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A Spatial Equilibrium Analysis of the Queensland Kangaroo Industry: An Examination of Harvest Off-Take Rates

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Abstract

Both State and Federal governments are keen to foster the development of new industries. Recently the harvesting of kangaroos for human consumption has emerged as a potential industry with important social, economic and conservation benefits. In order to satisfy the increasing consumer demand for kangaroo meat, the kangaroo industry needs to expand its infra-structure in terms of the number and location of harvesters, and storage and processing facilities. Using spatial equilibrium modelling theory this paper identifies the potential infra-structure of the Queensland Kangaroo Harvesting Industry resulting from changes in the harvest off-take rate.

INTRODUCTION

For decades property managers in the rangelands have relied solely on their sheep and cattle operations for income. Harrington *et al.* (1984) stated that the mulgalands of Queensland and New South Wales carried mainly merino sheep at a stocking rate of 0.2 to 0.5 animals / ha. Within the same area the kangaroo population has been estimated at 0.2 animals / ha (Caughley and Grigg 1982) to 0.3 animals / ha (Short and Bayliss 1985); and Sattler (1995) stated that the Queensland mulgalands supported approximately 4.3 million sheep and over 4 million kangaroos. A report by Queensland Department of Primary Industries (1994) highlights the financial burden many land owners face in the Queensland rangelands.

A possible solution for many land managers is to harvest the kangaroos present on their properties. Several researchers have investigated the potential economics of kangaroo harvesting at the property level. Both Alchin (1995) and Switala (1997) have examined in detail the financial returns derived from kangaroo harvesting to the land owner within the mulgalands of Queensland. A paper by Peter Hardman (1997) provides further discussion and financial analysis on the economics of kangaroo harvesting at the property level. Young and Wilson (1995) examined the economics of kangaroo harvesting at the property level within the rangelands of New South Wales. However, to entice businesses and governments to develop the kangaroo harvesting industry, some indication of the industry's potential size and value is required. A paper by Switala (1995) identified the potential quantity and value of kangaroo meat that can be produced at state and national levels.

More information is required in Queensland as to where kangaroos can and should be harvested, how many harvesters will be required, where processing facilities should be located, and how many personnel will be employed processing kangaroo meat when a market for kangaroo meat for human consumption develops?

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This paper provides some answers to these questions, and goes further to investigate the effects of harvest off-take rates. In general, quotas have been set at 10 to 20% (Pople and Cairns 1995). According to the logistic population growth model as used by Caughley (1987), the maximum sustainable yield is somewhere between 10 and 15%. Using a similar model, Pople and Cairns (1995) state that the maximum sustainable yield is in fact closer to 20%. In Queensland, the annual quota has been set at 15%, which some advocate is too high. However, in the short term, a harvest off-take rate above 15% may well be advisable to reduce kangaroo populations and therefore reduce total grazing pressure as many rangeland areas are overgrazed. In order to investigate the economics of various off-take percentages on the structure of the Queensland kangaroo harvesting industry, we provide results for harvesting rates of 10%, 12.5%, 15%, and 17.5%.

METHODOLOGY

The basis of the spatial equilibrium model to be applied to the Queensland kangaroo industry is that as developed by Takayama and Judge (1971). The model consists of maximising a quadratic objective function subject to a range of linear constraints, as developed by Takayama and Judge (1964a, b, c), and later applied by Takayama (1979). The model is a standard transshipment model with multiple supply regions, storage/collection points, processing points, and fixed demand points for processed kangaroo meat / consumption.

Advances in computer software allow much more complex programming. This study utilises these advances by incorporating a demand function with constant elasticity, reflecting a more realistic situation for the potential demand for kangaroo meat. Equations 1 to 9 below illustrates the formulation of the spatial equilibrium model used to examine the Queensland kangaroo harvesting industry.

