THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976 - 1980)

TECHNICAL REPORT

PHOSPHORUS EXPORT FROM COASTAL PLAIN CATCHMENTS

OCTOBER 1980

P.B. Birch

DEPARTMENT OF CONSERVATION AND ENVIRONMENT
BULLETIN No. 99

A TECHNICAL REPORT to

THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976-1980)

PHOSPHORUS EXPORT FROM COASTAL PLAIN CATCHMENTS INTO THE PEEL-HARVEY ESTUARINE SYSTEM WESTERN AUSTRALIA

by

P.B. Birch

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PUBLICATIONS:
THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976-1980)

This report is one of 14 technical reports that were presented to the Environmental Protection Authority's Estuarine and Marine Advisory Committee as part of the Peel-Harvey Estuarine System Study (1976-1980).

The publications arising from the study are listed below and are available from the Department of Conservation and Environment, 1 Mount Street, Perth WA 6000.

- The Peel-Harvey Estuarine System Study (1976-1980). A report to the Estuarine & Marine Advisory Committee December 1980. E.P. Hodgkin, P.B. Birch, R.E. Black, and R.B. Humphries, Department of Conservation and Environment, Report No. 9.
- The Peel-Harvey Estuarine System Study. A report by the Estuarine and Marine Advisory Committee to the Environmental Protection Authority, March 1981. Department of Conservation and Environment, Bulletin No. 88.

TECHNICAL REPORTS

BULLETIN No.

89 The Peel Inlet and Harvey Estuary System Hydrology and Meteorology. R.E. Black and J.E. Rosher. June 1980.

90 Sediments and Organic Detritus in the Peel-Harvey Estuarine System. R.G. Brown, J.M. Treloar and P.M. Clifton. August 1980.

91 The Ecology of *Cladophora* in the Peel-Harvey Estuarine System. D.M. Gordon, P.B. Birch and A.J. McComb. 1981.

92 The Decomposition of *Cladophora.* J.O. Gabrielson, P.B. Birch and K.S. Hamel. October 1980.

93 The Control of Phytoplankton Populations in the Peel-Harvey Estuarine System. R.J. Lukatelich and A.J. McComb. 1981.

94 Cyanobacteria and Nitrogen Fixation in the Peel-Harvey Estuarine System. A.L. Huber. October 1980.

95 Phosphatase Activities in the Peel-Harvey Estuarine System. A.L. Huber. October 1980.

96 The Sediment Contribution to Nutrient Cycling in the Peel-Harvey Estuarine System. J.O. Gabrielson. 1981.

97 Aspects of the Biology of Molluscs in the Peel-Harvey Estuarine System, Western Australia. F.E. Wells, T.J. Threlfall and B.R. Wilson. June 1980.

98 The Fish and Crab Fauna of the Peel-Harvey Estuarine System in Relation to the Presence of *Cladophora*. I.C. Potter, R.C.J. Lenanton, N. Loneragan, P. Chrystal, N. Caputi and C. Grant. 1981.

99 Phosphorus Export from Coastal Plain Catchments into the Peel-Harvey Estuarine System, Western Australia. P.B. Birch. October 1980.

100 Systems Analysis of an Estuary. R.B. Humphries, P.C. Young and T. Beer. 1981.

101 Peel-Harvey Nutrient Budget. R.B. Humphries and R.E. Black. October 1980.

102 Nutrient Relations of the Wetlands Fringing the Peel-Harvey Estuarine System. T.W. Rose and A.J. McComb. August 1980.

ABSTRACT

Excessive growth of the benthic alga *Cladophora* aff. *albida* in the Peel-Harvey estuarine system has coincided with greatly increased inputs of phosphorus from rivers over the last 20-25 years. At present, about 90% of phosphorus input is derived from rural coastal plain catchments, where use of superphosphate increased by four-fold over the period 1945-1975.

The present export of phosphorus from these catchments was found to be positively correlated with rates of superphosphate application, dairy farming, and presence of alluvial clay soils, and negatively correlated with beef farming. Reduction of phosphorus input to the estuary from the coastal plain therefore could be achieved by reducing or modifying the present use of superphosphate, and reducing run-off from dairy farms into waterways.

INTRODUCTION

Since about 1968 there has been excessive growth of benthic algae in the Peel-Harvey estuarine system in Western Australia (Cross 1974). These algae, which are dominated by a species of *Cladophora*[1], clog the nets of commercial fishermen and accumulate on once clean beaches causing foul conditions, which necessitate costly removal measures. Therefore a study was commenced in 1976 by the Western Australian Department of Conservation and Environment to determine the causes of the excessive algal growth and suggest remedies for its control. This paper deals with part of the study, that of the sources of phosphorus income to the estuary.

Investigation of the sources of phosphorus is necessary because studies of *Cladophora* nutrition have domonstrated that phosphorus is an important limiting nutrient for its growth and that reduction of phosphorus income to the estuary would be an effective means of reducing its biomass. This finding is based on culture work under controlled conditions (Gordon *et al.* 1981) and measurements of phosphorus concentrations in *Cladophora* tissue collected from the estuary (Birch *et al.* 1981).

Analysis of historical data on phosphorus income (Hodgkin *et al.* 1981) has shown that two of the major rivers flowing into the estuary, the Serpentine and Murray Rivers, delivered greatly increased amounts of phosphorus per unit flow during the years 1972-78 compared with 1949-56. For example, the

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Footnote 1. *Cladophora* aff. *albida*, specimen formally lodged with University of Western Australia Herbarium (U.W.A. 2806 a).

Serpentine River delivered at least ten times more phosphorus into the estuary in 1978 than in 1953, even though there was similar rainfall and river flow in both years. These increased inputs were associated with large increases in total phosphorus concentrations in the estuary, which, in parts, averaged 3-4 times higher in 1972-78 than in 1949-56.

