Relationships between cropping and livestock on mixed farms in southern Australia.

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Introduction

Spedding (1) defined a system as "a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks." Spedding also outlined the nature of Western mixed farming systems and their development to operate in market-economies.

An optimizing bioeconomic model of a mixed farm at Merredin, in the eastern wheatbelt of Western Australia, has been reported briefly (2) and in detail (3). Ewing and Pannell used the model to explore the likely benefits from research on pastures for the eastern wheatbelt, and Ewing decided to continue to focus his agronomic effort on pastures for "medium soil" where a 15 percent increase in production of pasture would make the model select a rotation that included pasture; whereas a 60 percent increase in production would be needed to displace lupin-wheat rotations on "good light land" (4).

This paper aims to review the main recognized biological interrelationships between the cropping and the "livestock and pasture" enterprises in mixed farming systems in Western Australia. The approach will be to outline the combined effects of the interrelationships that are easy to "switch off" in the models; to point out how sensitive the models are to different judgements about "soft" information, that is, information that is not definite; to report briefly the separate effects on farm profits of the nitrogen fixation and disease-break effects of pastures and of lupin crops on cereals; and to report in more detail, the biological as well as the business-effects of relationships that affect feed-budgets for sheep: the grazing of cereal and lupin stubbles, the value of extra pasture at different times of year, and the expected effects of cropping on pastures. Some other modifying factors will be mentioned in passing, to help recognize the extent to which other variables modify the effects of these inter-relationships.

The combined effects of inter-relationships.

Figure 1 shows some effects on whole-farm profits, of calculating with or without inter-relationships which it is easy to "switch off" in these models, namely:

- The effects on cereals of nitrogen fixed by pastures or by lupins.
- The effects on cereals of disease-break and other yield-boosting effects of pastures or of lupins.
- The effects on livestock and on the use of pasture, of grazing stubbles.
- The effects of cropping on growth by pasture.

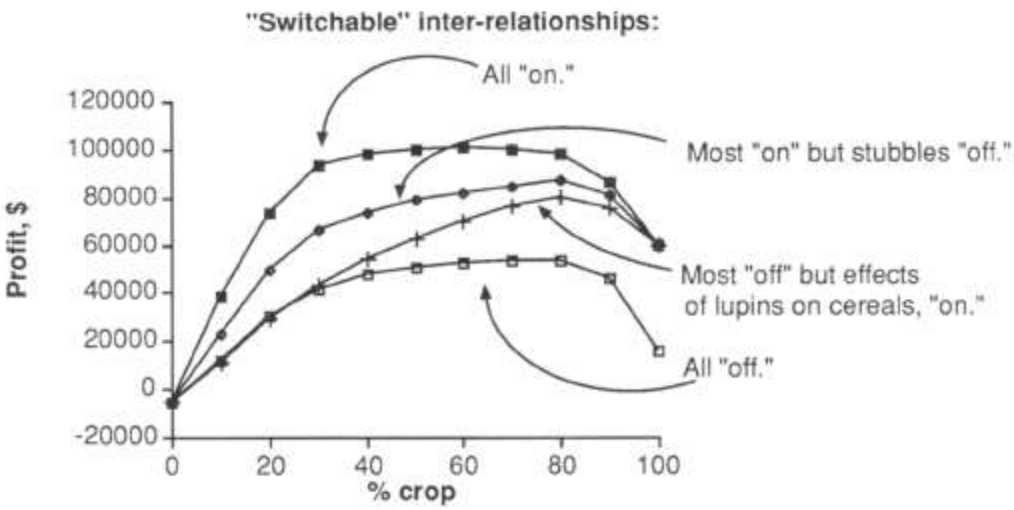

Figure 1. The overall effects, and selected individual effects, of the inter-relationships which it is easy to "switch off" in these models, on profits from a model of a farm in the Wickepin-Corrigin region at 1989 prices.

Each line in figure 1 was calculated by running the model eleven times, calculating optimal programmes for the farm if constrained to grow crops on 0, 10, 20, 30, ..… , or 100 percent of the arable area. With all the easily-switched relationships "on" (the top line), the models calculate far more profit than with all "off" (the bottom line). Either line indicates that about equal profits can be got from blends of cropping and grazing between 40 and 80 percent crop, provided that the right rotations are chosen on each soil.