Maximise

$$\left\{ \sum_k \left(\frac{P_k}{Q_k} \right) \left(\frac{b}{b-1} \right) (M_k^{b-1}) \right\} - \sum_i T_i^H C_i - \sum_i T_i^S C_i -$$

$$\sum_i \sum_j T_{ij}^R C_{ij} - \sum_i \sum_j T_{jm}^P M_j - \sum_j \sum_k T_{jk}^F M_{jk} \quad (1)$$

Subject to

$$\sum_i C_i < \sum_i L_i, \quad (2)$$

$$\sum_j C_{ij} > \sum_j M_j R_i^A \quad (3)$$

$$\sum_j M_j > \sum_j M_{jk} \quad (4)$$

$$\sum_j M_j < A_j \quad (5)$$

$$\sum_k M_{jk} < \sum_k M_k \quad (6)$$

$$\sum_i E_i^H = \sum_i C_i R_i^H \quad (7)$$

$$\sum_i E_i^C = \sum_i C_i R_i^C \quad (8)$$

$$\sum_i E_i^P = \sum_i M_j R_{jm}^D \quad (9)$$

Where

k = demand regions for processed kangaroo meat, $k = 1, 2, 3$.

j = processing regions, $j = 1, 2, \dots, 21$,

i = supply regions, $i = 1, 2, \dots, 43$,

m = processing plants, m = small, medium, large,

P_k = price point estimate in demand region k ,

Q_k = quantity point estimate in demand region k ,

b = own price elasticity,

L_i = maximum number of kangaroos available for harvest in region i ,

C_i = number of kangaroo carcasses harvested and stored in region i ,

C_{ij} = number of kangaroo carcasses transported from harvest region i to processing region j ,

M_{jk} = quantity of processed kangaroo meat transported from processing region j to demand region k ,

M_j = quantity of kangaroo meat processed by the j^{th} region,

M_k = quantity of processed kangaroo meat demanded by the k^{th} region,

A_j = processing capacity of region j ,

R_i^H = conversion coefficient for processing kangaroo carcasses into boneless meat,

R_i^B = conversion coefficient determining the number of harvestors required,

R_i^C = conversion coefficient determining the number of chiller boxes required,

R_{jm}^D = conversion coefficient determining the number of personnel required in processing plants m ,

T_i^H = per unit harvest cost for kangaroo carcasses,

T_i^S = per unit storage cost for kangaroo carcasses,

T_{ij}^R = per unit transport cost for kangaroo carcasses from harvest region i to processing region j ,

T_{jm}^P = per unit processing cost for small, medium or large processing facilities.

- T_{jk}^F = per unit transport cost for processed kangaroo meat from processing region j to demand region k ,
 E_i^H = number of harvestors required in harvest region i ,
 E_i^C = number of chiller boxes required in harvest region i ,
 E_i^P = number of personnel required in processing plants.

A total of 43 Shires within Queensland were identified as having commercially harvestable populations of kangaroos. Using past harvest records obtained from Gilroy (1996), and kangaroo population density maps prepared by Carter (1996), available kangaroo numbers for each Shire were estimated and imposed into the model as upper limits.

Harvest costs were based on projections made by Alchin (1995) and Switala (1997). Storage and processing costs were derived from real field data and synthetic model constructs, and validated against values identified by Hardman (1996).

The demand function is based on a projected annual per capita consumption of 3 kg. In comparison, the annual per capita consumption in Australia during 1990-91 for beef was 39.2 kg, lamb 14.1, pig meat 18.0 kg, and poultry 25.4 kg (ABS 1993).

As with per capita consumption, no information on the own price elasticity for kangaroo meat is available. A projected own price elasticity of -1.5 was utilised as the elasticity for kangaroo meat. Several authors investigating the Australian market including Gruen *et al.* (1968), Main *et al.* (1976), Fisher (1979), Murray (1984), Martin and Porter (1985), and Ball and Dewbre (1989), have identified the own price elasticity's for beef at -0.953 to -1.95, lamb at -1.131 to -1.89, and pork at -0.95 to -2.19.

RESULTS

Figures 1 to 4 graphically present the structure of the Queensland kangaroo harvesting industry under harvest off-take rates of 10%, 12.5%, 15%, and 17.5%. Table 1 provides a summary of key parameters including quantity and value of kangaroo meat produced, and the total number of personnel employed.