In the present study, stream monitoring has shown that about 90% of phosphorus input from rivers is derived from rural catchments of the Swan Coastal Plain, which in area represent only 28% (2,700 km^2) of the total undammed catchment of the estuary (Black and Rosher 1980; Fig. 1).

Soils of the Swan Coastal Plain are naturally deficient in phosphorus and, in agricultural areas, need to be supplemented with superphosphate, the use of which has greatly increased since 1945 (Fig.2). As a result, the major source of phosphorus presently entering the estuary from these catchments is probably from applied superphosphate. The purpose of this paper, therefore, is to investigate the relationship between use of superphosphate and export of phosphorus from coastal plain catchments to the estuary. In addition, the relation between phosphorus export and the proportions of different agricultural land uses and soil types in the catchments is examined.

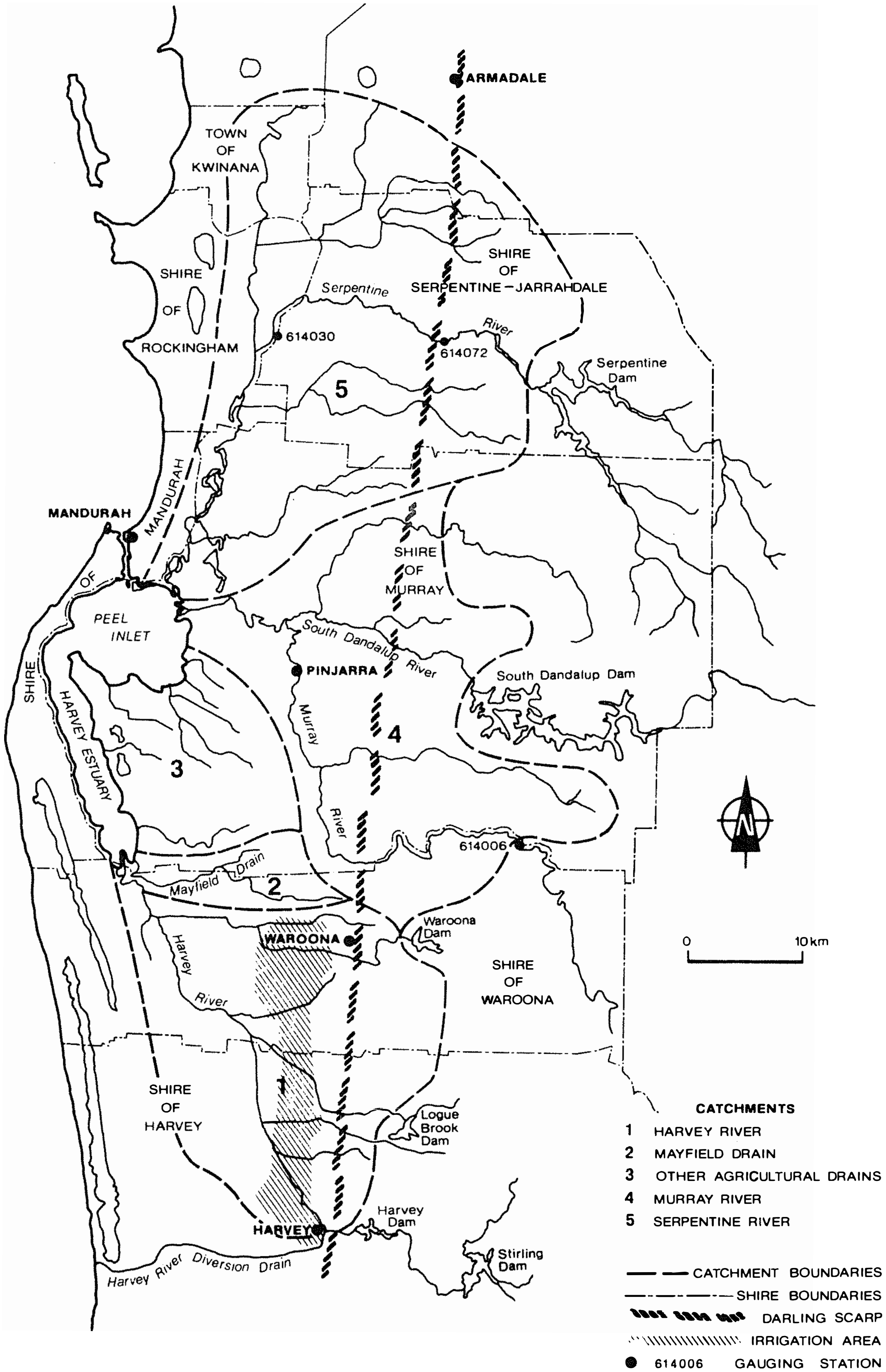

Fig. 1 Catchment boundaries for rivers and drains of the coastal plain drainage of the Peel-Harvey estuarine system.