The middle lines in figure 1 show selected examples of budgets that recognize some important inter-relationships but not all. Accounting for the effects of lupins on cereals while not accounting for any of the other "switchable" inter-relationships, would strongly encourage much heavier cropping. Omitting the effects of stubbles, similarly, would make budgets favour heavier cropping. This supports Pannell's conclusion in reference 3, that interactions influence analyses of profitabilities of mixed farms in Western Australia, and should be recognized in such analyses.

Many other inter-relationships which these models recognize, are defined in ways that do not allow easy "switching off" to check their individual effects. These include:

- technical facts like the disease-break effects of cereals on lupins, and effects of soil-types on growth by crops and by pastures;
- financial facts like effects of different buying and selling dates on cash-flows;
- and operational and machinery-utilization facts such as the way herbicides are used in current wheat-lupin rotations to manage weeds in this sub-system.

The differences in managing weeds mean that peak periods for labour and tractor-hours at seeding time, are often earlier for the wheat-lupin rotation than for most of the potential pasture-cereal rotations. Spedding's chapter 10 quotes more elaborate examples of how labour-peaks and other "details," have influenced the development of blends of enterprises in mixed farming systems in Britain (1).

Sensitivity to "soft information" - an example.

The low profit from 100 percent pasture (i.e. 0 % crop) in figure

despite assuming a return of 550 cents per kilogram of greasy wool, needs explanation. The local group of farmers who advise on many facts and relationships, judge that permanent annual pastures (PPPP) are less productive than third year pasture in CPPP rotations: 35 percent less productive on sandier soils (soils 1,

3) and 20 percent less productive on heavier soils (soils 4, 5, 6). If these farmers are to take any notice of the model, it should calculate the implications of what these farmers know or believe (5).

Figure 2 shows some of the implications for different people: the lower, middle or upper lines show implications for those who expect PPPP to be less productive, as the committee believes; or as productive; or 15 percent more productive; than third year pasture in a CPPP rotation. The model's calculations of maximal profits, and its allocation of soils to rotations, are sensitive to this judgement. Changing the assumed productivity of PPPP makes the model avoid or select PPPP, and so forces the selection of other, different, rotations to optimize the overall programme.

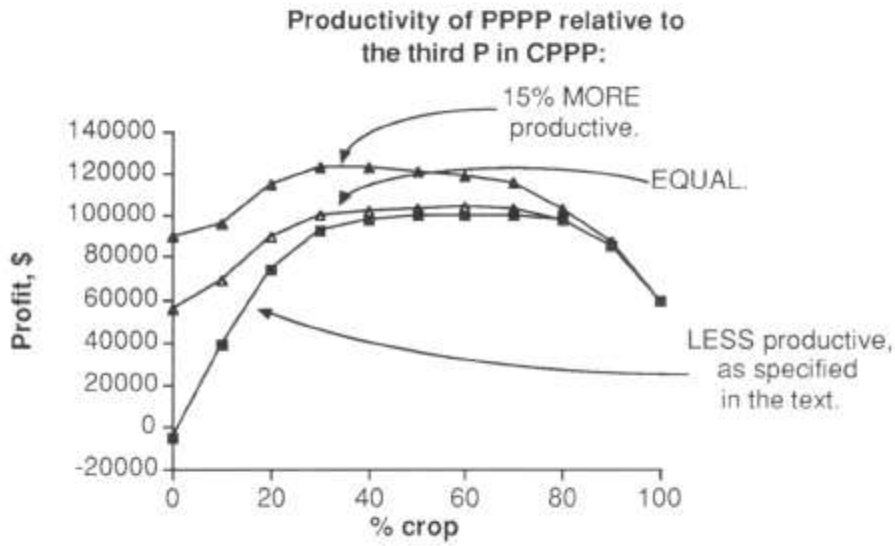

Figure 2. The effects of judgements or assumptions about a piece of "soft information:" the relative productivity of permanent annual pastures.

Numerical outputs from the models include shadow costs of unselected options. These are like opportunity costs and distinguish options that were almost selected from those that were rigorously avoided (see reference 3, page 71; and for technical details, pages 58-59).