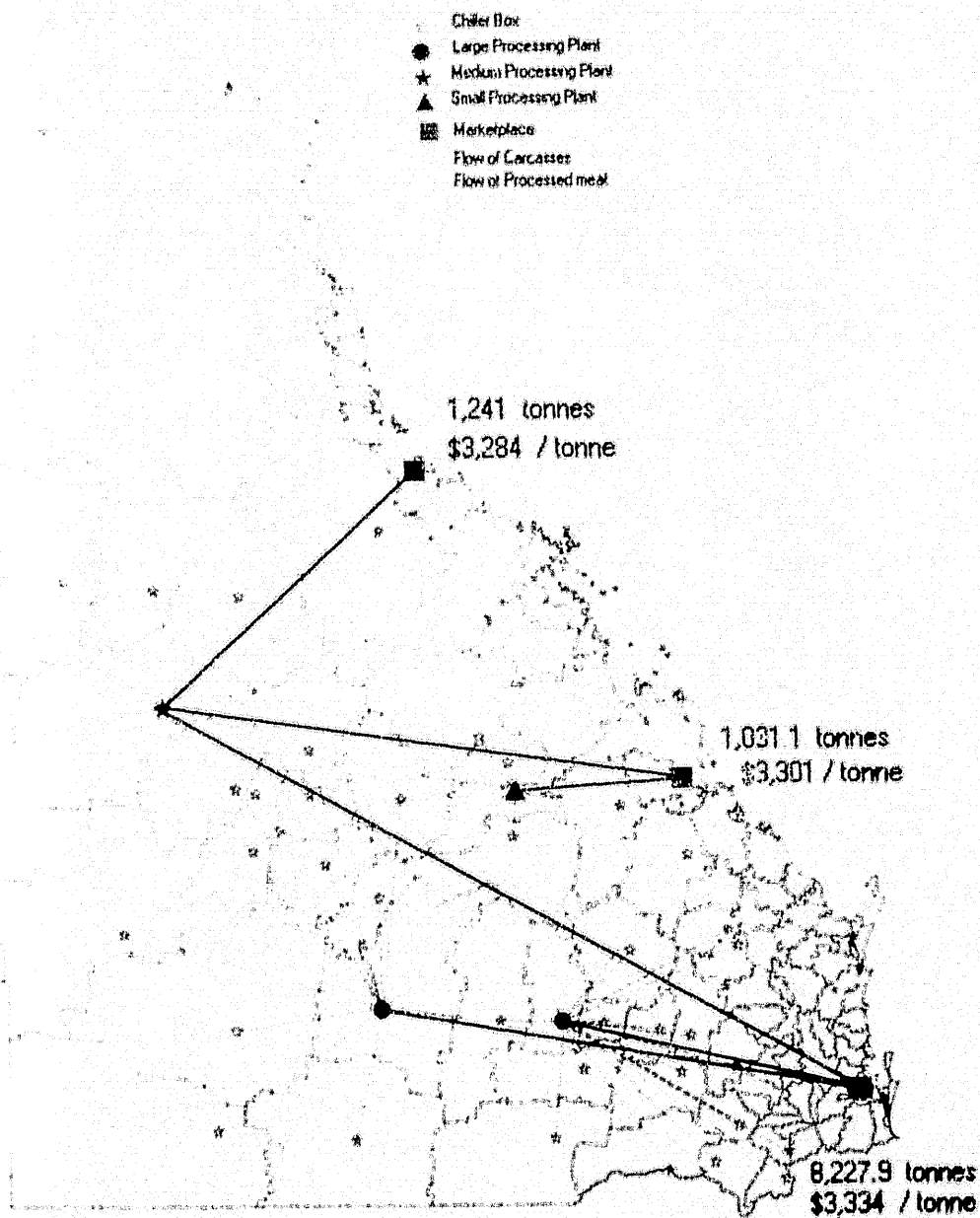


Figure 1 Structure of the Queensland Kangaroo Industry under a 10% harvest off-take rate