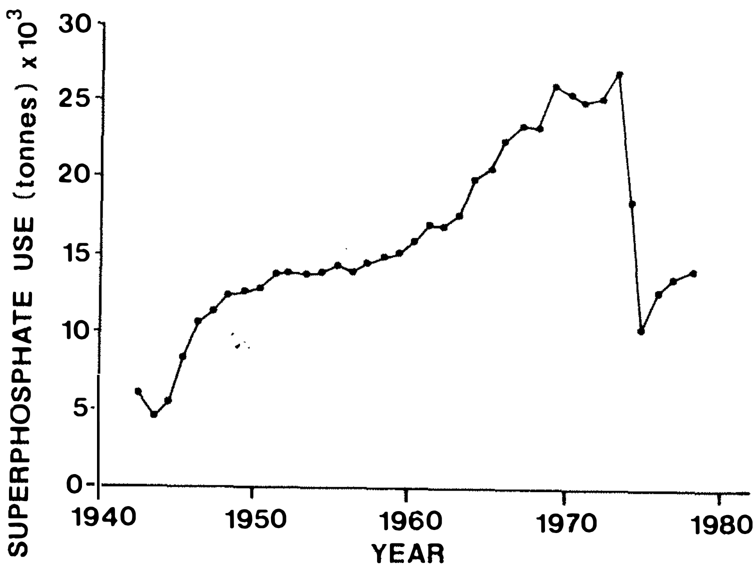

Fig. 2 Superphosphate fertilizer usage for coastal plain catchments. Data are based on shire figures from Australian Bureau of Statistics. The shire contributions are Harvey (33 per cent), Kwinana (50 per cent), Rockingham (70 per cent), Serpentine-Jarrahdale (100 per cent), Murray (100 per cent) and Waroona (100 per cent).

DESCRIPTION OF STUDY AREA

Climate and Soils

The Swan Coastal Plain of Western Australia is a narrow (20-30 km) strip of land bounded to the east by the Darling Scarp and on the west by the sea. It extends from just north of Perth to Dunsborough, 200 km south (Gentilli and Fairbridge 1951). The portion which drains into the estuary has three major catchments: the Harvey, Murray and Serpentine River catchments. In addition, numerous agricultural drains discharge into the estuary and these have been divided into the Mayfields Drain catchment and that of the "other" agricultural drains (Black and Rosher 1980; Fig. 1). The area experiences a mediterranean climate, receiving an annual rainfall of 900-1,000 mm, most of which falls between May and October.

The Swan Coastal Plan has been divided into five geomorphic elements (Fig. 3). These include three dunal systems of increasing age and distance from the sea; the Quindalup, Sprearwood and Bassendean dunes. Further inland there is the Pinjarra Plain and, easternmost, the Ridge Hill Shelf which forms the foothills of the Darling Scarp (McArthur and Bettenay 1960). These elements have been each divided into soil associations which are diverse in nature, and range from sandy soils of the Bassendean dunes to alluvial clays found within the Pinjarra Plain (Bettenay *et al*. 1960).

As the coastal plain is relatively infertile, significant advancement in agriculture did not come until the last 30-40 years consequent upon the introduction and widespread

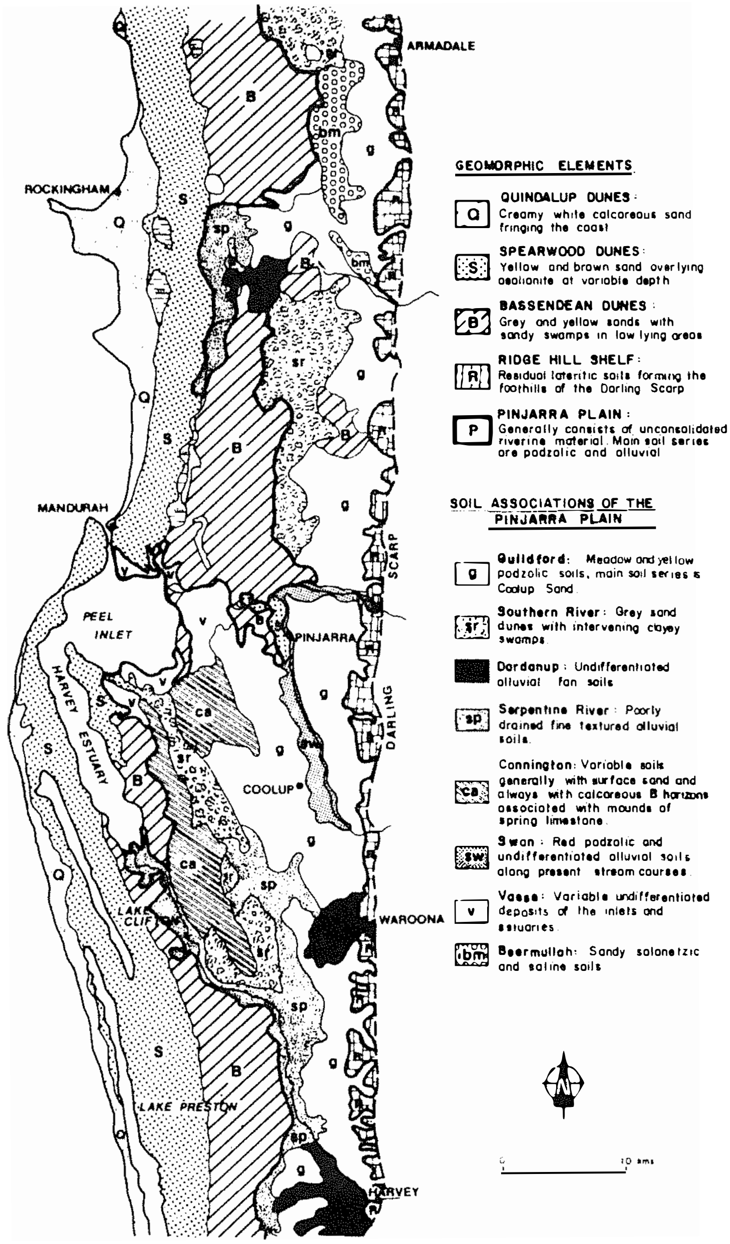

Fig. 3 Geomorphic elements and soil associations of the Swan Coastal Plain (After McArthur and Bettenay (1960) and Bettenay et al (1960).

use of phosphatic fertilizers and subterranean clover. At present the dominant land use in that portion draining into the estuary is raising of beef cattle, followed by dairy farming (Fig. 4). There is also a small but significant area between Waroona and Harvey under irrigation. This area is mainly used for pasturing dairy and beef herds.

