmer at sample collection. The remaining 3 cows did not yet have any pregnancy testing records at the time of sampling and were rebred by the farmer; all remained pregnant to the earlier insemination.

In this study the P4 Rapid cow-side progesterone assay was shown to have a similar diagnostic sensitivity and specificity to other progesterone ELISAs reported in the literature. In this study the sensitivity was 0.901 (95%CI 0.836–0.966) and specificity was 0.987 (95%CI 0.961–1.00). In an evaluation of eight on-farm milk progesterone tests, sensitivities ranged from 74.8% to 85.6% and specificities from 89% to 98.9%. Milk progesterone data collected from pregnant cows and goats in 1991 can be used to demonstrate sensitivities for the detection of high milk progesterone of 88.2–90.5% in pregnant cows and 90.6–100% in pregnant goats. In both previous studies the ELISA results were compared against milk progesterone concentrations determined by radioimmunoassay, whereas in the present study CL status was used. Despite the difference in methods used, the sensitivities and specificities calculated in each study are similar.

The results of this study indicate that at A$5 per test, routine use of the P4 Rapid assay to test every oestrus diagnosis (and then AI those with a low progesterone result) would cost a minimum of A$183.28 for each false-positive oestrus diagnosis detected for oestrus diagnoses that result in a first insemination. Costs associated with the farmer’s time as well as oestrus diagnoses that fail to yield an interpretable result mean that the cost of detecting each false-positive oestrus diagnosis is actually greater than A$183.28. For first inseminations postpartum, the average farmer would need to be using straws of semen costing more than A$183.28 for routine testing of every diagnosed oestrus to be viable. With a specificity of 98.7%, blanket use of the assay to confirm oestrus in cows detected in heat would result in an average reduction in submission rate of 1.3%, which would translate into an additional cost. For oestrus diagnoses that lead to second or subsequent inseminations, calculation of the cost of using cow-side milk progesterone assays is more complicated. In cows that have already been previously bred, the ability to diagnose CL-positive cows (which may be pregnant) will help farmers to avoid inseminating cows that may already be pregnant, particularly in herds with a low PPV of oestrus diagnosis. Previous studies have estimated that 13% of re-inseminated pregnant cows will lose the fetus, although the extent of losses vary with the number of days since insemination. Weaver et al. found that cows inseminated to oestrus and then re-inseminated into the uterine body 12–24 days later had a pregnancy rate of 4% versus 40.6% for controls. Similarly Macmillan et al. found that inseminating non-oestrus cows 3–21 days after an insemination associated with oestrus resulted in a pregnancy rate of 24% versus 53% for controls. Sturman et al. similarly estimated that 49% of conceptuses are lost when pregnant non-oestrus cows are re-inseminated into the uterine body, but also found that up to 19% of pregnant cows were re-inseminated. This previous research indicates that a herd with a low PPV of oestrus diagnosis would benefit most from using a cow-side milk progesterone assay via the prevention of iatrogenic abortion and embryonic loss. The maximum cost-offset associated with preventing iatrogenic abortion could be calculated as: cost of [cost of an iatrogenic abortion] × (1–[PPV of oestrus diagnosis]) × 0.5, where previous studies show that the rate of iatrogenic conceptus loss is approximately 50% in cows less than 24 days pregnant. Considering that semen is rarely as expensive as A$183, routine testing of oestrus diagnoses that lead to a first insemination is not recommended from an economic perspective.
The study results demonstrate that farmers will benefit from strategic testing of milk progesterone levels in oestrus-diagnosed cows that have previously been recorded as pregnant by enabling farmers to clarify pregnancy status and to decide whether to rebreed the cow. With a specificity of 98.7%, most cows previously diagnosed pregnant that lose a pregnancy and return to oestrus will record a low progesterone result and so will be rebred. With a diagnostic sensitivity of 90.1%, 1 in 10 pregnant cows diagnosed as being in oestrus will still be rebred despite use of the assay. Farmers participating in this study chose not to rebreed oestrus-diagnosed cows previously found to be pregnant, because of the risk of iatrogenic abortion. Although the sensitivity of the assay is not perfect it does allow for the majority of pregnant cows diagnosed in oestrus to be identified, enabling farmers to rebreed non-pregnant oestrus-diagnosed cows, while reducing the risk of iatrogenic fetal loss in pregnant oestrus-diagnosed cows. Strategic use of the P4 Rapid assay will therefore help to increase submission rates by identifying non-pregnant cows previously thought to be pregnant, contrary to routine use for every diagnosed oestrus, which may slightly reduce submission rates. The imperfect sensitivity and specificity serve as a reminder that use of cow-side progesterone assays will not satisfactorily replace the need for these cows to be definitively pregnancy tested, but they are a useful same-day decision-making tool for farmers deciding whether to rebreed oestrus-diagnosed cows.

Another limitation of progesterone assays is the testing of anoestrous cows. An anoestrous cow does not have a CL and would therefore be expected to return a low progesterone result. If an anoestrous cow was erroneously diagnosed as being in oestrus, interpretation of such a result would lead to the cow being inseminated. Similarly, testing an oestrus diagnosis a few days either side of ovulation and after luteolysis may also return a low progesterone result, resulting in insemination away from the optimal breeding time.