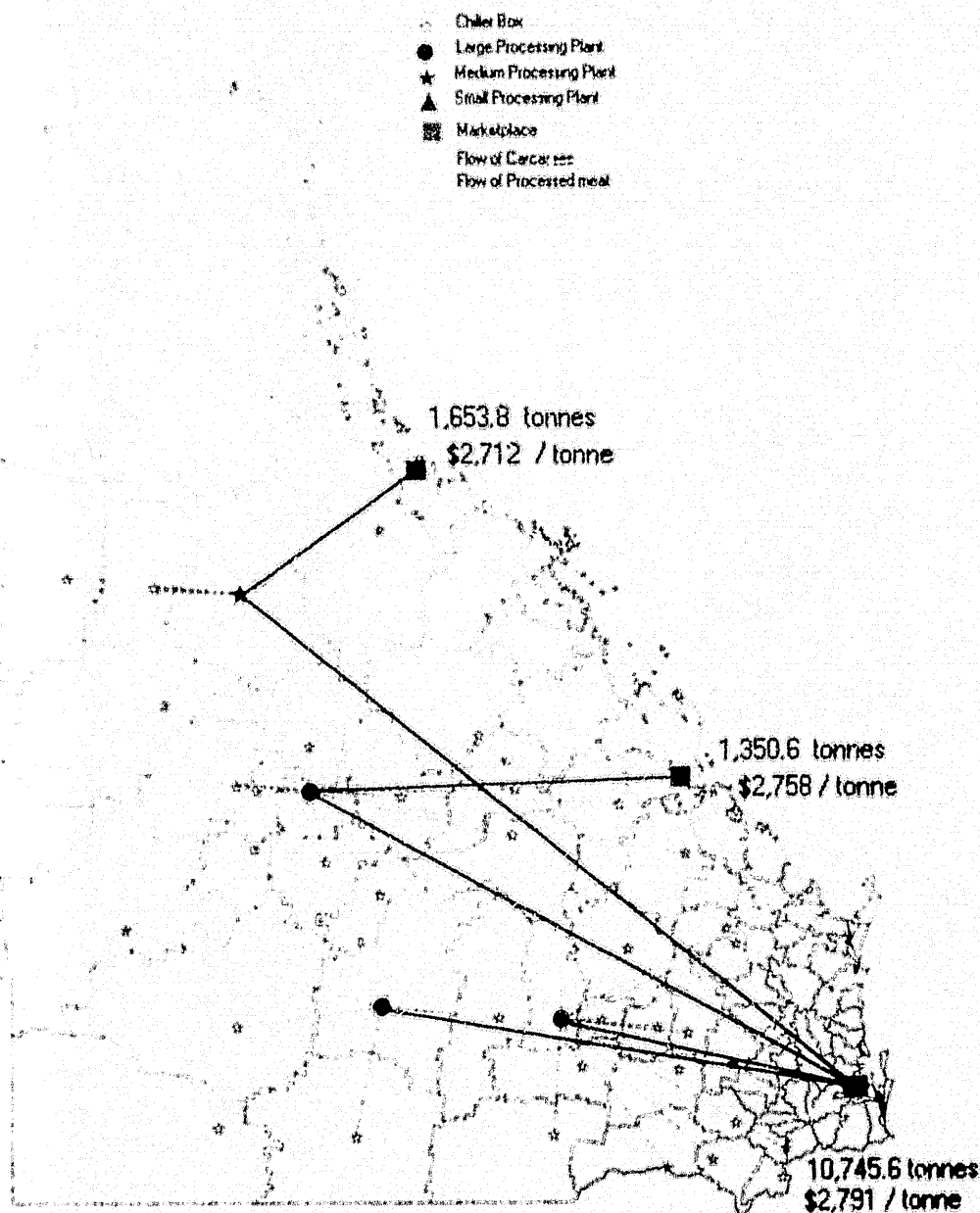


Figure 2 Structure of the Queensland Kangaroo Industry under a 12.5 % harvest off-take rate