Surveys in 1979-80 of superphosphate use revealed a relatively high application rate of 38 kg P ha^{-1} on irrigated paddocks compared with 18 kg P ha^{-1} on other paddocks in the coastal plain catchments. Most dairying farms were located in the irrigated region and thus had a considerably higher application rate (31 kg P ha^{-1}) compared with beef farms (16 kg P ha^{-1}) which were mostly located on non-irrigated pastures (J. Gabrielson, J. Guimelli and D. Kidby unpubl. data).

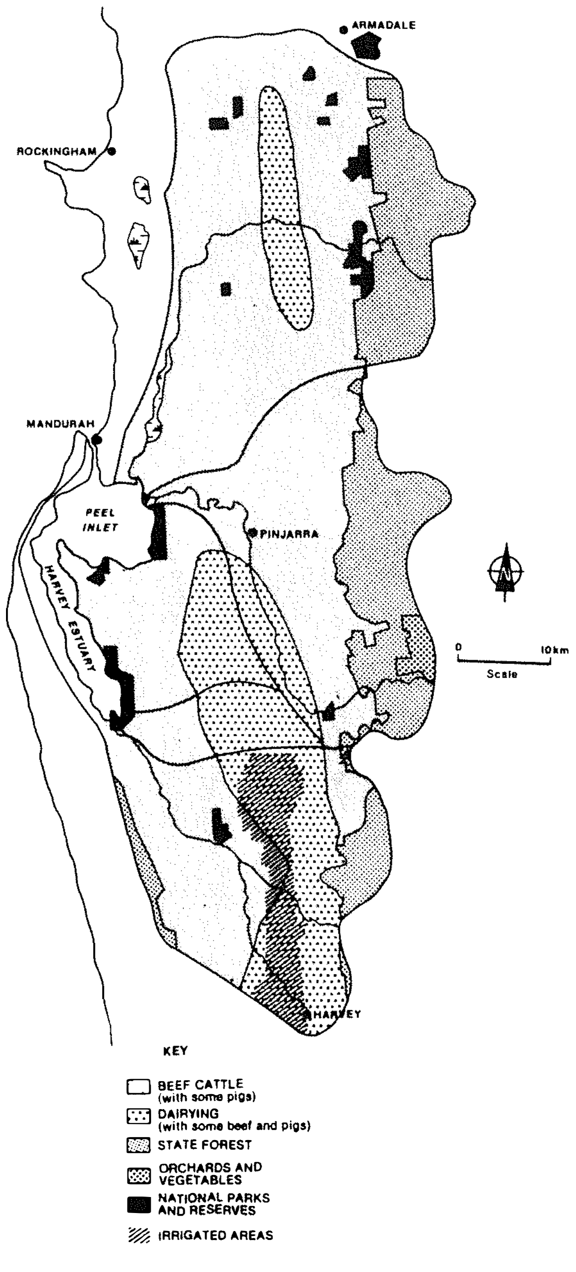

Fig. 4 Agricultural land use in the coastal plain drainage of the Peel-Harvey estuarine system. Data Sources : J. Higgins (Murdoch Univ.), W.A. Depts. of Agriculture, Forestry, Lands and Surveys, and Public Works.

METHODS

The relationships between export of phosphorus from catchments and (a) fertilizer use, (b) the proportions of various soil associations and (c) land uses in the catchments were determined by linear regression analyses. The proportions of soil associations and land uses in the catchments were calculated from Figures 3 and 4. Fertilizer use was estimated from shire statistics (Australian Bureau of Statistics 1979) by assuming that fertilizer was applied uniformly over the cleared portion of each shire in each catchment (Dept. Lands and Surveys maps). This permitted a reasonable estimation of contribution by shires to catchments and hence total fertilizer use and average application rates on catchments.

Catchment export of phosphorus was calculated from the amount discharged by rivers and drains and expressed as kg P ha^{-1} of catchment. Discharge was computed from weekly measurements of flow and phosphorus content of rivers and drains over the period October 1977 - September 1979 (Black and Rosher 1980). No samples were collected during periods of very low flow. Phosphorus contributions from the Murray River were divided into the coastal plain portion (Murray River, west) and the plateau portion (Murray River, east) at Public Works Department gauging station 614006 (Baden Powell Water Spout) some 50 km upstream (Fig. 1). Samples for total phosphorus were collected less frequently at station 614006 during 1978/79 (a year of near record low flow) but still averaged 2-4 samples per month over most of the "high" flow months. Calculations for this period were based on monthly averages and the ratio of Murray (east)/Murray (west) for loading was used to estimate loading for Murray (east) for August and September 1979, when no samples were collected at station 614006.

RESULTS

Fertilizer Application and Export

The estimated uses of superphosphate for individual catchments are summarised in Table 1. This table also includes data for the remainder of the estuary's catchment (Murray River, east) for comparative purposes. On the coastal plain the greatest quantities of fertilizer were applied on the Harvey and Serpentine River catchments, but on an areal basis, the highest average application rates were on the Harvey River catchment followed by the Mayfields and "other" drains catchments. Lower rates were applied on the Serpentine and Murray River (west) catchments.

The biggest exporters of phosphorus were the Harvey and Serpentine River catchments accounting for 60-70% of the total input to the estuary (Table 1). The amount of phosphorus reaching the estuary as a fraction of that applied as fertilizer ranged from 2% - 8% (average 6%) in all catchments except for the Mayfields Drain catchment, where the figure was 19% for 1977/78 and 14% for 1978/79.

Catchment export rate (kg P ha^{-1} yr^{-1}) varied by more than an order of magnitude in the coastal plain catchments. Highest export rates were determined for the Harvey River and Mayfields Drain catchments and lowest for the Murray (west), and Serpentine River catchments. The export from the remainder of the estuary's catchment (Murray River, east) was very low and explained why this large area contributed such a small proportion of the total phosphorus load.