Figure 2 does not directly help decision-makers to judge which assumption to accept, but such sensitivity testing can help them and their advisers to recognize which items of soft information warrant more effort to clarify or to define. Models and real systems are often insensitive to changed assumptions about some soft information but very sensitive to changed assumptions about other information. The soft information that the model and hopefully the real system, are more sensitive to, is the information which most needs clarifying.

Budgeters and other modellers should build models that allow users to change soft information easily and be able to see the calculated effects; that is, to be able to run sensitivity tests. Inevitably, critical managerial questions involve items of soft information as well as hard information (5). This applies as much to scientists' decisions about their personal priorities for their work (e.g. 4), as to farmers' decisions about managing farms. Easy sensitivity testing is similarly helpful in "purely scientific" models when the inputs are not completely "hard" information.

Figure 2 also illustrates a more fundamental truth: useful analysis of systems has always needed at least a small core of hard information about facts to which the real systems are particularly sensitive (e.g. 6, 7, 8) In the example in figure 2, a question which looked peripheral, is probably very important.

The effects of legumes on yields of cereal crops.

Rowland, Halse and Fitzpatrick reviewed the roles of legumes in Australian dryland farming systems (9). Successive years of leguminous pasture increase soil nitrogen content and improve soil structure, and increase yields of cereal crops. Successive cereal crops after pasture, reduce soil nitrogen, break down soil structure, and reduce yields of cereals (9, 10). Rowland et alia also reviewed the early evidence that lupins would be as useful as legume-based pastures, or better. This has been confirmed experimentally (e.g. 11) and farmers have been adopting lupins quickly (e.g. Ewing, Pannell and James in reference 3).

"Switching off" the effects on cereals of fixation of nitrogen by pastures or by lupins, reduced profits by only about $10,000 over most of the range of percentage crop (figure 3). However when disease-break effects of lupins or pasture on yields of cereals and the effects of nitrogen fixation are both omitted, calculated profits are $30,000 lower between 30 and 90 percent crop. The $10,000 or so of extra profit due to the effects on cereals, of fixation of nitrogen, is about the same as reported for a model of a farm at Merredin (2). The Wickepin-Corrigin model, for a wetter part of the wheatbelt, carries more sheep; and the price of wool has risen; so a $10,000 effect of nitrogen-fixation on cereals is proportionately less prominent. The disease-break effects of lupins on cereals have relatively larger implications, in line with the assumptions fed into the model.

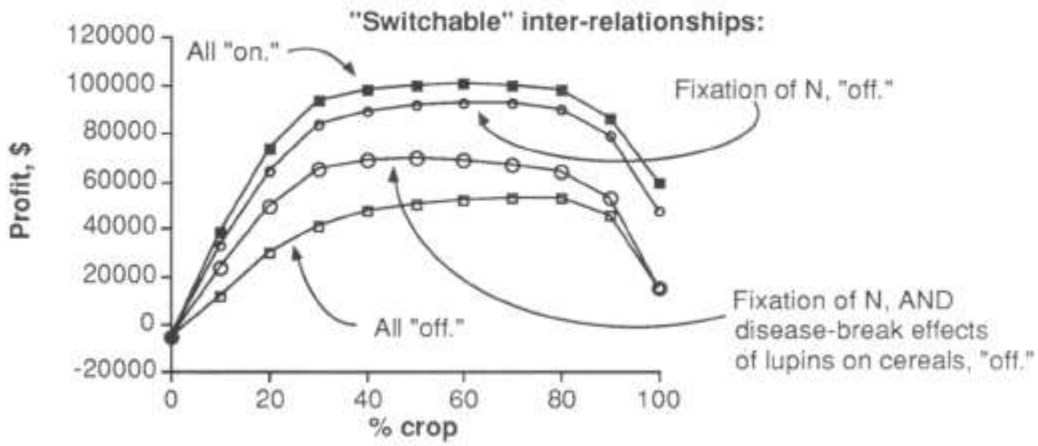

Figure 3. The effects on calculated maximal profits of the inter-relationships that are easy to switch on or off, in a model of a farm in the Wickepin-Corrigin region at 1989 prices.

A digression: how the models simplify feed-budgets.