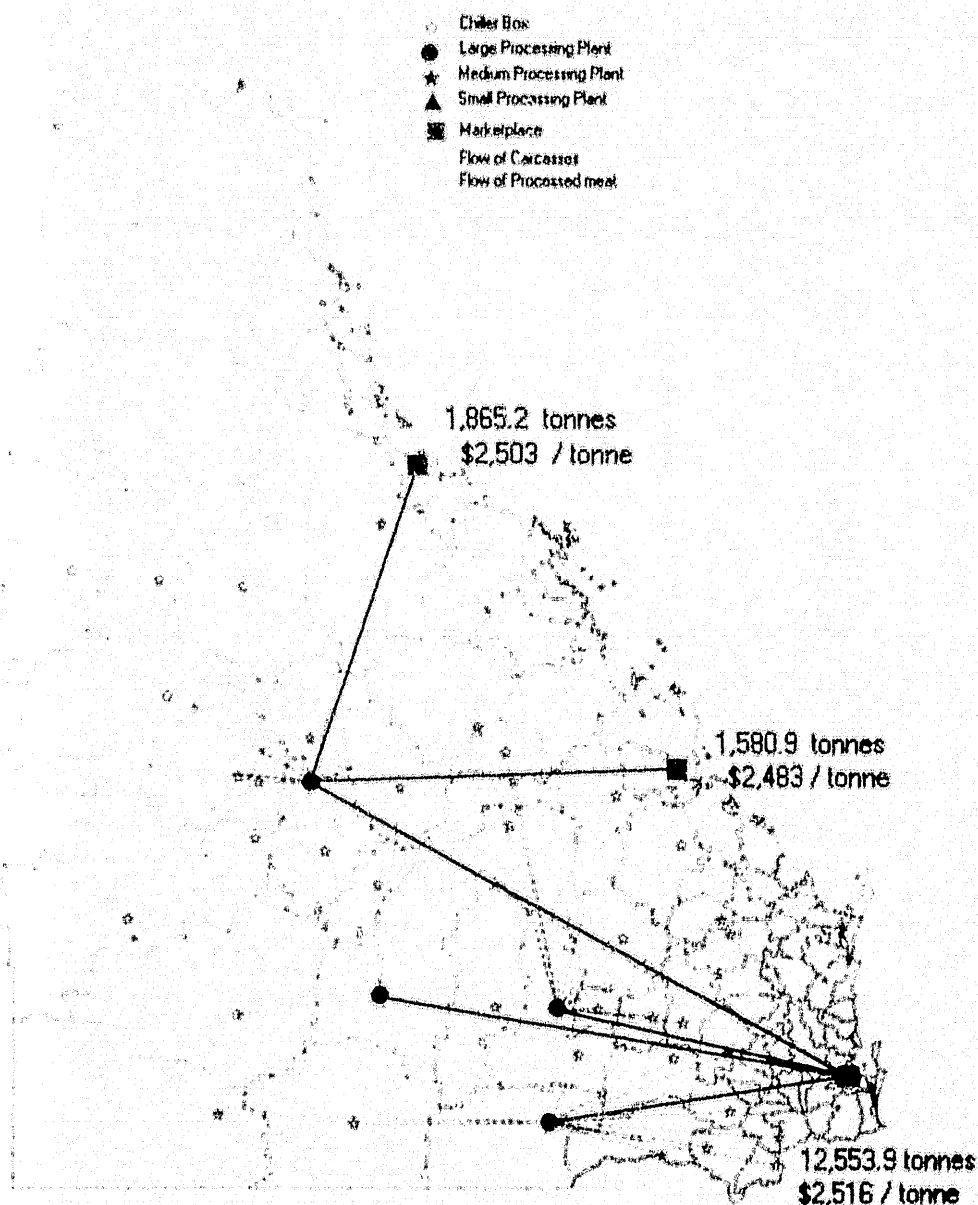


Figure 3 Structure of the Queensland Kangaroo Industry under a 15 % harvest off-take rate