<u>TABLE 1</u>

Superphosphate application (kg P ha^{-1}) and export of phosphorus from catchments draining into the Peel-Harvey estuarine system, 1977/78 and 1978/79.

CATCHMENTS	Area km^2	PHOSPHORUS APPLIED Tonnes	(% of total)	kg ha^{-1}	PHOSPHORUS EXPORTED Tonnes	(% of total)	kg ha^{-1}
		-------------------	--------1977/78	--------	----------	----------	----------
(a) Coastal Plain							
Harvey R.	590	580	(15)	9.8	48	(40)	0.81
Mayfields Drain	110	73	(1.9)	6.6	14	(12)	1.3
Other drains	290	160	(4.1)	5.5	11	(9.1)	0.38
Serpentine R.	1000	350	(9.0)	3.5	23	(19)	0.23
Murray R. (west)[1]	700	220	(5.7)	3.1	8.5	(7.0)	0.12
Total	2700	1400	(36)	4.8	104	(86)	0.39
(b) Plateau							
Murray R. (east)	6900	2500	(64)	3.9	17	(14)	0.025
TOTAL FOR ESTUARY	9600	3900	(100)	4.3	121	(100)	0.13
		-------------------	--------1978/79	--------	----------	----------	----------
(a) Coastal Plain							
Harvey R.	590	530	(13)	9.0	34	(51)	0.58
Mayfields Drain	110	68	(1.8)	6.2	9.8	(15)	0.89
Other drains	290	170	(4.0)	5.9	7.4	(11)	0.26
Serpentine R.	1000	400	(8.8)	4.0	12	(18)	0.12
Murray R. (west)[1]	700	230	(5.5)	3.3	3.6	(5.4)	0.05
Total	2700	1400	(35)	4.8	66.8	(99)	0.24
(b) Plateau							
Murray R. (east)	6900	2600	(65)	3.9	0.6	(0.9)	0.001
TOTAL FOR ESTUARY	9600	4000	(100)	4.3	67	(100)	0.071

1. Catchment of Murray River below Baden Powell Water Spout (614 006) including North and South Dandalup Rivers below dams, allowing for 40% spillover from North Dandalup pipehead dam (Metropolitan Water Board data).

Regression Analyses

Results of the linear regression analyses are depicted in Figures 5-8. Catchment export rate was positively correlated ($P < 0.05$) with fertilizer application rate, the proportion of Serpentine River soil association in the catchment, and dairy farming. A significant negative correlation was found with beef farming and catchment export rate.