Models are simplified versions of actual systems. The simplifications in the present optimizing models include limits to the grazing of green feed when it is scarce, a linear regression to estimate the feedback-effects of stocking rate on pasture growth, a pre-set pattern of liveweight through the year for each class of sheep, and calculation of feed-budgets in monthly steps. These and other simplifications make the feed-budgets cruder than animal specialists or pasture physiologists would like. Despite these and other simplifications, the models appear far more convincing than previous formal budgets, as descriptions of farms and farm-businesses.

A model being developed for the Kojonup district will use more elaborate feed-budgets to recognize the feedback-effects of grazing on current growth when green material is scarce. It will also let liveweights of sheep respond to differences in quality or quantity of feed by switching to one of several alternative preset patterns of liveweights (Young, unpublished). This more elaborate model should estimate more realistic stocking rates, levels of animal production, and marginal values for paddock-feed.

Stubbles for grazing animals.

Cereal stubbles.

In New South Wales and the A.C.T. where summer rains are common , the green bite in stubble paddocks is an important part of the diets of sheep (12, 13, 14). At Esperance in Western Australia, the green bite in stubble-paddocks seems to overcome weaner problems of sheep on mixed farms (15).

Rain in summer is less usual in the Western Australian wheatbelt. Even with no visible green bite, cereal stubbles provide useful feed for sheep (16, 17, 18). In two years, comparing the liveweights of sheep in stubble experiments and in an adjacent experiment on pastures, suggested that sheep on stubble grazed feed of broadly similar value to sheep on pasture (16).

Cereal stubbles can relieve grazing pressures on annual pastures in summer, so they should make it feasible to use more of the pasture during the growing season; that is, to increase the carrying capacities of farms "per winter-grazed hectare."

Lupin stubbles.

Lupin stubbles also can provide abundant feed in summer, but their use has depended on the sheep-disease, lupinosis (19). New cultivars of lupins reduce the risk or the severity of lupinosis and will make lupin-stubbles more reliable as a source of feed (20). Their quality as feed will still vary with the amount of grain left after harvesting (21); this amount is variable and often large.

Implications of stubble-grazing for farm-businesses.

Logic and simple feed-budgets suggest the value of extra stubble will decline as the quantity of stubble increases. The difference between the top line in figure 1, and the "stubbles excluded" line, shows the effects of recognizing or not recognizing the effects of stubbles, on expected profits. As Morrison et alia (2, their page 263) wrote, the inclusion of stubbles explained the closeness of profits at 60, 70 and 80 percent cropping in their Merredin model at 1985 prices. It contributed to the umbrella shape of the complete model's graphs by raising profits most at intermediate levels of cropping and less at the extremes. This is also the case for the Wickepin-Corrigin model at 1989 prices.

On Western Australian mixed farms the value of stubbles in general is high because of the effects of using stubbles on the use of pastures. The models calculate the effects of stubbles on feed-budgets, and without stubbles, fewer sheep could be carried through the growing season. The first 360 kg of stubble per "dry sheep equivalent," (cereal plus lupin stubbles, totalled) are worth $14 per tonne on average, but extra stubble will hardly affect profits. Figure 4 shows the marginal values of cereal and lupin stubbles in the Wickepin-Corrigin model at 1989 prices. These runs of the model assumed that lupinosis permits use of lupin stubbles in early summer but not in late summer. An extra tonne of stubble was worth $20 or more if the model farm grew crops on less than 10 percent of its arable area; but if 40 percent of the farm was cropped, an extra tonne of cereal stubble was worth only $1.70 and an extra tonne of lupin stubble was worth nothing.

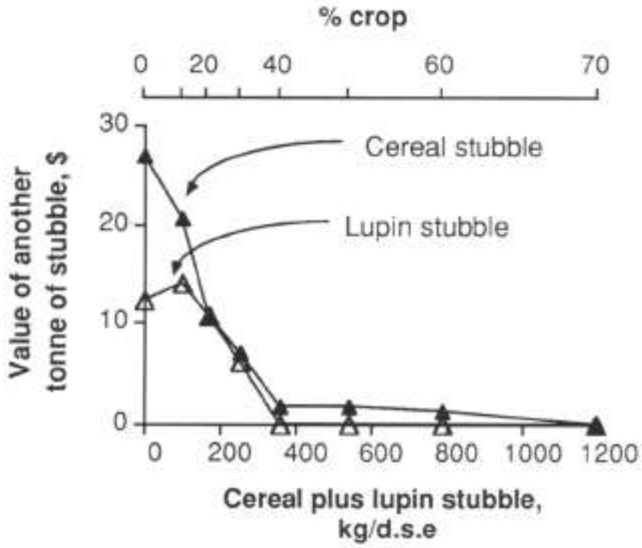

Figure 4. The values of EXTRA cereal or lupin stubble on a farm with different amounts of stubble already.