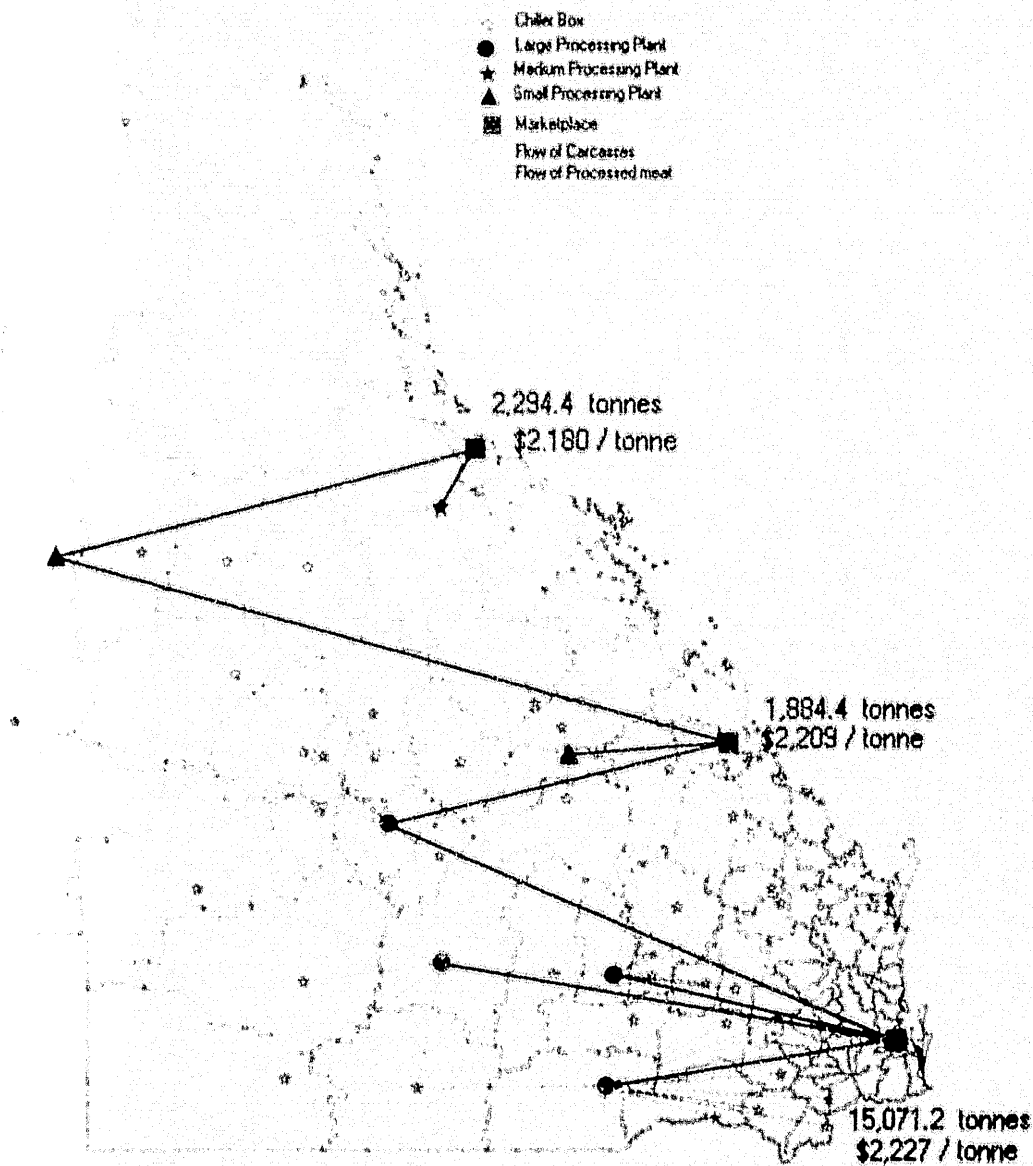


Figure 4 Structure of the Queensland Kangaroo Industry under a 17.5 % harvest off-take rate

Table 1. The structure of the Queensland Kangaroo Industry under different harvest off-take rates