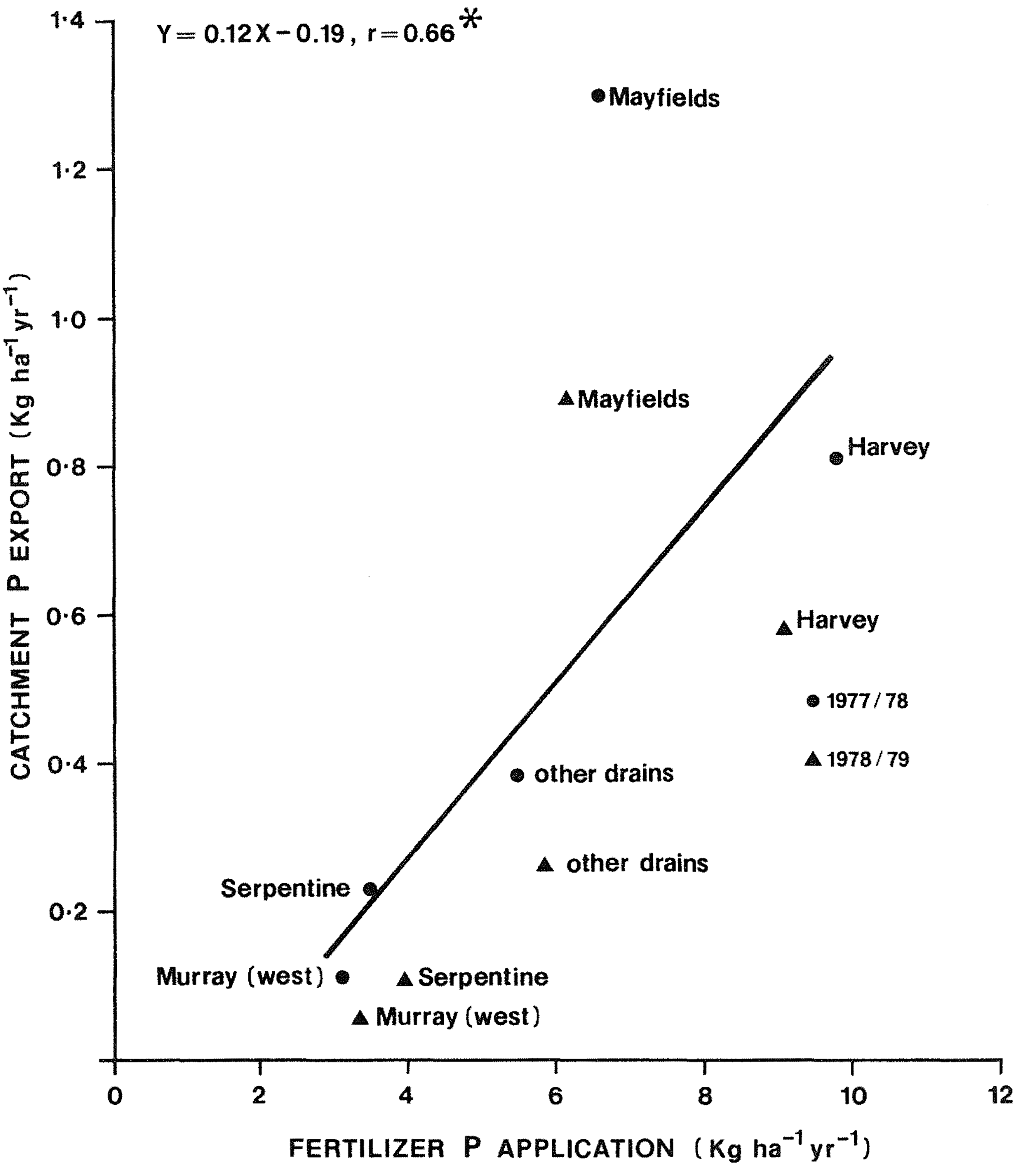

Fig. 5 The relationship between superphosphate application rate (kg P/ha/yr) and export rate of phosphorus from coastal plain catchments.

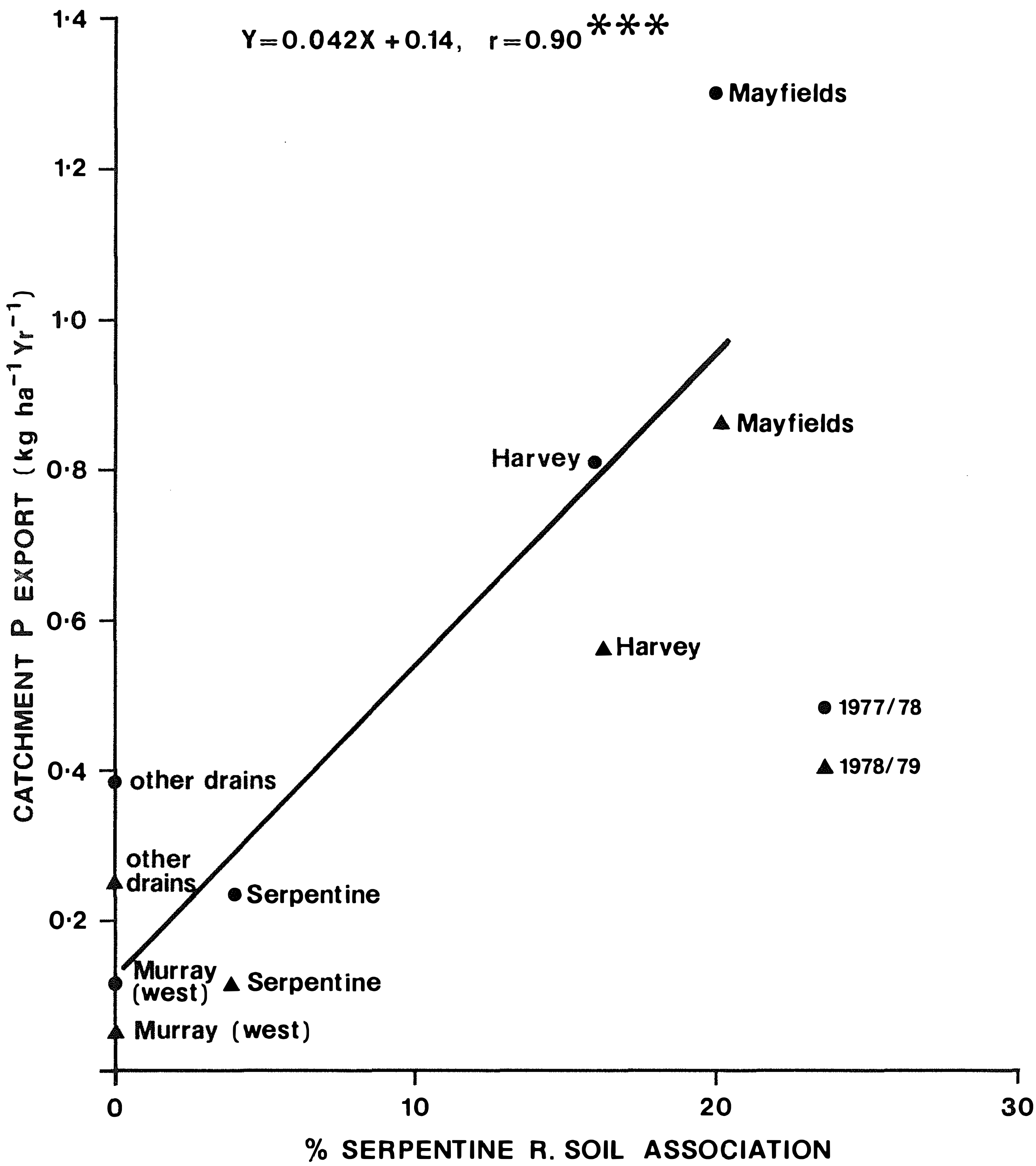

Fig. 6 The relationship between Serpentine River soil association and export rate of phosphorus from coastal plain catchments.