The effects of stubbles on budgets are much greater here than in the Merredin model at 1985 prices, perhaps because of the greater productivity of pasture in the Wickepin-Corrigin model and the higher price for wool.

Warren, Allen and Cowling assessed the economic impact of a new cultivar which resists the fungi which cause lupinosis (22). Experimental sheep grew better on the new cultivar, and it is clear that it reduces the risk of death or ill-thrift due to lupinosis. However the present models assume preset patterns of liveweight change, and were not run with an assumption about lower death-rates. Without these other effects, a model of a farm between Wickepin and Corrigin made some $3,000 more profit before tax (i.e. about 3 per cent more profit) by growing Gungurru lupins instead of Danja lupins. The new cultivar reduced the need to feed grain in March for ewes that lamb in May. Presumably it would be worth more for ewes that lamb in April, and more still in a model that let sheep respond to better feed by changing to another pattern of liveweight.

The value of early green feed.

Extra pasture is worth little when feed is not scarce, but can be highly valuable when feed is scarce. Feed-budgets that summarize data from stocking-rate experiments on dense pastures (with no stubbles) usually recognize shortages of dry feed in late summer and autumn at higher grazing pressures, and shortages of green feed in autumn and early winter; or perhaps late winter in some regions. Adjusting these feed-budgets to allow for stubbles on 20 or 30 percent of the area or more, suggests little chance of running out of low quality paddock-feed for sheep in summer or autumn. The adjusted feed-budgets permit at least slightly higher stocking rates per winter-grazed-hectare and usually suggest that green feed will be scarcer (per sheep) as soon as crop-paddocks are cultivated or sprayed. This applies even if cropping does not affect production of pasture.

The optimizing models calculate feed-budgets in more detail and show high values for extra green feed early in the season (Morrison, pers. comm.; also reference 23). Table 1 shows the values of extra edible green material in each month of the growing season, in models of farms in the Wongan Hills district when constrained to find optimal systems with different proportions of the farm in crop. Presumably omitting stubbles would have modified the marginal values of pastures in some months.

<u>Table 1.</u> Values of extra edible green material, cents per kilogram, with different proportions of the farm in crop. From D.A.Morrison, pers. comm.

Crop, %	May	June	July	Aug.	Sept.	October
10	17.2	2.1	2.1	2.1	2.1	2.1
30	17	2.3	2.3	2.3	2.3	2.3
50	15.5	7.7	7.7	1.1	1.1	1.1
70	15.2	11.8	11.8	0.1	0.1	0.1
90	14.9	12.4	12.4	0	0	0

The models estimate how many sheep to carry for the year, to maximize profit. They often feed grain when feed is scarce in order to carry more sheep for the whole year, as well as to support the pre-determined patterns of liveweights. As a first approximation, when paddock-feed is so scarce that the models feed grain, an extra kilogram of green feed is worth about as much as a kilogram of extra saleable grain. Slightly lower values in May reflect intake constraints because green bites are mixed with rotting dry feed (24).

The zero values reflect non-use of any extra paddock-feed produced at those times on farms with crop on 90 percent of their arable area. The values between zero and 2.3 c/kg in the table reflect the use of this extra pasture after it dries, not within the growing season. Its value is the value of extra dry feed later, including dry pasture eaten after pastures senesce but before stubbles become available. The values between 7.7 and 12.4 c/kg in June and July, with 50 to 90 percent of the arable area cropped, reflect the use of any extra paddock-feed then to carry more sheep. However the carrying of extra sheep is conditional upon feeding grain to the extra sheep throughout May; so extra paddock feed in June or July on these farms, is worth less than it would be worth in May.

These figures are based upon oversimplifications, but appear to be broadly valid.