The majority of high progesterone samples from pregnant cows came from herd 11. This farm had one of the lowest PPVs of oestrus diagnosis calculated in the study (89.8%), which appeared to show that herd 11 had more oestrus-diagnosed cows that were pregnant than on other farms. However, this observation can be better explained by herd 11’s unique staff structure. Oestrus diagnosis was carried out by milking staff, whereas AI was carried out by management. As a result, milking staff who did not have knowledge of the breeding history of individual cows were collecting milk samples from oestrus-diagnosed cows. On all other farms in the study, oestrus diagnosis and AI were carried out by the same personnel. Because participating farmers were instructed to collect samples from all cows inseminated during the study period, it is likely that farmers in these other herds observed oestrus behaviour in cows previously diagnosed pregnant, but chose not to sample or inseminate cows thought to be pregnant. It has been reported that up to 20% of second inseminations are in pregnant cows. It seems likely that observation by farmers of the return of pregnant cows to oestrus is more common than the data indicate. Some of these cows will be pregnant yet show signs of oestrus, whereas others will have experienced fetal loss and are truly in oestrus.

The difference in the way that the P4 Rapid assay was used in herd 11, as well as herd 11’s lower odds of diagnosing a true oestrus (vs herds 8, 10, 12, 13 and 14), serves as a reminder that the way a test is used can be open to human interpretation and can affect the PPV of oestrus diagnosis.

Of the 7.4% of milk samples that failed to yield an interpretable result (valid or invalid) on the initial test, 34% of the retested samples (19/56) yielded no interpretable result again on the second test. This suggests that an intrinsic property of the sample (e.g. viscosity) may have affected the number of failed and invalid tests.

Cow-side progesterone assays may also be beneficial to herd reproductive performance in other ways not investigated in this study. The manufacturer of the P4 Rapid assay advocates the use of cow-side milk progesterone assays 19–23 days post-insemination to enable the detection of low progesterone cows not diagnosed in oestrus by other means. One previous study found that 75% of phantom cows had high milk progesterone when return to oestrus was due, indicating that routine progesterone testing of potential phantom cows at 19–23 days may only detect a minority of eligible cows. Further research would be required to determine the extent to which a cow-side progesterone assay may help to increase oestrus diagnosis and submission in cows 19–23 days post-insemination.

Conclusions

There was a high PPV of oestrus diagnosis pooled across farms, indicating that heat detection accuracy was high across the 14 study farms. The P4 Rapid milk progesterone assay had a diagnostic sensitivity and specificity for detecting a CL that was consistent with the diagnostic sensitivities and specificities of other progesterone assays reported in the literature. Selective use of cow-side progesterone assays can improve reproductive performance by helping farmers to decide whether to rebreed oestrus-diagnosed cows that have already been diagnosed pregnant. Routine testing of all oestrous diagnoses associated with a first insemination is not economically warranted when the PPV of oestrus diagnosis is high and may even contribute to a slight decrease in the submission rate; however, use of this technology may help to prevent iatrogenic abortion and embryonic loss associated with second or subsequent inseminations on dairy farms that have a low PPV of oestrus diagnosis.

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References

BOOK REVIEW


Wildlife conservation in farm landscapes presents new scientific information about best practice ways to integrate conservation and agriculture in the temperate eucalypt woodland belt of eastern Australia. It is based on the large body of scientific literature in this field, as well as long-term studies at 790 permanent sites on over 290 farms extending throughout Victoria, New South Wales and south-east Queensland. Richly illustrated, with chapters on birds, mammals, reptiles, invertebrates and plants, this book illustrates how management interventions can promote nature conservation and what practices have the greatest benefit for biodiversity. Together the new insights in this book inform whole-of-farm planning.

A couple of things struck me when I first looked at this book. Firstly, I have never read, reviewed or seen a book dedicated to the taxpayer, a refreshing and welcome acknowledgement from the authors who have obviously received government support over a long period of time. Secondly, the images of the landscape, flora and fauna are stunning and add significantly to the impact of this volume. The ANU research team who contributed to this work has spent almost 17 years in Australian agricultural landscapes, especially in the temperate woodlands of southern NSW but also more recently in mixed grazing and cropping areas in north-east Victoria, central western and northern NSW, and south-east Queensland.

Written in a style that makes the content easy to understand, the information is well-ordered, current and comprehensive. Although much new research has been published in the peer-reviewed scientific literature, the authors recognise that very few of these articles will reach a wider readership. It is important to communicate this information to a far broader audience than scientists. This book is specifically targeted to farmers, catchment managers and revegetation practitioners; however, anyone interested in conservation, the environment and sustainable farming practices will be interested in this work.

A lot of new findings have emerged in the past 5 years from numerous projects in Australia’s wheat/sheep belt. These findings have revealed that many things can be done to conserve wildlife while at the same time maintaining other key aspects of farm productivity and profitability.

The authors’ objective was to report new findings that build significantly on their past work and in so doing, “hoped to empower all of those people in rural Australia in their efforts to meet the significant (but not insurmountable) challenges of integrating conservation with ecologically sustainable agricultural production.” I thoroughly enjoyed reading this book.

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