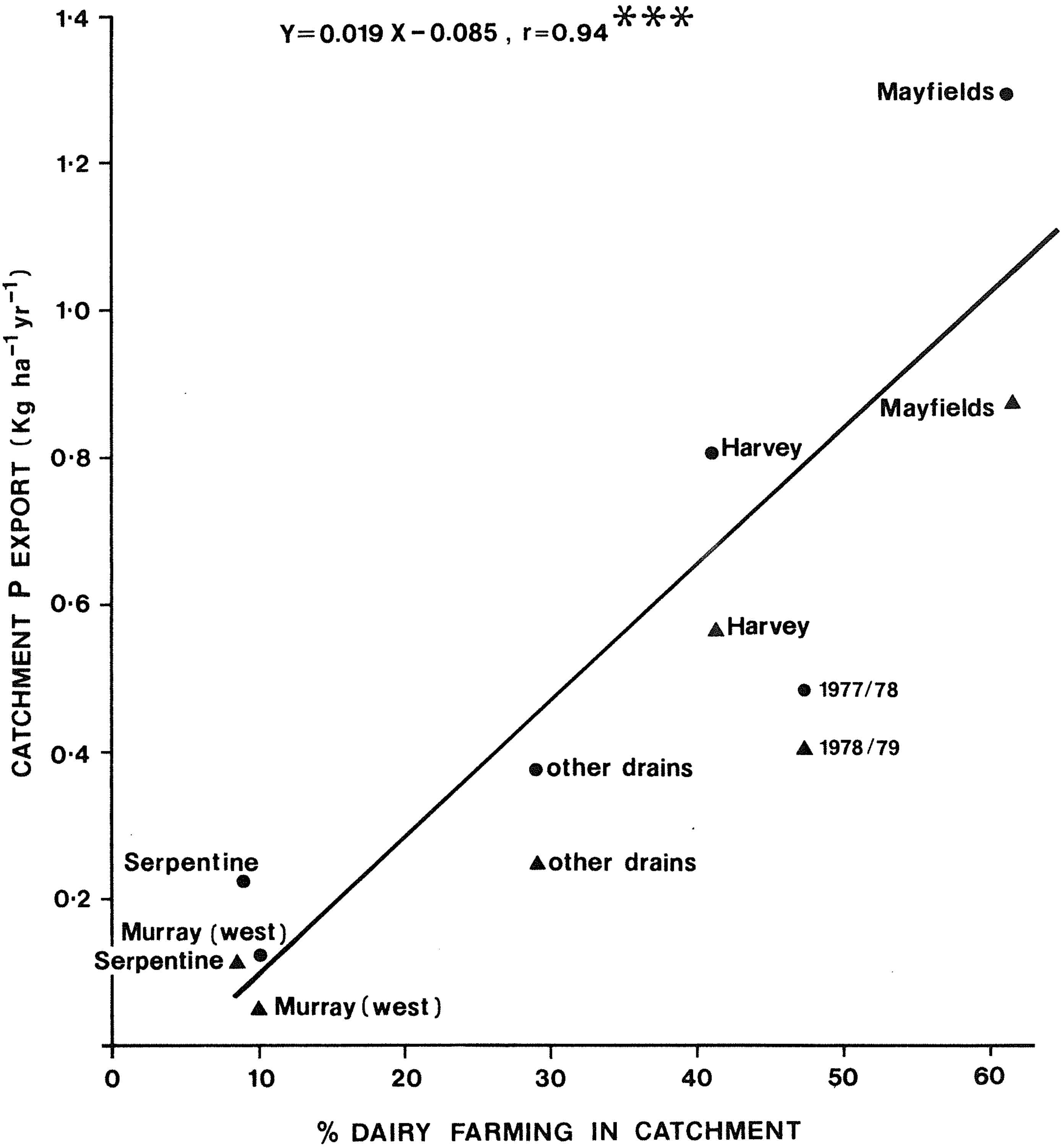

Fig. 7 The relationship between dairy farming and export rate of phosphorus from coastal plain catchments.