The spreadsheet model mentioned below, suggests that permanent annual pastures (PPPP) at Merredin grow more early feed than the Merredin committee expected; this let the model carry 50 percent more sheep and make 72 percent more profit, without changing rotations.

A promising way to avoid severe shortage of feed in winter and to use salty land ,that is not suitable for cropping, is to establish salt-tolerant shrubs which can be grazed hard for a month or two near the start of the growing season (25). Simple feed-budgets showed the general implications, and variants of the optimizing model showed in detail how grazing these shrubs at the start of the growing season can make them extremely profitable by letting the farm carry more sheep without the need for handfeeding (26, 27).

The effects of cropping on pastures.

In Victoria it has been accepted that cropping often reduces carrying capacities of pastures in the year after cropping (28, 29) but in Western Australia the usual belief through the 1970's was that cropping did not affect growth by pastures (e.g. 30).

Crops grown with normal control of weeds, tend to reduce or prevent production of seeds by non-crop species. When pastures regenerate after cropping, the densities of most species are usually lower than before the crop, although weedy crops sometimes increase the densities of the main weed species (31). Other things being equal, lower densities mean less growth early in the season (32); and grazing exaggerates the effects of low densities (32). A spreadsheet-model has been developed to examine the expected effects of cropping on seasonal growth of pastures, including the effects of density and the effects of soil-nitrogen status on growth by non-legume components. It suggests that cropping usually reduces early growth in the year after cropping, and to a lesser extent in the second year after cropping (31).

The particular outcome is modified by grazing or other defoliation (33, 34) and varies between years, e.g. with dates of the opening rains (or dates of planting experimental plots, 35). In some years, sparseness helps early seedlings survive autumn-droughts if they are not grazed hard, whereas denser early seedlings often die .of drought even if not grazed. After the real opening rains the sparse large plants will sometimes grow about as much per hectare per day as denser new seedlings in other paddocks where the dense early seedlings did not survive through autumn.

Most users of the optimizing models have accepted the suggestion that cropping usually reduces early growth by pastures. However the models have at least three reasons to avoid cereal-pasture rotations: higher assumed costs to control weeds; the calculated high profitability of the cereal-lupin rotations; and the assumed harmful effects of cropping on early growth by pastures. Therefore the models usually select more PPPP than pasture in rotations with cereals; so in optimal solutions of the models, the calculated effects of cropping on seasonal growth by pasture are not very important.

However the effects of cropping on seasonal growth would be more important in the models, and presumably on farms, if they include cereal-pasture rotations and no permanent annual pasture. To reduce those effects, and to develop opportunities for pasture-cereal rotations to approach the profitability of cereal-lupin rotations, it is reasonable to seek technical opportunities to reduce the harmful effects of cropping on pastures. In principle, delayed or lenient grazing of sparse pastures after cropping should usually help them catch up with denser pastures that have been setstocked (34, 36, 37). Other important partial solutions will be to use or to develop pasture-legumes that regenerate better after cropping. They will reduce the harmful effects of cropping on seasonal growth, partly by increasing overall density and partly by reducing the regenerating pastures' reliance on depleted soil-nitrogen. They may also increase the fixation of nitrogen for non-leguminous components in later years, and for cereals.

Almost all runs of the optimizing models reported so far, used committees' assessments of the effects of cropping on pastures. The spreadsheet-model suggests more severe effects, but these did not affect the Merredin farm-model's choice of rotations: using either the committee's or the spreadsheet's estimates of pasture-growth, the model avoided cereal-pasture rotations and chose cereal-lupin rotations and permanent pastures (Young and Fels, unpublished).

Conclusions.

inter-relationships influence analyses of profitabilities of mixed farms in Western Australia, and should be recognized in budgets and in other models. This applies even to scientists' decisions about their personal priorities for their work. Ewing and Pannell (4) demonstrated that optimizing models of whole farms can help biological researchers to explore the benefits they may expect from their own research.

Useful analysis of systems has always needed at least a small core of hard information about facts that the real systems are particularly sensitive to. It also needs models that are easily adjusted for sensitivity analysis. Many scientists may have preferred their own conceptual models and sums on the backs of envelopes, rather than formal models in "black boxes," because their simpler models let them test for sensitivity more easily. A compromise is for modellers to develop models with scope for easy sensitivity testing of inputs that others may regard as "soft" information.

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