Percentage off-take	10.0%	12.5%	15.0%	17.5%
Objective Function	\$89,323,766	\$94,979,766	\$97,932,039	\$100,313,988
Number of Kangaroos available	1,112,011	1,390,015	1,668,018	1,946,021
Number of Kang. to be harvested	1,050,000	1,375,000	1,600,000	1,925,000
Number of Harvesters required	137	179	208	251
Number of Chiller Boxes required	55	72	83	100
Market Quantity Brisbane (tonnes)	8,227.9	10,745.6	12,553.9	15,071.2
Market Quantity Rockhampton (tonnes)	1,031.1	1,350.6	1,580.9	1,884.4
Market Quantity Townsville (tonnes)	1,241	1,653.8	1,865.2	2,294.4
Market Price Brisbane (\$/tonnes)	\$3,334	\$2,791	\$2,516	\$2,227
Market Price Rockhampton (\$/tonnes)	\$3,301	\$2,758	\$2,483	\$2,209
Market Price Townsville (\$/tonnes)	\$3,284	\$2,712	\$2,503	\$2,180
Value of total meat demand	\$34,910,924	\$38,201,030	\$40,179,583	\$42,727,994
Average value (\$/tonne)	\$3,325	\$2,778	\$2,511	\$2,220
Quantity of kangaroo meat processed (tonnes)	10,500	13,750	16,000	19,250
Number of personnel in processing plants	226	286	328	412
Total number of personnel in production ^a	381	489	564	696

^a Sum of the number of harvesters, chiller box operators and processing plant personnel. The operation of three chiller boxes equates to one full time position.

DISCUSSION

The structure of the Queensland kangaroo harvesting industry under a harvest off-take rate of 15% is illustrated in Figure 3 (which is the current harvest rate). A total of 1.6 million kangaroos are harvested from an available population of 1.67 million (Table 1). Four large kangaroo meat processing facilities are located at St George, Roma, Charleville and Barcaldine (Figure 3). Total production is 16,000 tonnes of boneless meat, employing 328 personnel within the processing facilities (Table 1). The value of demand is \$40.2 million, and a total of 564 personnel are employed in the production sector (Table 1).

The effects of lowering the harvest off-take rate by 2.5%

Figure 2 illustrates the structure of the industry under a harvest off-take rate of 12.5%. A reduction in the harvest off-take by 2.5% has resulted in the relocation and downsizing of a large processing facility from St George to a medium sized facility at Hughenden. Total production decreased from 16,000 tonnes to 13,750 tonnes, and the value of demand decreased to \$38.2 million (Table 1). A total of 489 personnel are employed in the production sector, which represents a loss of 75 positions (Table 1).

The effects of lowering the harvest off-take rate by 5%

Figure 1 represents the industry under a harvest off-take rate of 10%. As illustrated by Figure 1, two large processing facilities are located at Roma and Charleville, one medium sized facility at Winton, and a small facility at Emerald. Of the 1.1 million kangaroos available, 1.05 million are harvested to produce 10,500 tonnes of boneless kangaroo meat. A total of 381 personnel are employed in the production sector, which is 183 positions (32%) fewer than under the industry structure operating at a 15% harvest rate (Table 1). The value of demand is \$34.9 million, an decrease of \$5.3 million or 13.1%.

The effects of increasing the harvest off-take rate by 2.5%

Figure 4 illustrates the industry under a 17.5% harvest off-take rate. The restructuring results in the relocation of the Barcaldine plant to Blackall, and one new medium sized facility at Charters Towers, and two small plants at Cloncurry and Emerald. Production rises to 19,250 tonnes, an increase of 3,250 tonnes (20.3%). An additional 325,000 kangaroos are harvested, while an extra 132 personnel are required to harvest, manage storage facilities, and process kangaroo meat (Table 1). The value of demand is \$42.7 million, an increase of \$2.5 million.

CONCLUSION

An increase or decrease in the harvest off-take rate from 15% has major implications in terms of the number and location of processing facilities, and therefore employment prospects in rural communities throughout Queensland. Others affected by harvest rates are obviously harvesters and storage facility operators (chiller boxes).

The setting of future harvest off-take rates (annual quota) by the State Government should take into consideration ecological factors (kangaroo population dynamics), economic (rural employment and income opportunities) parameters identified in this paper, and the environmental parameters (total grazing pressure and rangeland condition) which are currently gaining much attention.

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