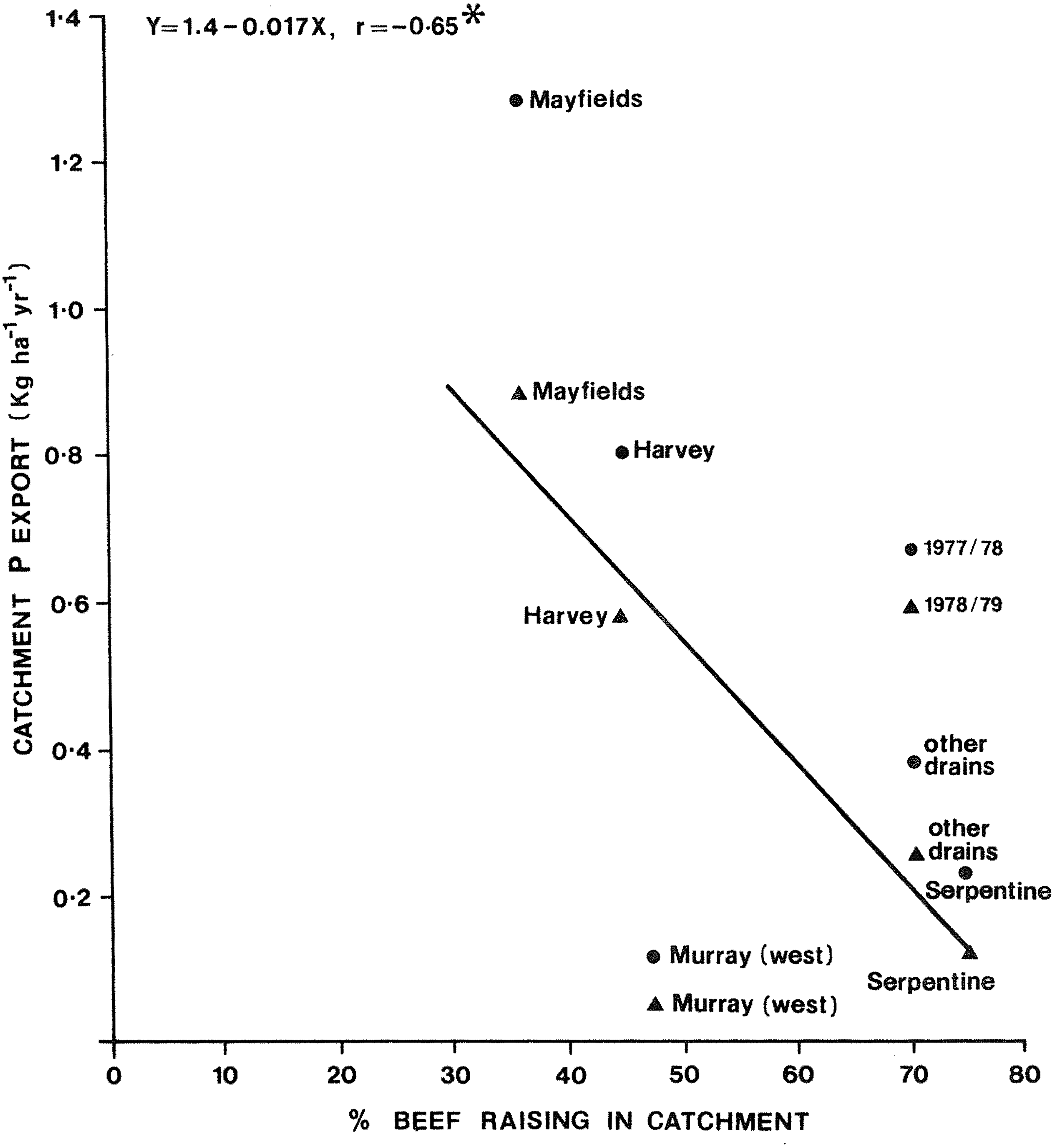

Fig. 8 The relationship between beef farming and export rate of phosphorus from coastal plain catchments.

DISCUSSION

Fertilizer Application and Export

An important outcome of the regression analyses in this study is the significant correlation between fertilizer application and phosphorus export, i.e. those catchments which received highest fertilizer application rates were those which had the highest export rates (Fig. 5). However, the correlation coefficient of 0.66 means that factors other than fertilizer application rates were also making a reasonably important contribution to the observed variation in catchment export rates. These could include the time and manner of fertilizer incorporation into the soil, the efficiency of fertilizer use by plants, the chemical reaction of fertilizer with soil, and the amount of leaching and soil erosion. All of these factors are related to the rainfall, soil types and land uses in the catchment.

Rainfall

The effect of rainfall between the two years is evident. The first year (October 1977 - September 1978) was near average with about 820 mm or 85% of the annual mean being recorded in the catchments. The second year was quite dry with only about 650 mm or 67% of the average being received and resulted in a decrease in phosphorus export. In the Harvey River, Mayfields Drain and "other" drains catchments the decrease was in proportion to the decrease in rainfall. Proportionately greater reductions occurred in the Serpentine River and the Murray River (west) catchments.

Soil Types

Of the major soil associations, a significant correlation was only found between catchment export and the Serpentine River soil association (Fig. 6). This suggests a further examination of phosphorus export from soils within this association may be useful. Bettenay et al. (1960) note that soils within the Serpentine River soil association are composed of fine textured, poorly drained clays. This may be an important factor for export of phosphorus since clays can be highly erodible and the dominant route for phosphorus losses from them is via surface runoff and erosion (Birch 1979).

The lack of significant correlations between phosphorus export and other major soil associations in the catchments does not necessarily mean that individual soil types within the associations are not high exporters or strong conservers of phosphorus. A more detailed investigation of them is required, especially within the Guildford soil association which contains soils with A horizons ranging from sand to heavy loams.

Land Use

Of the major land uses in the catchments, dairying is best correlated with phosphorus export rate (Fig. 7). A major reason for this could be relatively high fertilizer application rates in dairying areas, as indicated earlier. Furthermore, dairy cattle spend about 20% of their time in milking sheds. This leads to concentration of waste products which may result in excessive transport of phosphorus into neighbouring waterways.

Considering the above, it is not surprising to find a negative correlation between phosphorus export and beef farming (Fig. 8). This industry is associated with lower fertilizer use and the stocking rates are about half those on dairy farms (W. Russell, pers. comm.). In addition, the beef farming area includes most of the Bassendean association soils in the catchments. The deep sandy nature of these soils would be conducive to leaching rather than losses of phosphorus via surface runoff.

Differences in pasture composition and density between the two industries could also be important. For example, McColl (1979) has shown that tall grass on New Zealand catchments was effective in reducing phosphorus runoff.

Methods of Reducing Catchment Export of Phosphorus

The regression analyses suggest that reduction of phosphorus export from the coastal plain could be achieved by lowering fertilizer use. Also of possible importance would be modifying fertilizer practices, reducing soil erosion and reducing runoff from dairy farms.

In considering how fertilizer use may be reduced it is pertinent to note a decrease in use of ∿50% has already occurred in coastal plain shires over the last six years, following an increase in price in 1974/75 (Fig. 2). Although there has been a partial recovery it is believed that use may stabilise at current levels (equal to those around 1960) because farmers are now more critical of application rates and increasingly base their use on soil nutrient testing (J. Giumelli pers. comm.). However, the fact that the Serpentine River delivered about 10 times more phosphorus into the estuary in 1978 than in 1953, which was a year of similar rainfall, runoff and superphosphate application, indicates that there is a substantial fertilizer history effect. That is, even if fertilizer use continues at lower levels or is even further reduced, the effect of soil enrichment from 30-40 years of fertilization will be an important factor to be considered in future investigations of phosphorus movement in coastal plain soils.

Soil erosion is not a major problem in the coastal plain catchments at present, although it is probably greater than before agricultural development took place. Therefore there could be some scope for reduction, especially in areas of heavier soil types. McColl (1978) has shown that use of buffer strips of vegetation along stream banks may result in significant reduction in nutrient losses from the land. This practice warrants investigating in the coastal plain area.

As for dairy farming, the siting of milking sheds relative to waterways needs to be considered. Also there may be scope for treatment and/or recycling of dairy waste products which would reduce phosphorus export from farms, and possibly accrue other side benefits.

Acknowledgements

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